advantageous, and there appears to be no valid reason why yet closer adaptation of the pipes to the quantity of water they can be required to carry may not be made with further advantage.

By Order of the Board,

HENRY AUSTIN, *Secretary.*

Whitehall,
30*th January* 1852.

APPENDIX.

No. I.

In calculating the expense of forming drains or ditches, one of the chief items is the quantity of earth that has to be thrown out, which depends on the size of the drain. The cost of the labour will necessarily increase with the weight of earth that has to be removed; hence it is convenient to know the solid contents, or the number of cubic yards of cutting, in a drain of any given dimensions. This is found by multiplying together the length, depth, and mean width of the drain. Thus if a drain is 300 yards long, and the cutting 3 feet deep, 20 inches wide at the top and 4 inches wide at the bottom, the mean width would be 12 inches (or the half of the sum of 20 and 4), and if we multiply 100, the length, by 1, the depth in yards, and by $\frac{1}{3}$, the mean width in yards, and the product would be 100 cubic yards. The following table will serve to facilitate such calculations.

TABLE showing the NUMBER of CUBIC YARDS of EARTH in each ROD ($5\frac{1}{2}$ Yards in length), in Drains or Ditches of various Dimensions.

DEPTH.	MEAN WIDTH.											
Inches.	7 In.	8 In.	9 In.	10 In.	11 In.	12 In.	13 In.	14 In.	15 In.	16 In.	17 In.	18 In.
30	·89	1·02	1·146	1·27	1·40	1·53	1·655	1·78	1·91	2·04	2·164	2·29
33	·98	1·12	1·26	1·40	1·54	1·68	1·82	1·96	2·10	2·24	2·38	2·52
36	1·07	1·22	1·375	1·53	1·68	1·83	1·986	2·14	2·29	2·244	2·60	2·75
39	1·16	1·324	1·49	1·655	1·82	1·986	2·15	2·32	2·48	2·65	2·81	2·98
42	1·25	1·426	1·604	1·78	1·96	2·14	2·32	2·495	2·674	2·85	3·03	3·21
45	1·34	1·53	1·72	1·91	2·10	2·29	2·48	2·67	2·865	3·055	3·246	3·438
48	1·426	1·63	1·833	2·04	2·24	2·444	2·65	2·85	3·056	3·26	3·46	3·667
51	1·515	1·73	1·95	2·164	2·38	2·60	2·81	3·03	3·25	3·46	83·6	3·896
54	1·604	1·83	2·06	2·29	2·52	2·75	2·98	3·20	3·44	3·666	3·895	4·125
57	1·69	1·935	2·18	2·42	2·66	2·90	3·14	43·38	63·63	3·87	4·11	4·354
60	1·78	2·036	2·29	2·546	2·80	3·056	3·31	3·564	3·82	4·074	4·33	4·584

Along the top of the table is placed the mean widths in inches, and on the left-hand side the depths of the drains, extending from 30 inches to 5 feet. The numbers in the body of the table express cubic yards and decimals of a yard. In making use of the table, it is necessary first to find the mean width of the drain from the widths at the top and bottom. Thus, if a drain 3 feet deep were 16 inches wide at the top, and 4 inches at the bottom, the mean width would be half of 16 added to 4, or 10; then by looking in the table for the column under 10 (width), and opposite 36 (inches of depth), we find the number of cubic yards in each rod of such a drain to be 1·53, or somewhat more than one and a half. If we compare this with another drain 20 inches wide at the top, 4 inches at the bottom, and 4½ feet deep, we have the mean width 12, and looking at the table under 12 and opposite 54, we find 2·75 cubic yards, or two and three-quarters to the rod. In this case the quantity of earth to be removed is nearly twice as much as in the other, and hence, as far as regards the digging, the cost of the labour will be nearly double. But in the case of deep drains, the cost increases slightly for another reason, namely, the increased labour of lifting the earth to the surface from a greater depth.

The following extract from Mr. Raynbird's Essay on Measure Work, which received the prize of the Royal Agricultural Society, will serve to convey an idea of the usual cost of the labour of forming drains:—

"The cost of the labour required in draining depends, firstly, upon the nature of the soil in which the drains are dug; and, secondly, upon the depth and materials used for filling up. Draining on a sound clay free from stones may be executed at a cheaper rate per rod in length than on almost any other kind of soil, as from the firmness of the clay the work may be done with narrow spades, and but a small quantity of soil requires to be removed by manual labour. The draining wet sands, or gravels, or clays in which veins of sand abound, is more expensive than on the sound clays, because a broader spade has to be used, and consequently a larger amount of soil removed; and draining stony or rocky soils is still more expensive, because the pick has to be used: this adds considerably to the expense. On the sound clays of Suffolk and Essex, the price for digging drains, and laying in stubble, heath, brushwood, peat, or whatever else is used, and filling up drains so far as cannot be done with the plough, is about 4*s.* or 4*s.* 6*d.* the score rods, and 6*d.* for each eye.* These drains are made about 30 inches deep; the first spit is ploughed out, the two next dug with narrow draining spades; half a score rods of this kind of draining is reckoned a fair day's work. Sometimes, however, half a score is above an average, for I know a case on a hard clay, lying just above the chalk, which was so tenacious that the men could hardly dig and fill in 6 rods in a day. The cost of digging, laying in tiles, and filling drains four feet deep on a clay soil intersected with veins of sand, may cost about 6*d.* a rod. We have just completed digging a drain in a meadow, of an average depth of three feet, the first six inches turned up by the plough. It took 30 days' labour for one man at 20*d.* a day to dig 101 rods of drain, one man a day and three quarters to lay in the tiles (tops and bottoms), and about eight days to fill up the drain, making a total cost of nearly 8*d.* a rod. The soil was very wet, stony, and hard. On a loamy soil drained to the depth of four feet with a clay subsoil, the upper ten inches ploughed out, one man would on an average dig three and a half rods per day—throwing out about ten cubic yards of soil—would lay in about 60 rods of soles and tiles in a day, and fill in 13 rods in a day."

* The mouth of the drain.

No. II.

On the Quantities of Rain falling on Land; the Quantities passing through it by filtration; and the Quantities evaporated.

On this subject it is highly important that information should be obtained from the experience on well drained lands. The estimates first furnished are given in the following extracts from the writings of Mr. Josiah Parkes on Land-drainage:—

"The annexed Table, No. 1, contains the monthly and annual indications of the two gauges for the years 1836 to 1843 inclusive; those of the rain gauge being, Mr. Dickinson informs me, generally corroborated by another gauge kept by the Grand Junction Canal Company about 8 miles distant. Table 2 gives the mean result of the eight years' observations for each month, and the whole period in terms, of the depth of rain which fell on the surface; of the amount which filtered through the Dalton Gauge;* and of that which was evaporated, or again restored to the atmosphere in the shape of vapour, with two columns showing the proportion per cent. of filtration and evaporation.

"Table 3 presents to view the total amount of rain which fell in each year, with the per-centage of filtration and evaporation; and Table 4 illustrates the quantity of rain and the proportion of water disposed of by filtration and evaporation during the six hotter and six colder months of each year respectively. To these last tables I have added

* Described at p. 53.

columns exhibiting the weight of rain in tons per acre, as that expression may perhaps convey to the farmer a better idea of its amount than the more usual mode of stating it in inches of depth.

"By means of this tabular analysis we shall find the phenomena, as they may be applicable to agriculture, clearly brought before us.

"The first important fact disclosed is, that of the whole annual rain, about $42\frac{1}{2}$ per cent., or $11\frac{3}{10}$ inches out of $26\frac{6}{10}$ inches, have filtrated through the soil; and that the annual evaporative force is only equal to the removal of about $57\frac{1}{2}$ per cent. of the total rain which falls on any given extent of earth, 3 feet in depth (Table 2).

"By a closer scrutiny we learn (Table 4), that only about 25 per cent. of the rain which falls from October to March inclusive passes back to the atmosphere by evaporation in the same period; whereas from April to September inclusive about 93 per cent. is evaporated. It appears, then, that there is even a balance on the side of rain over evaporation during the six hottest months, and we discover only two years, 1840 and 1841, in which no filtration occurred within that period. Table 2 shows that in August the soil is in its driest state; but even in that month some filtration takes place in three out of the eight seasons recorded. It will be understood that though a near balance is shown to subsist between rain and evaporation during the six hottest months on an average of years, the hygrometric condition of a soil, *i. e.*, its state of wetness or dryness at any particular time, is not indicated by the Dalton Gauge.

"A soil may be in a state of drought or of humid saturation at different times during these months, and according to the season. It is, however, manifest from these registers, that if all the water derived from rain during the six colder months were allowed to accumulate in a soil, such land must be perfectly *wet;* and coupling this fact with the performance of drains which I am now enabled to exhibit, it appears that six months are expended in maintaining by the sole unaided force of evaporation an undrained retentive soil in a tolerably uniform moist condition, whilst deep-covered drains relieve the same soils of excess of humidity in a few hours after every fall of rain, even in the wettest season.

"Table 4 shows that the mean excess of rainwater to be disposed of during the six coldest months by some other process than evaporation amounts to no less a weight than about 1,050 tons per acre.

TABLE I.

Months.	1836.		1837.		1838.		1839.	
	Gauges.		Gauges.		Gauges.		Gauges.	
	Rain.	Dalton.	Rain.	Dalton.	Rain.	Dalton.	Rain.	Dalton.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
January -	2·40	2·32	2·40	2·10	0·31	0·04	1·40	1·04
February -	2·04	2·04	2·85	2·92	2·65	0·86	1·45	1·51
March - -	3·65	2·51	0·75	0·01	1·55	2·73	1·92	1·22
April - -	2·57	1·74	1·32	0·00	1·35	„	1·65	0·71
May - -	0·70	0·03	0·94	„	0·84	„	1·22	0·10
June - -	1·80	0·01	1·86	„	2·85	„	3·31	0·05
July - -	2·29	0·10	1·30	„	2·35	0·09	4·36	0·15
August -	2·24	0·15	3·00	0·05	0·95	„	3·65	0·09
September -	2·60	0·07	1·38	0·05	2·47	0·03	3·22	1·50
October -	4·55	3·82	1·55	0·02	2·68	0·07	1·68	0·09
November -	3·95	3·14	2·05	0·18	3·55	2·91	4·40	4·70
December -	2·21	1·72	1·70	1·62	1·58	1·84	3·02	3·75
Total -	31·0	17·65	21·10	6·95	23·13	8·57	31·28	14·91

Months.	1840.		1841.		1842.		1843.	
	Gauges.		Gauges.		Gauges.		Gauges.	
	Rain.	Dalton.	Rain.	Dalton.	Rain.	Dalton.	Rain.	Dalton.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
January -	3·95	3·05	1·50	„	1·36	0·60	1·46	1·25
February -	1·32	1·00	1·02	„	2·02	2·10	2·42	1·95
March - -	0·34	„	1·65	0·53	2·20	1·62	0·88	„
April - -	0·34	„	1·85	„	0·47	„	2·10	„
May - -	2·62	„	1·68	„	1·85	„	5·00	0·74
June - -	1·33	„	3·00	„	2·00	„	1·56	0·25
July - -	1·68	„	2·80	„	1·93	„	2·09	„
August -	1·90	„	3·62	„	1·40	„	2·66	„
September -	2·31	„	4·00	„	4·50	1·30	0·63	„
October -	1·50	„	4·40	5·99	1·41	0·30	4·82	0·91
November -	4·25	2·57	4·28	4·87	5·77	5·00	2·45	2·70
December -	0·40	1·57	2·30	2·80	1·52	0·84	0·40	0·30
Total -	21·44	8·19	32·10	14·19	26·43	11·78	26·47	8·10

TABLE II.

MEAN OF EACH MONTH, AND OF EIGHT YEARS.					
	Rain.	Filtration.	Evaporation.	Filtration.	Evaporation.
	Inches.	Inches.	Inches.	Per Cent.	Per Cent.
January - -	1·847	1·307	0·540	70·7	29·3
February - -	1·971	1·547	0·424	78·4	21·6
March - -	1·617	1·077	0·540	66·6	33·4
April - - -	1·456	0·306	1·150	21·0	79·0
May - - -	1·856	0·108	1·748	5·8	94·2
June - - -	2·213	0·039	2·174	1·7	98·3
July - - -	2·287	0·024	2·263	1·8	98·2
August - -	2·427	0·036	2·391	1·4	98·6
September -	2·639	0·369	2·270	13·9	86·1
October - -	2·823	1·400	1·423	49·5	50·5
November -	3·837	3·258	0·579	84·9	15·1
December - -	1·805	1·641	0·164	90·9	9·1
	26·778	11·112	15·666	41·5	58·5

TABLE III.

TOTAL OF EACH YEAR.				
Years.	Rain.	Filtrations.	Evaporation.	Rain, per Acre.
	Inches.	Per Cent.	Per Cent.	Tons
1836	31·0	56·9	43·1	3,139
1837	21·10	32·9	67·1	2,137
1838	23·13	37·0	63·0	2,342
1839	31·28	47·6	52·4	3,168
1840	21·44	38·2	61·8	2,171
1841	32·10	44·2	55·8	3,251
1842	26·43	44·4	55·6	2,676
1843	26·47	36·0	64·0	2,680
Mean -	26·61	41·5	58·5	2,695

TABLE IV.

APRIL to SEPTEMBER inclusive.							
Years.	Rain.	Filtration.	Evaporation.	Filtration.	Evaporation.	Rain per Acre filtrated.	Rain per Acre evaporated.
	Inches.	Inches.	Inches.	Per Cent.	Per Cent.	Tons.	Tons.
1836	12·20	2·10	10·10	17·3	82·7	212	1,023
1837	9·80	0·10	9·70	1·0	99·0	10	982
1838	10·81	0·12	10·69	1·2	98·8	12	1,082
1839	17·41	2·60	14·81	15·0	85·0	263	1,500
1840	9·68	0·00	9·68	0·0	100·0	- -	980
1841	15·26	0·00	15·26	0·0	100·6	- -	1,545
1842	12·15	1·30	10·85	10·7	89·3	131	1,099
1843	14·04	0·99	13·05	7·1	92·9	100	1,322
Mean	12·67	0·90	11·77	7·1	92·9	91	1,192
OCTOBER to MARCH inclusive.							
1836	18·80	15·55	3·25	82·7	17·3	1,574	330
1837	11·30	6·85	4·45	60·6	39·4	693	452
1838	12·32	8·45	3·85	68·8	31·2	855	393
1839	13·87	12·31	1·56	88·2	11·8	1,246	159
1840	11·76	8·19	3·57	69·6	30·4	829	362
1841	16·84	14·19	2·65	84·2	15·8	1,437	269
1842	14·28	10·46	3·82	73·2	26·8	1,059	387
1843	12·43	7·11	5·32	57·2	42·8	720	538
Mean	13·95	10·39	3·56	74·5	25·5	1,052	360

NOTE.—The quantities in the columns headed Filtration represent the required performances of drains in retentive soils. One inch of rain in depth amounts to 101·28 tons per acre.

No. III.

The next estimates furnished are those contained in a paper "On suiting the Depth of Drainage to the Circumstances of the Soil, by J. H. Charnock, an Assistant Commissioner under the Drainage Acts," given in the Journal of the Royal Agricultural Society, vol. x. part ii. pp. 515 to 518.

"Let me now direct your attention to some of those meteorological effects which, without pretending to any very intimate knowledge of that interesting science, I nevertheless believe exercise an important influence in promoting the efficiency of drainage, as well as that completeness in that operation will in its turn have an equally observable effect over meteorological causes themselves. It is very common to speak of undrained land as being *cold*, and a more significant designation could hardly be given, for it is literally so, and that at a time when, for the purposes of vegetation, it ought to be the warmest. The following observations on evaporation and filtration (for which we are indebted to the patient and carefully conducted experiments of my relation, Mr. Charles Charnock, of Holmfield House, near Ferrybridge,) present some curious facts for consideration, demonstrating the cause of, and suggesting the remedy for this baneful coldness. (See Table in next page.)

"In the first place, it is observable how much greater is the amount of evaporation from water than from land, and how near, as shown by columns 2 and 5, the evaporation from wet land is to that from water itself—hence the wetter the land the greater the evaporation, and, as the well-known consequence, the greater its excess of coldness. We have a familiar illustration of Nature's process in this particular, in the method often adopted to cool our wine on a hot summer's day, by wrapping a wet napkin round the bottle and exposing it to the full sun: as the moisture from the napkin is evaporated, the temperature of the wine declines to almost freezing-point. The schoolboy's experiment of producing ice before a fire, by incasing the vessel in wet flannel and adding a portion of salt to the water, is a similar example, with this additional lesson to the farmer—that to apply certain limes to wet land is only increasing the evil.

"You will then, in the second place, notice how much less the evaporation is in the shade than in the sun, and consequently that wet land must be the warmest when there is

An Account of Observations made, through a series of Five Years, at Holmfield House, near Ferrybridge, in the county of York,* by Charles Charnock, Esq., with a view to determine the amount of Evaporation and Filtration under the several circumstances on the Magnesian Limestone Soil.

Months.	1842.						1843.						1844.						1845.						1846.					
	Rain.	Evaporation.				Filtration.	Rain.	Evaporation.				Filtration.	Rain.	Evaporation.				Filtration.	Rain.	Evaporation.				Filtration.	Rain.	Evaporation.				Filtration.
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
		From Water.		From Soil.				From Water.		From Soil.				From Water.		From Soil.				From Water.		From Soil.				From Water.		From Soil.		
	On the Surface.	Exposed to both Sun and Wind.	Shaded from Sun, but exposed to Wind.	When Drained.	When Saturated.	Through the Soil from the Drain 3 feet deep.	On the Surface.	Exposed to both Sun and Wind.	Shaded from Sun, but exposed to Wind.	When Drained.	When Saturated.	Through the Soil from the Drain 3 feet deep.	On the Surface.	Exposed to both Sun and Wind.	Shaded from Sun, but exposed to Wind.	When Drained.	When Saturated.	Through the Soil from the Drain 3 feet deep.	On the Surface.	Exposed to both Sun and Wind.	Shaded from Sun, but exposed to Wind.	When Drained.	When Saturated.	Through the Soil from the Drain 3 feet deep.	On the Surface.	Exposed to both Sun and Wind.	Shaded from Sun, but exposed to Wind.	When Drained.	When Saturated.	Through the Soil from the Drain 3 feet deep.
January	2·70	1·69	1·13	1·66	1·59	1·04	1·48	2·57	1·71	0·69	1·87	0·79	1·31	1·61	1·08	0·85	1·50	0·46	1·74	1·53	1·02	1·28	1·49	0·46	2·18	2·07	1·58	1·22	1·94	0·96
February	0·76	1·23	0·81	0·68	1·04	0·08	3·25	2·65	1·10	2·29	2·78	0·96	2·22	1·31	0·88	1·66	1·11	0·56	0·73	0·71	0·47	0·43	0·94	0·30	0·47	2·59	1·69	0·44	2·09	0·03
March	3·48	1·92	1·28	2·40	2·52	1·08	0·95	3·05	2·03	0·72	2·43	0·23	2·27	2·13	1·42	1·58	1·50	0·69	1·88	2·91	1·94	1·33	2·89	0·55	0·93	2·56	1·55	0·86	2·16	0·07
April	1·51	2·98	1·99	1·11	2·31	0·40	2·19	3·22	2·05	1·84	2·39	0·25	0·27	3·83	2·55	0·27	3·42	—	1·54	4·79	3·19	1·05	4·06	0·39	5·97	1·91	1·27	2·98	1·49	2·99
May	2·98	4·14	2·76	2·89	3·82	0·09	2·81	2·91	1·94	2·47	2·65	0·34	0·42	5·77	3·85	0·42	4·86	—	2·24	2·84	1·99	1·97	3·26	0·27	0·82	4·52	3·02	0·73	3·89	0·09
June	1·94	4·18	2·79	1·94	4·27	—	2·31	5·12	3·41	2·10	4·86	0·21	1·24	5·31	3·58	1·20	4·95	0·04	3·18	3·10	2·06	2·98	2·98	0·25	1·65	4·88	3·25	1·58	4·73	0·07
July	3·74	4·16	2·73	3·26	3·89	0·48	2·70	3·76	2·50	2·55	3·49	0·15	2·76	4·17	2·78	2·43	4·28	0·33	3·49	2·86	1·89	3·30	2·79	0·19	2·90	4·44	2·96	2·74	4·39	0·16
August	1·49	3·36	2·24	1·37	2·39	0·12	3·99	3·71	2·57	3·77	3·74	0·22	2·85	4·70	3·14	2·44	4·63	0·41	4·61	2·56	1·70	4·24	2·43	0·37	2·65	3·08	2·05	2·46	3·28	0·19
September	2·44	2·69	1·74	2·24	2·88	0·20	1·07	2·06	1·34	0·90	2·18	0·17	1·92	4·91	3·28	1·62	3·96	0·30	1·36	2·79	1·86	0·95	2·29	0·41	1·07	2·99	1·99	1·00	3·14	0·07
October	1·12	2·00	1·37	0·92	1·99	0·20	1·10	1·80	1·20	0·82	1·93	0·28	1·41	2·79	1·86	1·17	2·93	0·24	3·36	2·77	1·84	2·69	2·89	0·67	4·09	2·23	1·49	2·40	2·76	1·69
November	3·19	2·26	1·50	2·49	1·83	0·70	2·30	1·64	1·09	1·69	1·48	0·67	1·98	2·84	1·80	1·47	2·78	0·51	1·01	2·13	1·41	0·73	2·20	0·28	1·15	1·63	1·09	0·88	1·74	0·17
December	0·76	3·00	2·14	0·60	1·49	0·16	0·28	1·68	1·78	0·27	1·39	0·01	0·35	0·79	0·53	0·29	0·93	0·06	3·04	3·57	2·38	2·36	2·87	0·68	1·36	1·79	1·10	1·09	1·67	0·27
Totals	26·11	33·61	32·48	21·56	30·02	4·55	24·49	34·17	22·72	20·11	31·19	4·28	19·00	40·16	26·75	15·40	37·85	3·60	28·18	32·56	21·75	23·26	31·09	4·92	25·24	34·69	28·04	18·38	33·28	6.76

Explanation.—Column 1.—Shows the Depth of Rain fallen, as registered by the ordinary Rain-Gauge.
Column 2.—Is the Amount of Evaporation from a Surface of Water fully exposed to both Sun and Wind.
" 3.—Is the Evaporation from Water shaded from the Sun, but exposed to the Wind.
" 4.—Is the Evaporation from what represented drained or dry land. } Into a leaden vessel, of a foot square and three feet deep, was put two feet of gravel and calcareous sand, so as to
" 5.—Is the Evaporation from the same when saturated. } represent the substratum of the farm, and the remainder filled up, to within an inch of the top, with an average quality
" 6.—Is the Amount of Water which filtered through the soil. } of soil. At the bottom a pipe was inserted which conveyed all the water that was filtered through into a bottle, which was regularly emptied and registered. The vessel was inserted in the ground to within an inch of the surface, keeping the level of the soil, inside and outside, alike, with an inch of the vessel above, to prevent any communication of water from without. The soil was kept free from weeds, and occasionally stirred, that it might not be more than ordinarily compact.

To determine the evaporation from *saturated* soil, a leaden vessel of 18 inches deep, and a foot square, was filled to within an inch of the top with soil and placed in the ground, in the same manner as the previous vessel, with a pipe level with the surface of the soil to carry off the excess of top-water into a receiver. The same quantity of water was then daily supplied to this soil as the evaporating dish of Column 2 showed was evaporated. The soil was stirred as in the former case, and thus represented wet and undrained land.

* Mr. C. C. is one of the Vice-Presidents of the *Meteorological Society of London*.

the least sun. From which cause no doubt arises that too vigorous growth of young wheat, so often observable on such land in the winter and spring months, which never fails to produce serious injury to the crop in all its subsequent stages. And, thirdly, you will remark how comparatively small a proportion of the rain which falls is shown to be carried off by filtration. Taking the average of the five years' experiments, it will be seen that only 4·82 inches, out of 24·60 inches of rain, passed through the land to the depth of three feet. We might, therefore, be led at the first glance to infer that land in general stands less in need of drainage, or may be drained by a less perfect system, than is supposed to be requisite, did not daily experience oppose such a conclusion. We must, therefore, endeavour to reconcile this seeming incongruity, and deduce at the same time, from the facts disclosed, such data as may guide us in determining the essential requisites to ensure completeness of effect in drainage.

" Now, although there can be no reason to question the accuracy of the experiments on filtration made by Mr. Dickinson, and recorded in the Journal of the Royal Agricultural Society of England, vol. v. part i., yet there is a very considerable difference in the aggregate result, as shown by them and the account before us. ' The first important fact disclosed,' says the commentator, page 148, ' is that, of the whole annual rain, about $42\frac{1}{2}$ per cent., or $11\frac{3}{10}$ inches out of $26\frac{6}{10}$, have filtered through the soil :' whereas in the Holmfield House experiments there is only shown, as we have already said, 4·82 inches out of 24·60, or about $5\frac{1}{10}$ per cent. against $42\frac{1}{2}$ per cent. This is certainly a very great and somewhat irreconcileable difference in the result of two experiments made professedly to ascertain the same fact. Now, on referring to the ' Memoirs of the Literary and Philosophical Society of Manchester,' vol. v. part ii., you will find a paper on rain, evaporation, &c., from the pen of the celebrated Dr. John Dalton (the father of the science of meteorology), wherein he explains a series of experiments made by himself and his friend Mr. Thomas Hoyle junior, to ascertain the amount of evaporation and filtration, and giving the following table of results, viz. :—

Months.	Water through the Two Pipes.			Mean.	Mean Rain.	Mean Evaporation.
	1796.	1797.	1798.			
January - - -	1·897	·680	1·774	1·450	2·458	1·008
February - - -	1·778	·918	1·122	1·273	1·801	·528
March - - - -	·431	·070	·335	·279	·902	·623
April - - -	·220	·295	·180	·232	1·717	1·485
May - - -	2·027	2·443	·010	1·493	4·177	2·684
June - - -	·171	·726	- -	·299	2·483	2·184
July - - -	·153	·025	- -	·059	4·154	4·095
August - - -	- -	- -	·504	·168	3·554	3·386
September - - -	- -	·976	- -	·325	3·279	2·954
October - - -	- -	·680	- -	·227	2·899	2·672
November - - -	- -	1·044	1·594	·879	2·934	2·055
December - - -	·200	3·077	1·878	1·718	3·202	1·484
	6·877	10·934	7·379	8·402	33·560	25·158
Rain - - -	30·629	38·791	31·259			
Evaporation - - -	23·725	27·857	23·862			

" ' Having got a cylindrical vessel of tinned iron,' says the Doctor, ' ten inches in diameter and three feet deep, there were inserted into it two pipes, turned downwards, for the water to run off into bottles: the one pipe was near the bottom of the vessel, the other was an inch from the top. The vessel was filled up, for a few inches, with gravel and sand, and all the rest with good fresh soil. Things being thus circumstanced, a regular register has been kept of the quantity of rain-water that ran off from the surface of the earth through the upper pipe (whilst that took place), and also of the quantity of that which sank down through the three feet of earth, and ran out through the lower pipe. A rain-gauge of the same diameter was kept close by, to find the quantity of rain for any corresponding time.'

" You will notice that the general result of these experiments accords pretty nearly with that of the Holmfield account; and yet it may be readily conceived that circumstances of situation and stratification may often occasion as wide a difference in the amount of filtration as is shown between Mr. Dickinson's and Mr. Charnock's observations.

" On an examination of the *details* registered in the account before us, it will be evident that the amount of filtration is not exclusively dependent on the fall of rain; but that a variety of other causes combine to affect its proportion. For instance, in March, April, May, June, and July, of 1842, the fall of rain was 13·65 inches, and the filtration for the same period was only 2·05 inches; whilst in

April 1846 there was 5·97 of rain and 2·99 of filtration. Similar instances are also noticeable in Mr. Dickinson's details. From March to October, inclusive, of 1840, a fall of 11·52 inches of rain is recorded, without any filtration; but in November 1842 the rain was 5·77, with 5 inches of filtration. Dr. Dalton's table also shows the same variations. The lesson, therefore, derivable from these experiments, so far as regards filtration by drains, is one rather of a speculative than of a definite character; for, although we are assured filtration must be secured, we are left with a large and varying margin as to the proportion. We must not, however, overlook the fact, that all the registered details show occasionally an amount of filtration nearly equal to the rain that falls, and therefore, in determining the size of pipe to be used, the ready exit of this *maximum* quantity must be provided for.'

No. IV.

On the Fitness of Soil for the Reception of the Seed in vegetable Production.

[Extract from a Lecture on Agricultural Science, by Dr. Madden, page 21.]

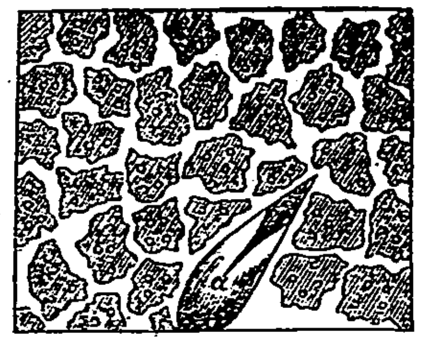
The first thing which occurs after the sowing of the seed is, of course, *germination;* and before we examine how this process may be influenced by the condition of the soil, we must necessarily obtain some correct idea of the process itself. The most careful examination has proved that the process of germination consists essentially of various chemical changes, which require for their development the presence of air, moisture, and a certain degree of warmth. Now it is obviously unnecessary for our present purpose that we should have the least idea of the nature of these processes: all we require to do, is to ascertain the conditions under which they take place; having detected these, we know at once what is required to make a seed grow. These, we have seen, are air, moisture, and a certain degree of warmth; and it consequently results, that wherever a seed is placed in these circumstances, germination will take place. Viewing matters in this light, it appears that soil does not act *chemically* in the process of germination; that its sole action is confined to its being the vehicle by means of which a supply of air and moisture and warmth can be continually kept up. With this simple statement in view, we are quite prepared

to consider the various conditions of soil, for the purpose of determining how far these will influence the future prospects of the crop, and we shall accordingly at once proceed to examine carefully into the *mechanical relations of soil.* This we purpose doing by the aid of figures.

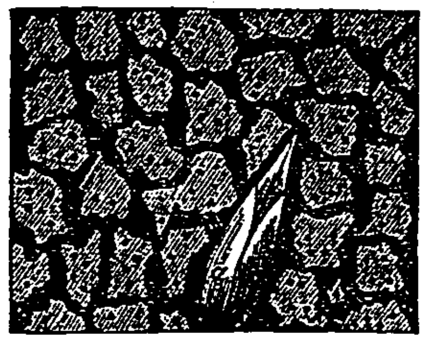
Soil, examined mechanically, is found to consist entirely of particles of all shapes and sizes, from stones and pebbles down to the finest powder; and, on account of their extreme irregularity of shape, they cannot lie so close to one another as to prevent there being passages between them, owing to which circumstance soil in the mass is always more or less *porous.* If, however, we proceed to examine one of the smallest particles of which soil is made up, we shall find that even this is not always solid, but is much more frequently porous, like soil in the mass. A considerable proportion of this finely-divided part of soil, *the impalpable matter* as it is generally called, is found, by the aid of the microscope, to consist of *broken-down vegetable tissue,* so that when a small portion of the finest dust from a garden or field is placed under the microscope, we have exhibited to us particles of every variety of shape and structure, of which a certain part is evidently of vegetable origin. In these figures I have given a very rude representation of these particles; and I must beg you particularly to remember that they are not meant to represent by any means accurately what the microscope exhibits, but are only designed to serve as a plan by which to illustrate the mechanical properties of the soil. On referring to Fig. 1 we perceive that there are two distinct classes of pores; 1st, the large ones, which exist *between* the particles of soil, and 2nd, the very minute ones, which occur in the particles themselves; and you will at the same time notice, that whereas all the larger pores—those between the particles of soil—communicate most freely with each other, so that they form canals, the small pores, however freely they may communicate with one another in the interior of the particle in which they occur, have no direct connexion with the pores of the surrounding particles. Let us now, therefore, trace the effect of this arrangement. In Fig. 1 we perceive that these canals and pores are all empty, the soil being *perfectly dry,* and the canals communicating freely at the surface with the surrounding atmosphere, the whole will of course be filled with air. If in this condition a seed be placed in the soil as at *a,* you at once perceive that it is freely supplied with air, *but there is no moisture;* therefore, when soil is *perfectly dry,* a seed cannot grow.

Let us turn our attention now to Fig. 2. Here we perceive

1.



2.

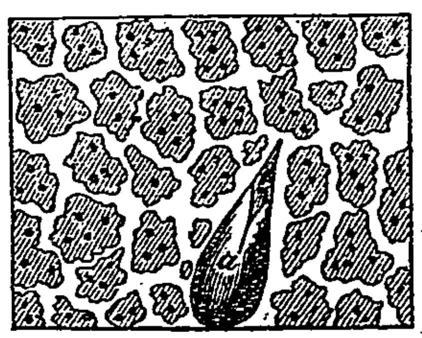


that both the pores and canals are no longer represented white, but black, this colour being used to indicate water; in this instance, therefore, water has taken the place of air, or, in other words, the soil is *very wet*. If we observe our seed *a* now, we find it abundantly supplied with water, but *no air*. Here again, therefore, germination cannot take place. It may be well to state here, that this can never occur *exactly* in nature, because water having the power of dissolving air to a certain extent, the seed *a* in Fig. 2 is in fact supplied with a *certain* amount of this necessary substance; and, owing to this, germination does take place, although by no means under such advantageous circumstances as it would were the soil in a better condition.

We pass on now to Fig. 3. Here we find a different state of matters. The canals are open and freely supplied with air, while the pores are filled with water; and consequently you perceive that, while the seed *a* has quite enough of air from the canals, it can never be without moisture, as every particle of soil which touches it is well supplied with this necessary ingredient. This, then, is the proper condition of soil for germination, and in fact for every period of the plant's development; and this condition occurs when soil is *moist* but not *wet*—that is to say, when it has the colour and appearance of being well watered, but when it is still capable of being crumbled to pieces by the hands, without any of its particles adhering together in the familiar form of mud.

Turning our eyes to Fig. 4, we observe still another condition of soil; in this instance,

3.



4.

as far as *water* is concerned, the soil is in its healthy condition —it is moist, but not wet, the pores alone being filled with water. But where are the canals? We see them in a few places, but in by far the greater part of the soil none are to be perceived; this is owing to the particles of soil having adhered together, and thus so far obliterated the interstitial canals that they appear only like pores. This is the state of matters in every *clod of earth*, *b*; and you will at once perceive, on comparing it with *c*, which represents a stone, that these two differ only in possessing a few pores, which latter, while they may form a reservoir for moisture, can never act as vehicles for the *food* of plants, as the roots are not capable of extending their fibres into the interior of a clod, but are at all times confined to the interstitial canals.

With these four conditions before us, let us endeavour to apply them *practically* to ascertain when they occur in our fields, and how those which are injurious may be obviated.

The first of them, we perceive, is a state of too great dryness, *a very rare* condition, in this climate at least; in fact, the only case in which it is likely to occur is in very coarse sands, where the soil, being chiefly made up of pure sand and particles of flinty-matter, contains comparatively much fewer pores, and, from the large size of the individual particles, assisted by their irregularity, the canals are wider, the circulation of air freer, and, consequently, the whole is much more easily dried. When this state of matters exists, the best treatment is to leave all the stones which occur on the surface of the field, as they cast shades, and thereby prevent or retard the evaporation of water.

We will not, however, make any further observations on this very rare case, but will rather proceed to Fig. 2, a much more frequent, and, in every respect, more important condition of soil: I refer to an *excess of water*.

When water is added to perfectly dry soil, it of course, in the first instance, fills the interstitial canals, and from these enters the pores of each particle; and if the supply of water be not too great, the canals speedily become empty, so that the whole of the fluid is taken up by the pores: this, we have already seen, is the *healthy* condition of soil. If, however, the supply of water be too great, as is the case when a spring gains admission into the soil, or when the sinking of the fluid through the canals to a sufficient depth below the surface is prevented, it is clear that these also must get filled with water so soon as the pores have become saturated. This, then, is the condition of *undrained soil*.

Not only are the pores filled, but the interstitial canals are likewise full; and the consequence is, that the whole process of the germination and growth of vegetables is materially interfered with. We shall here, therefore, briefly state the injurious effects of an excess of water, for the purpose of impressing more strongly on your minds the necessity of thorough-draining, as the first and most essential step towards the improvement of your soil.

The *first* great effect of an excess of water is, that it produces a corresponding diminution of the amount of air beneath the surface, which air is of the greatest possible consequence in the nutrition of plants; in fact, if entirely excluded, germination could not take place and the seed sown would, of course, either decay or lie dormant.

Secondly, an excess of water is most hurtful, by reducing considerably the *temperature* of the soil: this I find by careful experiment to be to the extent of 6½ degrees Fahrenheit in summer, which amount is equivalent to an elevation above the level of the sea of 1,950 feet. So that, supposing two fields lying side by side, the one drained, the other undrained, and supposing them both equally well cultivated, there will be nearly as much difference in the amount and value of their respective crops, as if the drained one was situated at the level of the sea, and the other had an elevation as high as the most lofty of the Pentland Hills.* But, besides this, and what is nearly equally bad, the temperature is rendered unnaturally high during winter; whereas it has been proved that one great source of health and vigour in vegetation is the great difference which exists between the temperature of summer and winter, which difference amounts in dry soil to between thirty and forty degrees, while in soil very much injured by an excess of water the whole range of the thermometer throughout the year will probably not exceed from six to ten degrees.

These are the two chief injuries of an excess of water in soil which affect the soil itself. There are very many others affecting the climate, &c.; but these not so connected with the subject in hand as to call for an explanation here.

Of course all these injurious effects are at once overcome by thorough-draining, the result of which is to establish a direct communication between the interstitial canals and the drains, by which means it follows that no water can remain

* Of course the field of high elevation must be *thoroughly* drained to equal even the *undrained* field at the level of the sea.

any length of time in these canals without, by its gravitation, finding its way into the drains.

The 4th Figure indicates badly-cultivated soil, or soil in which large unbroken clods exist; which clods, as we have already seen, are very little better than stones, on account of their impermeability to air and the roots of plants.

Too much cannot be said in favour of pulverising the soil; even thorough-draining itself will not supersede the necessity of performing this most necessary operation. The whole valuable effects of ploughing, harrowing, grubbing, &c., may be reduced to this: and almost the whole superiority of *garden* over *field* produce is referable to the greater perfection to which this pulverising of the soil can be carried.

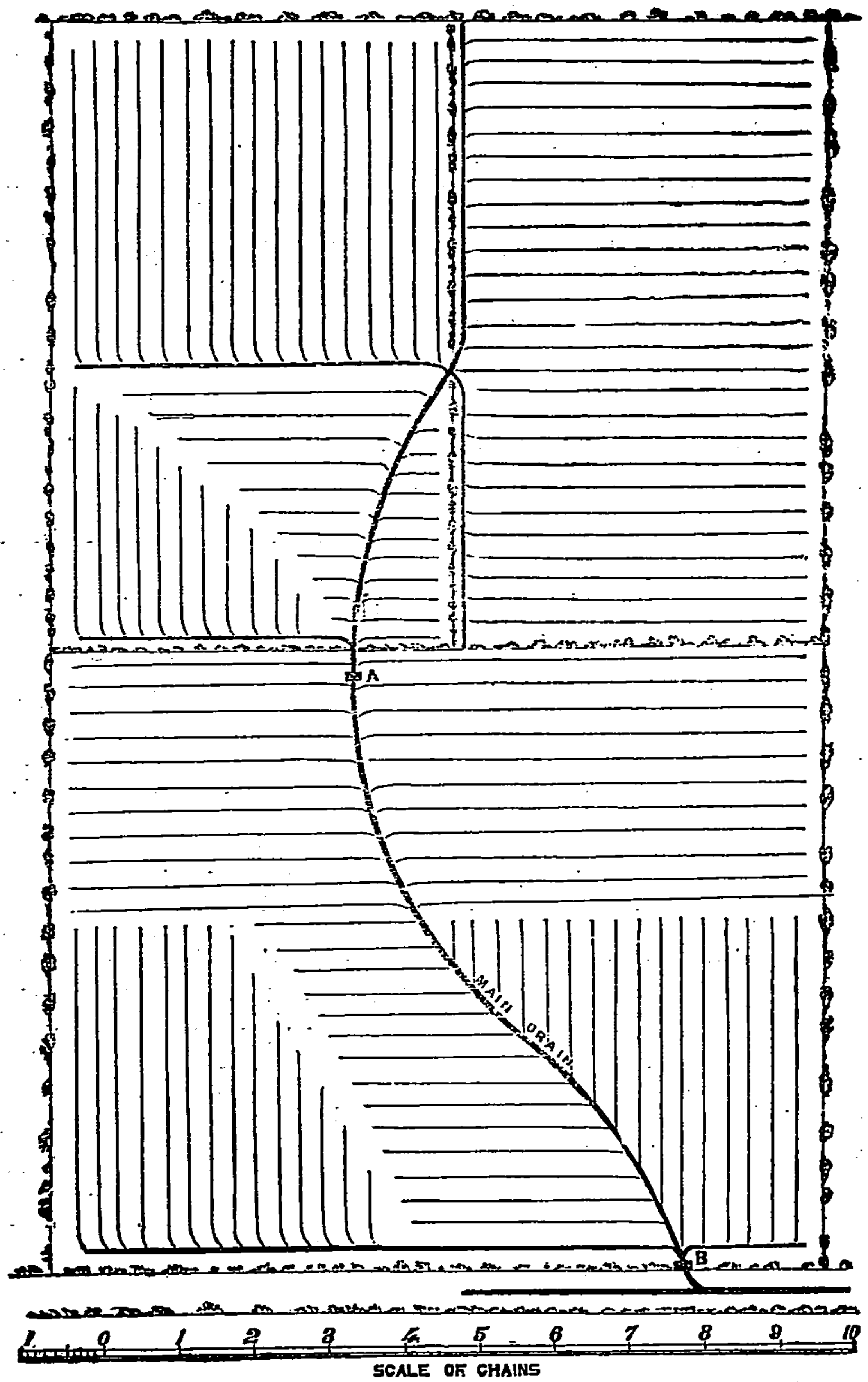
The immortal Jethro Tull has the honour of having first directed the farmer's attention forcibly to this subject; and so deeply impressed was he with its infinite importance, that he believed the use of manure could be entirely superseded, were this pulverising carried to a sufficient extent.

The whole success of the drill husbandry is owing, in a great measure, to its enabling you to stir up the soil well during the progress of your crop; which stirring up is of no value beyond its effect in more minutely pulverising the soil, increasing, as far as possible, the size and number of the interstitial canals.

Lest any one should suppose that the contents of these interstitial canals must be so minute that their whole amount can be of but little consequence, I may here notice the fact, that in moderately well pulverised soil they amount to no less than one fourth of the whole bulk of the soil itself: for example, 100 cubic inches of *moist* soil (that is, of soil in which the pores are filled with water while the canals are filled with air) contain no less than 25 cubic inches of air. According to this calculation, in a field pulverised to the depth of 8 inches, a depth perfectly attainable on most soils by careful tillage, every imperial acre will retain beneath its surface no less than 12,545,280 cubic inches of air. A familiar illustration of the space occupied by the spaces between the particles of loosened soil is afforded by the fact that when soil is disturbed it more than fills the space it previously occupied.

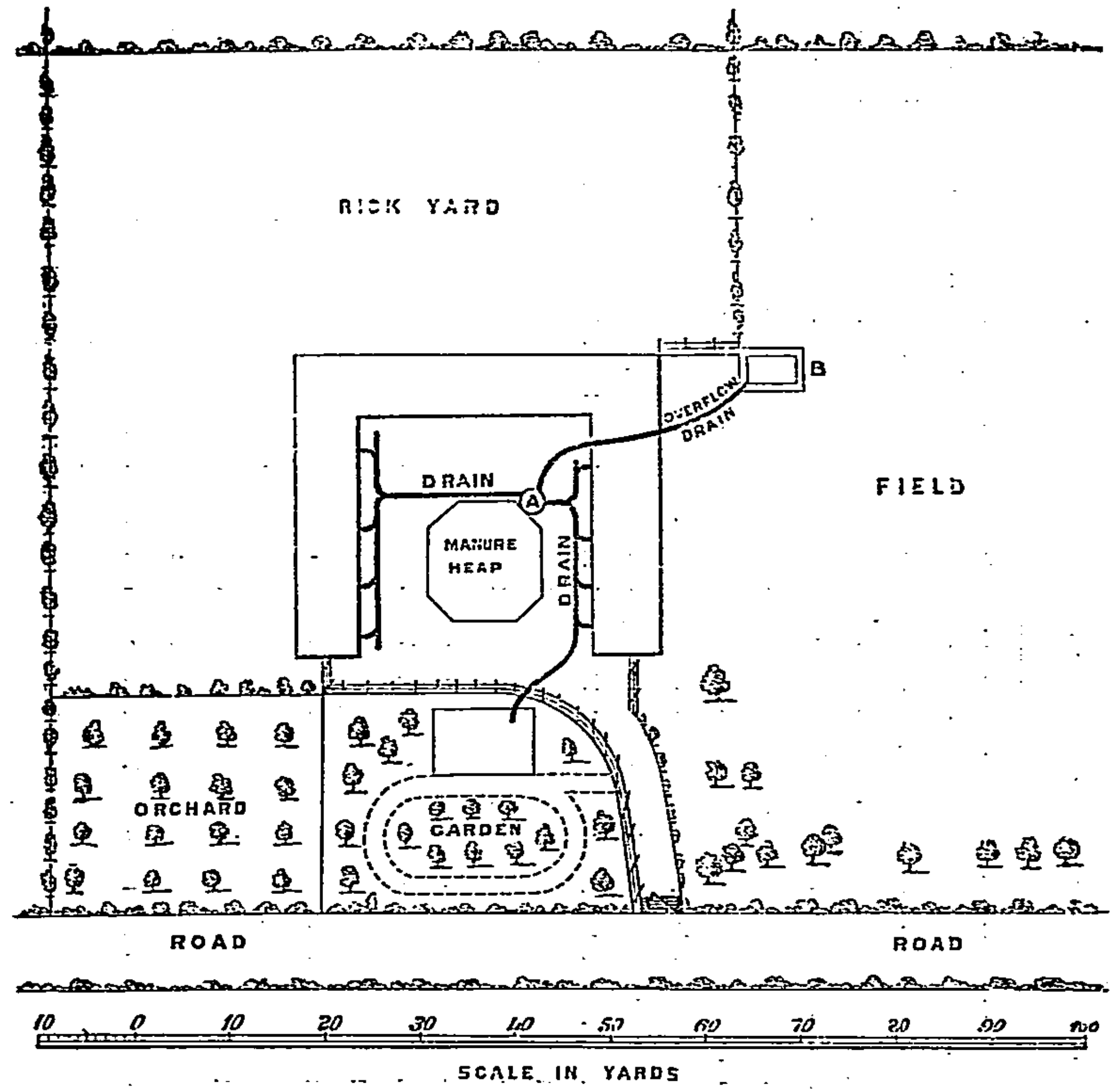
Taking into calculation the weight of soil, we shall find that with every additional inch which you reduce to powder (by ploughing, for example, 9 inches in place of 8), you call into activity 235 tons of soil, and render it capable of retaining beneath its surface 1,568,160 additional cubic inches of air. And, to take one more element into the calculation, supposing the soil were not properly drained, the sufficient pulverising of an additional inch in depth would increase the escape of water from the surface by upwards of 100 gallons a day.

A PLAN OF LAND DRAINS.



The letters A B *indicate where the sand pits may be placed.*

PLAN OF FARM HOMESTEAD.



A *Liquid manure tank.*

B *Supplementary tank for receiving the overflow from the tank in the court yard.*

No. V.—*Table of the Cost of Drain Tiles or Pipes, and Labour, per Acre.*

Distance of Drains apart in feet.	Per Acre.		Cost of Drain Tiles or Pipes per Acre, at various Prices of Tiles per Thousand.														
	Number of Rods of 5½ yards each.	Number of Feet or Tiles.	6s.	10s.	12s.	15s.	16s.	17s.	17s. 6d.	18s.	19s.	20s.	21s.	22s.	23s.	24s.	25s.
			£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
15	176	2,904⅓	0 17 5½	1 9 0½	1 14 10½	2 3 7	2 6 6	2 9 4½	2 10 10	2 12 3¼	2 15 2	2 18 0¾	3 0 11¾	3 3 11	3 6 9	3 9 8	3 12 7
16	165	2,722½	0 16 4¼	1 7 2¾	1 12 8½	2 0 10½	2 3 6½	2 6 3¼	2 7 7½	2 8 1¾	2 11 8½	2 14 5	2 16 8¼	2 18 11½	3 1 3	3 5 3¾	3 8 9½
16½	160	2,640	0 15 10½	1 4 6¾	1 11 9	1 19 8	2 2 3	2 2 10½	2 6 2¼	2 7 6	2 0 2	2 12 9½	2 15 5	2 18 0½	3 0 8	3 3 3½	3 6 0
18	146½	2,420	0 14 7	1 4 2¼	1 9 2	1 16 4	1 18 8½	2 1 1½	2 2 4	2 3 6½	2 6 0	2 8 4¾	2 10 9¾	2 13 2¾	2 15 10	2 18 0¾	3 0 6
20	132	2,178	0 13 1	1 1 9½	1 6 1½	1 12 7½	1 14 10	1 17 0¼	1 18 1¼	1 19 2¾	2 1 4½	2 3 6½	2 5 8½	2 7 10½	2 10 0	2 12 2	2 14 5¼
21	125	2,075	0 12 5½	1 0 9	1 4 11	1 11 1½	1 13 2	1 15 3	1 16 3¼	1 17 4	1 19 5	2 1 5¾	2 3 6½	2 5 7½	2 7 8¼	2 9 8¾	2 11 10
22	120	1,980	0 11 10½	0 19 9½	1 3 8½	1 9 9	1 11 8	1 13 8	1 14 7	1 16 6	1 18 5	1 19 7	2 1 6	2 3 5	2 5 4	2 7 4	2 9 6
23	115	1,894	0 11 4½	0 18 11¼	1 3 9	1 8 5	1 10 1½	1 12 2¼	1 13 2	1 14 1	1 15 11¾	1 17 10½	1 19 9¼	2 1 8	2 3 6¾	2 5 5½	2 7 4½
24	110	1,816	0 10 10¾	0 18 2	1 1 9½	1 7 3	1 9 0½	1 10 10¼	1 11 9	1 12 8	1 14 6	1 16 3½	1 18 1½	1 19 11½	2 1 8	2 3 6	2 5 5½
25	105½	1,742	0 10 5½	0 17 5	1 0 11	1 6 2	1 7 10¼	1 9 7¼	1 10 6	1 11 4¼	1 13 1½	1 14 10	1 16 7	1 18 4	2 0 1	2 1 10	2 3 6½
27	97⅔	1,613	0 9 9½	0 16 1½	0 19 7	1 4 2½	1 5 9½	1 7 5	1 8 2½	1 9 0	1 10 7	1 12 3	1 13 10¼	1 15 5½	1 17 0¾	1 18 6	2 0 3¾
28	94½	1,556	0 9 4	0 15 6¾	0 18 8	1 3 4	1 4 10½	1 6 4	1 7 1	1 7 10	1 9 5	1 11 1	1 12 7¾	1 14 2¼	1 15 9	1 17 3¾	1 18 0½
30	88	1,452	0 8 8½	0 14 6¼	0 17 5	1 1 9½	1 3 3	1 4 8	1 5 6	1 6 1½	1 7 7	1 9 0½	1 10 6	1 11 11½	1 13 5½	1 14 10½	1 16 3
32	82½	1,362	0 8 2	0 13 7½	0 16 4	1 0 5	1 1 9¼	1 3 1½	1 4 4	1 5 6	1 6 10¼	1 7 2½	1 8 7	1 9 11¼	1 11 3½	1 12 8	1 14 0½
33	80	1,320	0 7 11	0 13 2½	0 15 10	0 19 10	1 1 1¼	1 2 5¼	1 3 1½	1 3 9	1 5 1	1 6 4¾	1 7 8½	1 9 0½	1 10 4½	1 11 8	1 12 11
35	75½	1,244	0 7 5½	0 12 5¼	0 14 11	0 18 8	0 19 10½	1 1 2	1 1 9	1 2 5	1 3 8	1 4 10½	1 6 1½	1 7 4¼	1 8 7¼	1 9 10	1 11 1
36	73⅓	1,209	0 7 3	0 12 1	0 14 6	0 18 2	0 19 4	1 0 6½	1 1 2	1 2 4	1 3 6	1 4 2	1 5 4	1 6 6	1 7 8	1 8 10	1 10 0
39	68	1,117	0 6 8½	0 11 2	0 13 5	0 16 9½	0 17 10	0 19 0	0 19 6½	1 0 1¼	1 1 2½	1 2 4	1 3 5½	1 4 7	1 5 9	1 6 9	1 7 11
40	66	1,089	0 6 7	0 10 11¾	0 13 2	0 16 4	0 17 5	0 18 6	0 19 1	0 19 7	1 0 8	1 1 9¼	1 2 10½	1 3 11½	1 5 0¾	1 6 2	1 7 5
42	63	1,037	0 6 2¾	0 10 4½	0 12 5½	0 15 7	0 16 7	0 17 1½	0 18 1	0 18 8	0 19 8	1 0 8¾	1 1 9	1 2 9¼	1 3 9½	1 4 10	1 5 10¾
45	59	974	0 5 10	0 9 9	0 11 8¼	0 14 6	0 15 5½	0 16 5¼	0 16 11	0 17 5	0 18 5	0 19 4	1 0 4	1 1 3	1 2 3	1 3 2½	1 4 2
48	55	907	0 5 5½	0 9 1	0 10 10½	0 13 7½	0 14 6	0 15 5	0 15 9¼	0 16 4	0 17 2½	0 18 1½	0 19 0½	0 19 11½	1 0 11	1 1 10	1 2 9¼
49½	53⅓	880	0 5 3¼	0 8 9½	0 10 6½	0 13 3	0 14 1	0 14 11½	0 15 4½	0 15 10	0 16 8	0 17 7	0 18 5½	0 19 4	1 0 2½	1 1 1	1 1 11½
50	52⅔	871	0 5 2¾	0 8 8½	0 10 5½	0 13 1	0 13 11	0 14 9½	0 14 5½	0 15 8¼	0 16 7	0 17 5	0 18 3½	0 19 1½	1 0 0	1 0 10¼	1 1 8½

Distance of Drains apart in feet.	Per Acre.		Cost of Drain Tiles or Pipes per Acre, at various Prices of Tiles per Thousand.				Cost of cutting and filling Drains per Acre, at various Prices per Rod.										
	Number of Rods of 5½ yards each.	Number of Feet or Tiles.	27s.	28s.	29s.	30s.	2¾d.	3d.	3¼d.	3½d.	3¾d.	4d.	4¼d.	4½d.	4¾d.	5d.	5½d.
			£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
15	176	2,904⅓	3 18 5	4 1 4	4 4 3	4 7 2	2 0 4	2 4 0	2 7 8	2 11 4	2 15 0	2 18 8	3 2 4	3 6 0	3 9 0	3 14 4	4 0 8
16	165	2,722½	3 12 7	3 14 10½	3 19 4½	4 1 7¾	1 17 9¾	2 1 3	2 4 8½	2 8 1½	2 11 6¾	2 15 0	2 18 5½	3 1 10½	3 5 3¾	3 8 9	3 15 7½
16½	160	2,640	3 11 3	3 13 10	3 16 6½	3 19 2	1 16 8	2 0 0	2 3 4	2 6 8	2 10 0	2 13 4	2 16 8	3 0 0	3 3 4	3 6 8	3 10 0
18	146½	2,420	3 5 4	3 7 9	3 10 2	3 12 7	1 13 7½	1 16 9	1 19 8	2 2 10½	2 5 11¼	2 9 0	2 12 0¾	2 15 1½	2 18 2½	3 1 3	3 7 4½
20	132	2,178	2 18 9½	3 1 0	3 3 2	3 5 4	1 10 3	1 13 3	1 15 9	1 18 6	2 1 3	2 4 0	2 6 9	2 9 6	2 12 3	2 15 0	3 0 6
21	125	2,075	2 16 0	2 18 0¾	3 0 2	3 2 2½	1 8 8	1 11 4½	1 14 0	1 16 7	1 19 2	2 1 10	2 4 5	2 7 0½	2 9 8	2 12 3½	2 17 5½
22	120	1,980	2 13 5	2 15 5	2 17 5	2 19 4¾	1 7 6	1 10 0	1 12 6	1 15 0	1 17 6	2 0 0	2 2 6	2 5 0	2 7 6	2 10 0	2 15 0
23	115	1,894	2 11 2½	2 13 0¾	2 14 11½	2 15 5½	1 6 4½	1 8 9	1 11 2	1 13 6½	1 15 11¼	1 18 4	2 0 9	2 3 1½	2 5 6½	2 7 11	2 12 8
24	110	1,816	2 9 1	2 10 10½	2 12 8½	2 14 5½	1 5 2½	1 7 6	1 9 9½	1 12 1	1 14 4½	1 16 8	1 18 11½	2 1 3	2 3 6½	2 5 10	2 10 5
25	105½	1,742	2 7 0½	2 8 9½	2 10 6½	2 12 3	1 4 2	1 6 4½	1 8 7	1 10 9	1 12 11½	1 15 2	1 17 4½	1 19 7	2 1 9	2 3 11½	2 8 5
27	97⅔	1,613	2 3 6	2 5 1	2 6 8¼	2 8 4½	1 2 4	1 4 6	1 6 6	1 8 7	1 10 7½	1 12 8	1 14 8¼	1 16 9	1 19 9½	2 0 10	2 4 11
28	94½	1,556	2 0 5	2 3 6	2 5 1	2 6 7¾	1 1 8	1 3 7½	1 5 7	1 7 6	1 9 6	1 11 6	1 13 6	1 15 5½	1 17 5	1 19 4½	2 3 4
30	88	1,452	1 19 2	2 0 7½	2 2 1	2 3 6¾	1 0 2	1 2 0	1 3 10	1 5 8	1 7 6	1 9 4	1 11 2	1 13 0	1 14 10	1 16 8	2 0 4
32	82½	1,362	1 16 9	1 18 1¼	1 19 5½	2 0 10	0 18 11	1 0 7½	1 2 4	1 4 1	1 5 9	1 7 6	1 9 3	1 10 11½	1 12 8	1 14 4½	1 17 9½
33	80	1,320	1 15 6	1 16 10	1 18 1½	1 19 7	0 18 4	1 0 0	1 1 8	1 3 4	1 5 0	1 6 8	1 8 4	1 10 0	1 11 8	1 13 4	1 16 8
35	75½	1,244	1 13 7	1 14 10	1 16 1	1 17 4	0 17 4	0 18 10	1 0 5	1 2 0	1 3 7	1 5 2	1 6 9	1 8 4	1 9 11	1 11 5½	1 14 7
36	73⅓	1,209	1 12 7	1 13 9	1 15 0	1 16 3	0 16 9	0 18 4	0 19 11	1 1 5½	1 2 11	1 4 5	1 6 0	1 7 6	1 9 0	1 10 6½	1 13 6
39	68	1,117	1 10 2	1 11 3½	1 12 5	1 13 6	0 15 7	0 17 0	0 18 5	0 19 10	1 1 3	1 2 8	1 4 1	1 5 6	1 6 11	1 8 4	1 11 2
40	66	1,089	1 8 6	1 9 7	1 10 8	1 12 8	0 15 1½	0 16 6	0 17 10½	0 19 3	1 0 7½	1 2 0	1 3 4½	1 4 9	1 6 1½	1 7 6	1 10 3
42	63	1,037	1 7 10¾	1 8 11	1 10 0¼	1 11 1¼	0 14 5½	0 15 9	0 17 1	0 18 4½	0 19 8¼	1 1 0	1 2 2	1 3 7½	1 4 11½	1 6 3	1 8 10½
45	59	974	1 6 0	1 7 0	1 8 0	1 9 0	0 13 6¼	0 14 9	0 16 0	0 17 2½	0 18 5½	0 19 8	1 0 11	1 2 1½	1 3 4½	1 4 7	1 7 0½
48	55	907	1 4 7	1 5 6¼	1 6 5	1 7 4½	0 12 7½	0 13 9	0 14 11	0 16 0½	0 17 2½	0 18 4	0 19 6	1 0 7½	1 1 9¼	1 2 11	1 5 2½
49½	53⅓	880	1 3 8½	1 4 7	1 5 5½	1 6 5	0 12 2	0 13 4	0 14 5½	0 15 7	0 16 8	0 17 9½	0 18 10½	1 0 0	1 1 2	1 2 3	1 4 5
50	52⅔	871	1 3 5	1 4 3½	1 5 1½	1 6 1½	0 12 0	0 13 2	0 14 4	0 15 5	0 16 7	0 17 8	0 18 9	0 19 10½	1 0 11¾	1 2 1	1 4 3½

G. DONALDSON, *Assistant Surveyor.*

No. VI.

Cost at which tubular drain pipes were manufactured, in the course of experiments instituted by order of the Metropolitan Commissioners of Sewers as to the cost and manufacture of earthenware pipes:—

Size of pipes, inches in diameter.	Materials.		Cost of materials, labour, and burning, per 1,000 feet.					
	Clay.	Coals, 1 cwt. to a ton of clay.	Cost of clay, say at 7*s.* per ton, including royalty, digging, &c.	Labour in pugging, &c., at 2*s.* per ton.	Labour in moulding, carrying to drying shed, and attendance during drying.	Cost of coals, at 20*s.* per ton.	Extra for management, kiln-rent, waste, labour, packing, and drawing kiln.	Total prime cost per 1,000 feet in the field.
	ton. ct. lbs.	cwt.	£ *s.* *d.*	*s.* *d.*	£ *s.* *d.*	*s.* *d.*	£ *s.* *d.*	£ *s* *d.*
5	4 0 20	4	1 8 0	8 0	1 0 0	4 0	1 10 0	4 10 0
6	5 15 0	5¾	2 3 0	11 6	1 8 9	5 9	2 3 1	6 9 4
7½	6 16 70	6¾	2 9 9	13 7	1 14 2	6 9	2 12 0	7 16 1
8½	8 18 50	9	3 2 5	17 10	2 4 8	9 0	3 7 0	10 0 11

These pipes were moulded and burnt in the improved kilns of the Ainslie Tile Company. The above table shows the quantity of material, and the cost of each part of the production. The total shows what may be called the net prime cost of the goods at the kiln: a large percentage should of course be added for profit, carriage, &c. &c.

Each process of the manufacture is capable of very considerable improvement in respect of expense, time, and quality. It will, however, be seen by the following table, that, with the present incomplete and imperfect appliances, a very large reduction may be anticipated in the cost of these descriptions of goods, a result of the very highest importance, contemplating the immediate and large demand for sanitary purposes.

Table contrasting the prices of tubular drain-pipes.

Fifty per cent. is here added to the prices in the foregoing table for profit, carriage, &c. &c.

Size of pipes, inches in diameter.	Lengths.	Red earthenware pipes, if made by contract.	Red earthenware pipes at the present sale prices.	Stoneware glazed at the present sale prices.	Average gain. On red earthenware pipes, if made by contract, over the present prices.	Average gain. On red earthenware pipes, if made by contract, over glazed stoneware pipes.
		£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
	Per foot	0 0 1½	0 0 5	0 0 6	0 0 3½	0 0 4½
5	Per 1,000 feet	6 15 0	20 16 8	25 0 0	14 1 8	18 5 0
	Per mile	35 12 9	110 0 0	132 0 0	74 7 3	96 7 3
	Per foot	0 0 2¼	0 0 6	0 0 7	0 0 3¾	0 0 4¾
6	Per 1,000 feet	9 14 0	25 0 0	29 3 4	15 6 0	19 9 4
	Per mile	51 4 4	132 0 0	154 0 0	80 15 8	102 15 8
	Per foot	0 0 3¾	0 0 9	0 1 0	0 0 5¼	0 0 8¼
9	Per 1,000 feet	15 1 6	37 10 0	50 0 0	22 8 6	34 18 6
	Per mile	79 11 10	198 0 0	264 0 0	118 8 2	184 8 2

No. VII.

Queries issued at the request of the Metropolitan Sanitary Commissioners by the Right Honourable the Earl of Carlisle regarding the Drainage of Land; with Answers to the same by

James Smith, Esq., of Deanston.
Josiah Parkes, Esq.
Lucius Henry Spooner, Esq., Balmacara House, Loch Alsh.
Alexander Maccaw, Esq., Ardlochan, Maybole.
James F. Beattie, Esq., Surveyor and Valuator, Aberdeen.
Edward Scott, Esq.
Robert Neilson, Esq., Hallwood.

(*November*, 1848.)

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1. Can you give any examples of the effects of thorough-drainage in improving the healthiness of localities as respects both the population and the cattle, or stock?

(*Mr. Smith.*) In the alluvial clay districts of Stirlingshire, and west of Perthshire, where the drainage was formerly effected by large open ditches, in the Dutch fashion, ague was periodically prevalent, and rheumatism, fevers, and scrofulous affections were much promoted, until the introduction of thorough-drainage, 40 years ago; after which period those diseases began to disappear, or to be greatly mitigated in severity. Few cases of ague now appear. Fevers are seldom known, except in the usual course of fevers which prevail epidemically over the whole country; and it is generally observed by the inhabitants that their cattle or stock are now less subject to diseases. In the undrained condition of those districts they were subject to dense fogs, especially in the autumnal months when much rain had fallen, communicating a chilly feeling to the inhabitants; but since the general introduction of thorough-draining those fogs seldom prevail, unless in a general foggy tendency of the atmosphere of the country.

On the farm of Deanston, in the west of Perthshire, consisting of about 200 acres, and which was the first farm on which the entire system of thorough-draining and subsoil-ploughing was introduced, there was a marked effect produced. The farm, after periods of rain, used to be covered with chilly fogs, which entirely disappeared after the thorough-draining was effected. The cattle grazing on the farm were much subject to the disease called "red water;" since the draining there has been no case of that disease. In other parts of Scotland and England similar results have been stated to have followed the introduction of thorough-drainage.

(*Mr. Parkes.*) The complete drainage of town and rural districts is universally admitted to be conducive to the health of both man and animals. The medical profession are, however, best qualified to give testimony to the one, and veterinary surgeons to the other.

The disease of foothalt in sheep and deer has been perfectly removed in many gentlemen's parks, and in extensive pasturage grounds, by deep under drainage. The earlier seasonable maturity of venison, and a greatly improved flavour, are also the acknowledged results of complete drainage. Foothalt, however, is known to occur where sheep are turned on very luxuriant herbage, kept continually moist from the state of the atmosphere, though the land be not wet; so that drainage alone will not, on all soils, and at all times, exempt animals from suffering from this disease.

In respect of increased salubrity induced in towns and rural districts by drainage, I may instance the acknowledged disappearance of ague and other periodical maladies consequent on the great drainages effected in Cambridgeshire—as in the Isle of Ely, &c.—and in the Lincolnshire and other great marshes.

As an example of the good effects arising from the drainage of swamps, I may state that the Commissioners of her Majesty's Woods and Forests, of which your lordship is the chief, have recently caused me to drain an extensive tract of country in the New Forest, called the Weare's Lawn and Bog, adjoining which is a small hamlet, whose inhabitants previously suffered much from intermittent fevers. The hamlet is now healthy; the offensive gaseous emanations from the soil have ceased; and the inhabitants are supplied with abundance of the purest spring water, discovered during the operations of drainage, and appropriated to their use.

(*Mr. Spooner.*) Beyond the general improvement in a sanitary point of view, and the diminution of fever and ague, acknowledged to have resulted from the drainage of the fen districts of Cambridgeshire and Lincolnshire, and the marshes of Essex, I am not acquainted with cases in which improvement in the health of population can be traced to drainage as a sole cause; but in respect to stock a striking instance can be adduced of improvement in healthiness resulting from drainage alone, and attributable to no other cause. In the Highlands generally, and more particularly on the west coast, there exists a well known and fatal disease among sheep, incurable by any treatment, termed "Braxey," which on undrained lands and in wet seasons is a cause of very serious losses. This is, in a great measure, prevented by drainage, and the diminution of casualties alone is more than sufficient to cover its cost, independently of the increased quantity

and better quality of the fodder produced. This system has been extensively practised for several years, and invariably with the same beneficial results.

(*Mr. Maccaw.*) I cannot speak decidedly as to its effects on population; but from the evidence of parties still living fever and ague prevailed previous to the drainage of a marsh in my immediate neighbourhood, where that epidemic has not been known since. Similar instances of the same nature over the country have been well authenticated.

As to the health of cattle or stock I have the strongest evidence of the beneficial effects of drainage in many instances. On the lands which I possess, and on several others in the district, a disease called red water prevailed, in some years proving very fatal; but after drainage and cultivation of the marshy parts of the pasturage the stock has been free of that disease. I may mention that the first and most severe cases of pleura pneumonia in cattle that had occurred in this and a neighbouring county were on lands of a swampy undrained character. The surface drainage of sheep walks in every district is well known to promote the healthiness of the stock; and I believe the thorough drainage of a single swamp in any locality will be an important means of improving the health both of the population and stock connected with it.

(*Mr. Beattie.*) I am unable to state anything specially on this head. It is apparent that animals have more comfort and thrive better on dry lands than on wet.

I am aware of instances where marsh lands have been dried, and all the disagreeables and injurious effects arising from the swamps removed, such as frosts, fogs, and blights, &c. These lands have been again allowed to become wet, and all the evils formerly complained of have returned.

Where undrained lands produce bad herbage for the food of stock, and their influence in the neighbourhood are injurious to crops that produce the food of man, they must of necessity be injurious to the health of the population and stock, independent of the injurious influence of the atmosphere, which cannot be so easily determined.

(*Mr. Scott.*) The effects of thorough-drainage are very apparent in Roxburghshire within the last few years; formerly the agricultural labourers suffered greatly from the ague, and now a case seldom occurs. On well-drained lands cattle are not so subject to diseases of the lungs or violent colds.

(*Mr. Neilson.*) In the Altcar Meadows, belonging to the Earl of Sefton, a low level district about 8 to 10 miles north of Liverpool, a water-wheel was erected about 5 years ago, for the purpose of relieving the land from inundation; and though thorough-drainage has been very little adopted, the inhabitants already speak of the increased salubrity of the locality, while the equally increased fertility of the land has created a marked improvement in the condition of the stock. In my own neighbourhood, some low flat land of a stiff clay soil, and lying extremely wet, always had a scouring effect on the young stock turned on it in spring; and no application of manure produced any alteration. It was drained, and, without any other change in the management, the same species of stock throve on it extremely well.

This is easily accounted for; the wet prevented the manure from fermenting, and fostering that species of herbage best calculated to promote the vigorous growth of animal substances, and the land became covered with a verdure quite unsuited for that purpose.

The withdrawal of the water produced fermentation; the aquatic plants were superseded by a more food-producing species, carbonic acid gas was more speedily absorbed, and, instead of the exhalations of the marsh, a purer oxygen was evolved, increasing both the salubrity of the atmosphere and the condition of the stock.

I have also had several opportunities of witnessing similar effects in the West Indies, and particularly in British Guiana, where I resided several years. The surface is almost a dead flat, lower than the sea at high water, and drained only at considerable expense by large sluice-gates for each estate, which are opened each period of low water.

When an estate is abandoned this is neglected, and its neighbourhood is invariably the first to suffer on the approach of an epidemic; and I have known instances of the course of a fever thus produced being checked, and materially altered, by the neighbouring lands being drained, an alteration considerably accelerated by a small quantity of lime, in a finely-powdered state, being distributed on the lands during a windy day.

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2. Are there any instances of the application of drainage to forests, woods, and plantations? If so, with what effect, or with what expectations? Give especially any results applicable to suburban districts laid out as garden ground, or planted with ornamental timber?

(*Mr. Smith.*) Instances of the application of thorough-drainage to forests, woods, and plantations are few, although it is quite obvious that the application of the principle would be of immense advantage, both as regards the growth and quality of the timber, and as regards the influence on the wholesomeness of the atmosphere in the neighbourhood. About 25 years ago I made a comparative experiment of the effects of thorough-draining and subsoil-ploughing upon a small plantation on the farm of Deanston. I had in extent about an acre thoroughly drained and subsoil ploughed, adjoining several acres in a natural condition, but more dry. The whole was planted with forest trees, consisting of oak, elm, sycamore, larch, and Scotch and spruce firs. The trees upon the drained portion made rapid

progress from the start, and at the end of a period of six years they had attained double the height of those on the undrained land, with a healthy and vigorous appearance. At the end of the sixth year I had those portions drained which had been left undrained at first, and the result was that the trees began to make more rapid progress, although they are not even now advanced so far as the trees which grow upon the land drained before planting. The general practice of drainage for plantations is to dig drains of from 12 to 16 inches in depth, but most commonly the former, in the decidedly wet places only, leaving the drains open, by which they get choked in a short time with leaves, &c.; and never, in their best state, can they, from want of depth, effectuate thorough dryness, or any complete percolation of the rain-water through the soil. I have long recommended the uniform and complete drainage of woodlands by deep *covered* drains, which would be sufficiently efficacious at double or treble the distance that is necessary in arable land; but I have never yet been able to induce any one to follow out the recommendation on an extensive scale.

In the Island of Lews, where I directed some land improvements, I had some extent of thorough-drainage executed in deep moss land to receive plantation. The drains were made from 4 to 4½ feet deep, and were placed at from 40 to 50 feet apart. This land has been planted about two years, and so far the plants seem to thrive well; but of course there can be no certainty of the successful growth of large timber. I have always observed that where ground in woodland was laid dry by any accidental circumstances, there trees of all descriptions were found to grow in a superior manner.

Blights are often found to affect crops on fertile cultivated lands from the passage over them of currents of damp air, arising from extensive tracts of damp woodland in their neighbourhood.

In several of the suburban districts of large towns, considerable expense has been incurred in many instances in the drainage of land for ornamental timber; and in many instances where thorough-drainage has been effected for agricultural purposes, timber growing in the fields and hedge-rows has been improved in growth from the effects of the drainage.

(*Mr. Parkes.*) The following statement of the cost of draining a village may be interesting to the Board, although I am unable to state results in respect of increased salubrity in this case, as the work is only just completed.

The village of Hatherop, near Fairford, Gloucestershire, consists of a main street about thirty chains long, with a branch street about eight chains long.

It contains, including the vicarage house and two farm-houses, thirty-nine dwellings, thirty-six of which are cottages. Its inhabitants number 169, exclusive of about twenty children, who attend the village school daily from adjoining districts.

In addition to the stabling and cattle sheds attached to the farm-houses, there are stables at the vicarage, and two other stables in the village.

Total number of horses generally kept, about	-	34
„ cattle „ „	-	40
„ pigs „		from 60 to 80

the soakage from which, in many parts, stood in pools on the road-side and in front of the houses.

Hatherop Castle, the residence of Lord De Mauley, and the mansion of Sir M. H. H. Beach, Bart, are closely contiguous to the village, which is the property of the former.

A drain, laid four feet deep on the average, constructed of pipes of first-rate quality (from the works of Messrs. Peake, of Tunstall, Staffordshire), varying in their bore from four to nine inches, was laid throughout the village, partly along one side, and partly along both sides of the streets; from which drain issue thirty-three lateral branch pipes, destined to receive the water of drainage from the gardens and adjoining fields.

Eleven cesspools are formed in suitable parts of the main drain, six feet in depth, being two feet deeper than the drain itself, to receive the wash of the roads; these are severally covered with an iron grate, fixed in an oak frame, and secured with a bolt opened with a key, so that they can be examined and cleaned out when necessary.

The water passing through this drain is discharged into the ditch of a meadow of about nine acres in extent, which can be partially irrigated by it; but from the scarcity of water in the small village (which occupies the summit of a hill) irrigation cannot be more extended.

The cost of this little work has been as follows, viz.:

	£	s.	d.
Amount paid for labour - - - - -	29	11	2
Grates and frames for cesspools - - -	22	4	0
Building cesspools - - - - -	6	10	0
Repairs of tools and sundries - - -	2	7	1½
Pipes, and carriage from Staffordshire -	108	3	9
	£168	16	0½

The expense is borne as follows:

	£	s.	d.
By proportion of the work chargeable to Lord De Mauley for the use of the main drain for his fields and the village gardens	20	0	0
By Lord De Mauley (subscription) - -	20	0	0
By Sir M. H. H. Beech (ditto) - -	20	0	0
By the Rev. S. Burke, vicar (ditto) -	5	0	0
The remainder has been advanced by Lord De Mauley, and will be repaid to him in the course of three years, by instalments out of the highway-rate, as per agreement with the ratepayers of the parish - -	103	16	0½
	£168	16	0½

Besides the drainage of the streets, the main drain will serve to receive the water of drainage from the gardens attached to each of the cottages, and from about twenty-five acres of land adjoining.

A similar system is undoubtedly applicable to the improvement and drainage of many suburban districts with which I am acquainted; but the details and cost of the work will necessarily be modified by the circumstances of each particular case, the cost greatly depending on the proximity of a good tilery.

Many gardens have been deeply drained, and with uniformly beneficial results; and, although gardens necessarily contain numerous trees, and plants not annuals, no obstruction has yet occurred to the drains during several years. I may instance, among others, Mr. Woolryche Whitmore's garden, at Dudmaston, Shropshire; Sir Robert Peel's, at Drayton Manor, Staffordshire; and the Duke of Wellington's, at Strathfieldsaye, Hampshire, all of them having been drained without inconvenience from the roots of annuals, biennials, or trees. The productiveness of these gardens, their forwardness, and the perfection of the crops, have been greatly enhanced.

Fruit trees, which had previously been barren, have been thrown into fruit-bearing by deep and perfect drainage; and an instance of early ripening occurred last year (1848) at Strathfieldsaye, which may be cited, though a very simple fact, as illustrative of the advantage derived from deep drainage, by removing water from the roots of trees, and thereby greatly elevating the temperature of the soil. Morelli cherry trees occupy a wall in the Duke of Wellington's garden, facing the north; the plot in front of this wall was drained in the autumn of 1847, to the depth of five feet, the subsoil consisting of the well known retentive plastic clay of that district. One of the results of this drainage was the ripening of the Morelli cherries one month earlier than had been previously known (the time of gathering being annually recorded by the gardener), although the year 1848 will be long remembered by the gardeners and farmers of the midland and southern districts of England, as the wettest, perhaps, on record, and certainly remarkable for an uncommon absence of sunshine and ripening power.

As regards the application of drainage to forests, woods, and plantations, I may observe that woods and forests, if of ancient growth, cannot be expected to be improved by drainage; very old and dying trees seem to be more quickly killed by drainage if standing in very wet soils; sound trees, as oak of fifty years to three centuries growth, are not injured by drainage, whether standing single or in masses; but young plantations undoubtedly thrive much more vigorously if the land be prepared by draining previously to planting, in spaces left at proper distances. Numerous deep under-drains have also, to my knowledge, been carried through young plantations without inconvenience from stoppage by roots, proper precautions having been taken to secure the pipes with collars and other contrivances.

The drainage of churchyards and cemeteries is but too much neglected. When done in a very effectual manner, at depths greater than the usual depths of graves, it has, to my knowledge, given the greatest satisfaction to the inhabitants of the district, and drainages so effected have been accompanied, as I have been informed, and can well believe, with an appreciable increase of salubrity.

(*Mr. Spooner.*) I am acquainted with a few instances where surface-drainage has been beneficial to young plantations in the early stages of their growth; though, as a general rule, the drier situations are selected for plantation. But, on the other hand, instances are numerous of the effect produced by well grown woods on the general climate of districts, and this evidently not so much by the shelter they afford, as from the large quantity of water absorbed and kept in constant circulation for their support and increase. I have repeatedly observed instances where dry arable land, situated below plantations, has become springy and wet after the removal of the trees.

In populous districts the value of land for other purposes has been a hindrance to its employment for plantation to such extent as to manifest, or possibly to produce, sensible effects on the climate; but in the northern counties, where produce in plantation yields value to the owners equal, or nearly so, to that obtained from land under cultivation, and consequently extensive tracts have been planted, an undoubted improvement has been produced in the climate. That portion of Ross-shire called the Black Isle, situated between the Cromarty and Moray Firths, affords a good illustration of this remark; the climate of which is acknowledged, by all who have known it for any number of years, to have improved most materially within the last half century, during which time the great bulk of extensive woods now growing on it have been planted, and this improvement is generally attributed to the plantations; for although large portions of it have been brought into cultivation within that period, but little under-drainage has been practised till within the last two years.

(*Mr. Maccaw.*) Drainage, where effected on woods, forests, &c., has proved in its results equally beneficial as when applied to culture lands; the contrast between drained and undrained woods being as fully marked, the trees on the former appearing more vigorous in growth, free of moss, the bark healthy, and not bound to the tree. The reverse may be noticed where plantations exist on marshy undrained land.

I could refer to many cases over the country,—

1st. Of a plantation put down in 1833 on probably the worst land in the district, but well surface drained, and 2 feet deep; the timber now appears the best of its age, and forms a great contrast to other woods of the same standing on superior land, not so drained.

2d. Where a former plantation had failed from the wet nature of the soil, the ground has been drained as above; and the new plantation put down now looks most thriving. I may also record an instance of deep thorough-drainage with pipes, now four years executed, where trees of about fifteen years standing, the ground was wet and marshy and the trees were stunted in growth, but are now progressing with vigour.

As regards suburban districts, I might refer to many instances of nursery grounds, gardens, &c. where the beneficial effects of thorough drainage have been highly satisfactory.

(*Mr. Beattie.*) There are none of any moment in this neighbourhood.

(*Mr. Scott.*) There are instances of the good effects of drainage of woods and plantations by the superior growth of the timber and healthiness of the trees; also the great improvement in the climate by the removal of stagnant waters rendered unhealthy by the decay of vegetable matter. Instances of this kind can be produced in the woods in the vicinity of Raby Castle in the county of Durham.

The favourable results of drainage of garden ground and suburban districts is well established in the counties of Durham and Northampton.

(*Mr. Neilson.*) No experience.

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3. What are the obstacles to the introduction of drainage when the land is held in small plots and on different terms? and what are the modes of meeting such obstacles?

(*Mr. Smith.*) The chief obstacles to the drainage of land held in small plots and on different terms, is the difficulty in finding a concurrence of the parties; and that can only be effectually overcome by an enactment to enforce submission. From the extending knowledge of the advantages of good drainage, however, it may in most cases be practicable to induce concurrence by a conference with the parties. In many cases it may be necessary to provide money for the execution of the works, in the first instance, from some public fund, to be repaid, with interest, by an annual charge upon the land, divided over a period of 20 or 30 years, as is the case with reference to more extensive possessions under the Drainage Acts.

(*Mr. Parkes.*) Obstacles to the drainage of plots of land held in suburban districts, or elsewhere, by small proprietors, arise, firstly, either from the want of sufficient outfall belonging to a particular plot of land, or, secondly, from the expense of carrying an outfall through a neighbour's piece, even with his assent, or, thirdly, when the neighbour dissents; and in both these last cases an objection to drainage frequently arises from the difficulty of obtaining access to the neighbour's fields in order to repair drains.

An Act, commonly called "Lord Lincoln's Act," 10 & 11 Vict. cap. 38. was passed in order to enable parties to obtain compulsory outfalls, but with what success it has been attended I am unable to state, no one of my clients having had occasion to resort to it.

Nevertheless, I am aware that the knowledge of this enactment has prevented parties from objecting to drains being carried through their lands, although for the exclusive advantage of a neighbour.

(*Mr. Spooner.*) The chief obstacles to the introduction of general drainage when land is held in small plots, and on different terms, appear to me to be—

1st. The difficulty of getting a set of persons, whose opinions and interests differ, to unite for an object of common benefit.

2d. If agreed on this point, to assess the proportional amount of the general expense to be attached to each possession or tenement.

There is no provision with which I am acquainted adequate to to meet these obstacles in the different bearings of which they are susceptible, especially in situations where the interests are of so mixed a description as they are in suburban districts. The Act to facilitate the Drainage of Lands in England and Wales (10 & 11 Vict. cap. 38), the provisions of which, while they border on the question, seem only to authorize the encroachment on the property of another in cases where either benefit to the parties encroached upon would accrue, or, at least, no material detriment would result; whereas, in the present case, for a benefit derived by parties both far and near, individual interests might be not only not benefited, but possibly materially injured.

These observations apply more especially to the first-named obstacle; and as regards the second, it must be borne in mind how difficult it is to obtain correct valuations, real or contingent, of property of a mixed character, and to determine to what amount by such a general step one particular portion would be benefited, or another injured.

The only way of meeting these difficulties satisfactorily appears to me to be that of adopting a species of inquiry and examination similar to those instituted before a Parliamentary Committee in the case of railways or other similar projects.

(*Mr. Maccaw.*) The chief obstacles are want of proper outfalls, and where such would prove very expensive in relation to the extent of land to be drained; cases where an outfall has to be carried through another property on a lower level, where the owner or occupant is averse to any encroachment on his tenure, or where the outfall has to traverse garden or policy grounds, interfering with useful and ornamental trees; where heavy claims for compensation are demanded, or where heavy mortgages exist, and conflicting interests are involved; or, finally, where the owner or occupier cannot be convinced of the benefits arising from thorough-drainage.

I cannot presume to recommend to your board any additional means likely to prove available for meeting these numerous obstacles to the carrying fully out the drainage of wet and marshy lands in suburban districts, where the comfort and health of the surrounding population are involved, and where the parties are unwilling to confer upon themselves and their neighbours a positive benefit.

(*Mr. Beattie.*) The unwillingness of the holders to admit of any change, from prejudice or otherwise.

By ensuring the holders against ultimate loss, and compensating them for immediate or temporary damage during the execution of the works.

(*Mr. Scott.*) The great obstacle to the introduction of drainage where the land is held in small plots, is the want of unanimity amongst the owners and occupiers, which can only be met by a legislative measure, empowering the majority of the holders of such plots to drain the lands at the expense of the whole.

(*Mr. Neilson.*) The arrangement for the course and expense of excavation of the main drain is the principal difficulty, the party occupying the lowest level being independent of it. A B C D occupy portions of a line of declivity from A to D. D discharging his water at his lowest level requires no main drain, while the requirements of the other three increase according to their distances from the ultimate outlet.

A case of this kind occurred in the drainage of the Paddington estate, the property of Rowland Errington, Esq., by the Inclosure Commissioners, under my inspection.

The main watercourses came through the properties of the Earl of Shrewsbury, Mr. Errington, and Mr. Congreve, entering the estate of the latter at a depth quite insufficient for the drainage I contemplated executing.

I suggested to Mr. Stewart, the agent, to apply for permission to level into Mr. Congreve's land a sufficient distance to obtain the requisite depth, and to excavate it at his own expense. He did so this last summer, and has carried a very efficient main drain through Mr. Errington's property till it meets the lowest extremity of the highest line of small drains.

I have heard since that Lord Shrewsbury's agent intends applying for permission to take it on from this point into his lordship's estate.

A considerable extent of land has already been materially benefited by it; and one of the resident farmers told me last week that he considered it quite a "God-send, for it had taken the water from ditches and roads that he had never known dry before, but always filling the country with fogs and foul wind."

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4. State any obstacles that are found to occur to the drainage of land in some cases where the occupiers and owners are disposed to do all that lies with them towards it?

(*Mr. Smith.*) I have not experienced any obstacles under this head since the passing of the Act of 1847, providing for outfalls, &c. There may be a want of money by the parties, and there is no legal provision for supplying that want.

The chief obstacles to the drainage of land in the cases referred to arise partly from the frequent changes of ownership or occupancy, so that even when occupiers and owners are well disposed to do all in their power for the common benefit, their good intentions may be thus frustrated. Outfalls common to many may be neglected, it being no one's peculiar business to repair them, or to pay for their preservation, in the absence of a general compulsory measure to provide a common outfall, and maintain it.

(*Mr. Spooner.*) Supposing no obstacles to arise under the foregoing, and that all concerned in the land are agreed, and any objection from neighbouring parties overruled, two obstacles still present themselves, of which the one may prevent drainage in the ordinary way, the other injure or destroy it in after time.

The first of these is a want of natural outfall adequate at all times for efficient drainage, such as exists at the present time in the lands on the back or south side of Lower Rotherhithe and Deptford, and many other places similarly situated. Here the ditches are alternately filled and emptied as the tide advances or recedes in the Thames.

In such a case, the first object would be to prevent the river water from oozing through the soil, as it now does, by digging a ditch, in a course parallel to the river, of a depth somewhat greater than that of the proposed drainage, and filling it from top to bottom with closely-rammed clay, mixed with small gravel.*

The next object, that of securing an outfall, would be obtained by conveying the water to the river, when the tide is low, by drains, having sluice-boxes to exclude the entrance of the river water when the tide is high, or has risen above their level; or, if the supply of water from the land is greater than can be got rid of in this manner, it would be necessary to adopt the sytem practised in the fen districts, viz., that of collecting it into a reservoir, from which it is purified by the application of steam or some other mechanical force.

In either of these cases it is desirable that the leader drains should have a larger calibre than is found necessary in ordinary drainage.

The second obstacle, that of injury to the drainage in after time, may, and in suburban districts is not unlikely to arise, by the sinking of foundations for walls and other buildings down upon or through the drains. In providing against such a contingency, the situation and object to be secured would sanction a greater expenditure than in ordinary cases of drainage might be justifiable; and injury could be prevented by sinking the principal leaders to such a depth into the *solid* upon which foundations are laid as that they should be secure from interference, and constructing them of brick or stone similar to sewers, so as to enable them to bear greater weight than drains in the ordinary way have to sustain.

This suggestion is based upon the supposition of the tract being a deep sandy marsh, where the ordinary drainage would not reach the same depth as would be necessary to secure a foundation for heavy mason-work; and such, I think, will be found to be the description of some of the marsh districts in the vicinity of the metropolis.

* This mixture of clay with stones interspersed is less likely to contract and crack than clay alone.

(*Mr. Maccaw.*) In landward districts a very frequent obstacle has been, a mill-dam dyke in a river, or at the natural outlet of an extensive marsh, the right of which is held by parties who have no direct interest in the land to be reclaimed by drainage, although an Act may be passed authorizing the removal of such obstacles, on due compensation being given. Not only the value of an existing mill is claimed, but also claims are submitted for mills or other works that may be erected on the same land, where the water from the same source can be made available, thus summing up prospective compensation. These demands, whether reasonable or not, if settled through the court, prove serious matters of burden on the land intended to be reclaimed, over that of mere drainage expenses, and prove obstacles in the way of parties who are willing to execute drainage.

Obstacles of this kind have, I believe, arisen in the case of the Tarbolton marshes in the suburbs of that town in Ayrshire.

(*Mr. Beattie.*) I know of none, unless the land be below the level of the sea; or the want of money.

(*Mr. Scott.*) The chief obstacle to carrying out effective drainage is the want of capital.

(*Mr. Neilson.*) I know of no obstacle that can occur in this case, unless some obstruction exists in the watercourse receiving the outfall of the land in question, such as mill privileges, and the power of damming the water for mechanical purposes.

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5. Are there any other important improvements that drainage is found to pave the way for introducing?

(*Mr. Smith.*) Thorough-drainage will pave the way for introducing the most complete system of *garden* culture, whether in the field or in the garden. It will facilitate the introduction of the system of a succession of crops *in the same season;* it will greatly facilitate the modern improvement of applying manure in the liquid form; and, finally, it will afford great advantages in the application of a general system of irrigation on grass lands.

(*Mr. Parkes.*) In some places useful water-power has been obtained by the collection of the water of drainage on an estate, and without injury to other parties; but this method can only be practised in certain suitable situations. Lord Hatherton has executed a large work of drainage on this plan, with, I understand, economy and success.

The water of plain land-drainage, mixed with liquid farm manure, is often beneficially employed, by receiving it in pools, and using it for the irrigation of lands more lowly situated. The Duke of Portland's justly celebrated water meadows at Clipstone are a notable instance of the advantage of adding the soccage-water of a town (Mansfield) to a natural stream, as a vehicle of fertility by means of irrigation. It is my opinion that town sewerage water ought to be largely diluted with running water when applied to land closely adjoining towns, in order to guard against the effluvia from it becoming very prejudicial to human health, and the herbage injurious to the health of animals. It is also my opinion, that in all cases of the application of sewerage water, as well as in those of plain water, for the purposes of irrigation, land having a retentive subsoil should be first prepared by deep and effectual under-drainage, in order to cause the fluid to permeate, and not stagnate in the soil. Without this preparation, irrigated meadows are known to be eventually, and often quickly, converted into swamps; and evaporation from the dregs and deposit of sewerage water left on the surface must, in addition, contaminate the atmosphere.

(*Mr. Spooner.*) Apart from the benefits derived in an agricultural view, drainage on an extensive scale must ameliorate the climate of districts in which it is practised, and, in a great measure, tend to purify their atmosphere.

Water that is stagnant, shallow water, and water mechanically separated, as it is when held in soil, is far more susceptible of evaporation than when in motion as a river, or combined in a large body as in a lake or sea; and it is a well-known fact, that evaporation is always accompanied with a diminution of the temperature of objects from which it takes place. Now, the constant motion in which water is kept by drainage, and its removal at such a depth below the surface as to prevent its being acted upon by the sun's influence, must of necessity also prevent excessive evaporation, with its concomitant reduction of temperature.

Again, if ammonia and other gaseous products, the result of animal and vegetable decomposition, are, as there is every reason to suppose they are, the origin of miasma, and the fruitful source of fevers, their retention near the surface will be greater in proportion to the amount of water, the denser absorbent existing in or supplied to the atmosphere immediately surrounding that surface.

(*Mr. Maccaw.*) Thorough-drainage will be the means, as has been already proved, of introducing many great and important improvements, by the extended cultivation of root and green crops, thus increasing the fertility and extent of arable land over the kingdom, giving employment to our labouring population, increasing the quantity of and reducing the price of food, at same time raising the value of land thus improved, lessening the expense of labour and quantity of seed previously required for the same area of land that had been arable in its undrained state, and of increasing immensely the number of cattle and stock, which again will tend largely to increase substantial manures; it will also ameliorate our climate, and bring to earlier maturity our grain crops on the higher elevations of the country.

There are many other advantages to arise from extended thorough-drainage on soils of proper depth and character within the range of climate suited to bringing crops to maturity, and even in the production of permanent pasturage beyond that range.

In many other respects this question presents views for the consideration of the political economist. It is scarcely within my province, or suited to my ability, to enlarge on the prospective advantages of these improvements as connected with the social welfare of the country.

(*Mr. Beattie.*) Inclosing and sheltering, and in every respect admitting of a higher state of cultivation.

(*Mr. Scott.*) A superior course of husbandry, enabling the occupier of the lands to consume his green crops to the best advantage on the lands, to reap his corn crops earlier, and also facilitate the sowing of the grain during unfavourable seasons; a great saving of expense in the cultivation of all crops, and the destruction of many injurious weeds that will only vegetate in wet soils.

(*Mr. Neilson.*) The chief direct improvements by drainage are the increased salubrity of the climate and fertility of the soil; but the range of social improvement, emanating from these two by the field of profitable and productive labour thus opened out, is calculated to affect the comfort and wellbeing of every class of the community.

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6. Will you state generally the depths and distances of the drains that are in use in relation to the different descriptions of soil; what is the amount of discrepancy; and whether this is accidental, or ruled by district usages, or by the opinions of different engineers?

(*Mr. Smith.*) The depths and distances of drains that are in general use are very various, arising, not only from the proper difference necessary to suit the different nature of the soils, but also from the difference in the opinions of engineers and practical farmers. The soils being so varied in character, no settled rule can be laid down. The depths in use, since the introduction of thorough-draining, have varied from 2 to 3 feet, and, in occasional instances, 4 or 5 feet has been found preferable. The distances have ranged from 10 to 30 feet; whilst, in some cases, in peculiarly open subsoils, they have been extended to 40 feet with complete success. For a long time it was difficult to persuade practical men that depths beyond from 18 inches to 2 feet would be effectual in clay soils, at whatever distances they might be placed; but in the course of experience the results of the examples set by those who adopted depths of from 2½ to 3 feet have led to the general adoption of such depths for all clays or compacted drift soils. Where beds of gravel, sand, or other open strata occur within 4 or 5 feet of the surface, it is proper and usual to cut down to those beds when the outfall will allow; but these depths are seldom adopted except under such circumstances. Within the last four years depths varying from 4 to 6 feet, with distances of from 36 to 60 feet, have been advocated by some engineers under general circumstances, and several practical men have adopted the system, to some extent, on clay lands, in some instances, as they state, with satisfactory results; but in all such cases as have come under my observation the results have not warranted the appellation of "*thorough-draining*," when brought to the test of comparison with land drained at depths of from 30 inches to 3 feet, and with distances varying from 18 to 24 feet. Much of the soil that I have met with in the upland country in England, Scotland, and Ireland of the drifted formation is so difficult to cut at the greater depths, that the expense becomes too great to warrant its adoption unless under very obvious advantages; and it is yet an unascertained point how far is it beneficial to remove the free water to a greater depth from the surface than from 2½ to 3 feet. The advocates of the deeper system, so far as I have been able to observe, seem to be returning in practice to depths not exceeding 4 feet, and to distances varying from 24 to 30 feet.

An extent of about 10,000 acres has been drained in Scotland on one estate, none of the drains exceeding 2 feet in depth and 20 feet apart; yet, the thorough-drainage of a very stiff and compact clay has been accomplished to the satisfaction of the parties cultivating it, and to the satisfaction of agriculturists generally. Nevertheless, I am of opinion that from 2½ to 3 feet would have been preferable, as affording facility for a deeper working of the soil, without risk of injury to the channels of the drains.

Setting aside the moot question as to the proper depth at which free water should be retained, I do not so much object to greater depths than 3 feet as I do to greater distances in *all* soils, as I have invariably found, from experience, that when distances beyond 24 or 30 feet have been adopted in *compact* soils, there has not been a perfectly uniformly dry condition of the soil, especially when rain had recently fallen; so that, if expense is to be saved by greater distances, I would prefer incurring the expense to the diminution, in any shade or degree, of complete and quick drainage. The experience of a succession of seasons is necessary fully to test drainage; and the extent of deep and distant drainage, which has of late years been executed, will afford sufficient examples to test the practice in a cycle of seasons.

The circumstance which has the most influence in ruling the distances of drains, and through these in some degree the depths, is the arrangement of the existing ridges. The width of the ridges runs generally from 12 to 24 feet, most commonly 18 feet; and as the ridges are usually thrown up in the middle from 12 to 18 inches above the levels of the furrows, a great saving in the cutting is

effected by placing the drain in the line of the furrow: and, besides, when the ridges are much raised, there is a tendency of the surface-water to run towards the old furrow, even after the land has been drained; and if there is not a drain below or near to the furrow, there is an undue collection of water, which obtains for some years after the drainage has been executed, and until the ridges have been levelled down and the subsoil fully opened. The loss by this wetness, or damp, or incompleteness of thorough and uniform dryness, is greater than the cost of having the drains somewhat less distant. There is also some difficulty practically in getting the drains cut to uniform depths, when the surface in the lines of the drains is of various altitudes from the datum level of the bottom of the drains. Practically, therefore, it is found to be a much more ready method, and upon the whole cheaper and much more immediately fully effective, to adopt the furrows for the lines of the drains. In some cases, when the ridges are under 12 feet in width, I have found it expedient to place a drain in every second furrow only; and in cases where an inequality in the width of the ridges existed I have found it proper to adopt those unequal distances for the drains. Where such distances have been adopted generally, it has been found that depths of from 2½ to 3 feet have, on all soils, and at all times, produced a thoroughly dry condition of the soil.

In Ireland, where the lazy-bed system of cultivation is followed, the practice is to place the drains in each alternate trench, which makes the distances about 18 or 20 feet, and the depths adopted vary from 2½ to 4 feet. As stones are plentiful, and labour cheap, the channels of the drains are generally formed of stones. Tiles and tubes are now being introduced, and these will no doubt be extended in use.

In bog and marshy land the drains require to be made the deepest, because from the nature of the structure of such land there is generally much bottom-water to be removed, and the soil of bogs and marshes contracts and subsides much after being drained.

In the floating bogs very much deeper drains are required; and where outfalls can be had, the depth of the drains should be as great as to remove, if possible, the whole of the bottom-water, which can generally be done with a few deep drains, and the removal of the surface-water can thereafter be effected by frequent parallel drains of the ordinary depths and distances.

(*Mr. Parkes.*) As to the practice of draining in respect of depth and distance, my opinion is that the usage of the country, until within the last few years, has been rather a matter of accident than determined by or referable to any sound principles of experiments. The great proportion of the older drainages of England, which were generally of shallow depths varying from eighteen inches to three feet, formed of imperfect materials and executed in an imperfect manner, have either been entirely removed, or are being gradually superseded by drains placed at greater depths formed of more perfect and durable materials. The Inclosure Commissioners could give the most authentic and abundant testimony to the difference in practice and to the cost of modern draining, as compared with that of earlier times.

The principles which have governed my practice as a drainer will be found fully developed in two papers published in the journals of the Royal Agricultural Society of England, now reprinted in a separate form, and entitled "Essays on the Philosophy and Art of Land-Drainage." Longman and Co.

(*Mr. Spooner.*) In looking back to the origin of parallel drainage, it is easy to discover how the rules of the distance apart of drains have arisen. Before under-drainage was practised, strong and wet lands were rendered capable of arable culture by being ploughed up into the waving shape, termed ridge and furrow, the bottom of the latter forming the drain for the water from the former; but in consequence of the crops perishing in and by the sides of the furrows (or thoroughs), the system of drawing off the water from them, by shallow drains below each, kept open with straw or brushwood, was adopted, and was termed furrow or thorough-draining. Hence the ordinary width of the lands or ridges in any particular district indicates the distance at which the drains were usually placed from each other; and the distances now most commonly in use in different districts, and on the different sorts of soil have all reference to a width of ridge that either formerly was, or now is, in use in those districts; and it is a fact worthy of remark, that throughout the country the statements of the number of feet from drain to drain is in almost every instance divisible (when reduced to inches) by eighteen, that being the space of ground in inches moved by a single turn of ordinary ploughing.

I am particular in mentioning this subject, because I consider that the long-established usages of a particular district indicate the requirements of that district, and that the distance from furrow to furrow points out to a considerable extent the tenacity or porosity of the soil, or its capacity of retaining water on the one hand and transmitting it on the other.

The discordances in opinion existing among practical men on the subject of drainage appear to me to have arisen in a great measure from a want of due observance of these differences, and from the too frequent attempt to establish rules of general application founded on the successful practice of some one locality.

The following statement is intended to illustrate the concordance between the distance of drains and the usual width of lands in certain districts.

Width of land or ridge.	Number of turns of the plough (18 inches wide) to the land.	Some of the districts in which the respective widths of ridge are in common use.	General character of the soil.	Distances from Drain to Drain in common use.
Ft. in.				
7 6	5	Common in the county of Essex.	Tenacious and uniform clay.	Seven feet 6 inches; 15 feet, 21 feet, or every furrow, every other furrow, every third furrow, &c.
16 6	11	Parts of Surrey, Sussex, Kent, Middlesex, &c.	Same as above, fine and silthing clays, with beds of fine sand interspersed.	Drains 1 rod apart.
18 0	12	Parts of Yorkshire, Northumberland, South of Scotland, &c.	Clays, containing coarse sand and grit, interspersed with shale and slate fragments.	Drains 18 feet or 1 rod (Scotch measure) apart.
21 0	14	Common in the above and the Midland counties, &c.	Calcareous soils, and clays lighter than the above, with frequent intermixtures of sand and gravel.	Drains 21 feet apart.
24 0	16	Very common in the Midland counties and the Highlands.	Clays similar to the above, with rotten sandstone rock and more frequent intermixtures of gravel, &c.	Drains 24 feet apart.
30 0	20	Very generally adopted in the lighter clays throughout the country.	The lighter description of clays and clay gravels.	Drains 30 feet apart.
33 0	22	Parts of Berkshire, Herts, Suffolk, Cambridgeshire, &c.	Chalk districts, stone, brush, gravelly, and sandy soils; and the lighter description of lands, usually springy soils.	Drains 33 feet or 2 rods apart.
36 0	24	Same as above, and very general.	- - -	Drains 36 feet or 2 rods (Scotch measure) apart. The application of furrow drainage to the two last is comparatively of recent date.

The above quoted widths are those most commonly adopted throughout the country.

As regards the depth of drains, general opinion appears to have undergone considerable change, resulting from the more extended experience of the last few years. It was at one time commonly supposed that in strong clays water on or near the surface could not descend to deep drains; but this having been found erroneous, the practice of draining strong lands deeper than formerly has become common, and with them others of a lighter description; and the difference may be represented by that which exists between eighteen to thirty inches in the one case, and thirty-six to forty-eight inches in the other. The question of the depth of drains is affected by two considerations: first, their permanency; secondly, their efficiency. It is without doubt an established fact, that in most soils shallow drains are choked in the course of time, and in some in a very few years, and an examination into the cause has shown that they have become filled with the fine particles of soil washed down through worm and mole holes, cracks, and cavities occasioned by the ordinary processes of tillage. On the other hand, deep drains, being removed from the active soil, are exempt from such casualties, and thus their permanency secured.

No better evidence of the efficiency of a deeper system of drainage can be adduced than that the practice is daily becoming more general in every variety of soil and situation, and is found amply remunerative even in land previously drained to all the extent that shallow drainage will effect.

I consider that in the generality of soils drains are not safe at a depth of much less than three feet, and that they may to greater advantage be laid at a depth varying from that to four feet; but I have not seen evidence to prove that a greater depth than this is attended with such advantages as to sanction the increased incident expenditure.

I have avoided uniting the consideration of the depth of the drains with their distance asunder, because I think material errors are not unfrequently committed, on the supposition that the one bears an invariable ratio to the other; at the same time I am fully satisfied that an increase in depth will sanction a greater distance of drainage, but not in a uniform proportion.

Speaking in general terms, I should say that it is to the suitable distance apart of drains that we are to look for the efficacy of drainage, and to their depth for its permanency.

(*Mr. Maccaw.*) The depths and distances of drains are various in relation to the different descriptions of soils:—

1st. On a thin clay soil and subsoil of great tenacity, drains were formerly 12 to 15 feet apart, and 2 feet deep. That depth increased afterwards to 2½ and 3 feet. Since the Drainage Act came into operation the distance apart of drains was extended to 21 and 24 feet; the depth to 3½ and 4 feet. Soon after, however, the distance apart was contracted to 16 and 21 feet; the depth remaining the same; and this system now prevails generally on soils of the description named.

2d. On a clay soil of less tenacity, having more sand or gravel in its composition, drains are now generally made from 3½ to 4 feet deep, and 21 to 27 feet apart.

3d. On soils of greater porosity, with less clay in their composition, and where spring-water exists, drains are being made from 4 to 5 feet deep, and from 27 to 40 feet apart.

The main drains are generally cut a few inches deeper than the branch drains.

In some cases rock lying near to the surface interferes. Where this occurs, drains are put in at more contracted distances apart, and, if practicable, the rock is cut, at least through its loose surface, to form the bed of whatever material is used as a conduit, and the lines of drainage are then wrought out at no uniform depth or distance apart.

In drainage of moss-lands, where the drains cannot be cut through the moss, they are now generally cut to 5 feet deep and from 18 to 24 feet apart; but where the moss can be cut through about this depth, the distance apart of drains is very much extended, depending on the nature of the subsoil, from, say 24 to 36 feet. Where this can be attained it is very effective.

Moss of a very wet and soft character cannot be properly drained in one season, particularly when of great depth. This description of moss generally occupies a very level position, and the inclination for the proper discharge of the water must be wrought out in the drains. After drainage it subsides more at its centre, or where its deepest body exists, than at its edges; consequently, the drains at those deep parts become depressed beneath their first levels, and often below that of their outlet, and hence the propriety of keeping the drains open during the first season at as great a depth as practicable. By cutting their sides perpendicular they are found to stand better than by sloping them. In the second season they are cut out and finished.

The discrepancy between the former system of shallow drainage, where the materials used were chiefly small or broken stones, or horse-shoe tiles of large dimensions, and that mode now generally adopted, when pipes partly connected with collars or socked pipes are used, cannot be better illustrated than by the estimates in these early applications under the Drainage Act submitted to the Inclosure Commissioners, which show an average acreable cost of

	£	s.	d.
about - - - - - -	£8	10	0
While on the present system it amounts to - -	5	10	0
Showing a difference in favour of the latter of	£3	0	0

I believe this favourable discrepancy has arisen from various causes; chiefly from the known results of the beneficial effects of drainage formerly executed, and of experiments conducted with a view to ascertain the most effective system at the least cost, the great facility in procuring capital under the Drainage Act by parties desirous to improve their lands by drainage, and the pretty stringent regulations insisted on by the Inclosure Commissioners, under the Act, to have that money expended on drainage on the best known principles in regard to cost, efficiency, and durability, who, from their extended information, are enabled to decide as to the most approved methods, their opinions on this head being more generally adopted than ruled by the usages of any particular district or engineer.

(*Mr. Beattie.*) The depth of drains in agricultural lands are seldom made less than 3 feet.

On the rich clayish lands 3½ feet and 4 feet.

On marshy or mossy soils, from 4 feet to 6 and upwards, as circumstances may admit.

Every description of soil subsides after being thoroughly drained. Marsh lands in some instances will subside one or two feet. Ample allowance should be made in the depth of the outfalls and the drains for this subsidence.

Thorough-drainage, under the influence of the Inclosure Commissioners, has now become nearly an universal system, and most engineers agree that the deeper drainage at moderate distances apart is most effectual and permanent.

(*Mr. Scott.*) Drains are generally 3 to 5 feet deep and from 20 to 50 feet apart; in strong retentive pure clays, from 3 to 4 feet deep, placed at distances of from 20 to 36 feet apart, in porous subsoils, such as gravel or sand, 4 to 5 feet deep and 40 to 50 feet apart. In some cases the drains are made deeper and placed farther apart.

A great difference of opinion exists in different localities as to depth and distance of drains. It frequently occurs from prejudice, influenced by the custom that has prevailed in each district. There is a difference of opinion on this point by draining engineers, but the prevailing opinion is in favour of deep drainage.

(*Mr. Neilson.*) Though the depth and distances of drains are relatively, in a great measure, dependent on each other, I consider the former ought invariably to be regulated by the nature of the substratum in which it is laid and the soil through which it passes, presuming, of course, that the outfall is a good one.

In stiff clayey and tenacious soils the drains cannot act so promptly, and therefore I should not place them so distant, and consequently not so deep, as in gravelly, sandy, or more porous soils.

I am at present inspecting a considerable extent of drainage on the estates of the Marquis of Londonderry in the county of Durham, where the soil is principally of the former character. The depths have varied from 3 feet to 3 feet 9 inches, and the distances from 8 to 12 yards, according to the presence of more or less porosity of the soil, and the result has hitherto been highly satisfactory.

In other parts of England and Wales, in lighter and more porous soils, I have found 4 feet deep and from 15 to 18 yards apart equally efficacious; though in stiff clay greater depths and distances have not, in my limited experience, given similar satisfaction.

Though the prejudice is great among farmers of the old school against deep and distant draining, I consider much of the discrepancy of modern artists arises from the different doctrines of Mr. Smith and Mr. Parkes, both equally celebrated as farmers, but whose opposition to each other led them each to recommend one unvaried system of drainage to every species of soil.

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7. Give two or three examples that would furnish fair specimens of the cost of the work in each leading class of the circumstances that commonly determine cost?

(*Mr. Smith.*) The following examples will afford a fair idea of the cost per acre for draining in the leading class of soils and under the most ordinary circumstances:—

EXAMPLE I.

Alluvial Clay.

Drains { feet deep. / feet apart.

	£	s.	d.
Cost of cutting and filing, per acre	2	1	10
Cost of materials (tubes at 20s. per 1,000)	2	2	0
Chargeable per acre (average) for main drains, outfalls, engineering, &c.	0	18	0
Total cost per acre	5	1	10
The same, if executed with peat tubes, per acre	3	9	6

EXAMPLE II.

Upland clay, or till, full of stones.

Drains { 2 feet 9 inches deep. / 21 feet apart.

	£	s.	d.
Cost of cutting and filling, per acre	3	2	9
Cost of materials (tubes at 20s. per 1,000)	2	2	0
Chargeable per acre (average) for main drains, outfalls, engineering, &c.	1	2	0
Total cost per acre	6	6	9

EXAMPLE III.

Compact gravelly drift with boulder stones.

Drains { 2 feet 9 inches deep. / 24 feet apart.

	£	s.	d.
Cost of cutting and filling, per acre	3	4	0
Cost of materials (tubes at 20s. per 1,000)	1	16	3½
Chargeable per acre (average) for main drains, outfalls, engineering, &c.	1	1	0
Total cost per acre	6	1	3½
The same, allowing the drains to be 4 feet deep and 30 feet apart, per acre	6	5	4½

Example IV.

Open sand and gravel, with moorish bottom.

Drains { 4 feet deep. / 40 feet apart.

	£	s.	d.
Cost of cutting and filling, per acre -	3	6	0
Cost of materials (tubes at 20*s.* per 1,000)	1	1	9¼
Chargeable per acre (average) for main drains, outfalls, engineering, &c. -	1	2	0
Total cost per acre - - -	5	9	9¼

Example V.

Peat moss, forming its own channel.

Drains { 3½ feet deep. / 18 feet apart.

	£	s.	d.
Cost of cutting and filling, per acre -	1	4	5
Chargeable per acre (average) for main drains, outfalls, engineering, &c. -	0	6	0
Total cost per acre - - -	1	10	5

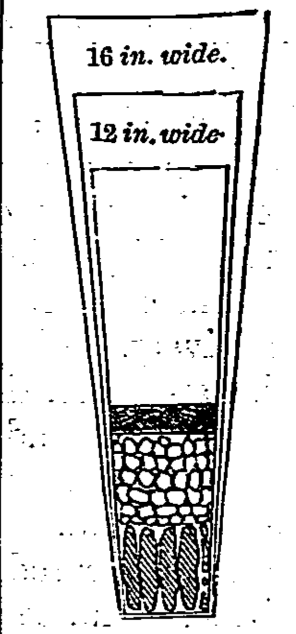
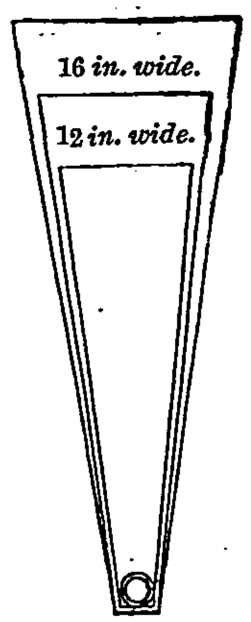
(*Mr. Parkes.*) It would be difficult to cite any estate of magnitude the subsoil of which is composed of one uniform quality; whilst the cost of drainage necessarily varies with the texture of the soil, both as to expense of cutting and in respect of the distance to which water will filtrate through the land, so as to ensure a sufficiently quick and perfect drainage during and after rain. It has been found that the cost of draining land, at depths of from 4 to 6 feet, the drains being laid with pipes and collars, varies from about 3*l.* per acre, in free gravel and sandy soils gorged with water, to 5*l.* 10*s.* and 6*l.* per acre in clayey ground with rock at bottom, requiring to be blasted, a common case in hilly countries, or where bore-holes are required in addition to drains in springy lands. Plain pure clay drainage (which is the simplest and easiest of all drainage) does not exceed in cost from 4*l.* to 4*l.* 10*s.* per acre, according to its texture, which varies, however, more than any other distinctive quality of soil. Alluvial soils, such as the extensive warplands on the banks of the Humber and other estuaries, are drainable at the depth of from 4 to 5 feet, at a cost of from 3*l.* 10*s.* to 4*l.* 10*s.* per acre. It will be understood that all quotations of the cost of drainage must greatly depend on local circumstances, such as the proximity of tileries, the wages of labour, &c.

(*Mr. Spooner.*) The principal circumstances which determine the cost of drainage-works are :—The labour of cutting and filling the drains, the material of which the drain itself is formed, and the outlets for the discharge of water Of these, the last increases in proportion as the ground is steep and irregular, or unusually flat, and can only be included in a general estimate where the surface gently undulates: the material also varies greatly in cost, arising, in the case of tiles, in the supply being near at hand and equal to the demand, or otherwise, and in the case of stones, in the distance of carriage.

It was formerly considered that the cost of drainage was equally divided between that of the labour and material; and in 2½ to 3 feet drains filled with stones or horse-shoe tiles, on soles, this is about the case: but the more general introduction of pipes, and the improved methods of making them, have occasioned a considerable balance in favour of material, while increase of depth has increased the cost of labour.

This latter item can be determined with sufficient accuracy by referring it to a standard pretty generally known, viz., the value of moving a solid yard of earth of any one description of hardness; and to illustrate this, I have drawn up the following table, which supposes two sets of drains, the one opened for stones, the other for tiles, and at depths of 3 feet, 3½ feet, and 4 feet, respectively. I have shown the average width of the cutting for each size and sort, the number of lineal yards required to equal a solid yard, in each; and assuming three descriptions of soil, the differences in hardness of which make the cost of moving their solid yard, 4*d.*, 6*d.*, and 8*d.*, respectively. I have calculated the labour-value per yard, and per rod, linear, of the different depths and sorts; and these will be found to tally very closely with the prices at which the work is done.

It is a common remark, that the cost of making drains is double, by every foot of increased depth given, and the same in proportion for every part of such increase: the following table shows that this is so.

	Depth of each Drain.		Average Width of Drain.	Running yards of Drain to the cubic yard.	Sandy Soils, light Loams, and light Clays. Easy digging.			Stiffer Clay and Gravel, requiring some pickwork.			Hard Clay and close Soils, requiring pickwork before they can be done.		
					At 4*d.* per cubic yard.			At 6*d.* per cubic yard.			At 8*d.* per cubic yard.		
					per yd	per rod.		per yd	per rod.		per yd	per rod.	
			Inches.		*d.*	*s.*	*d.*	*d.*	*s.*	*d.*	*d.*	*s.*	*d.*
STONE DRAINS.	4 feet	18 *in. wide.*  8 *in. wide at bottom.*	14	2 +	2	0	11	3	1	$4\frac{1}{2}$	4	1	10
	$3\frac{1}{2}$ feet		12	$2\frac{1}{2}$—	$1\frac{3}{5}$	0	9	$2\frac{2}{5}$	1	$1\frac{1}{4}$	$3\frac{1}{5}$	1	$5\frac{1}{2}$
	3 feet		10	$3\frac{1}{2}$ +	$1\frac{1}{7}$	0	$6\frac{1}{4}$	$1\frac{5}{7}$	0	$8\frac{1}{2}$	$2\frac{1}{2}$	1	$0\frac{1}{2}$
PIPE TILE DRAINS.	4 feet	18 *in. wide.*  3 *in. wide at bottom.*	$10\frac{1}{2}$	$2\frac{1}{2}$ +	$1\frac{3}{5}$	0	9	$2\frac{2}{5}$	1	$1\frac{1}{4}$	$3\frac{1}{5}$	1	$5\frac{1}{2}$
	$3\frac{1}{2}$ feet		$9\frac{1}{2}$	$3\frac{1}{4}$	$1\frac{3}{13}$	0	7	$1\frac{11}{13}$	0	$10\frac{1}{4}$	$2\frac{6}{13}$	1	2
	4 feet		$7\frac{1}{2}$	$5\frac{1}{15}$	$0\frac{3}{4}$	0	$4\frac{1}{4}$	$1\frac{1}{5}$	0	$6\frac{1}{2}$	$1\frac{1}{2}$	0	$8\frac{1}{4}$

The (+) and (—) signs attached to the third column of figures, imply a small fraction greater or less than the number stated.

In the price per rod, the fractional parts are reduced to the farthings nearest to them.

Thus it may be seen that the cutting, &c. of a stone drain of one depth, say $3\frac{1}{2}$ feet, may cost 9*d.*, 1*s.* $1\frac{1}{4}$*d.*, or 1*s.* $5\frac{1}{2}$*d.* per rod, according to the hardness or otherwise of the soil.

The cost of labour in a similar drain made for pipes would be 7*d.*, $10\frac{1}{4}$*d.*, or 1*s.* 2*d.* per rod.

So also a pipe drain in one description of soil may cost in labour but $4\frac{1}{2}$*d.* per rod, the same in another description $8\frac{1}{4}$*d.* per rod, and the same, if for stone, 1*s.* $0\frac{1}{2}$*d.* per rod.

Having ascertained the cost per rod at which the labour can be performed, it is easy to arrive at the number of rods of drains, and number of tiles, required for an acre, at any given distance of drainage; and many tables have been drawn up for facilitating these calculations. The one circulated by the Inclosure Commissioners is the best I have seen.

By referring to these tables, and the foregoing labour statement, we may arrive at the cost of the work in the following manner:—

Soil of the class No. 2. Clay and gravel, the working of which is worth 6*d.* per cubic yard.

Drains 24 feet apart, 3 feet deep, laid with pipes $1\frac{3}{4}$ inches in the bore.

Per acre.		£	s.	d.
110 rods of drains, at $6\frac{1}{2}$*d.* per rod	-	2	9	7
1,815 $1\frac{3}{4}$-inch pipes, 12 inches long, at 21*s.* per 1,000 - - -	-	1	18	$2\frac{1}{2}$
Total per acre	-	4	7	$9\frac{1}{2}$

Again, soil of class No. 3, at 8*d.* per cubic yard, laid with horseshoe tiles on slate soles.

Per acre.	£	s.	d.		£	s.	d.
110 rods of drains, at $8\frac{1}{4}$*d.* per rod				-	3	15	$7\frac{1}{2}$
1,815 2-in. by $2\frac{1}{2}$-in. tiles, 12 inches long, at 25*s.* per 1,000	2	5	4				
1,815 slate soles, at 16*s.* 6*d.* per 1,000 - - -	1	9	$11\frac{1}{2}$				
	3	15	$3\frac{1}{2}$		3	15	$3\frac{1}{2}$
Total per acre				-	7	10	11

In both these cases I have excluded extra estimates for leaders, and for larger sized tiles to lay in them, because I find that, as a general rule, when extended over tracts of any size, the estimated quantity exceeds the actual by an amount sufficient to cover the expenditure under that head.

I do not consider it necessary to multiply instances of cost, further than as illustrations of the manner of arriving at them, since the variety of circumstances is such as that the cost in one case cannot be taken as a criterion for that in another.

(*Mr. Maccaw.*) First Class.—Being drains on a very tenacious soil, averaging 18 feet apart, and 3½ feet deep:—

Cost per acre.	£	s.	d.
Cutting and filling 147 rods at 5*d.* -	3	1	3
2,425 pipes, 12 inches long, 2 inches tube, at 20*s.* per 1,000 - - -	2	8	6
Cartage, say 4 miles, at 4*s.* per 1,000 -	0	9	8
Cost, extra, on mains, large pipes, outfall, &c.	0	6	7
	£6	6	0

Second Class.—Soil and subsoil less tenacious, drains 24 feet apart, 3½ to 4 feet deep:—

	£	s.	d.
Cutting and filling 110 rods at 6*d.* -	2	15	0
1,815 pipes, 12 inches long, 2-inch tube, at 20*s.* per 1,000 - - - - -	1	16	4
One third connected with collars where bottom soft or sandy - - -	0	4	2
Cartage, say 4 miles - - -	0	8	0
Extra cost on mains, pipes, outfall, &c. -	0	6	6
	£5	10	0

Third Class.—Deep marshy soils; subsoil various, clay, running sand, gravel, &c.; springs exist; drains from 27 to 40 feet apart, say average 33 feet:—

	£	s.	d.
Cutting and filling 80 rods, 4½ feet deep to 5 feet, at 9*d.* - - -	3	0	0
1,000 pipes, 2 inches bore, 12 inches long, with collars or socket pipes, at 26*s.* per 1,000 - - - - - -	1	6	0
320 pipes, 3, 4, and 6-inch tubes, average 40*s.* per 1,000 - - -	0	12	10
Cartage, 4 miles, at 6*s.* 6*d.* per 1,000 -	0	8	7
Extra cost on outfall, days work, and superintendence - - -	0	8	7
	5	15	0

Fourth Class.—Moss drains, 5 feet deep, 18 feet apart,	£	s.	d
147 rods cutting and filling, wedge turf material, at 7*d.* per rod - - - - - - -	4	5	9

(*Mr. Beattie.*) The expense of furrow drainage at 3 feet	£	s.	d.
deep and 24 feet apart, with tile pipes, may be reckoned at an average of - - - - - -	6	10	0
Outfalls and incidents, say 5 per cent. - - -	0	6	6
Per imperial acre	6	16	6

In the drainage of extensive marsh lands the expense of the outfalls is generally a large item of the whole.

Large open cuts through soil may be estimated at from 6*d.* to 1*s.* per cubic yard, and through rock at 2*s.* to 4*s.* per cubic yard.

I am engaged at present in the survey of a marsh of about 200 acres, common to eight or ten parties; the outfall is a small stream that requires to be deepened 8 to 10 feet for half a mile.

The expense of the outfall and main subdivision ditches between each lot will be about 3*l.* per acre.

The expense of furrow-draining each lot, say 6*l.* per acre.

Incidental expenses, say 1*l.* per acre. In all 10*l.* per acre.

(*Mr. Scott.*) In pure clays, free from stones, the cost will amount generally to about 4*l.* 10*s.* per acre, calculating the drains to be made 4 feet deep and 30 feet apart, laid with pipe-tiles of 1½ inches internal diameter; the price of the pipes not to exceed 15*s.* per thousand.

In strong clayey subsoils containing stones, and those with veins of sand and gravel, mixed with large stones, requiring the pipe-tiles to be collared, the cost will amount generally to about 5*l.* per acre.

In light easy working soils the expense ought not to exceed 4*l.* per acre.

(*Mr. Neilson.*) The principal circumstances that determine the cost of drainage are the prices of labour and tiles. The former varies considerably in different districts, and is influenced by the propinquity of a manufacturing town or a railway in progress of construction; the latter, according to the nature of the clay for making tiles, and the price of coals, or the price at which the tiles can be bought, including the cost of conveyance. To this must be added the expense of the main watercourse, which in some instances is considerable, and ought to be spread over the whole acreage to the drainage of which it is subservient. Digging and filling-in these drains is from ¾*d.* to 1*d.* per yard, and the price of tiles, with coals laid down at the yard at 11*s.* per ton, is as follows:—

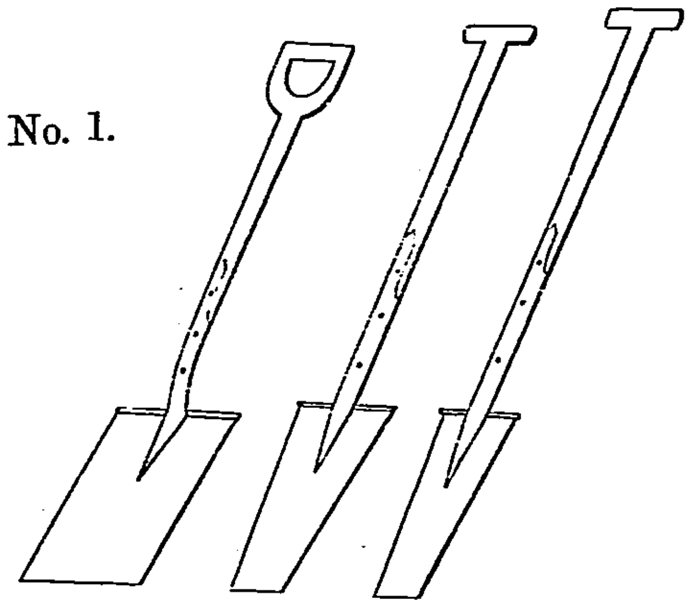
Bore, 1¾ in.,	13 in. long,	at	10*s.* 6*d.*	per 1,000
" 2¼ in.,	"		12*s.* 6*d.*	"
" 2¾ in.,	"		20*s.* 0*d.*	"
" 3 in.,	"		25*s.* 0*d.*	"
" 4 in.,	"		35*s.* 0*d.*	"

So that though the drainage of a single acre might only cost from 2*l.* 10*s.* to 2*l.* 15*s.*, I have generally found the average over a quantity of land to vary from 3*l.* to 3*l.* 10*s.*, and even 4*l.*

8. Are there any implements in course of being introduced that will tend to facilitate and reduce the expense of drainage?

(*Mr. Smith.*) I have heard of one or two implements that are about being introduced which are said to possess the power of facilitating and reducing the expense of drainage, but how far they will become efficient in this respect I have as yet had no means of judging. Ploughs to facilitate the cutting of drains have been in use for many years in districts where alluvial clays prevail, and when used they cheapen the cost of drainage considerably; but from the great number of horses (from 8 to 12) required to work them, and from the difficulty in managing so many horses and such large implements, the use has been confined to a few enterprising and energetic individuals.

No. 1.



The first plough of this sort was invented by a farmer on the Blairdrummond estate near Stirling. It is in the form of the old Scotch plough, but of large dimensions and of great length. It throws out at once a furrow 18 inches in depth and of considerable width; the remaining depth is taken out by spades of the usual draining form. The throwing out of the furrow costs from 2*d.* to 3*d.* per rood of 36 yards, and the farther spade-work and laying in of the tiles or tubes varies with the depth. For drains 2 feet deep from the surface, 6*d.*, 26 inches, 8*d.*, and for 3 feet, 1*s.* per rood of 36 yards, is paid.

Another farmer near Stirling brought forward an improved drain-plough, about seven or eight years ago, which with eight horses and six men takes out, at two cuts, a drain of from 2 feet to 30 inches deep, of very neat form; and the tiles or tubes are laid in either on the bottom left by the plough, or after taking out a levelling spit of from 6 to 9 inches, and in some cases 12 inches deep.

Many persons prefer making use of the common plough to facilitate the cutting of the drains, taking out by it one or two furrows; and unless, the land is very rough and stony, this plan may be adopted most advantageously.

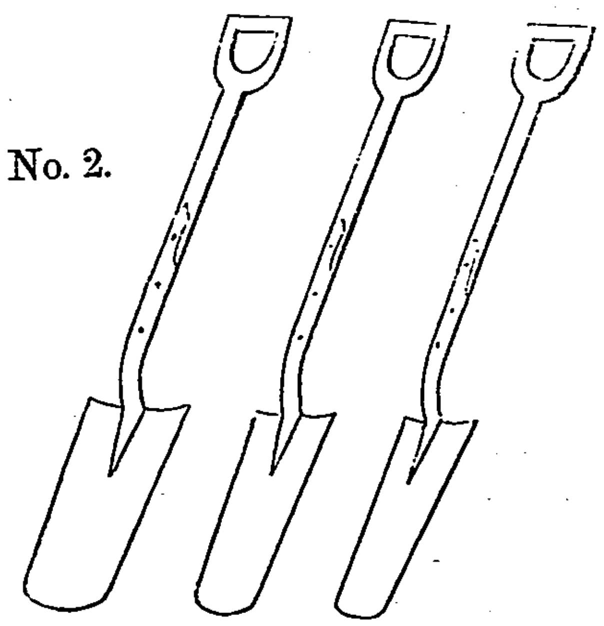
(*Mr. Parkes.*) I am not aware of any implements of recent invention which are calculated to reduce the cost of cutting drains, or to facilitate the execution. I refer to implements requiring the use of mechanical power. Plain draining tools undergo continual improvement.

(*Mr. Spooner.*) The cutting of drains is both facilitated and cheapened by the use of implements adapted to this species of work. In these the objects to be attained are as follows:—Strength, combined with lightness and handiness; width, sufficient to remove at one cut all the earth required to be taken out of a drain at any one part of it; shape of the blade, such as that it shall, when lifted, raise the earth cut, leaving the least possible quantity of crumb or broken earth to be removed afterwards.

Spades of different widths are required for cutting the different parts of a drain, so that it shall have a regular wedge shape, and a sufficient width at top to enable a person to work in it, while the bottom should be only just wide enough to receive the material to be laid.

Implements of various shapes and quality have been introduced by different manufacturers, many of them having considerable merit; but there are two sorts of drain-spades, in some respects similar to each other, that are superior to any other shape for working in ordinary soils, and very much so in the more difficult ones. Of these, one has been introduced by Mr. Darby, to which he gives the name of the "Markly Spade." This implement is admirably adapted for taking out the lowest 16 or 18 inches of a drain, and shows its superiority in shape and make in the ease with which a hard gravel or rocky bottom is cut through and lifted out. The other is a description of spade used in Kent, originally made to the order of Mr. T. P. Hilder, by F. Seeley, Aldington, near Hythe, and improved by Messrs Hunt and Sons, Brade's Steel Works, near Birmingham, who are now manufacturing them to a considerable extent. I have recently introduced them into Ross-shire and other parts of Scotland, where they are found both to improve the method of cutting the drains and materially to cheapen their execution. With implements such as these a drain 10 to 12 inches wide at top, 3 inches wide at bottom, and 36 to 40 inches deep, may be opened by a single cut from each of three sizes.

No. 2.



Drains 40 to 48 inches deep require a double cut in width and depth, by the largest of the three spades.

(*Mr. Maccaw.*) The implements for drainage have been improved from time to time, partly introduced from those in use by Mr. Parkes, and partly improved to suit the locality. On lands consisting of a stony subsoil, the implements required are somewhat different from those in use where a clay subsoil exists. Drains are now cut to a greater depth and with the removal of less earth than formerly.

(*Mr. Beattie.*) I do not know of any; but clever workmen frequently fashion their tools to give greater facilities to their labour, according to the obstacles met with.

(*Mr. Scott.*) The only implements which facilitate draining, and reduce the expense, are proper tools for the workmen to cut the drains and lay the pipes,—such as are manufactured by Messrs. Lyndon of Birmingham.

(*Mr. Neilson.*) Several attempts have been made to drain by different constructions of ploughs, and some assistance has been given, by thus throwing out a trench of 12 or 14 inches deep; but the expense thereby incurred has seldom been fully allowed for by the contract workman, who finishes the drain, and it has ceased to be much employed. Messrs. Nasmyth, the iron-founders, and Mr. Clyburn of Uley have both contemplated draining by steam-power, but nothing has, as yet, been produced to supersede the spade.

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9. What is the ordinary statement of the expectations of the return for the drainage outlay, and what is stated as to actual results?

(*Mr. Smith.*) The ordinary expectations of the results from thorough-draining varies very much according to the nature and previous condition of the land. A sixth of increase in produce of grain-crops may be taken as the very lowest estimate, and in actual result it is seldom less than one fourth. In very many cases, indeed, after some following cultivation, the produce is doubled, whilst the expense of working the land is much lessened. There is in every instance a great increase of straw for adding to the manure heap; and a less quantity of manure put upon the land will, in its altered condition, produce a full effect. Above all, the *thorough* cleaning of the *land* is facilitated; the *pulverisation* of the soil is at all times more certainly and completely attained, and at less expense; and the labour of the farmer is seldom interrupted when rain has not recently fallen. On most lands the actual result in a short course of years will enable the tenant to pay 10 per cent. on the cost of drainage, and he will be well repaid himself besides, and should be also in a better condition to pay his rent. In few instances in Scotland have the tenants refused to pay the 6½ per cent. demanded on the Government money advanced in aid of drainage.

(*Mr. Spooner.*) Drainage is ordinarily expected to yield a return of not less than 10 per cent.; and I consider, where the work is executed at a reasonable price and in an efficient and permanent manner, this estimate to be low. In many instances a return of fully 25 per cent. on the expenditure is realised, and in some even more. Such returns will not appear exaggerated on considering the various items of which the improvement consists; such as the increased quantity of every crop, the earlier cultivation, earlier seeding, and hence earlier maturity of corn, and, as a consequence, its improvement in weight and quality; the facility it affords of working the ground at most seasons of the year; the preservation of manures,

and consequent economy in their application; and other minor or local advantages which in the long-run are productive of considerable profits.

I have statements in the course of preparation intended to show the average expense of the different items of improvement now in operation under the Drainage Act in those cases in which I am concerned, together with a comparison (so far as it can be ascertained from time to time) of the produce and value before and after improvement. The present occasion affords facilities which never before existed of ascertaining facts relative to the value of improvement on the different descriptions of land which I consider might be turned to very useful account.

(*Mr. Maccaw.*) The ordinary expectations are from 8 to 10 per cent. It is, however, difficult to state accurately what returns may be actually realized, owing to the various circumstances of the natures of soils, altitude of the land drained, proximity to population, &c. Other considerations are also involved with the cost of drains, by the fencing, cleaning the surface, and enclosing the land; the making of roads; building new or adding to existing farm buildings; and also the capital required, over and above this cost, to give profitable returns by thorough after-cultivation, without which drainage of itself would not, in many cases, repay the capital involved.

The returns are generally calculated from results actually realized out of lands already drained, of similar character to that intended for improvement by drainage; viz., by ascertaining the value of the land in yearly rent previous to drainage, and its subsequent value realized after drainage and cultivation. The following cases may serve as illustrations:—

Acreable Rates.

Nos.	Character of Soil.	Original annual value.	Cost of drainage.	Present annual value.	Increased annual value.	Rate per cent. realized from outlay on drainage.	Remarks.
		s. *d.*		*s* *d.*	*s.* *d.*	Per cent.	
1	Deep soil, a part mossy.	15 0	Outfall £3 4 5 Drainage 6 16 1 £10 0 6	40 0	25 0	12½	This piece of land consisting of lochs, water-meadow of little value. Expensive outfall.
2	Loamy soil. Springs existed.	20 0	£7 7 4	32 0	12 0	8¼	Drained 4 feet deep. Land long under cultivation.
3	Thin clay soil; stiff subsoil.	12 0	£6 6 0	30 0	18 0	13¼	Drained in 1843. Afterwards a 5 years rotation in cropping.
4	A weak thin soil; gravelly, with clay.	20 0	£5 10 0	36 0	16 0	14¾	Drained in 1845. Near a town. Drains 36 feet apart, 3½ deep. Crops sold by auction.
5	Mossy soil.	2 6	Drainage and trenching, £8.	14 0	11 6	7 1/8	Mossy surface; clay and gravel subsoil. High climate.

The actual results realized from No. 3, after being drained, in a rotation of crops, 1st year, potatoes; 2d, wheat; 3d, hay; 4th, pasture; 5th, oats - - - - - £49 0 0

On which expended on drainage, subsoil ploughing, ordinary cultivation, rent, and all charges, for 5 years - -	36	5	6
Balance of profit in 5 years - -	£12	14	6

being at the rate of 2*l.* 10*s.* 10*d.* per acre annually. This was on land where green crops could not previously be raised, and on which the crop of oats preceding drainage (1843) did not yield more by public sale than an average of 2*l.* 5*s.* per acre.

No. 4. was drained in 1845. Three crops have since been disposed of by public sale, realizing - - - - £32 0 0

Expenses of drainage, cultivation, rent, manures, &c. - - - -	21	0	0
Profit - - -	£11	0	0

being at the rate of 3*l.* 13*s.* 4*d.* of annual profit.

In the case of a marsh drained on the same farm, the outfall costing at the rate of 2*l.* 10*s.* per acre, trenching 6*l.*, drainage 4*l.* 10*s.*, rent 5*s.*, planting potatoes, seed, and manure, total cost - - - - - - £22 10 0

£25 per acre was refused for the crop, which became afterwards slightly diseased, but sold for - - -	22	0	0
Thus proving one crop to have paid all costs, except - - -	0	10	0

These are, however, rather favourable cases, from the superior cultivation and manuring over that generally given to land where drainage has been effected, and from the favourable nature of the seasons, and high rates received for crops, sold almost without any failure. Calculations of drainage returns cannot altogether be based on such favourable cases; great allowances require to be made. However, I could instance several farms which, after drainage and high cultivation, now keep more than double their former stocks of cattle, &c., and even exceed that in their increased grain crops. Indeed I know few cases, under the worst circumstances, where thorough drainage has been efficiently executed, that the parties concerned have not been satisfied of its beneficial results.

(*Mr. Beattie.*) From 10 to 20 per cent. On rich soils under agriculture, 33 to 50 per cent. has been satisfactorily shown as the improved value.

The expense of cultivating wet lands is frequently double that of dry lands, whilst the returns are of inferior quality and much less in quantity.

(*Mr. Scott.*) The general return for the drainage outlay is expected to be from 7 to 12 per cent. From my own experience, the actual results have been from 10 to 20 per cent.

(*Mr. Neilson.*) My experience and observation have chiefly been in heavy clay soils where the result of drainage is eminently beneficial, and where, taking quality and quantity into consideration, I should estimate the increased crop at 6 to 10 bushels per statute acre. But this is not the only benefit arising to the occupier by the drainage of heavy land, for the decreased wear and tear in both live and dead stock from the lighter draught, the increased facilities of working the land, and the greater number of days on which it is approachable by horse-labour during rainy weather, will enable him to work a farm of 220 acres on the four-course system, with one pair of horses and their appurtenances less than would be requisite for the same system of cultivation previous to its drainage; and if to this be added the amount gained in interest by the reduction of his invested capital, the clear saving to the tenant will be equal to 10*s.* per acre, exclusive of the advantage derived from the increased productiveness of the land.

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10. State any instances where drainage has qualified a soil for a species of crop that it was formerly unfit for?

(*Mr. Smith.*) There are innumerable instances of the effect of thorough-draining and deep-working having so changed the condition of soils as to fit them for the growth of plants they could not have carried to perfection previously. The whole of the heavy alluvial clays of the carses of Scotland, on which potatoes were seldom grown successfully, and turnips never, now carry freely heavy crops of both, more especially turnips, which are followed by excellent crops of wheat. Open or naked summer fallow is becoming more rare, as the farmers find it more profitable to fill their fallows up with green crops.

On all the clays of the upland country the thorough-draining has rendered the growth of wheat certain where previously it was precarious, and such lands have become safe turnip lands. The muirish and moss lands have also been made to carry abundant green crops. There is a capability of growing, by the aid of thorough-draining, almost anywhere over the Highlands of Scotland, turnips and hay for the full winter food of an increased stock of sheep and cattle.

(*Mr. Parkes.*) There can be no doubt that from the average of soils in England requiring drainage a return is obtained after drainage considerably exceeding the legal interest of the sum expended per acre. Large breadths of land previously unable to carry wheat have been rendered capable of producing superior crops. Land, also, which in its natural state is too wet for the growth of turnips, is commonly qualified by good drainage to produce that crop in perfection. The turnip system is, on many soils, the only sure preparation for grain crops, and, generally speaking, it is the secret of profitable husbandry.

To cite any particular instance of increase of produce would be simply the recital of the acknowledged effect of drainage in most instances.

(*Mr. Spooner.*) In districts in the north of Scotland instances are numerous of crops of all sorts being cultivated in land which, without doubt, would not carry them previous to drainage. Of such description are all the moss and marsh lands now under tillage; and, in the West Highlands, crops ripen in good season on the land, when drained, which barely ripen in favourable weather, and were cut green, having never ripened in wet weather, when the land was undrained.

There are other instances, of not uncommon occurrence, applicable to a remarkable extent to this question, in the case of low-lying situations which, in popular language, are said to be affected with mildew; and this is described as being a substance having the appearance of fog, at certain times overhanging the affected district; and where this occurs the crops are coated by that peculiar parasitical substance which goes by the name of mildew. And there are localities, the cultivation of which has been abandoned in consequence of the recurrence of this evil to such extent as to render cultivation profitless. This evil is removed by drainage.

(*Mr. Maccaw.*) Drainage has qualified thin clay soils in the higher districts of every county in Scotland where it has been applied to grow green and root crops. Lands where formerly marshes existed, and parts entirely covered over with water, and unfit for cultivation, now grow crops of all the various kinds, superior in many instances to those on the old and naturally dry cultivated lands. Instances of this character are to be noticed in almost every district. It might appear invidious were I to name solitary cases, when the fact is borne out by so many throughout the country. In Ayrshire alone there are many thousands of acres, formerly unproductive, or unfit for cultivation to repay, now producing grain and green crops; a result attributable to drainage.

(*Mr. Beattie.*) Stiff clays, both of rich and poor quality, and rich coarse soils, have been brought to produce turnip crops, by furrow-draining, previously quite unmanageable for that purpose.

Black and yellow soft loam, upon hard retentive subsoil, particularly where a pan existed, by furrow-draining have been made to yield fine grass and a close sward, where nothing beyond a scanty coarse herbage ever grew before.

(*Mr. Scott.*) On my own farm at West-side House, near Staindrop, I grow white wheat, barley, and turnips, upon lands that were incapable of growing those crops previous to draining.

(*Mr. Neilson.*) A portion of my present farm, which is of stiff clay, lies low and level. Previous to drainage, the waters of winter seldom disappeared before the heat of summer had opened a passage by cracking the land. My predecessor had endeavoured to get a green crop, but always failed. The crop, the year previous to my taking it, did not produce above three tons of turnips to the acre, in consequence of the inefficiency of the manure from the stagnant water.

I drained it the following winter, and the summer after I obtained 27 tons of turnips per acre off the whole field.

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11. What is the prevalent material used for forming the drains, and what is deemed on the whole the preferable?

(*Mr. Smith.*) The prevalent material for forming drains is now, in most parts of the country, tiles or tubes. When these are difficult to be had, and dear, stones are used. Stones, when properly executed, form a very perfect and durable drain; but tubes of from $1\frac{1}{2}$ to 2 inches in diameter are decidedly preferable to all other kinds or forms of material.

Tubes made of peat earth or moss have lately been introduced, and have been well received by agriculturists, whose experience has assured them of the durability of peat. The tubes are made by a machine, and cost only from 5*s.* to 6*s.* per 1,000, dried in the open air. In Highland districts they will be a great boon.

(*Mr. Parkes.*) The most prevalent material now used in land-drainage consists of burnt cylindrical clay pipes, about 12 inches in length, and of various sized bores. This practice has become general during the last five or six years, although the use of pipes has been traced back fully forty years.

Broken stones have been heretofore much used in Scotland and in the North of England. This material is now, however, generally abandoned, as the drains formed with it are found to choke up, and the cost is very much greater than that of pipes. Horse-shoe tiles, with or without soles, have also been heretofore much used, and they are still used to some extent, but the conduit so formed is imperfect. These tiles are also more expensive than pipes, both as to first cost and carriage, and the use of them is fast passing away.

My own practice is to use cylindrical pipes, of 12 to 14 inches in length, of sizes adapted to the volume of water to be conveyed away; and in all cases where collars are procurable the pipes are joined freely together at the place of junction by means of this shorter and larger piece of pipe (called the collar), which centres each pair of pipes, and maintains an unbroken line of a true bore. This plan also secures a line of drain-pipes against the entrance of sand or deposit of any kind; and, in so far as the experience of a few years shows, drains thus constructed have been found to be safe against the entrance of roots, and of all earthy obstructive matter.

(*Mr. Spooner.*) The prevalent material used for laying in drains, at the present time, decidedly is tiles, or pipes, which, as the supplies increase, are daily becoming more so, and an increase in the supply is creating a greatly increased demand, in part resulting from their diminished price, consequent upon improved methods of making, and in part from the evident superiority of the material itself.

Where these cannot be procured, stones are employed; but much of the success of stone drainage depends on the manner in which the stones are placed, their size and quantity. Elkington's drains were usually built with an eye, and this is certainly a very efficient species of drain, but very costly.

Stone drains of every description are more liable to casualties than those laid with tiles on soles, or pipes; while the latter, even with a less apparent capacity, discharge the greater quantity of water.

In soils containing beds of running sand, stone drains are very liable to be silthed up, by sand accompanying the water as it enters them in small streams. This accident can be entirely avoided by the use of pipes, if immediately around them the earth be so closely packed that the water cannot collect into a stream, but passes into the pipe in the same minutely divided shape in which it percolates through the ground.

These are the prevalent materials used, and, with the exception of certain local usages, dependent upon the peculiar soil of certain districts, such as the wedge drain in moss, and the plug drain in clays that do not silth, are the only materials considered efficient and permanent.

For the above and other reasons I think pipes decidedly the preferable material, and that these should have a calibre of not less than $1\frac{1}{4}$ inch diameter, varying from that to 2 inches, for the ordinary drains, with an increase of size for leader or main carriers in proportion to their length and the quantity of water they will have to convey.

(*Mr. Maccaw.*) The materials first in use under the thorough-drainage system were small or broken stones, placed in the bottom of the drain in various methods so as to form a conduit; afterwards the horse-shoe tile was introduced, with a sole; and latterly pipe tiles of the cylindrical form, and in some cases collars to connect them, particularly with those pipes of less tube than 2 inches, or where the bottom of the drain is running sand, when collars are in request to connect those of 2-inch tube. The socket pipe has more recently been introduced, and is generally preferred to any other material, where it can be procured. Pipes for the mains are of larger tube, with holes in the sides of a few, to admit the smaller pipes from the branch drains.

Small or broken stones, when used in drains where the course is somewhat level and subsoil soft, have in many instances become inoperative, from the action of the water not being sufficiently rapid to clear the conduit of earthy matter taken in through its loose materials. On firm bottomed land, however, with sufficient declivity, and where stones are abundant, and the distance far from any other material, they are still used to a limited extent, with a proportion of pipes or tiles for the level or soft parts of the land, and for the main drains connected with stone drainage. Well-built stone drains with covers have long and efficiently done their duty where spring-water exists.

The horse-shoe tile with sole is still preferred by a few parties; but the pipe tile of 2-inch tube is much more in request, even without collars, for general drainage. In the former, many cases of failure have been observed; in the latter, few instances have yet been known; and in my opinion they are preferable, and certainly very superior if connected with collars, or socketed, which I would prefer, for the following reasons:—

First.—The well-formed pipe combines the greatest strength with the least weight, requires less material in its manufacture, and its hollow tube will run a greater quantity of water in a given time than the horse-shoe tile with sole of greater cavity on the same inclination.

Second.—Water running in the hollow tube of the pipe with rapid action will carry more quickly to its terminus any earthy matters taken in at its junctions than when wandering over the flat surface of a tile-sole, as it runs with less velocity.

Third.—The best made horse-shoe tiles with soles are far from being closely joined, the greatest quantity of drainage water, therefore, enters between the tile and sole; not at their vertical joints; thus presenting too much orifice by which earthy matters are admitted with the water. Pipes do not present so much for the admission of either, but more, as has been ascertained, than necessary for all the water of drainage ever required to enter their tubes. This is proved by the rapid discharge at their outlets, which is much more quick than from the tile with sole. They have continued efficient in this respect for several years, and I do not see why they should not continue as long as the horse-shoe tile with sole.

Fourth.—If the weight of pipes discharging the same quantity of water be one third less than tiles with soles, as I believe it to be, the saving of cartage will prove to the same extent, and generally the cost is much less at the tilery. Under these views, with the general impression over the country in favour of pipes, I have no hesitation in concluding they are the most preferable of all materials yet in use for general drainage purposes.

In drainage of deep moss, the conduit of the drain is generally formed by the wedge turf, and in some cases with the peat tile. The latter, however, in a very damp season, cannot be sufficiently dried; consequently the former is more in use, and has now for a considerable period proved satisfactory, when the conduit is left of sufficient dimensions.

I have presumed to extend my replies on the matter of materials probably beyond due limits; but as much dubiety still exists upon the question with extensive proprietors, who have been and are still investing large sums in drainage of their lands, I have considered it my duty here to represent my views on the merits and deficiencies of the several materials in use.

(*Mr. Beattie.*) Tile pipes, from $1\frac{1}{2}$ to 3 inches bore, 1 foot long; and broken stones, to pass through a ring of $2\frac{1}{2}$ to 3 inches, put into narrow-bottom drains, 9 to 12 inches deep of stones; wedge-shaped stones, set on end, in drains 9 to 10 inches wide in the bottom, and covered over with broken stones.

Pipes are the preferable, in respect that there are greater facilities in using them, and they afford a clearer channel for the water, with much less risk of its being obstructed. Moles and rats work down upon the stone materials and admit stuff and sand to be washed down and mixed with the stones. Pipe drainage is generally less expensive. Large pipes, glazed inside, and joined together, are used for outlets, culverts below streets, &c., and are preferable to masonry.

(*Mr. Scott.*) The cylindrical pipe-tile of from 1 to 2 inches in internal diameter, with collars for the pipes.

(*Mr. Neilson.*) Experiments are at present in progress by Mr. Whitehead of Preston in Lancashire, for making pipe-tiles of peat, which, if successful, will materially diminish the cost both of production and of cartage; but up to the present period pipe-tile draining is decidedly preferable to any other mode yet adopted, for cheapness, efficiency, and durability.

Open or horse-shoe tiles ought always to be laid on slate or flat tile soles. Pipe tiles, if less than 1½ inch in diameter, ought to be laid with collars; and for larger sizes the excavation of the bottom of the drain ought to be carefully scooped, to fit the periphery of the tile, so as to insure an unobstructed run for the water; and in all cases, though the drains may be cut by task-work, *the tiles ought to be laid by a trustworthy and careful man* at good day wages, to prevent his hurrying the work, and to induce him to take every precaution in laying them firm and even.

Drainage is as important as a building, and if well executed will last as long.

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12. What effects has extensive drainage had on the main watercourses of a district?

(*Mr. Smith.*) When surface-drainage became general, in consequence of the extended cultivation of the country, and the improvement of waste lands, and more especially when open sheep-drains were extensively adopted on the hill-grazings, it is notorious that the excess of floods was greatly increased, and that the streams of the country dried sooner in dry periods. The introduction of thorough-draining has, on the contrary, had a tendency to restrain the excess of floods, as the rain falling on the surface has to fill the vacuities of the drained soil, and it takes at least 48 hours to drain fully off after rain has fallen; so that the crisis of the flood from the surface-water of the undrained land has passed before the percolating water comes to increase its volume. The effects of a general thorough-drainage will be to diminish much the excess of floods in the streams, whilst the quantity of mud carried off will be vastly reduced, as the water from the thorough-drains generally runs nearly free from suspended matter.

During dry periods, more particularly in summer, the water in the streams is greatly lessened by thorough-draining; for there is so great a mass of comparatively dry and absorbent soil to receive the rain, that summer showers, unless very heavy and continuous, will be entirely absorbed.

(*Mr. Parkes.*) The intention and effect of a complete and systematic under-drainage is the liberation of the water of rain more quickly from the land than if it were not drained; and therefore the natural vents or rivers very generally require enlargement or deepening, in order to pass off the drainage water in sufficiently quick time, and so as to avoid flooding lower lands.

The sluggish rivers of the midland and southern counties of England especially oppose great obstacles to land-drainage, being usually full to the banks, or nearly so, and converted into a series of ponds, by mill-dams erected at a few miles distance below each other, so that frequently no effectual drainage of the richest alluvial soil composing the meadows can be made without forming embankments or by pumping, or by resort to other artificial and expensive means.

The greater number of the corn and other water-mills throughout England ought to be demolished, for the advantage of agriculture, and steam-power should be provided for the millers. I believe that such an arrangement would, in most cases, prove to be economical both to the landholder and the miller.

A striking example of the economical and beneficial result arising from the destruction of mill-dams, and the substitution of steam for water-power, has recently been exhibited under the operation of the Rye and Derwent Drainage Act, resulting from the wise and friendly co-operation of the Earls Carlisle and Fitzwilliam (the chief proprietors) with other landowners to knock down three mill-dams, give the millers steam, thereby restoring the river to its natural bed and proper function as the great artery of drainage, and enabling thousands of acres of land to be drained and reclaimed, or brought into more profitable cultivation at a very moderate cost. This excellent work has its terminus at New Malton in Yorkshire.

Every old authority and all modern writers on land-drainage in England have condemned water-mills and mill-dams; and if all the rivers of England were surveyed from the sea to their source, the mills upon them valued, the extent of land injured or benefited by such mill-dams ascertained, and the whole question of advantage or injury done to the landowner appreciated and appraised, I have little doubt but that the injury done would be found so greatly to exceed the rental of the mills, deduction being made of the cost of maintaining them, that it would be a measure of national economy to buy up the mills, and give the millers steam-power.

(*Mr. Spooner.*) The effect which extensive drainage produces on the main watercourses of districts is that of increasing the height of their rise at flood-times, and rendering the flow and subsidence more rapid than before. I have repeatedly heard the river Tweed adduced as a striking instance of this fact, and that the change has taken place within the observation of the present generation.

(*Mr. Maccaw.*) It has been observed that after extensive surface-drainage on the sheepwalks in the higher parts of the country, and when the lower lands were enclosed by ditches, and partially drained for the purposes of cultivation, all rivers flowing therefrom rise more rapidly after heavy rains or falls of snow, and discharge their surplus waters more quickly, than under former circumstances.

(*Mr. Beattie.*) It renders them more speedily flooded, and to a greater height, and they fall sooner.

Rivers are lower in summer and higher in winter.

(*Mr. Scott.*) I cannot speak to this from local knowledge.

(*Mr. Neilson.*) The immediate effect of the drainage of higher lands has often been to inundate the lower levels, because, generally speaking, the ordinary waters are barely sufficient to discharge the more protected approach of the waters from the previously undrained land; but when these courses have been properly adapted to the more rapid discharge of water consequent on the land being drained, they are, in most cases, maintained in order at less expense.

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13. Have any important applications been made of the additional water-streams thus derived, or are any possible applications apparent?

(*Mr. Smith.*) In a few places I have observed, and in some cases I have advised, the useful application of the water from drains for irrigation, &c. The most extensive and perfect application of water derived from thorough-draining which I have had an opportunity of examining, is upon the estate of Lord Hatherton in Staffordshire. His lordship has there had collected very cleverly the drainage water of the higher lands of his estate, he has erected several ponds for storing it, and he has it carried to his farmyard, where it drives a powerful water-wheel, which does all the thrashing, milling, chopping, &c., and drives a saw-mill besides. From the mill the water is carried in canals of gentle fall to lower meadow ground, where it is used in extensive and profitable irrigation.

Drain-water always contains more or less of the manure and soluble parts of the soil in suspension, and the fertilising properties of the drain-water on this estate are particularly marked by the very luxuriant growth of grass it produces on the meadows. This experiment forms a noble example of an econ)my in agriculture worthy of imitation, and is one which can be carried out to a greater or less extent on all farms having surfaces at different altitudes.

I have been long of opinion that it would be found profitable to have a large pond at the lowest point of every farm to receive and store the water from the drains, and to have a steam-engine to pump and convey it in pipes for watering the fields during dry periods. By this means the crops would be much refreshed, and whatever matter had been taken off the land by the drain-water would in great part be returned. This system would be the more profitable if the steam-engine and pipes were likewise used to distribute liquid manure over the fields, as is now done on a farm of 300 acres in extent near Glasgow.

(*Mr. Parkes.*) See reply to question 5th.

(*Mr. Spooner.*) The only useful purpose to which I can conceive water-courses derived from general drainage to be applicable is, that the additional quantity quickly supplied would render them the more valuable in situations where water meadows can be formed, as the greater rapidity and increase in quantity of the water passing down from the drains, through the smaller tributaries, the greater will be the sediment of fine earthy mater deposited at any one time, and the greater, therefore, I conceive, will be the benefit produced in such situations.

(*Mr. Maccaw.*) I am aware that water of drainage has, in some instances, been conducted into millponds to augment the usual supply in propelling machinery; it has also been conveyed to farm steadings for domestic purposes and the use of stock. Deep drainage has in many cases given a continued supply for the use of cattle in fields, the water being conducted into reservoirs where the natural supply had been indifferent in quality and deficient in quantity; in other instances it has been applied to the irrigation of meadow lands on a lower level. In some respects its extended application in this way may prove of much importance.

(*Mr. Beattie.*) None, beyond the usual application, as additional supply for machinery power, watering fields and houses, &c.

(*Mr. Scott.*) Water derived from the drainage of land may be applied for the irrigation of grass lands adjoining on a lower level.

(*Mr. Neilson.*) In many instances, where the undulation of the land allows it, the waters from the higher levels are collected, and beneficially applied for mechanical and other purposes, such as thrashing the corn, irrigating the lower levels, &c. &c.

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14. Are there any cases known where observations have been made as to the quality of the water derived from the land drainage, that is, as to its temperature, clearness, and as to the salts and vegetable and animal products that it contains, with a view, either of determining its fitness for domestic or other uses, or for finding to what extent it has carried down matters from the soil?

(*Mr. Smith.*) The water flowing from drains is generally very limpid and pure, although at times, when much manure has been recently put upon the land, it is impregnated to a considerable degree with soluble matter, and sometimes colouring. It is, nevertheless, usually fit for domestic purposes, and is much prized where there are but few springs, and where the people previous to the introduction of thorough-draining had to bring the water for domestic purposes from a distance, by carts, at great expense. They now form wells to retain a supply of the drainage-water for the dry seasons, by which their health and comfort have been greatly promoted. The cattle are also supplied with wholesome water in the summer.

The temperature of the water flowing from drains depends in a great measure upon its origin, as to what proportion comes from under-springs, and what from rain-water passing through the soil. The deep drains, of course, catch more of the spring-water than the shallow ones. The water yielded by drains that derive their supply chiefly from the rain which falls upon the surface of the land is frequently, during the summer months, raised considerably in its temperature, owing to the heated condition of the atmosphere and of the ground on which it has fallen.

Mr. John Wilson, an excellent chemist, at present manager of the Agricultural College at Cirencester, made a series of analyses of drain-water from a farm in East Lothian, in the year 1844; and he found a considerable quantity of salts and organic matter, especially after manure has been recently applied.* The following is a note of Mr. Wilson's analysis of two samples of drain-water:

Analysis No. 1.

The water taken from drains upon the 29th April, when there had been a moderate fall of rain. The land was in plough as winter fallow.

18 lbs of drainage-water on evaporation gave 15·2 grs. of solid residue, or about ·844 gr. to the pound.

Organic matter and water in combination	3·4
Silica	0·9
Silicate of alumina	0·4
Chloride of magnesium	1·12
Chloride of sodium	0·8
Chloride of calcium	3·0
Sulphate of alumina	0·85
Peroxide of iron	2 1
Phosphate of lime	0·3
	13·87

* The particulars of this drainage are not stated exactly, but it would appear either that some water had reached the drains which had not filtered through the soil, or that manure had been applied in excessive quantity, that is, more than the soil could absorb; for Professor Way found that a moderate quantity of foul liquid, filtered through only six inches of soil, was deprived of all its manure. The following table gives the contents, in grains, of a gallon of the liquid before and after filtration, according to his analysis:—

	Before.	After.
Organic matter and ammoniacal salts	301·82	—
" " destitute of nitrogen	—	60·58
Sand, &c.	20·69	—
Soluble silica	12·51	—
Phosphoric acid	10·44	—
Sulphuric acid	14·73	—
Sulphate of lime	—	17·49
Carbonic acid	15·59	—
Lime	24·53	—
Carbonate of lime	—	104·98
Magnesia	2·87	—
Peroxide of iron and alumina	6·2	—
Potash	48·13	—
Soda	1·51	—
Chloride of calcium	—	8·89
" magnesium	—	·67
Common salt	33·24	52·73
Loss	—	3·16
	492·26	248·50

Analysis No. 2.

The water taken from drains after the field had been sown with guano and barley seed upon the 16th May.

18 lbs. of drainage-water on evaporation gave 27·5 grs. of solid residue, or about 1·525 gr. to the pound.

Organic matter, &c.	7·8
Silica	0·7
Silicate of alumina	0·2
Protoxide of iron	2·25
Phosphate of magnesia	1·8
Magnesia	1·69
Chloride of sodium	2·605
Chloride of calcium	2·107
Carbonate of alumina	2·7
Phosphate of lime	3·1
Phosphate of alumina	0·45
	25·412

(*Mr. Parkes.*) I am not aware of any analyses which have been made of the water of drainage. It is a subject which pre-eminently deserves attention in an agricultural point of view.

The results of my experience tend to show that the water issuing from deep under-drains in land is generally soft, that it is relished for drinking by stock, and approved for household and washing uses in villages and hamlets, where I have had to conduct water from the drainage of land to serve those purposes. The water derived from a shallow system of drainage is often troubled after rain or after the ploughing up of fields, and it is offensive to the taste and smell after the manuring of lands. The water of deep drainage is generally perfectly pellucid, and I should consider a drainage to be imperfect if sand or earthy matter were carried off from the soil by drains.

As regards the temperature of the water derived from drainage at different seasons of the year, I am unacquainted with any published facts. This is a subject of the highest import, as thermometric observations may be rendered demonstrative in the truest manner of the effect of drainage on the climate of the soil. I have myself paid attention for some years past to this subject, and am now collecting facts bearing upon it, in many counties in England. I am not, however, prepared at present to make known the results of these observations, and must limit myself to saying, that I have never known the water of drainage issue from land drained at Midsummer, to depths of 4 and 5 feet at a higher temperature than 52 or 53 degrees Fahrenheit; whereas, in the following year and subsequent years, the water discharged from the same drains, at the same period, will issue at a temperature of 60 degs., and even so high as 63 degs., thus exhibiting the increase of heat conferred during the summer months on the terrestrial climate by drainage. This is the all-important fact connected with the art and science of land-drainage, but into which I feel sure your lordship will excuse my entering at length, in thus cursorily replying to the questions of the Sanitary Commissioners.

(*Mr. Spooner.*) I am not acquainted with a sufficient number of comparative cases under this head to arrive at any certain conclusions.

(*Mr. Maccaw.*) I have found few instances of drainage-water being analysed, or extended observations made on its qualities, so as to enable me to submit to your Board that important information required on this question, as in my opinion any single instance or two may not prove sufficient to form conclusive evidence of the qualities, &c. of drainage-water in general over the country. I had submitted to your former president, the Earl of Carlisle, an analysis of water by Professor Penny, taken from drains in my farm in December 1848. This water was taken immediately after very heavy falls of rain. The drains were 36 feet apart and 3½ feet deep. The main drain, from which the water was taken, discharged the drainage-water of about 5 acres of land, the drainage of which was effected early in the season of 1847. Afterwards, the land was well manured with farmyard dung; 15 to 20 bushels crushed bones, and 3 cwt. Peruvian guano, per acre, applied to a turnip crop, one half of which was fed on the ground by sheep, afterwards a top dressing of lime and earth compost applied, and in 1848 a crop of wheat taken, sown out with grass and clover seeds; both crops excellent. The land had previously been in poor condition and wet, being a thin porous soil, on a subsoil of sandstone gravel, with a small mixture of clay. I have taken the liberty to mention these matters, as much may depend on the state of the land from which an analysis of drainage-water is taken. The following will show that the animal and vegetable products in the soil from this case have not been carried off by the water to any great extent. I may add, I had never noticed, on any former occasion after heavy falls of rain, a greater discharge from the same outlet than at the time this water was collected.

The following is the chemical analysis by Professor Penny of Glasgow:—

"The specific gravity of this water is 1·00018. An imperial gallon when evaporated to dryness left a solid residue which weighed 12·1 grains; this residue is the total amount of foreign matter contained in the water, and it contains the following ingredients in solid residue.

Carbonate of lime and magnesia	- 5·9	grains.
Sulphate of lime - -	- 1·6	„
Animal and vegetable matter -	- 1·55	„
Common salts - -	- 2·54	„
Chloride of magnesium - -	- Trace	
Silicious matter - -	- 0·42	„
Alkaline sulphates - -	- 0·09	„
	12·1	„

"Remarks.—This water is bright, clear, and colourless. It contains an insignificant quantity of floating or mechanically suspended matter, which readily subsides on exposure, and is completely and easily separable by filtration. It is comparatively a soft water, containing only a very small proportion of lime and magnesia, on which the quality of water termed 'hardness' depends.

"The ingredients given in the foregoing table of analysis exist in the water in a state of solution, and cannot therefore be separated either by filtration or subsidence; none of these ingredients are hurtful to health or animal life. This water is perfectly free from deleterious gases and from injurious metallic impregnations. It does not become offensive or putrescent on being kept, and will not give rise to noxious effluvia on being collected into ponds or other large reservoirs, and it cannot therefore obviously tend to produce or in any way to contribute to disease.

"This remark applies only to this particular sample, and not to drainage-water generally, which as yet has not been frequently enough analysed to warrant us in forming a conclusive or satisfactory opinion.

"This water contains nothing to render it unfit for domestic use, either as a beverage or as a detergent; it contains a less amount of foreign matters than many waters supplied to large towns; it has a slightly insipid taste, arising from the small proportion of lime salts dissolved in it, and also from a deficiency of fixed air or carbonic acid gas.

"From its comparative purity this water is well adapted for many manufacturing purposes."

Another instance of the analysis of drainage-water is recorded in the "Rural Cyclopedia," edited by the Rev. John Wilson, under the article "Manures."

The depths of drains are not mentioned, but it may be concluded that they were shallow, probably not more than 2 feet, the deeper system not then being introduced.

Three analyses were taken from three specimens of drainage-water caught from the discharge of subsoil drains of a farm in East Lothian.

1st. After the drains had been dry for many weeks, in November 1844;

2d. On 29th April; and

3d. On 16th May 1845, when the land had been sown with a grain-crop after a winter fallow; the manure applied to the crop was guano.

The result shows the quantity of salts and of vegetable and animal products found in the water to be a very serious affair in respect to the extraction of their valuable fertilising matters, while their retention in the water rendered it unfit for domestic purposes. In another analysis taken at the same time of the turbid water from the surface of the same land, the results appear to have been little different from those of the water from the subsoil drains.

These last analyses show very different results from that of the drainage-water from my farm. It occurs to me partly to have arisen from the water of the latter being that of deeper drains; it being evident, on inspection, that after heavy falls of rain, drains of little depth discharge their waters in a very turbid state, compared with that of drains of greater depth under similar circumstances; consequently those fertilising ingredients held in suspension by the water are more subject to be carried down into the shallow than to the deeper drain, the latter presenting a much greater body of soil for filtrating its water.

I have noticed in the suburbs of Glasgow, where liquid manure has been extensively applied over a large extent of land, by means of a powerful steam engine and pipes, that the water from the drains of about 2½ feet deep (the soil a tenacious clay) was highly impregnated with the liquid, and that all the open watercourses into which those drains discharged gave strong indications of the escape of this fertilising manure being rapidly carried off, chiefly by the drains.

The case appears different where the same process is being also extensively applied to lands in my immediate neighbourhood, where the soil and subsoil were porous, and the drains of four feet in depth, and at greater distances apart, the water being discharged from those drains comparatively pure.

A recent analysis of the water from a deep-seated spring, rising out of sandstone rock in the lower part of a town in my neighbourhood, showed that it contained a large quantity of animal and vegetable matter in a state of solution, proving that such, even by filtration through a great depth of soil, cannot be extracted from water.

I have no doubt that by the process of thorough deep drainage a considerable portion of valuable fertilising matters may be extracted with water from the lands, but not a tithe of what would be carried off by water from the same soil previous to drainage.

I have hitherto made no experiments as to the temperature of water from drains, but can instance a striking fact as to its effects on the temperature of the soil when deep drainage has been executed, which has now been confirmed by parties who have had their attention directed to it in different parts over the country; viz., that snow melts away much more quickly from drained than undrained land. I can instance a field in my neighbourhood, on which a portion has been drained under a shallow and imperfect system, and a part of it under a deep and thorough system; where I have observed repeatedly the fact of snow being much sooner cleared away on the surface of that portion under the deep drainage than from the shallow. This is still more apparent on soils of a similar character and exposure where drained and undrained; from which fact it is evident that the effects produced on temperature of soils by drainage is highly beneficial, and quite satisfactory, without the test of any minute experiments.

(*Mr. Beattie.*) I am not aware of any. Water from perfect thorough-drainage is always clear, and, I think, generally fit for domestic purposes.

The main streams are less adulterated by deleterious matter after extensive drainage.

The stagnate and putrid water on the surface of undrained marsh and moss lands is washed out every flood, in many instances rendering the rivers almost black. If these grounds were drained and cultivated the water would flow gradually away from the drains in a filtered and clear state.

(*Mr. Scott.*) Water that flows from deep drains is more pure and clear than that from shallow drains. The difference in the temperature of the water varies from 2 to 3 degrees in favour of the deep drains, I find, from my own observation.

Water from shallow drains frequently carries away the salts, vegetable and animal products, contained in the manures applied to land, which is very apparent where good farmyard manure has been laid on a fallow, and heavy rains follow immediately after.

(*Mr. Neilson.*) I have never made any chemical experiments sufficiently accurately to be given here.

I may, however, state, that in draining the fields I have already alluded to I cut through a stratum of ocherous gravel, about 4 inches thick, varying from 8 to 12 inches from the surface. During the green crop I subsoiled it, about 16 inches deep, and soon after the commencement of the autumn rains I observed the vegetation, at the sides of the watercourse into which the main drain was discharged covered with a yellow scum. I found the same appearance of yellow sediment in two or three places which I examined in the main drain, but before the winter was over this had all disappeared, and the water came away perfectly clear, and has done so ever since.

The temperature at daybreak in winter of water discharged from the mouth of the drain, after rain on the previous day, is higher than that lying on the surface of an undrained field immediately adjacent to it; and the difference between a thermometer plunged in the soil near a drain, and one placed at the same depth in an undrained part of the same field, varies from 5 to 8 degrees, according to the season; the colder the weather the greater the difference.

In conclusion, I beg to annex extracts from letters I have received from Mr. Pearson, the medical officer of Much Woolton, and Mr. Tyrer, the relieving officer of the Prescot Union.

These two places, between which I reside, have, for several years past, being visited each autumn with both typhus fever and dysentery, in great severity, owing to the want of proper drainage, and the stagnant cesspools caused by the excessive numbers of the lowest classes of Irish who nightly crowd their houses with men, women, and children indiscriminately, to the number of 12 or 14 in a room. As one of the county magistrates, I last year assisted these officers in enforcing some strict sanitary measures, and the following extracts are from their replies to some queries I lately made to them, with reference to the probable approach of cholera.

EXTRACT FROM MR. PEARSON'S LETTER.

"The sanitary improvement you enforced last year in the district of Much Woolton, assigned to my medical care, proved of the greatest possible benefit in the suppression of typhus fever and dysentery.

"Where it *was* carried out, fever quickly subsided, and eventually disappeared, and since then I have not seen a case of it; but where it *was not* carried out, we have had both fever and dysentery, and I have, at this time, several cases. In support of this I enclose a copy of my sick-list returns for the last half of last year, as sent weekly to the guardians, and also for the same period this year.

"I may also add, that last year we had in our dispensary 667 cases, whereas this year we shall not have more than 330, which I attribute entirely to the sanitary improvement alluded to.

	Medical Relief List, Cases of Fever and Dysentery. List for 1847.	Woolton District, Prescot Union List for 1848.
July	25	None
August	30	2
September	17	7
October	9	4
November	9	3
December	12	No return
	102	16

(Signed) "JOHN ARMITAGE PEARSON,
"Medical Officer."

EXTRACT FROM MR. TYRER'S, PRESCOT.

"I am strongly of the opinion that the result of the measures of improvement you enforced here last year, by drainage, has been most beneficial to the health of the inhabitants in the localities where the fever and dysentery committed such ravages previously, for I well know that there has been much less illness of any kind there since.

(Signed) "THOS. TYRER,
"Relieving Officer."

These opinions are of much value, particularly Mr. Pearson's, who has given much time and attention to the subject.

ROBERT NEILSON.

Hallwood, 2d December 1848.

No. VIII.

The following description of Mr. Fowler's draining-plough is copied from a Report to His Royal Highness the President of the Commission for the Exhibition of the Works of Industry of All Nations on Agricultural Implements, Class IX, by Philip Pusey, M.P., published in the Journal of the Royal Agricultural Society, Vol. XII. No. xxvii., pp. 639—641.

"THE DRAINING PLOUGH.

"But for the American reapers, Mr. Fowler's draining-plough* would have formed the most remarkable feature in the agricultural department of the Exhibition. Wonderful as it is to see the standing wheat shorn levelly low by a pair of horses walking along its edge, it is hardly if at all less wonderful, nor did it excite less interest or surprise among the crowd of spectators when the trial was made at this place, to see two horses at work by the side of a field, on a capstan, which by an invisible wire-rope draws towards itself a low framework, leaving but the trace of a narrow slit on the surface.

"If you pass, however, to the other side of the field which the framework has quitted, you perceive that it has been dragging after it a string of pipes, which still following the plough's snout, that burrows all the while 4 feet below ground, twists itself like a gigantic red worm into the earth, so that in a few minutes when the framework has reached the capstan, the string is withdrawn from the necklace, and you are assured that a drain has been invisibly formed under your feet. The jury decided as follows:—

"The implement went through the trial very well, laying in the tiles with great apparent ease, worked by *two* horses, with a capstan, which was firmly and easily fixed into the ground, and afforded a firm traction to the plough by means of a wire rope and pulley. Progress has been made since

* The machine is made by Messrs. Fowler and Fry, Temple-gate, Bristol.

the implement was exhibited at Exeter, in rendering the level of the drains in a degree independent of the level of the surface; but there is still room for further improvement in giving to the drain a *uniform* incline. The award, therefore, of the jury was honourable mention.

" Since that trial I have thought it right to make further inquiry into the work of the draining-plough. In the first place, the trial drains were opened, and laid bare from end to end. Straightness is, of course, one requisite, and the pipes were laid straight; closeness of contact another, and they were perfectly joined. In level, the point on which the jury doubted the perfection of the work, there was some deficiency which, on entirely flat ground such as this, was a decided fault. That fault, however, has since been remedied for clay land at least. As the plough was shown last year at Exeter, it could not possibly lay a level drain, because its under and upper parts being fixed at an unvarying distance, any unevenness of an undulatory surface must be faithfully copied by an undulating drain below. This year the two parts were so connected, that the workman by turning a screw can raise or lower the underground snout which burrows out the drain. But at the trial the use of this screw depended on the workman's judgment, which cannot give the drain absolute accuracy. A balanced level, however, has now been added to the plough, by which the changes of surface are made plain to his eye. Other improvements have also been made in the implement. The horse-power required has been reduced by a fourth, and the windlass at which the horses work need now be shifted only once in the day. As to the economy of using the draining-plough, it is too expensive to purchase, unless for a large landowner, but it may be hired by the year or the month. Its inventor is also ready to execute work at his own risk by contract, at a saving of from one third to two thirds on hand labour, the greater the depth the greater being the saving. I have only seen the actual cost of two drainages that have been made by this plough. They were both without tiles and shallow, being only $2\frac{1}{2}$ feet deep; taking the highest of them, and adding the cost of tiles, the price of tile-draining land at that depth, and at 33 feet apart, would be 14*s.* only for work, and $1\frac{3}{4}$ inch pipes at 15*s.* per 1,000, 18*s.* 9*d.* for tiles; all together 1*l.* 3*s.* 9*d.*, including horses and hire of machine.

" The plough goes as well, however, at a depth of 4 feet, nor could the additional cost be material. The plough has worked on the following farms:—

	Acres.	Depth.	
" Mr. Fowler, Melksham	14 -	2 ft. 6 in.	with pipes.
" Mr. Newman do.	10 -	2 " 0 "	"
" Mr. Blandford, near do.	30 -	3 " 6 "	"
" Mr. Purch, Doun Ampney - -	100		without pipes.
" Mr. Hall, Brentwood	200 -	2 " 6 "	with and without.
" Wormwood Scrubbs	40	from 2 ft. to 4 ft.	with tiles.

" Mr. Harris, Darlington (now working), 3 ft. 6 in.

" In clay subsoils, with a gentle fall, the success of this new implement seems to be beyond doubt; and in all circumstances the inventor is ready to undertake the risk of the execution."

Table showing the equal Annual Amount of Principal combined with Interest viz. from 3 to 6 per cent. per annum,

Number of Years in which Loans to be repaid.	3 per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1.	£100.	3½ per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1.	£100.	4 per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1.	£100.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1	1·030000=1 0 7¼	103 0 0	1·035000=1 0 8½	103 10 0	1·040000=1 0 9½	104 0 0
2	·522611=0 10 5½	52 5 2¾	·526400=0 10 6¼	52 12 9½	·530196=0 10 7¼	53 0 4¾
3	·353530=0 7 0¾	35 7 0¾	·356934=0 7 1¾	35 13 10½	·360349=0 7 2½	36 0 8¼
4	·269027=0 5 4¾	26 18 0¾	·272251=0 5 5¼	27 4 6	·275490=0 5 6	27 10 11¾
5	·218354=0 4 4½	21 16 8½	·221481=0 4 5¼	22 2 11½	·224627=0 4 6	22 9 3
6	·184597=0 3 8¼	18 9 2¼	·187668=0 3 9	18 15 4	·190762=0 3 9¾	19 1 6¼
7	·160506=0 3 2½	16 1 0¼	·163544=0 3 3¼	16 7 1	·166610=0 3 4	16 13 2½
8	·142456=0 2 10¼	14 4 11	·145477=0 2 11	14 10 11¼	·148528=0 2 11¾	14 17 0¾
9	·128434=0 2 6¾	12 16 10½	·131446=0 2 7½	13 2 10¾	·134493=0 2 8¼	13 8 11¾
10	·117231=0 2 4¼	11 14 5½	·120241=0 2 4¾	12 0 5¾	·123291=0 2 5½	12 6 7
11	·108077=0 2 2	10 16 1¾	·111092=0 2 2¾	11 2 2¼	·114149=0 2 3½	11 8 3½
12	·100462=0 2 0	10 0 11	·103484=0 2 0¾	10 6 11¾	·106552=0 2 1½	10 13 1¼
13	·094030=0 1 10½	9 8 0¾	·097062=0 1 11¼	9 14 1½	·100144=0 2 0	10 0 3½
14	·088526=0 1 9¼	8 17 0½	·091571=0 1 10	9 3 1¾	·094669=0 1 10¾	9 9 4
15	·083767=0 1 8	8 7 6¼	·086825=0 1 8¾	8 13 7¾	·089941=0 1 9½	8 19 10½
16	·079611=0 1 7¼	7 19 2¾	·082685=0 1 7¾	8 5 4½	·085820=0 1 8½	8 11 7¾
17	·075953=0 1 6¼	7 11 10¾	·079043=0 1 7	7 18 1	·082199=0 1 7¾	8 4 4¾
18	·072709=0 1 5½	7 5 5	·075817=0 1 6¼	7 11 7½	·078993=0 1 7	7 17 11¾
19	·069814=0 1 4¾	6 19 7½	·072940=0 1 5½	7 5 10½	·076139=0 1 6¼	7 12 3¼
20	·067216=0 1 4¼	6 14 5¼	·070361=0 1 5	7 0 8¾	·073582=0 1 5¾	7 7 2
21	·064872=0 1 3½	6 9 9	·068037=0 1 4¼	6 16 1	·071280=0 1 5	7 2 6¾
22	·062747=0 1 3	6 5 6	·065932=0 1 3¾	6 11 10¼	·069199=0 1 4½	6 18 4¾
23	060814=0 1 2½	6 1 7½	·064019=0 1 3¼	6 8 0½	·067309=0 1 4¼	6 14 7½
24	·059047=0 1 2¼	5 18 1¼	·062273=0 1 3	6 4 6½	·065587=0 1 3¾	6 11 2
25	·057428=0 1 1¾	5 14 10¼	·060674=0 1 2½	6 1 4¼	·064012=0 1 3¼	6 8 0¼
26	·055938=0 1 1½	5 11 10½	·059205=0 1 2¼	5 18 5	·062567=0 1 3	6 5 1½
27	·054564=0 1 1	5 9 1½	·057852=0 1 2	5 15 8½	·061239=0 1 2¾	6 2 5½
28	·053293=0 1 0¾	5 6 7	·056603=0 1 1½	5 13 2½	·060013=0 1 2½	6 0 0¼
29	·052115=0 1 0½	5 4 2¾	·055445=0 1 1¼	5 10 10¾	·058880=0 1 2	5 17 7¼
30	·051019=0 1 0¼	5 2 0½	·054371=0 1 1	5 8 9	·057830=0 1 1¾	5 15 8

Rule.—To find the Annual Instalment to repay any amount with Interest in any number of Years from 1 to 30, at any rate of Interest from 3 to 6 per cent., multiply the sum to be repaid with Interest in equal Annual Instalments by the fraction of £1, which would repay £1 with Interest at the given rate in the given period, as shown in the first column of the Table opposite the number of Years.

1st Method:— ·070682 × £5,722 = £404 8 10

or ·070682
5722
———
141364
141364
494774
353410
———
404·442404
20
———
8·848080
12
———
10·176960 = £404 8 10

Note.—These tables have been examined and certified by John Finlaison, Esq., Actuary of the National Debt Office.

which is requisite for the Repayment of Loans at the under-mentioned rates of Interest, in any period of from one to thirty years.

4½ per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1.	£100.	5 per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1.	£100.	6 per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1.	£100.	Number of Years in which Loans to be repaid.
£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	
1·045000=1 0 10¾	104 10 0	1·050000=1 1 0	105 0 0	1·060000=1 1 2½	106 0 0	
·533998=0 10 8¼	53 8 0	·537805=0 10 9	53 15 7¼	·545437=0 10 11	54 10 10½	2
·363773=0 7 3¼	36 7 6½	·367209=0 7 4¼	36 14 5	·374110=0 7 5¾	37 8 2¾	3
·278744=0 5 7	27 17 5¾	·282012=0 5 7¾	28 4 0¼	·288591=0 5 9½	28 17 2¼	4
·227792=0 4 6¾	22 15 7	·230975=0 4 7½	23 1 11½	·237396=0 4 9	23 14 9½	5
·193878=0 3 10½	19 7 9	·197017=0 3 11¼	19 14 0¼	·203363=0 4 0¾	20 6 8¾	6
·169701=0 3 4¾	16 19 5	·172820=0 3 5½	17 5 7¾	·179135=0 3 7	17 18 3¼	7
·151610=0 3 0½	15 3 2¾	·154722=0 3 1	15 9 5½	·161036=0 3 2¾	16 2 0¾	8
·137574=0 2 9	13 15 1½	·140690=0 2 9¾	14 1 4½	·147022=0 2 11¼	14 14 0½	9
·126379=0 2 6¼	12 12 9	·129505=0 2 7	12 19 0	·135868=0 2 8¾	13 11 9	10
·117248=0 2 4¼	11 14 6	·120389=0 2 5	12 0 9¼	·126793=0 2 6¼	12 13 7	11
·109666=0 2 2¼	10 19 4	·112825=0 2 3	11 5 7¾	·119277=0 2 4¾	11 18 6¾	12
·103275=0 2 0¾	10 6 6½	·106456=0 2 1½	10 12 11	·112960=0 2 3	11 5 11	13
·097820=0 1 11½	9 15 7¾	·101024=0 2 0¼	10 2 0½	·107585=0 2 1¾	10 15 2	14
·093114=0 1 10¼	9 6 2¾	·096342=0 1 11¼	9 12 8¼	·102963=0 2 0¾	10 5 11¼	15
·089015=0 1 9½	8 18 0¼	·092270=0 1 10¼	9 4 6½	·098952=0 1 11¾	9 17 11	16
·085418=0 1 8½	8 10 10	·088699=0 1 9¼	8 17 4¾	·095445=0 1 11	9 10 10¾	17
·082237=0 1 7¾	8 4 5¾	·085546=0 1 8½	8 11 1	·092357=0 1 10¼	9 4 8½	18
·079407=0 1 7	7 18 9¾	·082745=0 1 7¾	8 5 5¾	·089621=0 1 9½	8 19 3	19
·076876=0 1 6½	7 13 9	·080243=0 1 7¼	8 0 5¾	·087185=0 1 9	8 14 4½	20
·074601=0 1 6	7 9 2½	·077996=0 1 6¾	7 16 0	·085005=0 1 8½	8 10 0	21
·072546=0 1 5½	7 5 1	·075971=0 1 6¼	7 11 11½	·083046=0 1 8	8 6 1	22
·070682=0 1 5	7 1 4¼	·074137=0 1 5¾	7 8 3¼	·081278=0 1 7½	8 2 6¾	23
·068987=0 1 4½	6 17 11¾	·072471=0 1 5½	7 4 11¼	·079679=0 1 7¼	7 19 4¼	24
·067439=0 1 4¼	6 14 10½	·070952=0 1 5	7 1 11	·078227=0 1 6¾	7 16 5½	25
·066021=0 1 4	6 12 0½	·069564=0 1 4¾	6 19 1½	·076904=0 1 6½	7 13 9¾	26
·064719=0 1 3½	6 9 5¼	·068292=0 1 4½	6 16 7	·075697=0 1 6¼	7 11 4¾	27
·063521=0 1 3¼	6 7 0½	·067123=0 1 4¼	6 14 3	·074593=0 1 6	7 9 2¼	28
·062415=0 1 3	6 4 10	·066046=0 1 4	6 12 1	·073580=0 1 5¾	7 7 2	29
·061392=0 1 2¾	6 2 9½	·065051=0 1 3¾	6 10 1¼	·072649=0 1 5½	7 5 3½	30

Or less exactly by proportion in sterling money,—as £100 is to the sum to be repaid, so is the Annual Instalment which would repay £100 in the given period, with the given rate of Interest, to the Annual Instalment required. The Instalment necessary to repay £100 is shown in the third column opposite the given number of Years. Example:—To find the Annual Instalment to repay £5,722 with Interest at 4½ per cent. per annum in 23 equal Annual Instalments.

2d Method:— As £100 : £5,722 :: £7 1 4¼ : £404 8 3¼

20
———
141
12
———
1696
4
———
6785
5722
———
13570
13570
47495
33925
———
100)388237(70
4)388237
12)97059–¼
20)8088–3
———
£404 8 3¼

No. X.

TABLES of LOANS of different AMOUNTS repayable by equal INSTALMENTS of PRINCIPAL
ANNUAL CONTRIBUTIONS from

FIVE YEARS.

Number of Houses.	Loan of 6d. per house. — Average annual instalment of principal and interest at 5 per cent.	Loan of 1s. per house. — Average annual instalment of principal and interest at 5 per cent.	Loan of 2s. 6d. per house. — Average annual instalment of principal and interest at 5 per cent.	Loan of 5s. per house. — Average annual instalment of principal and interest at 5 per cent.	Loan of 1l. per house. — Average annual instalment of principal and interest at 5 per cent.	Loan of 5l. per house. — Average annual instalment of principal and interest at 5 per cent.	Loan of 10l. per house. — Average annual instalment of principal and interest at 5 per cent.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1	0 0 1¼	0 0 2¾	0 0 7	0 1 1¾	0 4 7½	1 3 1¼	2 6 2½
5	0 0 6¾	0 1 1¾	0 2 10¾	0 5 9½	1 3 1¼	5 15 5¾	11 10 11½
10	0 1 1¾	0 2 3¾	0 5 9½	0 11 6¾	2 6 2½	11 10 11½	23 1 11¼
20	0 2 3¾	0 4 7½	0 11 6¾	1 3 1¼	4 12 4¾	23 1 11½	46 3 10¾
25	0 2 10½	0 5 9¼	0 14 5¼	1 8 10½	5 15 5¾	28 17 5¼	57 14 10½
50	0 5 9¼	0 11 6½	1 8 10½	2 17 8¾	11 10 11¾	57 14 10¾	115 9 9
100	0 11 6½	1 3 1¼	2 17 8¾	5 15 5¾	23 1 11½	115 9 9½	230 19 6
250	1 8 10¼	2 17 8¾	7 4 4¼	14 8 8¾	57 14 10½	288 14 4½	577 8 9
500	2 17 8¾	5 15 5¾	14 8 8½	28 17 5¼	115 9 9	577 8 9	1,154 17 5¾
1,000	5 15 5¾	11 10 11¾	28 17 5¼	57 14 10½	230 19 6	1,154 17 5¾	2,309 14 11½
5,000	28 17 5¼	57 14 10½	144 7 2¼	288 14 4½	1,154 17 5¾	5,774 7 4¾	11,548 14 9½
10,000	57 14 10½	115 9 8¾	288 14 4½	577 8 8¾	2,309 14 11½	11,548 14 9½	23,097 9 7¼
15,000	86 12 3¾	173 4 7¼	433 1 6¾	866 3 1¼	3,464 12 5¼	17,323 2 2¼	34,646 4 4¾
20,000	115 9 9	230 19 5¾	577 8 8¾	1,154 17 5¾	4,619 9 11	23,097 9 7¼	46,194 19 2½
30,000	173 4 7¼	246 9 2½	866 3 1¼	1,732 6 2½	6,929 4 10½	34,646 4 4¾	69,292 8 9¾
40,000	230 19 5½	461 18 11¼	1,154 17 5¾	2,309 14 11¼	9,238 19 10	46,194 19 2¼	92,389 18 4½
50,000	288 14 4¼	577 8 8¾	1,443 11 10¼	2,887 3 8¼	11,548 14 9½	57,743 14 0	115,487 8 0
100,000	577 8 8¾	1,154 17 5¾	2,887 3 8½	5,774 7 4¾	23,097 9 7¼	115,487 8 0	230,974 16 0
250,000	1,443 11 10¼	2,887 3 8¾	7,217 19 3	14,435 18 6	57,743 14 0	288,718 10 0	577,437 0 0
1,000,000	5,774 7 4¼	11,548 14 9½	28,871 17 0	57,743 14 0	230,974 16 0	1,154,874 0 0	2,309,748 0 0

THIRTY YEARS.

Number of Houses.	Loan of 6d.	Loan of 1s.	Loan of 2s. 6d.	Loan of 5s.	Loan of 1l.	Loan of 5l.	Loan of 10l.
1	0 0 0¼	0 0 0¾	0 0 2	0 0 3¾	0 1 3¾	0 6 6	0 13 0¼
5	0 0 1¾	0 0 3¾	0 0 9¾	0 1 7½	0 6 6	1 12 6¼	3 5 0¾
10	0 0 3¾	0 0 7¾	0 1 7½	0 3 3	0 13 0¼	3 5 0¾	6 10 1¼
20	0 0 7¾	0 1 3½	0 3 3	0 6 6	1 6 0¼	6 10 0¼	13 0 2½
25	0 0 9¾	0 1 7½	0 4 0¾	0 8 1½	1 12 6¼	8 2 7½	16 5 3
50	0 1 7½	0 3 3	0 8 1½	0 16 3	3 5 0½	16 5 3	32 10 6¼
100	0 3 3	0 6 6	0 16 3	1 12 6¼	6 10 1¼	32 10 6¼	65 1 0½
250	0 8 1½	0 16 3¼	2 0 7¾	4 1 3¾	16 5 3	81 6 3¼	162 12 6¾
500	0 16 3¼	1 12 6½	4 1 3¾	8 2 7½	32 10 6¼	162 12 6¾	325 5 1¾
1,000	1 12 6	3 5 0½	8 2 7½	16 5 3	65 1 0¼	325 5 1¾	650 10 3¾
5,000	8 2 7½	16 5 3	40 13 1¼	81 6 3¼	325 5 1¾	1,626 5 8¾	3,252 11 5¼
10,000	16 5 3	32 10 6	81 6 3¾	162 12 6¾	650 10 3¼	3,252 11 5¼	6,505 2 10½
15,000	24 7 10½	48 15 9¼	121 19 5	243 18 10½	975 15 5	4,878 17 2	9,757 14 3¾
20,000	32 10 6	65 1 0¼	162 12 6¾	325 5 1¾	1,301 0 6¾	6,505 2 10½	13,010 5 9
30,000	48 15 9	97 11 6¾	243 18 10	487 17 8¼	1,951 10 10½	9,757 14 4	19,515 8 7½
40,000	65 1 0¼	130 2 0¾	325 5 1¼	650 10 3¼	2,602 1 1¾	13,010 5 9½	26,020 11 6
50,000	81 6 3¼	162 12 6¾	406 11 5	813 2 10½	3,252 11 5¼	16,262 17 2¾	32,525 14 4½
100,000	162 12 6¾	325 5 1¾	813 2 10½	1,626 5 8½	6,505 2 10½	32,525 14 4½	65,051 8 9
250,000	406 11 5	813 2 10¼	2,032 17 1¾	4,065 14 3¼	16,262 17 2¼	81,314 5 11¼	162,628 11 10½
1,000,000	1,626 5 8½	3,252 11 5¼	8,131 8 7	16,262 17 2¼	65,051 8 9	325,257 3 9	650,514 7 6

NOTE.—In framing these Tables, in order to avoid the introduction of decimals, the nearest fraction

No. X.

and INTEREST in FIVE YEARS and THIRTY YEARS, made to estimate the AMOUNTS of
Places of different Population.

FIVE YEARS.

Loan of 20l. per house. — Average annual instalment of principal and interest at 5 per cent.	Loan of 25l. per house. — Average annual instalment of principal and interest at 5 per cent.	Loan of 50l. per house. — Average annual instalment of principal and interest at 5 per cent.	Loan of 100l. per house. — Average annual instalment of principal and interest at 5 per cent.	Loan of 250l. per house. — Average annual instalment of principal and interest at 5 per cent.	Loan of 500l. per house. — Average annual instalment of principal and interest at 5 per cent.	Number of Houses.
£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	
4 12 4¾	5 15 5¾	11 10 11¾	23 1 11½	57 14 10½	115 9 9	1
23 1 11¼	28 17 5¼	57 14 10½	115 9 9	288 14 4½	577 8 9	5
46 3 10¾	57 14 10½	115 9 9	230 19 6	577 8 9	1,154 17 5¾	10
92 7 9½	115 9 9	230 19 6	461 19 0	1,154 17 5¾	2,309 14 11½	20
115 9 9	144 7 2¼	288 14 4½	577 8 9	1,443 11 10¼	2,887 3 8½	25
230 19 6	288 14 4½	577 8 9	1,154 17 5¾	2,887 3 8½	5,774 7 5	50
461 19 0	577 8 9	1,154 17 5¾	2,309 14 11½	5,774 7 4¾	11,548 14 9½	100
1,154 17 6	1,443 11 10¼	2,887 3 8½	5,774 7 5	14,435 18 6	28,871 17 0	250
2,309 14 11½	2,887 3 8½	5,774 7 5	11,548 14 9¾	28,871 17 0	57,743 14 0	500
4,619 9 11	5,774 7 5	11,548 14 9¾	23,097 9 7½	57,743 14 0	115,487 8 0	1,000
23,097 9 7¼	28,871 17 0	57,743 14 0	115,487 8 0	288,718 10 0	577,437 0 0	5,000
46,194 19 2½	57,743 14 0	115,487 8 0	230,974 16 0	577,437 0 0	1,154,874 0 0	10,000
69,292 8 9¾	86,615 11 0	173,231 2 0	346,462 4 0	866,155 10 0	1,732,311 0 0	15,000
92,389 18 5	115,487 8 0	230,974 16 0	461,949 12 0	1,154,874 0 0	2,309,748 0 0	20,000
138,584 17 7½	173,231 2 0	346,462 4 0	692,924 8 0	1,732,311 0 0	3,464,622 0 0	30,000
184,779 16 9	230,974 16 0	461,949 12 0	923,899 4 0	2,309,748 0 0	4,619,496 0 0	40,000
230,974 16 0	288,718 10 0	577,437 0 0	1,154,874 0 0	2,887,185 0 0	5,774,370 0 0	50,000
461,949 12 0	577,437 0 0	1,154,874 0 0	2,309,748 0 0	5,774,370 0 0	11,548,740 0 0	100,000
1,154,874 0 0	1,443,592 10 0	2,887,185 0 0	5,774,370 0 0	14,435,925 0 0	28,871,850 0 0	250,000
4,619,496 0 0	5,774,370 0 0	11,548,740 0 0	23,097,480 0 0	57,743,700 0 0	115,487,400 0 0	1,000,000

THIRTY YEARS.

Loan of 20l.	Loan of 25l.	Loan of 50l.	Loan of 100l.	Loan of 250l.	Loan of 500l.	Number of Houses.
1 6 0¼	1 12 6¼	3 5 0¾	6 10 1¼	16 5 3	32 10 6¼	1
6 10 1¼	8 2 7½	16 5 3	32 10 6	81 6 3½	162 12 7	5
13 0 2½	16 5 3	32 10 6¼	65 1 0¼	162 12 6¾	325 5 1¾	10
26 0 5	32 10 6¼	65 1 0¼	130 2 0½	325 5 1¾	650 10 3½	20
32 10 6¼	40 13 1¾	81 6 3¼	162 12 6¾	406 11 5¼	813 2 10¼	25
65 1 0½	81 6 3¼	162 12 6¾	325 5 1¾	813 2 10¼	1,626 5 8¾	50
130 2 0¾	162 12 6¾	325 5 1¾	650 10 3¾	1,626 5 8¾	3,252 11 5¼	100
325 5 1¾	406 11 5	813 2 10¼	1,626 5 8½	4,065 14 3½	8,131 8 7	250
650 10 3¾	813 2 10¼	1,626 5 8½	3,252 11 5¼	8,131 8 7	16,262 17 2¼	500
1,301 0 7	1,626 5 8¾	3,252 11 5¼	6,505 2 10½	16,262 17 2¼	32,525 14 4½	1,000
6,505 2 10½	8,131 8 7¼	16,262 17 2¼	32,525 14 4½	81,314 5 11¼	162,628 11 10½	5,000
13,010 5 9	16,262 17 2½	32,525 14 4½	65,051 8 9	162,628 11 10½	325,257 3 9	10,000
19,515 8 7½	24,394 5 9½	48,788 11 6¾	97,577 3 1½	243,942 17 9¾	487,885 15 7½	15,000
26,020 11 6	32,525 14 4½	65,051 8 9	130,102 17 6½	325,257 3 9	650,514 7 6	20,000
39,030 17 3	48,788 11 7	97,577 3 1½	195,154 6 3	487,885 15 7½	975,771 11 3	30,000
52,041 3 0	65,051 8 9½	130,102 17 6	260,205 15 0	650,514 7 6	1,301,028 15 0	40,000
65,051 8 9	81,314 5 11¼	162,628 11 10½	325,257 3 9	813,142 19 4½	1,626,285 18 9	50,000
130,102 17 6	162,628 11 10½	325,257 3 9	650,514 7 6	1,626,285 18 9	3,252,571 17 6	100,000
325,257 3 9	406,571 9 8¼	813,142 19 4½	1,626,285 18 9	4,085,714 16 10½	8,131,429 13 9	250,000
1,301,028 15 0	1,626,285 18 9	3,252,571 17 6	6,505,143 15 0	16,262,859 7 6	32,525,718 15 0	1,000,000

of a penny has been taken, which will account for the slight difference in some of the amounts.

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