LAND DRAINAGE

G. S. MITCHELL, F.S.I.

A HANDBOOK

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PRINCIPALLY BASED UPON THE REQUIREMENTS OF THE
SYLLABUS ISSUED BY THE SURVEYORS' INSTITUTION

BY

G. S. MITCHELL, F.S.I.

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LAND DRAINAGE

CHAPTER I

THEORY OF DRAINAGE

"*A man who has lived all his life in England has no adequate conception of the* English climate. *Including with it that of Scotland and Ireland, it stands alone in the world. Its sudden smiles and sudden tears are something truly hysterical. Like some fair maiden who weeps she knows not why—then stops and smiles a bit—a fickle smile—then falls to weeping again; there is no knowing when or where or how, to be up to all her moods. She is the very April among nations.*"—TALPA, OR CHRONICLES OF A CLAY FARM.

Rainfall.—This, which is, of course, the primary source of all the water with which we have to deal, varies very considerably in its volume, not only with every year, but in every season of the year. It is also varied by geographical position and by local circumstances, such as proximity to the sea and position of mountain ranges.

The average taken over a series of years, and at various stations, amounts for Great Britain to about 34 inches, and for England to about 25 inches—that is to say, that if accumulated for an average twelve months without waste by percolation or evaporation, it would attain a depth of so many inches all over the surface, supposing it were level.

TABLE OF MONTHLY AVERAGES OF RAINFALL TAKEN FROM OBSERVATIONS FOR THE SIXTY-NINE YEARS—1841–1909—AT THE ROYAL OBSERVATORY, GREENWICH.

	Inches
January	1·88
February	1·47
March	1·53
April	1·59
May	1·88
June	2·08
July	2·38
August	2·33
September	2·11
October	2·80
November	2·21
December	1·84
Total for twelve months	24·10

It will thus be seen that the months of February and March have usually the least rainfall, and July and October the greatest. It must not, however, be supposed that these figures are anything like constant, as the variations in the same station will often be very great. For example, we find at Greenwich the highest annual record for some years back to be 35·31, and the lowest 16·74 inches.

As may, moreover, be readily understood, the western side of our island, receiving as it does the warm winds which, travelling from the west, have in passing over the large expanse of the Atlantic, taken up much moisture, has a much greater rainfall than the east ; the consequence naturally being that the lands affected thereby are more generally in grass than is the case upon the eastern coast.

For practical purposes, the annual rainfall in the north-western section of this country may be taken at 38 inches, the south-western 34 inches, in the centre 28 inches, and in the east at 24 inches, though be it remembered every district, and indeed every farm, has its own peculiar circumstances, which render its rainfall different from everywhere else. Thus Cornwall, Wales, Cumberland, and the Western Highlands have a rainfall of about 55 inches ; and at Seathwaite, in the Lake District of Cumberland, a station known as holding the record readings for England, it has been as much as 145 inches.

In this connection it is worthy of note that every inch of rainfall means a fall of 101 tons, or 22,635 gallons per imperial acre ; and it will thus be seen how large an amount of direct rainfall in the course of a year the land receives.

The greatest rainfall in England within the twenty-four hours is about three inches, though such a heavy fall is rare.

TABLE CF RAINFALL

Inches of Depth	Cubic feet per Acre	Tons per Acre	Imperial Gallons per Acre
1	3,630	101·1	22,635
5	18,150	505·5	113,174
10	36,300	1,011·0	226,349
12	43,560	1,213·2	271,619
24	87,120	2,426·4	543,238
28	101,640	2,830·8	633,777
34	123,420	3,437·4	769,587
38	137,940	3,841·8	860,126

Percolation.—Of this rainfall only a certain portion (proved by Messrs. Lawes and Gilbert's experiments to be considerably less than half) is absorbed by the earth and becomes of service for the nourishment of plants, the remainder being either again taken up by the air by evaporation or running off into the nearest watercourse over the surface ; both of which latter processes are sources of injury to plant life ; the first because loss of heat is involved—

(*a*) By radiation during the time the water is lying on the ground ;

(*b*) By the absorption of heat during the process of evaporation ;

and the second because the water running over the surface carries off in its train the most valuable portion of the soil, namely, the finest of the surface tilth, which is the most readily available for plant life. This injurious effect of water running over the surface may often be noticed after a heavy thunderstorm, when the rain, falling more quickly than the earth can absorb it, washes the fine surface mould into the furrows and ditches. One chief aim of drainage, then, is to *increase the percentage of percolation* of the rainfall, thereby enabling the upper stratum of the soil to fix the valuable fertilising matters which rain-water holds in solution—ammonia, nitric acid, carbonic anhydride, gypsum, common salt, &c.—having taken them up during its passage through the atmosphere. It has been computed that every acre of drained soil in England gains by rainfall 10 lbs. of nitrogen per annum.

The passage of the rain-water through the land also induces a healthy *state of movement* of water, and consequently of air, in the soil, which, as a farmer would put it, "sweetens" the land. The land is mechanically benefited and the natural drainage improved by the soil being alternately wet and dry, on account of the immense opening effect of the contraction and expansion which then takes place. Chemists tell us that the, at present little understood, process of nitrifaction can only take place in a drained soil, as the organisms causing it can only exist in moist aerated soil (seeds rot in cold, wet soil) ; also that the saline substances in the soil have a natural tendency to rise to the surface, and, in undrained land are washed away by rain ; but, when the rain is induced by drainage to sink through the soil, it carries with it and redistributes these saline matters for the use of the roots.

Stagnation means sourness and disease, movement means health and life.

Evaporation.—As a general rule, we need all the sun-heat we can get for the proper growth and perfecting of our crops; and most particularly is this the case during the winter period of the year, when we are most troubled with water upon the land.

Now it cannot fail to be recognised by every one that, if this sun-heat is utilised by the agriculturist in evaporating the water which lies stagnant on or in his land, he thereby loses its beneficial effects upon his crops. Certainly I have seen the water running from a peat bog dammed back upon the potato patch, "because it is the only *manure* the plants get"; but I do not think such barbaric treatment would benefit the crop very largely.

Heat cannot pass through water, and, when his land is full of water, not only does the farmer lose the effect of the sun-heat, which is thus intercepted without reaching his crop, but the mere process of evaporation, by reason of the absorption or rendering "latent" of its heat, also diminishes the temperature of the soil itself to a very injurious extent.

That this is so is most forcibly shown by the late Mr. Bailey Denton's experiment, in which, by holding a bottle of wine wrapped in a wet flannel before a hot fire, he proved that, as the flannel dried, so the wine became perceptibly colder.

If any one doubts that the presence of stagnant water tends to keep land cold, let him, as has been done many times before, insert a thermometer 10 inches or a foot below the surface of undrained land and at the same depth in drained land. He will find a difference of several degrees in the temperature recorded.

Evaporation takes place at a much lower rate in a level country than in a hilly or rocky one, and a sandy soil will give off the same weight of water as vapour, as will a clay or a peat, and in one-third the time. It is less upon a hill than in a valley, and less upon cropped land than on fallow. Apart from expiration by plants, the mean daily evaporation in England amounts to about ·08 of an inch. Bailey Denton states that every gallon evaporated robs soil of as much heat as would raise $5\frac{1}{2}$ gallons of water from freezing to boiling point, and Sir Lyon Playfair estimated that 219 tons of coal would be required to evaporate an annual rainfall of 30 inches from one acre of undrained land.

Relation between Soils and Humidity of the Atmosphere

The presence of stones upon the surface tends to diminish evaporation, and this is the reason why it often happens in a dry summer that a root crop can be secured upon poor flinty land, when complete failures are the rule on better land which has no surface stones.

A surface of good tilth prevents the escape of moisture, and therefore prevents drought in a dry season. To a certain extent no doubt land in fine tilth benefits from the hygroscopic moisture of the air. Land which has lately borne a crop is always drier than a bare fallow.

The nature of the soil has a direct effect upon the humidity and temperature of the atmosphere—thus whereas a clay soil, being of a wet nature, gives off by evaporation a large amount of watery vapour, and so renders the air more humid and of lower temperature; a porous soil, by reason of its power of infiltration, will have the exactly contrary effect.

Soils of dark colour cool most rapidly, and mists and fogs are most prevalent upon these soils. Of all soil constituents sand has least, and humus the greatest capacity for retaining moisture.

Sandy soils absorb heat most rapidly, and cool with corresponding speed; this rapid alternation of temperature it is which causes the "burning" of our thin sandy pastures.

Radiation and Convection.—By the principle in physics known as convection, undrained land is rendered colder by reason that, when the temperature of the atmosphere is lower than that of the ground, the water lying near the surface becomes chilled by radiation and sinks by its weight through the warmer liquid below, which, in its turn, becomes similarly chilled, and likewise sinks, whilst, if the temperature of the air be higher than that of the ground, the upper surface of the water will be warmed, but, by reason of its lightness, cannot sink and allow colder particles to take its place, and warmth cannot descend on account of the bad conductivity of water; whereas, after draining, every warm shower in its passage through the earth considerably raises the temperature.

Notes on Water

Specific Gravities—

Distilled water being 1·000.
Rain water is 1·001.
Sea water is 1·027.

Fresh Water—

1 cubic foot of water = 62·425 lbs. = ·557 cwt. = ·0278 ton = 6·235 gallons.
1 cubic inch of water = ·03612 lbs. = ·003607 gallons.
1 imperial gallon of water = 10 lbs. = ·16037 cubic foot = 277·274 cubic inches.
1 cwt. of water = 1·8 cubic foot = 11·2 gallons.
1 ton of water = 35·94 cubic feet = 224 gallons.

Sea Water—

1 cubic foot = 64·11 lbs. = 6·4 gallons.
1 cwt. = 10·897 gallons = 1·75 cubic feet.
1 ton = 217·95 gallons = 35 cubic feet.

To Convert—	Multiply by	Converse.
Cubic inches into gallons	·003607	277·274
Lbs. into cubic inches of water	27·70	0·0361
Lbs. into cubic feet of water	0·016	62·425
Lbs. into cwts. of water	0·00893	112
Cubic feet into tons of water	0·0278	35·9
Cubic feet into gallons	6·235	0·16

1 gallon (imperial) = 277·274 cubic inches.
1 old barn or Winchester gallon = 268·8013 cubic inches or 0·96944 of imperial gallon.
1 new barn gallon = 589·203 cubic inches or 2·1249 of imperial gallon.

Rainfall—

Inches of rainfall × 2,323,200 = cubic feet per square mile.
Inches of rainfall × 14½ = millions of gallons per square mile.
Inches of rainfall × 3,630 = cubic feet per acre.
Inches of rainfall × 22,635 = gallons per acre.
Inches of rainfall × 101·1 = tons per acre.

Water Supply—

Provide for each man, woman, and child, 16 gallons of water per day in non-manufacturing, and 20 gallons in manufacturing towns (11 gallons has been found the average quantity used in prisons).

Provide for each horse 16 gallons, four of which are consumed with his food (army allowance per horse is 8 gallons for cavalry and 10 gallons for artillery).

Provide for each cow 8 gallons.

Provide for each four-wheeled carriage 16 gallons, and for each two-wheeled carriage 9 gallons.

If source is rainfall, provide tankage for 120 days' supply in rainy districts, or 200 days' in dry districts.

Service tanks should hold three days' supply.

Available rainfall from roofs in England may be estimated at 18 inches per annum. Six-tenths of rainfall available.

Every acre of land cultivated by steam needs about 100 gallons for engine use.

Pressure of water per square inch per foot of depth = ·4335 lbs., and may be considered as acting at a point two-thirds of the total depth from the top.

Pressure of water in lbs. per square inch × 2·31 = head of water in feet.

A "miner's inch" of water is the quantity discharged through a hole 1 inch square 6 inches below surface of water, measuring from the top of the opening.

Cubic feet per minute × 9,000 = gallons per 24 hours.

On freezing, water expands one-twelfth of its bulk

One cubic foot of ice at 32° F. = 57·96 lbs.

Chapter II

THEORY OF DRAINAGE

(*Continued*)

"*To hesitate to drain the land, is to hesitate to confer a benefit upon oneself.*"—R.A.S.E. Journal, vol. ii., p. 295 (1841).

Practical Benefits of Drainage.—The principal benefits which accrue to a farm which has been properly drained, as opposed to the same in a wet state, are :—

1. As by increased aeration plant food is rendered more easily available, root action is stimulated, the crop perfects more quickly, and the result is an earlier and larger harvest of better quality.

2. A greater variety of crops may be grown, and land previously unsafe may be made to carry live stock ; green cropping may be introduced, and even wheat and roots grown where previously only scanty oat crops could be depended on. Bare fallows, which on stiff wet land had previously been a necessity, may, after draining, often be dispensed with.

In the case of pasture land, the moisture-loving plants, which have but little nutriment for stock, will disappear, and their place will be supplied by a better class of herbage. The early and late growth of grass is promoted, and the early autumn and late spring frosts do not so greatly affect drained land.

3. The plants being in a stronger position to assimilate them, manures and feeding stuffs may be used with better and more remunerative effect. Undrained land demands more culture, more seed, more manure than similar land when drained.

4. The ravages of insect and fungoid attacks are less serious in extent, as the plants are strong and may be artificially pushed beyond the particular stage at which they are liable to succumb.

5. The season is lengthened at both ends, and the early spring growth which is due to the increased warmth of the surface soil, tends to cause an even ripening of crops.

6. The processes of tillage are easier and less expensive, as it is possible to work upon the land more days in the year and to keep tillage operations well up to date, so as not to be so seriously at the mercy of the weather. How rarely a farmer realises that his only profit consists in the labour of his horses! Had he to pay at per acre for the workings of his land he would rarely have a single crop which paid expenses; and *vice versa*, the fewer the days his horses are idle in the stable the better it should be for their owner's pocket.

7. The loss of land entailed by the necessity of high narrow ridges and frequent furrows is no longer incurred, and economy in harvesting is promoted, as the deep furrows having disappeared, reapers and binders driven by horse-power can supersede hand cutting and tying.

8. In addition to these direct benefits to agriculture, the health of the population and of live stock is greatly improved by drainage operations—the malignity of fever, "shakes," and ague is much mitigated when miasmatic ponds and swamps are drained.

Causes of Wetness.—In addition to the surface wetness due to rainfall, land may be wet from springs, and these, again, may be divided into two heads—those which soak from land at higher levels and crop up on the surface in a more or less definite manner, and may be described as "effluent"; and those which, prevented from sinking by an impenetrable stratum beneath, force their way up through the subsoil and permeate the whole ground in the form of what is known as "bottom" or "diffluent" water.

It frequently happens that a free soil, which in one field clears itself naturally by percolation of all its excess moisture, is the immediate cause of wetness to a less permeable field lying at a somewhat lower level, and a free soil having a clay subsoil will need to be drained quite as much as one that is of retentive character throughout. In the case of these latter soils it is a rather remarkable fact that sometimes when they are liable to burn in a hot summer, the action of drainage will be to prevent this, by reason that whereas the roots formerly could not penetrate into the soil further than to the plane of stagnation, after drainage the depth to which they can ramify places them beyond the power of surface drought.

Signs of Necessity for Drainage

When called upon to advise as to the draining of particular land, there are several indications as to its necessity or otherwise.

1. Does water lie upon it to any extent after rain ?

2. Are there rushes and waterweeds present in the herbage ; and are these in one or two patches indicating a local spring or " soak " ; or are they more or less all over the land ?

The following common grasses and weeds may be taken generally to indicate wetness, and upon draining the land many of them will disappear :—

Slender Foxtail or Black Bent (*Alopecurus agrestis*), Floating Foxtail (*A. geniculatus*), Tussac, or Hassock Grass (*Aira cæspitosa*), Marsh Bent (*Agrostis vulgaris*), Floating Meadowgrass (*Poa fluitans*), Purple Melic Grass (*Melica cærulea*), Water Whorlgrass (*Catabrosa aquatica*), Sedge or Carnation Grasses of many varieties (*Carex*), Reed Canary Grass (*Phalaris arundinacea*), Common Reed (*Arundo phragmites*), Horse Knot or Black Knapweed (*Centaurea nigra*), Selfheal (*Prunella vulgaris*), Marsh Thistle (*Cnicus palustris*), Bogrush or Toadrush (*Juncus bufonius*), Marsh Cudweed (*Gnaphalium uliginosum*), Marsh Orchis (*Orchis latifolia*), Spotted Orchis (*Orchis maculata*), Water Crowfoot (*Ranunculus aquatilis*), Silverweed (*Potentilla anserina*), Sharpdock (*Rumex acutus*), Great Waterdock (*R. hydrolapathum*).

3. The glazed, sad condition of the newly turned furrow slice is a sign showing excessive wetness.

4. The crops upon wet, sour land usually look starved and stunted in growth.

5. In winter snow will lie longest on the wettest, and consequently, coldest, land.

It is always well to particularly notice whether the occupier keeps the ditches and watercourses clear and open. It is unfortunately only too commonly the case that a tenant asks to have a particular field drained when he has never taken the trouble to clean out the adjoining ditches, much less to keep the outfalls of any existing drains open—surely not a very encouraging augury for the future efficacy of the work he asks to have done.

In connection with the wetness caused by direct rainfall the reason in many cases why percolation is at a standstill is that a hard pan or " moorband " formed by the treading of horses or by the deposit of iron salts, lime, etc., prevents any water getting through. Land is too often ploughed at one uniform depth for long periods of time, and the natural result is an indurated pan which neither roots nor water can penetrate. Truly in many cases the chief, and some, times only, reason why land does not pay is that it is never cultivated to any greater extent than the mere scratching of the surface to the extent of a paltry three or four inches.

As some proof of the effect a pan has upon drainage, I may mention that, having some clay land thrown into the landlord's hands some time back, I steam-scarified it as deep as the machine would go, and the result is, that though the usual water-furrows were cut, which before had been urgently necessary, they have never since run at all. Another benefit of deep cultivation (which, of course, must only be done with judgment) is that, to a certain extent, it is a substitute for rain, as every farmer knows that in a dry season the well-cultivated land bears the drought best, the reason being that moisture can rise from below.

Loss of Plant Food by Drainage.—It has been often asserted that a great deal of plant food is washed out of the soil by drainage water, and passes away in solution in the effluent after every heavy fall of rain.

Though the injury, which, after all is only occasional, has been much exaggerated, it is true to a certain extent that such a loss does take place, because the soil does not appear to possess the retentive power necessary to prevent the washing away of nitrates (one of the most important of plant foods) and the loss in wet seasons, especially in uncropped land of open texture, may be considerable.

Lime is easily lost in drains, and possibly this is one reason why the liming process is of such benefit when carried out a short time after a new system of drainage has relieved land of its superabundant water.

Experiments have proved that the loss of fertilisers by drains is inappreciable when a growing crop is on the land —thus it follows that grass land does not suffer loss, and only in the case of a bare fallow is there any great waste from the arable land.

The remedy would then appear to be in the farmers' own hands to a very large degree ; for instance in the case of light soils (which are especially of low retentive power), he should apply his farmyard manure in a rather long state, and in spring rather than in autumn.

His more soluble manures, such as nitrate of soda (which is so highly soluble that the dew is quite sufficient to dissolve it), should always be applied in small, and if necessary repeated, doses not larger than the plant is able to assimilate at once and without chance of loss.

Then again, as it is so especially the uncropped land which suffers from the washing out of its soil nitrogen, by the sowing of mustard, vetches, rape, rye, turnips, &c., on the early stubbles, the loss may be obviated to a very large extent—to carry out this method of catch-cropping to advantage it is of course essential that the land be in a clean state.

Chapter III

THEORY OF DRAINAGE

(*Continued*)

" *The raison d'être of drainage is the* removal of surplus water *in the soil, and is* not *the drying of that soil.*"

Characters of Soils and Subsoils

For drainage purposes all soils and subsoils may be divided into three great classes—(*a*) *free,* (*b*) *medium,* (*c*) *retentive,* with many subdivisions, and including stones or rock in each case.

(*a* and *b*) *Free and medium soils and subsoils* naturally do not so frequently claim the drainer's attention as the other class. They are, if wet, usually so from position, receiving the superfluous water from land at a higher level; and, provided this can be intercepted by open ditch or pipes, they do not need very expensive treatment.

It may be, however, that they are wet by reason of an impervious stratum lying underneath them, causing rainfall water, or any water which soaks through from a higher level, to rise " diffluently " ; and when this is the case, they must be drained as thoroughly as in the case of more retentive soils, though, on account of their open nature, the drains may be at wider intervals. It was in this class of soil that Elkington, by tapping the springs, made his system so famous.

(*c*) *Retentive or Clay Soils.*—Whereas in the free and medium soils the land is wet from " bottom to top," in these soils it as a rule happens that the cause of wetness is simply the impermeability of the soil and the consequent difficulty which water has in getting through. This will be shown to be the fact if, when digging a trial hole, it be found, as is not infrequent, that the land is drier below than it is at the top. It is quite possible for these soils and subsoils to be also wet, by reason that they receive the discharge from higher lands or from a combination of both causes.

Aeration.—Plants need warmth, air, and water in order that they may thrive, and in waterlogged soil the first two of these elements are absent.

It is for this reason that irrigation without drainage (natural or artificial) is useless.

The key to the whole problem of land drainage lies in the words " perfect aeration," and the true theory of drainage insists upon the removal of all superfluous water in order that air may take its place ; and it is quite reasonable to suppose that the benefit (especially to the mechanical condition of the soil) is increased every time the air gets renewed, as must happen to a greater or less degree after every fall of rain and passage of water through to the drains.

Interstitial water, *i.e.*, water held in the soil by capillary attraction, is necessary for plant life, but stagnant water is prejudicial, and should be removed from the land.

It almost goes without saying that where water goes there air can follow, and if the denser medium be withdrawn from the soil, then the more rarified medium, urged by an atmospheric pressure of 15lbs. per square inch, must follow, taking with it the necessary oxygen to decompose the vegetable matters lying dormant in the soil, and to change the injurious ferrous oxide into the beneficial ferric oxide, sulphides into sulphates, &c.

Air Drains.—In order to facilitate the entrance of air into a drainage system, and thus to accelerate the flow, an air drain has sometimes been laid connecting the upper extremities of the minor drains, and this method certainly has the effect of rendering the pressure more even through the system than it otherwise would be. In practice, however, I do not think that the advantage gained will be found to be sufficient compensation for the extra outlay involved, and personally prefer to run some of the minors—say every other one—into a dry ditch if one be near, taking care to so guard the opening by means of a grate or stones that nothing likely to cause an impediment should obtain entrance ; and in any case if the upper end of a minor is run into a dry brow beyond the saturated portion of its course, the entrance of air will be much facilitated. If openings be thus made into a ditch they may be so arranged as to also act as safety valves, and in case of over-pressure in a drain would prevent its bursting. In cases where it is deemed advisable to have inspection holes or chambers, these may with advantage be utilised as air inlets. Where a drain is found to have an intermittent gurgling discharge it is a sign either of a stoppage or that the bore of the pipes is too small to allow of the entrance of air, and if means can be found to admit air higher up a cure will usually be effected. When pipes have been laid a year or two, the ground cracks and air drains are thus rendered more than ever unnecessary. The action of earth-worms no doubt greatly tends to promote the aeration of the soil; especially in old pasture land, where the plough never disturbs the surface.

Water Table.—This term is applied to the upper surface of the water in the soil, and as that water increases or decreases in volume so does the water table approach or recede from the surface. This is best explained by a diagrammatic view as shown in Fig. 1, where A B is the surface of the soil, and C D the water table. Now, if drains be laid at E, F, and G, they will draw off the water lying in the space C D G E until the water table sinks to the level E G, thereby increasing the depth to which roots can penetrate from the original depth A C to the increased depth A E.

It will, of course, be readily understood that, given water

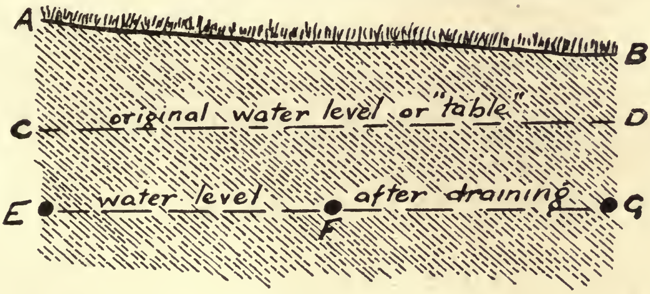

FIG. 1

enough, there is nothing to prevent the water table rising to such an extent as to become higher than the soil and to overflow the surface; but if efficient drains be inserted, they will commence to run immediately the water table reaches the level at which they are placed, and continue to discharge so that the water table is kept permanently at that level. Water enters a drain from below, and runs by reason of lateral pressure.

The section of soil A E G B is then only wet during the time rain is passing downwards through it, and by capillary attraction, which draws up a certain amount of moisture in the small capillary tubes or spaces between the soil particles, the quantity so held suspended diminishing of course according to the distance above the water table. A clay soil having smaller pores will absorb and hold by capillary attraction more water than a loam, and considerably more than a sand, and water will ascend to a height in a clay of nearly three feet above the water table as compared to eighteen inches only in sand.

In judging of the depth to which a particular field should be drained, it is useful in porous and medium soils to open test-holes in various places in order to find out the present water level, and the speed with which that level rises after a shower. The test-holes may be two or three feet square, and may be left open while drainage operations are going on in order that its effect may be watched as it progresses.

It is well to keep the water table three feet below the surface, in order that the deeply-rooted plants may have the necessary room for their rootlets to ramify.

Over-draining.—It has been said that it is quite impossible to over-drain land, and the reason given for this is that although we speak of a drain " drawing," yet it really forms a *passive* water channel only, and exercises *no active power of suction.* This is very good and true as a proof that it is not possible to lay *too many* drains in any particular piece of land (leaving the expense out of consideration for the moment), but it is *no proof that it is impossible to drain too deeply.*

To state a case, let us imagine a light or medium soil, which has been drained thoroughly at a depth of 4 feet or 4 feet 6 inches, cropped with a shallow-rooted plant such as barley. The effect of a hot summer will probably be to burn this, because the plant, having first exhausted the supply of moisture in the soil immediately at the top (and, be it remembered, the quantity of moisture exhaled by all growing plants is immense, and that, unless this evaporation is replaced from the soil, the plant must perish from drought), can procure no further water from the soil, because the land is drained to such a depth as to utterly preclude the possibility of any supply rising to the roots by capillary action from the water table.

A soil may be in one of three main conditions: 1. *Wet*, containing both *interstitial* water held by capillary attraction and *free* water which runs without pressure. 2. *Moist*, containing *interstitial* water only, and no free water. 3. *Dry*, containing insufficient *interstitial moisture*.

The water, which rises by molecular attraction, cannot be injurious in a soil, as it does not fill up the interstices to such an extent as to prevent the free passage of air. It is the stagnant, *free* water which, being in excess of what the soil will hold by capillary attraction, acts injuriously by occupying air space in which the rootlets would otherwise ramify freely; provided this is removed, all further drying of the soil is useless. The true test of good drainage work is the condition of the soil for agricultural purposes, and not merely the number of gallons of water drawn out of that soil. Baron Liebig, in his "Natural Laws of Husbandry," well says: "If we regard the porous earth as a system of capillary tubes, the condition which must render them best suited for the growth of plants is unquestionably this: that the narrow capillary spaces should be filled with water, the wide spaces with air, and that all of them should be accessible to the atmosphere. In a moist soil of the kind affording free access to atmospheric air, the absorbent root fibres are in most intimate contact with the earthy particles; the outer surface of the root fibres here may be supposed to form the one, the porous particles the other wall of a capillary vessel, the connection between them being effected by an extremely fine layer of water."

Again, in the case of a retentive soil, it has been stated that one must drain deeply in order to overcome capillary attraction; but it should be remembered that these soils are wet "from top to bottom," from rain and not from "bottom water"; and though it would be unreasonable to say that rain-water could not percolate to a drain laid at 4 feet deep, is it not nevertheless likely that it would reach a drain laid at 2 feet 6 inches, or 3 feet more readily? and at a greater depth the percolation would not be sufficiently rapid to admit of the full benefit of the drainage being reaped.

In this class of soil there is but little likelihood of draining too deeply, as the cost of the labour thereby involved prevents so doing. This question of cost is, after all, the strongest practical argument against deep drainage, and would have long ago exploded all notion of draining over 4 feet in depth (save in exceptional cases), were it not that many persons have rushed to the opposite extreme, in the interests of economy, with the erroneous idea that excessive depth will compensate for excessive width, an idea which a little thought will convince one is incorrect in retentive soils.

One other comparatively unimportant case in which it is unwise to drain too thoroughly is that of upland sheep runs, which, though in their wet state probably growing little but moss, would very possibly relapse into a state of absolute sterility were the water completely removed.

Reciprocal Action of Drains.—A single drain, whether open or piped, when laid in retentive soil, has in itself but very little effect, probably because the continuity of the water is unbroken, and air has no chance to penetrate ; but if several drains be laid at sufficiently close intervals they will be found to assist one another, and the friction, which a solitary drain was in itself powerless to cope with, is overcome.

It is probable that this reciprocating action is caused by the fact that each drain acts more or less as an air-duct to its neighbour, as it is quite reasonable to suppose that water lying in the extremely small pores of a clay soil cannot free itself unless its mass be first broken up by the introduction of air. This will also explain the reason why in clay soils the drains do not attain their maximum effect for some time after laying, as they cannot receive the full amount of water they are intended to receive until by the action of expansion and contraction, caused by alternations of moisture and temperature, channels of more or less constant character are formed in the soil through which water can percolate to the drain.

CHAPTER IV

HISTORY OF DRAINAGE

"*Quid dicam . . . quique paludis collectum humorem bibula deducit arena?*"—VIRGIL'S GEORGICS, lib. i. 113.

THOUGH not necessary for practical purposes, it is yet of considerable interest to know a little of the past history of the art. It has been practised in a more or less rude form from time immemorial; indeed, may be said to be contemporary with any cultivation at all. Many of the ancient Roman writers refer to drainage, as it was then applied, to the freeing of bogs or of land which lay under water, and there is no doubt that that portion of the art has been practised for many centuries. Cato directs drains to be made three feet broad at top, four feet deep, and a foot and a quarter wide at the bottom; to be filled with stones or with willow rods placed crosswise, or twigs tied together. Columella says both open and covered drains are to be made sloping at the sides, and the bottom to be made narrow. He recommends a rope of twigs to be firmly pressed into the drain and covered with leaves or pine branches before filling in. Pliny says the ropes may be of straw, and that flint or gravel may also be used for the waterway, the excavation being filled to within eighteen inches of the top.

The earliest record of draining in the British Isles is said to be contained in a pamphlet dated 1583, and now in the possession of the Society of Antiquaries.

Though evidences exist of much earlier drainage work in the district, the systematic drainage of the fens in Lincolnshire and Cambridgeshire, proposed in the reign of James I., was not commenced until the time of the Protectorate. Under a company of adventurers, at whose head was the first Duke of Bedford, the drainage of the famous Bedford Level—310,000 acres—was mainly due to the exertions of the director of the works, Sir Cornelius Vermuyden, a

Dutchman who had been engaged in drainage in the Low Countries.

Subsequently a great impulse was given to drainage work by the general introduction of the turnip as a field crop, which naturally greatly altered the previous methods of cultivation. One of the greatest advantages of the growth of root and green fodder crops being the feeding upon the land by sheep, necessitated a greater dryness in the surface of the land, and proved the beginning of a higher and more scientific style of agriculture than had hitherto existed.

So recently as 1794 more than half the arable land of England and Wales was cultivated on the unfenced, open field common-farm system. The arable land of a parish was usually divided into three portions, two being cropped with corn and the third lying fallow. Each villager had his strip in each field, so that from seed time to harvest the strips were in the possession of individuals, but so soon as the crops were cleared, the common rights of pasturage revived, and the livestock of the village roamed over the whole !

Under such a plan no improvement could take place, but the Inclosure Acts multiplied rapidly under the stimulating effect of the high prices of the Napoleonic wars. The rapid fall of values when peace came caused great agricultural distress in the first half of the 19th century, but the ultimate result of the depression was the improvement of the agricultural systems and the gradual evolution of our present generally high state of cultivation.

The theory of deep drainage as applied to swamps and water meadows was powerfully treated upon in 1646 by Captain Walter Blith, an over in Cromwell's army (generally credited with the introduction of the swing turnover plough from Holland) ; but it does not appear to be until 1764 that the freeing of land from what may be called "interstitial water," as opposed to water lying on the surface, was at all attempted. In that year, Mr. Joseph Elkington, being the occupier of a poor, wet farm at Princethorp, in the parish of Stretton in Dunsmore, Warwickshire, discovered, by accident, the method of strata drainage, which has since been distinguished as the "Elkington system."

This system may be applied in land where springs occur (caused by the alternation of free and impervious beds), and may best be understood by reference to a diagram (Fig. 2), which roughly represents a section through part of the field of wet clay, almost a swamp, in which the discovery was made.

A represents a porous soil charged with water, which cannot escape on account of impenetrable clay beds, B, underneath. The water thus penned up will rise until it reaches the level D, E, when it will burst out in the form of springs.

The discovery is thus described :—

" In order to drain this field, he cut a trench about four or five feet deep a little below the upper side of the bog, or where the wetness began to make its appearance ; and after proceeding with it so far in this direction and at this depth, he found it did not reach *the main body of subjacent water* from whence the evil proceeded. On discovering this Mr. Elkington was at a loss how to proceed. At this time, while he was considering what was next to be done, one of his servants accidentally came to the field where the drain was making, with an iron crow, or bar, which the farmers in that country use in making holes for fixing their sheep hurdles. Mr. Elkington having a suspicion that this drain

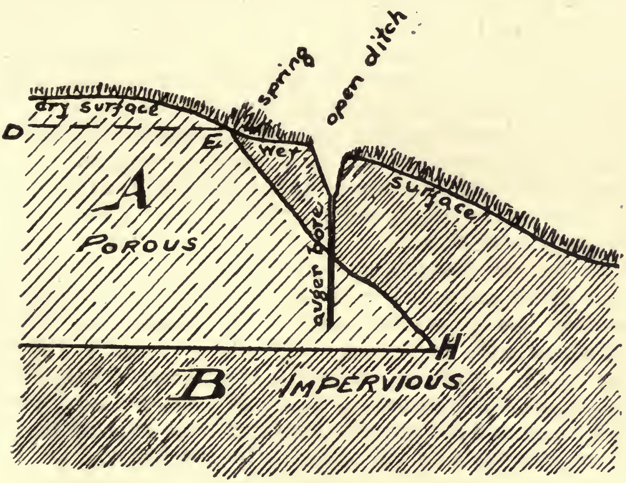

FIG. 2

was not deep enough, and a desire to know what kind of stratum lay under the bottom of it, took the iron bar from the servant, and after having forced it down about four feet below the bottom of the trench, on pulling it out, to his astonishment, a great quantity of water burst up through the hole he had thus made and ran down the drain. This at once led him to the knowledge of wetness being often produced by water confined farther below the surface of the ground than it was possible for the usual depth of drain to reach, and induced him to think of applying an auger as a proper instrument in such cases."

Encouraged by this wonderful occurrence, which of course "every schoolboy" can now explain by the fact that "water always finds it own level," Elkington proceeded to utilise the knowledge thus acquired in laying dry similarly situated land both on his own farm and on others, his operations extending to many thousands of acres, chiefly in the Midlands.

The Charter of the first Board of Agriculture (created by Pitt in 1792) was finally sealed on August 23, 1793, with Sir John Sinclair as president and Arthur Young as secretary. This Board dissolved in 1822 and must not be confounded with the present Board of Agriculture, which was only founded in 1889.

In the year 1795 Mr. Elkington's services to agriculture were rewarded, at the instance of Sir John Sinclair, by a grant of £1,000 from the English Government, and a report of his methods was published under Parliamentary authority by Mr. John Johnstone, an Edinburgh surveyor. The second and third editions of this work, published in 1801 and 1808 respectively, will be found in the library of the Surveyor's Institution.

This system of drainage may even now be pursued with advantage in cases of alternating strata of free and retentive character, though a pipe drain would take the place of the open drain and auger-hole. It will be readily seen on reference to the diagram (and of course somewhat similar arrangements of beds can be multiplied almost indefinitely), that a drain laid at the point H would, if sufficiently large in bore, relieve not only the lower section B, but the whole of A in addition.

The next we hear of the progress of the drainage art is that in 1836, Mr. William Smith, a Perthshire farmer, described to an agricultural committee of the House of Commons his "frequent drain system," and during the next few years we find a hot controversy raging upon the subject, Smith upholding his own "Deanston" system of "frequent" drains at from ten to twenty-four feet intervals, laid at a depth not exceeding thirty inches, the drains themselves being made of stones of about such size as would pass a three-inch ring, and not of tiles; whereas his chief opponent, Mr. Josiah Parkes, consulting engineer to the R.A.S.E., was for less frequent drains, at intervals of from twenty-one to fifty feet, laid at a minimum depth of four feet, the materials used being pipes of one-inch bore, his idea being that increased depth justified increased width.

Both sides appear to have agreed that Smith's arrangement of parallel drains at regular distances, and of the minors down the steep, with the mains in the bottom, was the most effective. Interesting information as to this discussion will be found in the earlier numbers of the R.A.S.E. "Journal," and also in the "Transactions" of the Highland Agricultural Society.

Later experience has shown that, while both systems, taken as they stand, have their demerits, yet the controversy to which they gave rise had the effect of bringing forward a large amount of evidence which has, undoubtedly, tended to bring the art of drainage to its present state of efficiency.

Parkes' principle of tapping the "subterranean water," and so lowering the water level in the soil, has supplied the key to the solution of the whole problem of land drainage, whereas we can now realise that Smith's great mistake lay in his idea that "surface" water *only* was injurious. On the other hand, it has been abundantly shown that Parkes' one-inch pipes were in reality too small in bore, and that Smith's ironical epithet of "pencilcases" was justified by results. It has also been conclusively proved that Parkes' contention for extreme cheapness in drainage execution (£3 per acre being his maximum) has lead to much inefficient work since, by reason that to complete drainage for such a low estimate it is necessary to place drains at much wider intervals than is justifiable.

The Taxes on bricks and tiles first imposed by 24 Geo. III. c. 24 at 2s. 6d. per thousand were increased to 4s. by 34 Geo. III. c. 15. and to 4s. 10d. per thousand under the Act of 43 Geo. III. c. 69.

The 1826 Act (7 Geo. IV. c. 49) exempted drain tiles and bricks used for drainage from any tax, and by 3 Will. IV. c. 11 (1833) the duties on all kinds of tile were repealed.

The 1839 Act (2 & 3 Vic. c. 24), while increasing the duty on bricks of any shape to 5s. 10d., specially exempted bricks used for draining marshy lands.

The duty on bricks was not entirely removed until 1850 (13 & 14 Vic. c. 9).

Tiles for drains were introduced about the year 1810, and were at first received with suspicion, as it was thought they would decay, and the large capital outlay no doubt militated against the system whilst it was as yet untested.

Though locally used some twenty years earlier, cylindrical pipes were first generally introduced about the year 1843, when some were exhibited at the Royal Agricultural Society's Show at Derby.

In 1836, on the passing of the Tithes Act, three Tithe Commissioners were appointed. In 1841, when the Copyhold Act passed, its administration was entrusted to Commissioners, but it was provided that the Tithe Commissioners for the time being should be the Copyhold Commissioners.

In 1845 the first General Inclosure Act was passed, and under this Inclosure Commissioners were appointed who were distinct from the Tithe and Copyhold Commissioners, and one of whom was to be the First Commissioner of Woods and Forests for the time being. The Land Drainage Act of 1846 was administered by the Inclosure Commissioners.

There were thus two bodies of commissioners until in 1851 they were merged into one, and a single department was formed, presided over by officials who were styled Tithe, Copyhold, or Inclosure Commissioners according to their respective functions. This arrangement lasted for upwards of thirty years, till on the passing of the Settled Land Act of 1882 the former titles disappeared, and the Commissioners became known thenceforward as the Land Commissioners. Finally in 1889, on the passing of the Board of Agriculture Act, the Land Commission was merged in the newly constituted department, and the title of Land Commissioners was abolished. Great impetus was given to draining by the Acts of incorporation of the various drainage and loan companies, and the history of drainage since is almost entirely that of development by these companies. The great authority on the subject (the late Mr. J. Bailey Denton) was engineer for one of the largest.

The earlier Drainage and Improvement of Land Acts depended on capital advanced by the State (Public Money Drainage Act, 1846, and Private Money Drainage Act, 1849), the later on private capital. To supply this four companies were incorporated by Act of Parliament :—(1) The [1] General Land Drainage and Improvement Company, 1849 ; (2) the Lands Improvement Company, 1853 ; (3) The Scottish Drainage and Improvement Company, 1856 ; (4) *The Land Loan and Enfranchisement Company, 1860.

The Land Drainage Act of 1861 was passed for the purpose of furthering Arterial Drainage only. It was for drainage of a public character, undertaken for the benefit of a district, carried on with money raised by public rates, and administered by public bodies.

This was no new thing, as since the time of Henry VIII. public drainage acts have been carried out by Commissions of Sewers, many of which continue to exist even at the present moment. It will, of course, be understood that drainage under the act of 1861 is confined to the clearing of land from water.

A Commission of Sewers lasts until superseded by the Crown, from whom it first derived its authority.

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[1] "The General Land Drainage and Improvement Company," and * "The Land Loan and Enfranchisement Company," are now merged into "The Lands Improvement Company."

CHAPTER V

OPEN DRAINS AND WATERCOURSES

> "*Humidiorem agrum fossis concidi atque siccari, Utilissimum est.*"—PLINY.

OPEN drains are used on a large scale to take the discharge from considerable areas, when they are known as "trunk" or "arterial" drainage, and on lands of small capital value, such as sheepwalks, &c., for the purpose of drawing off water from bogs, hollows, &c. They are commonly cut in the lowest places, because that is where the water collects, but are sometimes cut at higher level to intercept water coming from above.

In the case of plantations and woodlands, open drains are the only means which can be adopted for running off the water, as any other kind of channel would be stopped very quickly by the tree roots, though deep open drains in a plantation detract from its value and are very objectionable. It is not so essential in the case of an established plantation that the drainage should be so perfect as in the case of agricultural land, for the reason that trees to a large extent free the land of water by means of the exhalation from their immense leaf area.

In this connection it should not be forgotten that many of our most valuable forest trees thrive best in damp soils (though not in stagnant water), and the thorough drainage of such soils would therefore be a grave mistake.

What forester, for instance, has failed to notice that the best seedling oaks are often found in moist, almost marshy, land? Elm, ash, hornbeam, and alder also delight in a moist soil.

The most common form of open drain is that of the ordinary ditch, which, with a system of water furrowing executed with the plough every autumn, is often the only system of drainage existing upon a farm. Would that the farmers of England could be made to comprehend that their ditches *are* the drains of their farm, and not the proper places to shoot down heaps of docks, stones, and rubbish.

I have known a farm taken in hand by a landowner, whose outgoing tenant said it was " too wet for anything, and unsafe to ride over in the winter," which, within two years, and without any capital outlay other than that of opening out the ditches (which the late tenant had left untouched for some fourteen years) and laying pipes under gateways, in conjunction with a slight amount of water-furrowing, has become of more than average dry character.

Personally, I consider that, when land is at all inclined to be wet, whether it be tile-drained or not, there should be an open ditch between every field and its neighbour. The ground that a ditch occupies is not valuable, as it is usually shaded by the fence and not infrequently by trees, and the expense of regular cleansing is more than compensated for by the benefit derived. Ditching will cost from 2d. to 1s. per rod, according to circumstances. In the case of hill pastures the drains should not be cut too deep, on account of danger to lambs. They will cost from 9d. to 1s. 6d. per chain, according to character of soil and quantity of heather, &c., on the surface. A usual size for upland drains in the North of England is 14 in. to 16 in. deep and 18 in. wide. They are usually cut transversely to the line of slope to lead the water gently and without scour.

The same principle should be adopted in the case of open drains as in the case of pipe drainage—namely, mains (which may take the flow from 10 to 15 acres) in the lowest place, and minors either straight down the steep or, especially where the wash is likely to be large by reason of sharp flow, diagonally across the slope. The reason of this arrangement is that the mains, carrying more water, do not need so much fall as the minors in order to clear themselves. In order to do this effectually and to remain in working order without attention as long as possible, an open drain should have a minimum fall of 1 in 200 in friable soils, and of 1 in 100 in clays ; but if more fall can be obtained it will be better. The reason that more fall is required in the case of clays is that, on account of increased friction and capillary attraction, the flow is slower than in the case of more open soils. In the case of rivers, anything exceeding a slope of

1 in 250 is unnavigable, and an average fall is about 2 feet per mile or, 1 in 2,640. Smeaton says that large and deep rivers will run with a fall of 1 foot per mile, but small brooks require at least 4 feet fall per mile (1 in 1,200), and ditches should have 8 feet per mile (1 in 600). Fall from ridge to furrow should be much more, often 1 in 10.

Where a natural fall is not obtainable it will be necessary to dig the drain deeper at the lower end than at the upper. Mains should always be cut a few inches lower than minors. The minors should not enter the main at right angles, but at an acute angle with the main, and, of course, in the same direction of flow. No two minors should enter the main directly opposite one another, or the wash from one will possibly choke the other. They should be arranged to enter on opposite sides alternately, herring-bone fashion.

It occasionally happens that the only possible outfall for an open drain is into a closed one, a combination decidedly to be avoided on account of the danger of choking the covered drain; but, when unavoidable, a catchpit should be formed of brick or stone, deeper than the inlet to the drain, and a grate hung to cover the pipe. It is important to keep the catchpit clean.

Batters.—The correct batters which should be given to open water channels depend upon the nature of the soil through which they are cut and the rapidity of the current; but, as a rule, the slopes should not be stiffer than the natural angle of repose of the soil of which they are composed. Owing to the solidity of unmoved soil, it will stand at something stiffer than this angle; but unless the banks are turfed and not liable to trampling by stock, it will not be a very lasting slope, as the tendency of all soils is to wash and weather down to their natural angle of repose. Should it be obligatory to make the slopes much steeper than this, they should be protected by piling, walling, or other similar means.

Table of Angles of Natural Repose (with the Horizontal Line

Moist sand	22°	Chalk	55°
Dry sand	38°	Rubble	45°
Vegetable earth	28°	Well-drained clay	45°
Shingle	39°	Wet clay	16°
Gravel	40°	Loose peat	14°
Compact earth	50°	Firm peat	45°

A turf is 36 in. by 12 in. by 1 in., and where land is free from stones the cutting will cost 1s. to 1s. 6d. per 100 turves. The operation is performed by means of a line and " rase," having a blade about 2 in. in length, for marking out the turves, which are then cut by means of a " turfing iron." A waggon will hold from 200 to 250 turves, and a cart from 60 to 70.

Earthwork.—In measuring up earthwork in the case of open watercourses, the same method must be adopted as in the case of railway cuttings, and for works of any magnitude the tables published in most books on surveying may be utilised to advantage. A useful rule is to calculate (from measurements taken, or from cross-sections plotted on paper) the superficial area of cross-sections taken at equal distances—say at every ten chains' length—and multiply the mean of these by the length of the cutting.

More elaborate rules than the foregoing may be found in any work on mensuration, but this is accurate enough for any ordinary drainage work. The cost of earthwork will depend chiefly on the hardness of the digging involved, as, though a man will throw up ten cubic yards of loose earth per day, yet five cubic yards of hard or gravelly soil is good work. It will also depend on the distance to which the soil has to be wheeled, the rate of wages current in the district, and the state of the weather, as a man not only expects higher pay on account of working in discomfort, but is unable to get through so much per day as he could in favourable weather. In the case of the cutting of a new watercourse, under ordinary circumstances the soil can be removed at a cost of threepence to fourpence per cubic yard, and placed in the old channel, if not more than twenty yards " run." The following data may be of service :—

A man will dig and fill into carts or barrows, in a day's work of ten hours, the following quantities:

Sand	12 cubic yards.
Easily-got earth	11 ,, ,,
Strong clay	9 ,, ,,
Hard earth or chalk	7 ,, ,,
Soft stone	4 ,, ,,
Hard stone	2 ,, ,,
Very hard stone	1 ,, ,,

Height of perpendicular face which various soils will retain for a short space of time without falling :

Clay	9 to 12 feet.
Drained loam	5 ,, 8 ,,
Ordinary earth	2 ,, 3 ,,
Dry sand or gravel	1 ,, 2 ,,

A cubic yard of earth before digging will occupy one and a half cubic yards after it has been moved. A usual allowance for decrease of height in an embankment after settlement is one inch for every foot of original height, but the settlement is sometimes as great as three inches per foot.

NOTES ON EARTHWORK.

To convert—

Linear.	Multiply by	Converse.
Feet into links	1·575	·66
Yards ,, ...	4·545	·22
Feet into miles	·000189	5·280
Chains ,, ...	·0125	80
Square.		
Square feet into square inches	144	·00694
,, ,, acres	·0000229	43560
Square yards ,, ,,	·0002066	4840
Cubic.		
Cubic inches into cubic feet	·000579	1728
,, feet ,, yards ..	·03704	27
,, ,, ,, bushels ..	·7794	1·283

Approximate weights of various earths, &c., per cube yard.

Mud	.. about 24 cwt.	Chalk	.. about 36 cwt.
Marl ..	,, 26 ,,	Sandstone ..	,, 39 ,,
Sand (dry)	,, 21 ,,	Quartz ..	,, 41 ,,
Sand (wet)	,, 30 ,,	Granite ..	,, 42 ,,
Gravel ..	,, 30 ,,	Slate ..	,, 43 ,,
Clay ..	,, 31 ,,	Trap rock ..	,, 42 ,,

Excavating and wheeling data.— Cost per cube yard.

	s.	d.
Excavate common soils to not exceeding one throw (or 6 feet) in depth	0	6
,, stiff clays ,, ,, ,,	0	8
Filling and wheeling for first 20 yards run	0	8
Wheeling for every additional run of 20 yards ..	0	3
Filling and carting to distance not exceeding half-a-mile	0	8
,, ,, ,, one mile	2	6
Soiling slopes of embankments and cuttings ..	0	3

Number of cubic feet of various earths in a ton.

Loose earth ..	24	Earth with gravel	17·8
Clay	18·6	Common soil ..	15·6
Coarse sand or gravel	18·6	Clay with gravel ..	14·4

Increased volume of earth in embankment over the same unmoved.

Sand, one-seventh more. Clay, one-fifth more. Gravel, one-eleventh more. Large rocks, one-half more. Chalk, one-third more.

Equivalents of slopes.

½ to 1	= 63° 30′	1¾ to 1	= 29° 44′
¾ to 1	= 53°	2 to 1	= 26° 44′
1 to 1	= 45°	3 to 1	= 18° 25′
1¼ to 1	= 31° 40′	4 to 1	= 14° 12′
1½ to 1	= 33° 42′		

Chapter VI

OPEN DRAINS AND WATERCOURSES

(*Continued*)

> "*Omnia mutantur; nihil interit . . .*
> *Hæc quoque non perstant quæ nos elementa vocamus.*"—Ovid.

Scour.—In the case of open watercourses there is always a certain amount of wear and tear going on to the banks and bed, and this is especially the case where the flow is rapid and the channel crooked. The erosive powers of a river depend almost entirely on the rapidity of its current, and the following calculations have been made :—

A velocity of	3	inches per second	will move	fine clay.
,,	6	,,	,,	fine sand.
,,	8	,,	,,	coarse sand.
,,	12	,,	,,	fine gravel.
,,	24	,,	,,	rounded inch pebbles.
,,	36	,,	,,	slippery angular stones of the size of an egg.
,,	50	,,	,,	conglomerate.

In the case of navigable rivers and canals there is also considerable wash occasioned by the passage of vessels, especially if they travel with any speed. As a great deal of damage is often done to the adjoining lands by scour, and the channel is sometimes blocked by the débris, it is essential that precautions should be taken to prevent this scouring action.

The readiest means of protecting the banks of a river or stream are as follows :—

(*a*) In very important positions, and when the wear is very great, such as the waste and tail water from a mill, stone, brick, or concrete, walling and paving may be employed, care being especially taken that the foundations are well below the reach of water, as so soon as water gets below or behind such walls, their failure becomes a mere question of time.

(*b*) Timber piling or "camp sheathing," of more or less stoutness, according to the circumstances, may be used, and will last for years if properly executed. Beech or elm plank, cut and used while still green, will be found to answer extremely well below water for this purpose, and has the additional merit of cheapness. The top plank, which probably is sometimes below water, sometimes above, should be of oak, and where appearance is of consideration, an oak capping 2 or 3 inches deep and the full width of pile and plank combined adds a great deal to the neatness of the work. The plank should always be placed behind the piles unless under special circumstances appearance demands it should be otherwise. The piles used should be of oak, be placed from 3 to 6 feet apart, and be from 4 × 4 inches to 6 × 6 inches in dimension. In places where it is difficult to drive, the piles should be shod with iron, as it is of no service to put in piles unless they can be driven well and solidly home.

Stockholm tar applied cold in two coats may if desired be used to dress the timber.

(*c*) Large, loose boulders may be of some service to avert scour, and in many places they are found ready to hand in the river bed.

(*d*) Fascines in the shape of bundles of dead brushwood may be lashed or wattled to stakes driven firmly into the bed of the stream, and, if cut and used green and laid with cut ends exposed, they will last some considerable time.

(*e*) The slopes may be planted with alder or willow, so that their roots may keep the banks together ; all that is needed to be done is to cut the growths from old stools into lengths of about fifteen or eighteen inches each, and to insert them slantwise into the ground for about nine inches, when a growth will spring up from every eye.

Another plan useful when the wash is large or mud upon the banks needs keeping up is to make a live wattle fence of willow, inserting the end of each piece in the ground along the base of the slope, and, in case of the junction of two streams, this fence may be advantageously carried out a short distance, so as to tend to divert the flow into the centre of the stream ; if desired, extra large-sized stakes may be inserted here and there to form little pollards.

In all cases where it is desirable to have any withy growing in places where it will be constantly in water the proper kind to use is the famous *Salix caprea*[1]—sallow, or goat palm—which is the only common member of the willow tribe which will continue to flourish under these circumstances. It can readily be distinguished by its broad, rough leaves of roundish ovate shape. It bears about Eastertide a most brilliant yellow catkin of large size. It will grow from layers, if required, to fill up gaps.

It often happens that the chief reason of the existence of scour lies in the tortuous nature of the course, and it is sometimes judicious to straighten the channel to the great improvement of its powers of discharge ; in fact, it occasionally happens that the success of a drainage scheme depends upon the extra fall which the straightening of a natural bed will give. By the term "straighten" is not meant generally the formation of one straight channel, but the substitution of easy curves for abrupt ones, and the reduction of the number of corners and right lines, though of course the nearer it approaches the straight line the better for drainage purposes.

Where the land on either bank is the property of different owners the stream may usually be straightened by means of the familiar "give and take" arrangement, by which each owner will get his just quota of land back, often in an improved shape, and the awkward question of purchase value is avoided. The survey and setting out of the new course is often a very pretty piece of work, and will test a surveyor's skill well-nigh as much as the setting out of a railway curve.

For protection against scour it is very desirable that the banks should be covered with turf, and for this purpose the Meadow Grasses (*Poa nemoralis* and *P. pratensis*) are best for binding banks together. For light sandy banks by the sea nothing can be better than the Sand Reed or Marrem grass (*Psamma arenaria*), the Bent Star, or Sand Carex (*Carex arenaria*), and Lyme Grass (*Elymus arenarius*).

Catchwater Drains.—In cases where land lies too low to be drained in the usual way, a free outfall must be secured

[1] *Salix Caprea* thus described by Sowerby:—*Great Sallow*, leaves very broad, roundish ovate, downy beneath. Stipules semi-cordate Stigmas nearly sessile, entire ; hedges and thickets ; common ; 10 feet to 30 feet ; April and May ; scales blackish.

by conducting the drainage waters by means of a system of catchwater drainage to a point at a lower level, where the necessary discharge can take place.

Thus, in the case of marsh land lying below the level of a river, and so without a natural outfall, it will be necessary to cut a drain or open watercourse in a direction more or less parallel with the river, so as to utilise a portion of the fall of the river itself to carry away the drainage water to a point where sufficient fall can be obtained to empty it into the river. Thus it often happens that drainage water has to be caried in this way so as to empty below a mill-dam in a river, or below a lock in a canal. It often happens, too, that catchwater drains must be provided in cases where land is liable to flood, and by means of thus providing an extra channel capable of carrying off the overflow from the main stream this may be averted. In other cases catchwater drains are the vehicles for the conveyance of drainage water from land lying below the level of the adjacent river or sea to the various points where it can be lifted artificially over the sea wall or retaining embankment. They may also be cut to intercept the drainage from higher lands in such a way that this water may have a separate and higher outfall to that which serves for the lower levels, and thus ensure that in such a case as that of a tidal opening the lower water may be effectually discharged within the limited time during which the outfall is free.

Again, the power acquired by the discharge of this water from the upper levels may be utilised to drive machinery for lifting the drainage effluent from lower lands ; or the water may be impounded for the purpose of irrigating lower lands, or for manufacturing or other purposes

CHAPTER VII

METHODS OF DISCHARGE, &c.

"Science is mind brought into connection with Nature."
HUMBOLDT.

IN ordinary drainage work the lift is usually from 5 to 10 feet and very rarely exceeds 15 feet.

It has been calculated in the Eastern Counties that provision should be made for the removal of 4 gallons of drainage water per acre per minute, a quantity which will be greatly exceeded in the Western Counties or in Ireland.

Allowance should be made for any high land draining on to the low land and for soakage through the retaining banks.

In specifying for pumping machinery, economy of fuel and maintenance is of vastly more importance than is the question of first cost.

There are several ways in which drainage waters may be discharged from low-lying lands.

(*a*) In the case of tidal waters, it is often possible to arrange outfalls in such a manner that they will discharge during a portion of each tide, and by means of valved outlets that their action shall be suspended during that portion of the tide when a backflow would otherwise set in. In these cases it is necessary that the area of discharge should be large enough to allow the whole of the drainage water to pass in the time during which the outfall will be open, and that the capacity for storage during the intermission of discharge should be sufficient to obviate any injurious "backing up" on the drained lands. This form of outlet has the merit of being automatic in its action, and of, therefore, requiring little or no supervision.

(*b*) Similarly, a system of syphonage may be arranged, so as to deliver over the sea wall at all such times as the level of discharge is lower than the level of intake.

(*c*) In cases where it is obligatory to raise drainage water, a "scoop" or "dash" wheel (similar to a "breastwheel" reversed) may be used for slight lifts ; a more simple means of raising large bodies of water 10 or 12 feet can hardly be devised, nor one less liable to derangement by ice, weeds, or driftwood ; and for greater lifts, a "noria" or some one of the numerous kinds of pumps must be employed, the centrifugal being usually the most effective for lifts up to 25 feet, though its best results are obtained at below 20 feet lift. The effective power of a centrifugal pump with curved arms may be taken at from 60 to 70 per cent. of the power employed.

The cost of maintenance of pumps is usually great on account of the friction occasioned by the earthy character of drainage waters.

The pumps selected may be driven by wind, water, or steam power. Perhaps of these the most familiar object to the traveller in our Eastern Counties and the Netherlands is the windmill, and though, of course, in the very nature of things, they are dependent on the inconstant character of the wind, which may vary from the just perceptible velocity of a mile an hour to the hurricane speed of eighty or more miles per hour, yet the modern self-governing windmill is a very effective machine.

Windmills can be obtained practically proof against damage by tempest, are automatic in their action, are well suited for intermittent work, and require but little more engineering skill to manage than the ordinary labourer can bestow. During calm summer weather they cannot be depended upon to work more than four to six hours of the twenty-four ; but, at that time of year, their continuous action is not so much needed for drainage purposes as is the case in the spring and winter.

"Open-wheel" mills are governed by means of the tilting of the sections of which the wheel is composed, while "solid-wheel" mills are governed by the turning of the whole wheel (which is mounted on sensitive ball bearings for the purpose) at an angle, more or less direct to the wind, in accordance with the pressure existent at the time. To ensure obtaining the full benefit of a mill in all winds, however light, it is, of course, necessary that it should be mounted at such an altitude as will command the wind from all quarters.

With a breeze blowing at a velocity of from ten to fifteen miles an hour, a mill of 10-feet diameter will develop about half horse-power; a 15-feet mill about one horse-power; and a 20-feet mill from two to three horse-power, and can be erected at a cost of from £20 for a 10-feet mill to £80 for one of 20-feet diameter.

The drainage water from a higher level may sometimes be economically utilised to drive wheels or turbines for the pumping up of the water from a lower level. In fact, when it is readily available, water-power is the cheapest power in existence.

The "Undershot" wheel (sometimes termed by mill-wrights "sweepshot") is used in cases where the fall is slight and quantity of water large. It is useful as a flood wheel, or for obtaining power from the ebb and flow of the tide. The velocity of the periphery of the wheel should not exceed half that of the water. The Breastshot also necessitates a large supply of water, and is used where there is a moderate fall, say 6 or 7 feet; while Overshot wheels need a high fall, though a much smaller supply of water will drive them than in either of the other cases, as water possesses more power when acting by gravity and pressure than by impulse.

In "Undershot" wheels the water is introduced at the lower part of the wheel; in "Breastwheels" at the breast or in line with the axis; and in "Overshot" at the apex of the wheel.

In all water-wheels it is necessary that water entering should have at the moment it impinges upon the bucket a velocity at least equal to the speed of the periphery of the wheel. If it has not naturally such a velocity, it must be allowed to fall through a sufficient space to acquire it, or the wheel will be retarded by striking water and some will be dashed over and lost, while the buckets will not be so well filled. On the other hand power will be lost if too great a velocity be given.

Provision must be made for the escape of air from the buckets of a wheel when the water enters, either by using specially shaped buckets, or by making the feed-trough from 4 to 6 inches narrower than the buckets.

Formerly water-wheels were made with iron rims and axle and with wooden buckets, but these are now superseded by all iron wheels.

The cost of wheels 2 feet 6 inches to 3 feet in width is about £2 per foot of diameter; for wheels 3 to 4 feet wide about 5s. per foot of diameter more; larger sizes in proportion.

When the formation of the ground does not admit of a surface channel to supply a wheel, raised wooden or iron troughs termed "launders" must be used.

Whether the fall and water supply be large or small, and more particularly where the supply is irregular in amount, a turbine will be found to develop a greater power at less expense than any kind of wheel, and this comparatively recent invention is therefore rapidly displacing the more cumbersome wheels of all sorts, especially where there is a large head, giving a high pressure of water. Turbines occupy but small space, can be obtained for fixing in either horizontal or vertical position, with guide-blades so placed as to render them self-governing if required, and can be driven at a high speed (from 80 to 1,400 revolutions per minute), so that, if required, machinery may be driven direct from the shaft, without need of any intermediate gearing. They may be divided into three classes. (1) *Parallel flow*, where the water flows parallel with the axis or driving-shaft of the turbine and impinges upon a wheel having inclined blades like an air propeller. (2) *Inward flow*, where the water enters at the circumference, and, acting tangentially upon the blades, generally escapes near the centre. (3) *Outward flow*, where the water enters near the centre and flows out at the periphery of the wheel.

A very great advantage of the turbine is that it need not be run at its full power unless so desired, but can be used at various degrees of its capacity to suit whatever work there may be in hand.

A very valuable property of the turbine is that it may be used for falls of water so high or so low that an ordinary wheel cannot be used. M. Fourneyon (the inventor of the true turbine) built one which worked very satisfactorily with a fall of 9 inches only; but in practice the lowest fall which may reasonably be utilised by a turbine is 2 feet 6 inches.

One very important point in all water motors is that the tail water should get away freely. It is thus essential that in the case of a wheel the tail race should have such a fall as will give the escaping water a velocity greater than that of the wheel, and in the case of a turbine the fall should be such as to prevent the tail water rising higher than about the top of the casing, though tail water is not so detrimental to the effective working of a turbine as in the case of a wheel.

Freedom from noise and splashing is a sign that all the energy has been taken out of the water. The grand condition of all water power machinery is that the water should reach the motor without shock, and leave it without relative velocity.

Local circumstances must in every case modify the reasons for the use of a particular motor, *e.g.*, price of fuel, motive power of adjacent stream, price of labour, transport, facility for repairs, &c.

Steam power must be utilised in cases where no other means can be economically adopted, but is more expensive, both in installation and maintenance, than any of the before-mentioned methods of lift, though, owing to its greater reliability and to the fact that it is always available, it has to a large extent superseded the wind-mills and other engines formerly so much employed in raising water from large areas.

Horse-power of Water.—To calculate the horse-power which a stream of water will afford, the process is simply to multiply the weight of one cubic foot of water ($62\frac{1}{2}$ lbs.) by the number of cubic feet of water passing per minute (ascertained by gauging); multiply the product thus obtained by the number of feet in the fall, and divide the result by 33,000 (the number of pounds raised in one minute one foot high by "one horse-power").

Expressing this as a formula, we get the following as a rule for calculating the *theoretical* horse-power of water:—

$$HP = \frac{62{\cdot}5 \times W \times H}{33{,}000} = {\cdot}001892\ WH.$$

Where HP = theoretical horse-power required.
62·5 = weight in pounds of one cubic foot of water.
W = cubic feet of water falling per minute.
H = head (*i.e.*, fall) in feet.
33,000 = foot pounds for one HP.

The theoretical horse-power is, of course, never obtained on account of loss by friction and otherwise, and for practical purposes we need to ascertain the effective power which can be utilised. The comparative effective powers of various motors are as follows, the theoretical power being 1·00 :—

				Suitable for a fall of
Undershot wheel	..	·30 to ·35	..	1 to 5 feet
Low Breastshot wheel	..	·30 to ·50	..	5 to 8 feet
High ,, ,,	..	·60 to ·75	..	8 to 15 feet
Overshot wheel	..	·65 to ·75	..	15 to 50 feet
Pressure engine	..	·75 to ·85	..	50 feet upwards
Turbine ..	..	·70 to ·80	..	2 ft. 6 in. upwards

For the purpose of calculation these percentages may be incorporated in the above formula thus :—

To ascertain the effective horse-power which may be obtained from a stream of water if an undershot wheel be used:—

$$HP = \frac{62\cdot5 \times W \times H \times \cdot35}{33{,}000} = \cdot00066 \text{ WH.}$$

And similarly for the other motors the effective horse-power may be ascertained by inserting the corresponding figure.

To find the horse-power required to lift a given quantity of water to a certain height, multiply the weight in pounds of the water required to be raised per minute by the lift in feet and divide by 33,000.

As a formula this may be expressed thus :—

$$HP = \frac{(10 \times W) \times H}{33{,}000}$$

where HP = horse-power required.
10 = weight of a gallon of water in lbs.
W = number of gallons of water to be raised.
H = height of lift in feet.

A margin of 50 or 60 per cent. should be added beyond the horse-power actually required to allow for contingencies, leakage, &c., and an allowance must be made for friction of both engine and pumps. A very usual addition for friction is 20 per cent. upon the horse-power found by the foregoing method.

The margin should be large enough—by duplicate or triplicate plant—for accident or repairs. This may be accomplished, say, by having three engines, each of which is capable of doing half the work, thus leaving one in reserve.

In a newly-drained district which has been saturated for all time, much more pumping is necessary at first than is ever afterwards the case.

CHAPTER VIII

GAUGING AN AREA OF DISCHARGE—GAUGING RIVERS AND STREAMS

"*A life without investigation is worth nothing.*"—SOCRATES.

FOR the purposes of water supply or irrigation, for the utilisation of water power, for calculating the power necessary to lift them to a point of discharge, or for other reasons, it is often desirable to gauge the flow of rivers, streams, or drains.

It is frequently necessary to ascertain the compensation due to millers and riparian owners for water to be abstracted from their existing supply. There are several methods of doing this, and it depends chiefly upon the size of the stream as to which particular means should be adopted.

It may be carried out :—

1. In uniform open channels.
2. By surface velocity in centre of stream.
3. By means of sluices or orifices.
4. By means of current meters or other instruments for observing velocities at various depths.
5. By means of weirs.

(*a*) If the discharge is but a small one, it may be very accurately measured by means of buckets of known capacity, into which the flow may be received for a certain number of minutes ; by dividing by this number the discharge per minute may then be arrived at. Sufficient accuracy would not be obtained if only one or two minutes were taken, as there would likely be a few seconds at the commencing and ending which could not be reckoned in calculation, though they would make a large difference in a day's discharge.

(*b*) In the case of small streams, the readiest and most reliable way in which flow can be gauged is by damming up the stream for its whole width by means of a board furnished with a rectangular or triangular notch, as shown in the sketch.

The board, which is secured in its place truly vertical and at right angles to the stream by means of stakes, must be cut to a thin edge on the upstream side, in order that the water may get away easily and freely. The edges A B and E F must be in the same straight line, and the edge C D absolutely parallel to them and a certain number of inches below. The angles B C D and C D E should be true right angles, and the width of the notch C D an even number of inches or feet for easy calculation. In fixing the notch board the edges A B and E F must be parallel with the water, and the lower edge of the board must be puddled with clay on the upstream side so that no water shall pass save through the notch. The puddle should not, however, reach so high as the level of the notch.

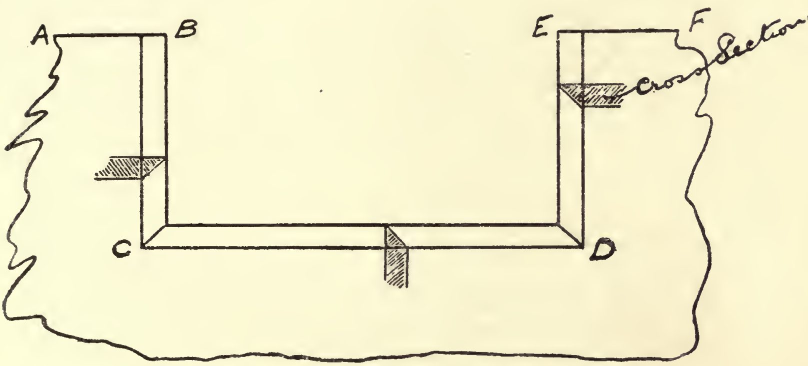

FIG. 3.—FRONT VIEW OF SQUARE NOTCH

The only measurement required, the dimensions of the notch being known, is the depth of the water flowing over the sill after it has ceased to rise in level, and as the water at this particular point is falling over, if will be curved a little in a downward direction, and if measured on the board itself will register too little. To obviate this, it is well to drive in a stake a little above the notch-board, having the level of B or E accurately marked upon it.

In small streams the distance of the gauge-stake may be from 1 to 2 feet; in very large streams 20 to 25 feet, in order to avoid the overfall. The depth of water on the upstream side must not be less than three times the depth of that flowing over, and the difference in level between the surface of the water on the downstream side and the sill must be not less than half the maximum depth of the flow over.

Measuring upon the gauge, obtained as above, down to water level, the depth of still water over the sill may be arrived at by subtracting this measurement from the known depth of the notch. The number of cubic feet of water passing per minute may then be calculated by multiplying together the height in feet of water surface above the sill, the width in feet of the sill, and the velocity in feet per minute of the stream above the dam.

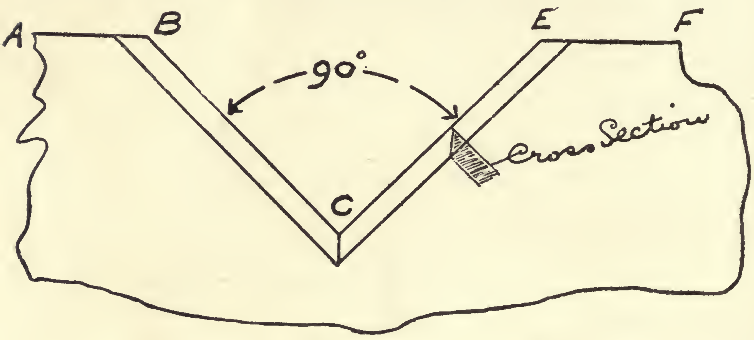

FIG. 4.—FRONT VIEW OF "V" NOTCH

Expressed as a formula, this becomes :—

$$D = H \times W \times V,$$

where D = discharge over the sill in cubic feet per minute.
H = height of water surface above sill in feet.
W = width of sill in feet.
V = velocity of water flowing to the notch in feet per minute.

For very exact purposes, a notch of the form of a right-angled triangle should be employed, being fixed in the same way as described in the case of the rectangular notch. The above formula would then need to be modified to the following :—

$$D = \tfrac{1}{2} H \times W \times V.$$

To obtain the velocity of the stream, hollow floating bodies, such as a not too large bottle, must be observed upon a calm day and timed in passing two fixed points.

If the floats are too deep the true surface velocity will not be obtained. The best floats to use are either a thin piece of wood (say ¼ inch thick); a leaded cork; an orange, or some other substance but little lighter than water, in order that being nearly submerged the wind may have but little effect upon it.

A portion of the stream should be chosen which has a fairly uniform fall, and as straight as may be for a sufficient

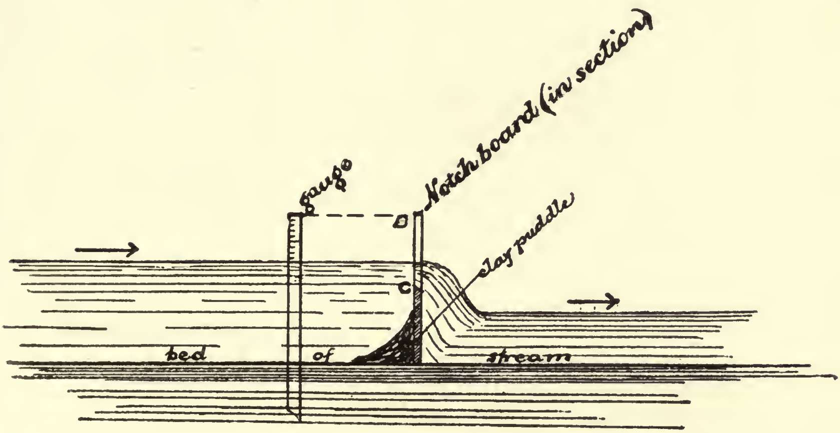

FIG. 5.—LONGITUDINAL SECTION OF STREAM, SHOWING NOTCH-BOARD IN POSITION.

distance. Care must be taken that the float has the same velocity as the stream when it passes the first point, and this may be secured by placing it in the stream some distance higher up. The velocity thus obtained will be the greatest velocity, as it will be taken at the upper centre of the stream precisely where the flow is greatest, and it must be heavily discounted (say by one-fifth) to allow for the friction at the sides and bottom. The precise amount to be allowed for friction will depend upon the size of the stream, as it will be very great in a small one. Weeds, again, have a great frictional power, they having been known to increase it tenfold.

Box says the mean velocity may under ordinary circumstances be taken at 84 per cent. of the maximum.

(*c*) In the case of rivers or streams too large to be stopped by a board, careful cross sections of the bed, with breadth and depth of water at each, must be taken at various places. The mean sectional area in feet thus ascertained must be multiplied by the velocity of the current in feet per minute, the product being the number of cubic feet passing per minute. Care should be taken that no tributary joins the course between any of the cross-sections. A portion of the river should be chosen which is of even width, has an uniform fall, and without bends for a good length (say 1,000 feet). Here the current will have a nearly uniform flow. It is well-nigh impossible to gauge with anything approaching accuracy a river having many sinuosities.

In all cases of gauging one operation should not be taken as final and sufficient, as, of course, the flow will vary according to the season and the rainfall sometimes to a remarkable degree, and, therefore, for the sake of accuracy, gauging should be repeated twice or even more times.

Sectional Area for Required Discharge.—It has been stated with authority that rivers almost always form their own beds, the process being carried on in accordance with the velocity of the stream and the natural resistance of the material of which the bed and banks are composed—such material as chalk or clay causing a much greater resistance, and consequently being of a more permanent character than is the case with sand or mud, though in course of time all beds, even if of hard rock, become worn away by the action of water flowing constantly over them. One of the most widely known instances of this erosion of solid rock is that of the falls of Niagara, which are known to have retreated some considerable distance even in historic times.

In rivers which have but very slight falls, and, therefore, but slow flow, the converse is the case, as it often happens that these, especially in their mouths and lower reaches, raise their beds and contract their channels by the deposition of mud gathered during their earlier and more rapid course.

This deposition of mud is caused by the fact that swiftly-flowing water can bear in its course much heavier particles than when it becomes more sluggish. It is, therefore, the heavier particles which are first deposited, and afterwards the lighter ones. Also the cause of greater deposition near the banks (and naturally the same is true of the bottom also) is that on account of friction the river, which continues to flow in the centre by reason of any fall, however slight it may be, is almost, or even completely, stopped near the banks, and, therefore, will deposit almost the whole of its suspended matter. The natural result of this action is that, as the ancient bed becomes raised, the waters overflow the banks and flood the surrounding country whenever there is a fall of rain in quantity in the upper reaches. It thus becomes necessary to raise the banks even sometimes to a considerable height ; as in the case of the River Po, which, there is ample reason for believing, was once upon a level with the plains of Lombardy, though now considerably above them.

This silting up of a river bed will tend to decrease the velocity of its discharge considerably, firstly, because the lower reaches, being partially choked, the water cannot get away freely, and, secondly, because by the laws which govern the motion of bodies upon inclined planes, the deeper the water in the channel the more rapid its flow, and the shallower the stream becomes the more friction it has to overcome. The velocity which water flowing over an inclined bed will acquire varies as the square root of the fall of that bed, but in cases where the bed is level and not inclined (such as the sections of a canal) water will, upon the opening of the locks or sluices, flow by its weight alone, and its velocity will vary directly in proportion to the weight of the upper water over that below. Rocks lose one-third their weight in water. The transporting power of water increases as the sixth power of the velocity, *i.e.*, if velocity is doubled, the transporting power is increased $2 \times 2 \times 2 \times 2 \times 2 \times 2 = 64$ times and so on.

The sectional area required to accommodate water in a channel varies directly as the volume. Thus, if two streams of equal volume meet, the channel below must have a sectional area equal to that of the two upper channels together, though this rule is subject to modification by circumstances.

Thus, if the upper channels have a steep fall, and, consequently, quick flow, whereas the combined channel has but small fall, it will be necessary to enlarge the lower course to more than equal the combined area of the upper two.

A small stream may sometimes empty into a large one without either increasing its width or depth, for the reason that the sudden augmentation of volume at, perhaps, greater velocity than the larger stream may tend to move the water in the larger channel at a greater speed than before, and thus the same sectional area of channel may discharge a greater volume in the same space of time.

It should be remembered that in cases where there is not a large drop in the river bed and no free outfall, increased depth is no substitute for breadth, as the result will only be the formation of a stagnant pool below the general river bed, because unless the receiving channel be deeper than the bottom of the tributary, only the upper part of the latter stream can possibly flow.

To increase the power of discharge of a stream, the following plans may be adopted either singly or more or less in combination with one another :—

(*a*) Increase the breadth.

(*b*) Increase the depth.

(*c*) Increase the velocity of the current.

(*d*) Decrease the length of the channel by straightening the course.

Care should be taken that the fall in a channel is greatest in its upper reaches, in order that the water may not as it increases in volume also increase in velocity, and so reach the outfall more rapidly than it can be discharged.

For the purpose of calculating the volume of water which a certain channel will discharge it is necessary to determine its declivity in order that the velocity of flow may be determined ; when, with this in conjunction with the sectional measurements of the channel, after allowance for friction, the amount of discharge may be determined thus :—

Let V = mean velocity in feet per second.
D = mean hydraulic depth (see below).
S = slope or sine of inclination of channel (*i.e.*, fall $\div$ length).
C = co-efficient for friction (see below).
A = sectional area of channel.
W = volume of water discharged per second.

Then to determine the mean velocity the formula

$$V = \sqrt{\frac{C \times D}{S}}$$

may be used, and taking the velocity thus found we get

$$W = A\,V.$$

The exact value of the frictional co-efficient will depend upon the character and size of the channel; thus, in very large rivers or clean brick channels where friction is reduced to a minimum, the amount of C will be from 8,500 to 9,000, in earth from 6,800 to 7,200, and in rough rocky channels full of boulders from 4,700 to 5,400.

The "mean-hydraulic depth" or "hydraulic radius," is obtained by dividing the "sectional area" by the "wetted perimeter," or "wetted border." The length of the wetted perimeter is obtained by adding twice the mean depth to the mean width of the channel. For example, taking a case where the mean width is 6 feet and the mean depth is 2 feet, we get as sectional area 6 feet × 2 feet = 12 feet, and as wetted perimeter 6 feet + 2 feet + 2 feet = 10 feet. Dividing the sectional area (12 feet) by the wetted perimeter (10 feet) we obtain the mean hydraulic depth—viz., $1\frac{1}{5}$ feet.

To calculate the discharge in pipes, the following formula is one of the simplest :—

$$W^2 = 4{\cdot}72 \sqrt{\frac{D^5 \times H}{L}}$$

Where W = cubic feet of water discharged per minute.
D = diameter of interior of pipe in inches.
H = head of water in feet.
L = length of pipe in feet.

The sectional areas of the cylindrical pipes most commonly used are as follows :—

Diameter in Inches	Area in Square Inches
1	·785
2	3·141
$2\frac{1}{2}$	4·908
3	7·068
4	12·566
6	28·274
8	50·265
9	63·617
12	113·097

It should be remembered that, though drain pipes may be made and sold as of, say, 2 or 3 inch bore, they do not always measure their reputed diameter, as they will vary according to the strength of the clay from which they are formed and the amount of shrinkage in burning, &c.; and although a manufacturer is supposed to vary the size of his moulds or dies in proportion to the character of his material, yet he does not invariably do so, and consequently one finds the tiles from one yard will have much better measure than those from another. These variations in size will be found to extend also to the length of pipes.

The volume of water which may be discharged in twenty-four hours by drain pipes of the most usual sizes at various falls will, when running full, be somewhat as follows:—

Fall	Velocity in feet per second	Discharge in twenty-four hours in imperial gallons
For 2-inch pipes:—		
1 in 400	0·7	10,575
1 in 200	1·1	15,528
1 in 100	1·7	22,891
1 in 50	2·5	33,868
1 in 25	3·5	48,058
1 in 20	4·0	53,814
1 in 10	5·7	75,902
For 3-inch pipes:—		
1 in 400	0·9	24,687
1 in 200	1·3	36,482
1 in 100	1·9	52,215
1 in 50	2·8	77,628
1 in 25	4·0	109,448
1 in 20	4·5	122,339
1 in 10	6·3	173,359
For 4-inch pipes:—		
1 in 400	1·0	43,698
1 in 200	1·5	60,691
1 in 100	2·1	86,181
1 in 50	3·0	121,382
1 in 25	4·2	171,554
1 in 20	4·7	192,189
1 in 10	6·7	271,499

Liberal allowance must, of course, be made for slight faults in pipes, inequalities in laying, and for the possible presence of sand or sediment in the bore.

Drain-pipes should always exceed rather than be deficient in the dimensions actually needed to afford passage for the water they are expected to take, in order that air may obtain admission to the interior of the drain.

Were pipes mathematically true the following would be useful data (and may be taken as correct in metal pipes as used for water supply).

Diameter of pipe squared × ·034 = gallons per foot run
Area of tube in inches ÷ 23·1 = gallons per foot run.
Diameter of tube squared × ·34 = weight in lbs. per foot run.
Area of tube in inches ÷ 2·31 = weight in lbs. per foot run.

Discharge of Water through Orifices, Sluices, &c. :—

Let A = area of orifice in square feet.
H = depth of water from surface to centre of orifice in feet
W = quantity of water discharged in cubic feet per second.
V = velocity in feet per second.
C = coefficient for various orifices.

Then $V = C \sqrt{H}$.

And $W = A V$.

"C" = 4·98 for all orifices in thin plates.
6·00 for short tubes.
5·00 for sluices without side walls, &c.
6·50 for narrow openings.
7·00 for sluices with side walls or wide openings whose bottom is level with that of the reservoir.

Chapter IX

UNDER DRAINAGE

"*Hollow draining, which in wet lands is the sine quâ non of husbandry. It is in vain to think of farming them to any profit without this improvement.*"—Arthur Young's "Farmer's Kalendar."

Under Drainage.—Mere surface drainage of agricultural land, however good its effects, is, speaking generally, an inefficient method of freeing land of surplus water, notwithstanding that the expense of renewing it annually is very great in proportion, and we will therefore pass on to consider the more permanent system of under drainage.

This is usually executed by means of cylindrical pipes of sizes varied to suit the flow they are expected to receive. Many other sections of pipe have been at one time or another suggested and used, but the round one is now almost universally adopted, as it is the section giving the largest bores for its weight, and the one most easy to lay with the least amount of digging, and with most perfect joints. Theoretically, an egg-shaped pipe, laid narrow end down, would be the best as regards flow and clearing power, but it would, to say the least, be exceedingly difficult to lay.

A good drain tile should be well and evenly burnt, of good, true shape and full bore, smooth, straight, free from ragged ends, and should ring well when struck. To ensure these characteristics it must be made from well-tempered clay, free from stones, and without too large an admixture of sand or lime.

Drain pipes should be well burned, as though overburning renders them brittle, yet underburning is so much the worse in that after absorbing moisture and getting alternately frozen and thawed they rot and fall to pieces.

Sizes of Pipes.—The sizes of drain pipes cannot be calculated on any fixed rules or hydraulic formulæ (as in the case of other pipes; by head, inclination, &c.) as they are not one continuous tube, the quantity of water to be carried is uncertain and irregular, and the inclination varies with every change of surface level, so that in parts of the same system the flow is sometimes rapid, sometimes slow. For these reasons it is necessary to allow plenty of room by employing large-sized pipes—their use is not really a loss, because if even they should be too large for the flow of water, they act beneficially by allowing air to penetrate to the soil.

The sizes of the drain pipes usually employed vary from 1 inch up to 6 inches internal diameter, but it will generally be found best not to employ any pipes of less diameter than 2 inches ($2\frac{1}{2}$ inch being a usual standard size), as in the case of pipes smaller than that a slight fault in laying, or after-sink (easily caused by the action of water or work of a mole) dislocates and renders useless a whole length of pipe, whilst with a larger pipe a slight settlement is not so serious a matter; and though the pipe may often be too large for the flow, the vacant space is nevertheless very useful as a means for the admission of air. Personally I prefer to use 4-inch and 6-inch pipes for mains, and $2\frac{1}{2}$-inch or 3-inch for minors; as regards the extreme upper ends of 4-inch mains, 3-inch pipes may be employed, or similarly 2-inch pipes may be used at the top of minors with economy.

A 4-inch main should take the drainage from 7 to 12 acres of land, while a 6-inch pipe will take the flow from 20 to 25 acres, and an 8-inch pipe from 40 to 45 acres, according to porosity of soil and consequent speed of flow.

In cases where deposits from water are troublesome, and would soon choke a drain laid in the ordinary way, it is well to substitute collar pipes for the common butt joint; the water must then (somewhat more slowly, it is true) find its way through the porous pipe itself instead of through the open joints, and, so to speak, gets filtered in its passage.

Sandy soils, by reason of the quantity of iron in their composition, and the fine state of division in which the sand itself will penetrate, will be found especially troublesome in this respect.

The percolation of fine sand is occasionally quite as troublesome as deposits of iron. To a certain extent this may be obviated by laying the pipes in straw.

In the earlier types of pipe holes were often made to allow for the entrance of water ; but it has been found that the joints between the pipes are amply sufficient for this purpose.

What is really needed to cause a pipe to run well is a positive vacuum.

Root Obstruction.—It is well known how harmful the roots of trees may be when they obtain entrance to a drain, filling the pipes in a comparatively short time with root fibres until the flow is either completely stopped or very seriously checked. The trees especially liable to cause impediments in drains are alder, ash, poplar, and willow, the soft-wooded trees being particularly troublesome.

In cases where trees or hedgerows are situate in the immediate vicinity, say 30 feet, of a newly-laid drain, special precautions should be taken to prevent damage by roots.

If it be out of the question to apply the drastic remedy of cutting the trees, some one of the following means of prevention may be applied to the portion of the drain length which is in danger :—

(*a*) Lay it in socket pipes with cement joints, not clay merely (such pipes costing per foot run about 6d. for 4-inch, 8d. for 6-inch, and 1s. 2d. for 9-inch).

(*b*) Iron pipes may be used, the most convenient kind being common rain-water stack-pipe (costing for 4-inch 2s., and for 6-inch 4s. 4d. per yard, and weighing about 18 and 28 lbs. per yard respectively). Second-hand gas or water main may sometimes be procured for pipes of larger bore than this.

Iron pipes are especially useful when a drain passes under a hedgerow ; they are usually made in 6-feet and 3-feet lengths, the former being the best to employ in such a case.

(*c*) Stones laid below the pipes are said, by their greater moisture, to attract the roots to themselves rather than to the drain, but they are not nice to lay pipes upon ; indeed, to be sure of a pipe lying true, it is necessary that it should be laid upon the natural unmoved bottom.

(*d*) Gravel or ashes laid round pipes, with gas tar (which is very obnoxious to roots) poured over it, is reported to be efficacious.

It is not an unknown thing for the roots of agricultural crops—such as mangel wurzel—to cause stoppages in drain-pipes, and, from whatever cause they are choked, it is a very expensive and wearisome process to take the whole drain up and relay, though this is the only remedy in such a case. Confervæ and parasitic plants have been known to stop drains.

Best Positions for Mains and Minors.—Since the time when Smith, of Deanston, laid down the rules that the mains should be in the lowest places of a drainage system and that the minors should run down the steep, with submains along each hollow, that arrangement has been the one most usually pursued, and it certainly has some good reasons in its favour. This arrangement of parallel drains has been termed the "gridiron system."

It is a generally accepted fact, and is proved by the action of nature, that the more water a channel contains the less fall is necessary in order to give an effective flow; and, applying this principle to pipe drainage, the natural inference is that the minor drains carrying less water need a stiffer fall than do the mains which receive the water collected by their many tributaries.

Of course, this rule of "minors down the steep" is, in common with other rules, subject to certain exceptions, and in such cases, as where the minors laid rigidly in this manner would have a very much greater rate of inclination than the main to which they were tributary, it is well to modify the scheme so as to obviate the necessity for such an arrangement. Thus, imagine 2-inch minors laid at an inclination of 1 in 50, emptying into a 4-inch main laid at 1 in 400. If two of these minors were to run full bore they would fill the main, and the extra pressure of the other contributories would tend to burst it, and so to create a fault which would be likely in the future to become a fruitful source of stoppages by reason of the entrance of soil.

Another reason assigned for the practice of running a minor directly down the slope is that it then acts equally upon both sides of its length, and collects more water than it otherwise would do.

Messrs. Risler and Wery, of the National Institute of Agronomy in France, some time ago published an account of some interesting researches in land drainage made by them at Caleves and Montargis, and they have come to the conclusion that the practice of laying the small drains in the direction of the inclination of the ground and mains along the gentler slopes of the lower levels is irrational. They advocate the exactly opposite plan of giving less inclination to the small drains, and laying the mains down the slope, and in proof of their theory have published a lengthy demonstration, the chief points upon which they claim advantage for their system being that plenty of fall being given to the mains they are thereby rendered self-cleansing, and that their arrangement gives the greatest possible efficiency in the least possible space of time. The student will at once see that the chief point in favour of this system is the self-cleansing powers of the mains, but he should bear in mind at the same time that this is acquired *at the expense of the minors,* and that on account of the smaller flow through the small drains they are always much more liable to choke than in a main having the same fall. Steep drains emptying into those of much less inclination are apt to deposit and form dams which impede further usefulness. The question of time is not of great importance in our climate, as the greatest rainfall we ever obtain within twenty-four hours is about three inches, and drains laid in the usual way are quite capable of dealing with such a quantity before it becomes injurious to vegetation.

Cross-draining.—Now, although the force of argument is all in favour of " minors down the steep," as against the laying of small drains *directly across* the slope, I yet venture to think there are many cases in which a minor laid *diagonally* across the slope will have a much greater effect than if laid in any other position ; and, further, that in a system of drainage where the minors are so laid diagonally across the steep (" herring-boned " or " switched," as the process is sometimes called), joining the main at a more or less acute angle (usually about 45 degrees) they tend to assist one another much more than if each one entered the main at more or less right angles, their scouring effect is much greater, and the pressure throughout the system is more equable than it otherwise can be.

Though it is generally acknowledged that a trench (and therefore a covered drain) cut *across* the line of descent will intercept more water than if cut *with* the slope, it has yet been urged against such an arrangement that a drain laid obliquely will bleed from its lower side, and so fail to carry off so much water as it rightly should. Now, though this is true to a certain extent in very porous soils, yet the danger has been greatly exaggerated, as it cannot be reasonable to suppose, save in the case of a stoppage in the pipe, that water will rather pass though the joints of the pipes into a very much denser medium than it leaves than flow away as it should through a free channel laid to an adequate fall ! A much more valid point against cross-draining is that a drain so laid acts almost entirely on one side ; but even if this were absolutely true, what difference does it make in a system of parallel drainage ? Such a drain acts to a so much greater distance uphill that its want of effect on the lower side is more than compensated for ; and so true is this that drains laid obliquely across the slope may usually be placed with perfect safety at wider intervals than if down the steep. Were it not so the plan of cross-draining would have ere this become untenable, as at equal distances it will usually be found to need more pipes than if laid down the slopes.

The question is not, however, whether so many drains in the line of descent will lay the field dry, but it is whether fewer drains across that line will do the same amount of work.

As a matter of fact the plan of laying minors up and down the steep is most favoured because it is an easy and safe method, comparatively free from chance of failure, but it is certainly not always the most economical plan.

Chapter X

UNDER DRAINAGE

(*Continued*)

"*Skill in agriculture does not so much consist in the discovery of principles of universal application, as in the adaptation of acknowledged principles to local circumstances.*"—Sir James Graham.

Connections.—The places where the minors and submains join with the main are, next to the outfall, the most important points to be looked after in the execution of drainage work, and even more care should be taken in laying and protecting from injury this portion of the work than any other.

The minors should be laid a little shallower—say from 3 to 6 inches—than the main, in order that they may discharge well into its crown, and the junction should be very carefully cut with a handpick, the main being pierced with a hole corresponding to the angle at which junction takes place, and the minor being gently chipped off at the end, so that no portion of the pipe will project inside the main to impede the flow, and the whole being made to fit accurately by repeated test. Broken pieces of tile, slate, &c., may be laid over the joint to protect it. In some localities ready-made junction pipes may be obtained, but the foregoing is the usual method of making connections. In the case of very important junctions or changes of direction in a drain, an inspection chamber of brick, stone, or concrete may be provided, the outlet drain being laid a few inches lower than the inlet to allow of the free egress of the water from the upper section, and the ingress of air so far as possible. The bottom of this chamber, which should be of hard material, should be placed 18 inches or 2 feet below the level of the outlet, in order that sediment may settle at the bottom for the purpose of removal.

Small inspection holes may, if desired, be formed by means of ordinary drain-pipes placed perpendicularly above the drain, and finished just above the surface, by covering with a wooden plug or flat tile. These latter are of no service for cleansing purposes, but are useful in a case of a stoppage as indicating, with more or less certainty, the point at which it has taken place. They are, however, a source of weakness, and should only be inserted where the fall is slight and the flow therefore more sluggish and liable to stoppage than it should rightly be.

In making connection between drains at right angles to one another the lower few pipes of the minor should be gently curved round, so that it may empty into the main in the same general direction as the flow in that pipe.

If there are minor drains entering upon both sides of a main they should do so chequerwise, and never opposite one another, or one, or possibly both, will assuredly choke.

Watering places for stock may be formed in the course of a drain flowing pretty constantly by leaving a length of eight or ten feet open, cutting a slope down to it on one or both sides, and laying stones in the bottom, with a rail round the exposed sides, so as to prevent trampling by stock, or a special branch drain may be laid for the purpose, leaving the main above the watering place and joining it again lower down. Care should be taken to protect the open ends of the pipes by laying large stones round them.

Outlets.—The most important and critical point of a drainage system is that of the outfall, and it should be the first endeavour of the drainage engineer to secure an outfall which shall always be free for the egress of water, and yet at low enough level to allow of sufficient depth for the proper drainage of the lands to be dealt with. It is, in fact, perfectly useless to drain land unless such an outlet can be found, and, in the case of large undertakings, it will sometimes be even found advantageous to drive a tunnel (though at great expense) through an intervening hill or high ridge of land, for the purpose of obtaining the necessary free outfall beyond. By the Land Drainage Act, 1861, certain powers are given to private owners by which they may obtain a right of outfall through adjoining lands, when it is impossible to secure one in any other way. In the case of every-day land drainage, the necessary outfall will usually be found in a stream or ditch (which should invariably be cleaned out before commencing operations), and the discharge should always be made in the direction in which the stream is flowing—never in the slightest degree up stream. In cases where a porous soil underlies a retentive one, an outfall may often be satisfactorily obtained by discharging the drains into a "swallow-hole," or "absorbing well," bored into the underlying stratum. For the proper protection of an outfall it is advisable to face it up with masonry or brickwork in mortar or cement, with a paved portion of the bed to receive the force of the effluent.

The discharge pipe should project an inch or so beyond, so as not to pour its effluent down the face, and the end of the pipe (which, for the last two or three feet of its length, is often iron) should be protected from inroads of vermin by an iron grate, which, in cases where deposit from water is liable to fur up the pipes, is better made to hinge from the top and to fasten at the bottom with a pin, in order that a wire or rod may be passed up when stoppage occurs. The bars of such a grate should be vertical, and not horizontal (at the bottom, at all events) and as narrow as may reasonably be, in order that they should not impede the flow any more than is unavoidable. It is a good plan to have the number of each outfall marked upon it, so as to correspond with similar numbers upon the estate map.

In the case of unimportant drains, where it is not thought necessary to brick up a face, a grate for the exclusion of vermin may be furnished with a circular head to fit on the pipe, and secured by an iron leg, driven into the bank. Loose stones laid round an outlet are better than nothing at all; but it is always best to provide a grating. Where the bank is too insecure to admit of foundation for the brick facing, the end of the drain may be laid in a square, wooden trunk, three or four feet long, with a grate fixed in the exposed end, or a length of iron pipe may be employed.

As every unnecessary outfall is a source of weakness to a drainage system, their number should not be multiplied any more than can be avoided. There is then less fear of choke, and a single outfall is more likely to receive attention from a tenant than if there are two or three of them to be attended to, and as a greater volume of water will be flowing, it is less likely to be choked or overlooked.

The cost of long lengths of large pipes, increasing in size as they go, is, of course, apt to become prohibitive, but the work is easier to maintain than if a large number of outlets be employed.

One outfall may, where the ground will allow of it, discharge the drainage water from ten to twenty acres, according to the nature of the land ; a porous soil filling the drains more quickly, will require more outlets than will be necessary for a more retentive soil.

Every outfall should have a clear drop into the ditch or watercourse of at least a few inches, in order that it shall discharge itself easily. In cases where there is reason to fear backwater carrying mud (especially in tidal waters) back into the drains, it is well to furnish the outfall with a valve or flap trap. Such an one in stoneware, with ground surfaces and galvanised iron flap, will cost about 4s. for 4-inch, and 5s. for 6-inch bore.

Depths and Distances.—Probably in no department of the drainage problem has there been such a wide divergence of opinion or so many mistakes made and capital wasted as in this question of depth and distances of drains, and it behoves us, therefore, to particularly study the practices and opinions of our predecessors in this respect.

In open soils, where water can pass freely, it is, of course, not necessary to set out drains so close together as in the case of compact clays, in which, on account of the smallness of the pores, the friction to be overcome before water can flow is considerable. The question of depth is to a certain extent connected with that of distance between the drains, because the deeper a drain is, within certain limits, the larger the cubical quantity of land it will free from water ; and this is clearly proved by the fact that it is the deeper drains which run first and continue to run longest after rainfall. To a certain extent, then, it may be taken that extra depth, more especially in free soils, will compensate for extra width ; but it is well to pause here and consider to what depth it is advisable to go. Even with the increased depth to which the modern scientific farmer cultivates his land, he does not, in the extreme cases of hand cultivation, subsoiling, or steam-digging, go deeper than from twenty to twenty-four inches. It therefore follows that a drain must be laid so that its top may be a few inches deeper than this, if only because it must be safely beyond the reach of accident ; but there is naturally a limit to the depth to which it is advisable to drain, and, personally, I believe that in agricultural drainage everything beyond 3 feet for minors and 3 feet 6 inches for mains is an economical, as well as practical, mistake, because beyond that depth labour becomes very heavy, and the whole thing much more costly than there is any necessity for, and rather than lay drains too deeply I would prefer to spend the extra money in adding more drains, though it should be borne in mind that over-shallow drains are quite as objectionable as over-deep ones. A drain at 3 feet deep is well below the reach of accident, whether from cultivation, the trampling of stock, or the passage of heavy loads. There are, of course, exceptional cases in which one is obliged to drain at a deeper level than this, but the only soils in which 4-feet drains can, as a rule, be justified are very porous gravels, in which percolation is extremely rapid. As a rule, then, if the drainer places his minors at from 2 feet 6 inches to 3 feet 3 inches, and his mains at from 3 feet to 3 feet 9 inches, he will not be far wrong. To secure an outfall for low-lying land it is sometimes necessary to go to depths of 8 to 10 feet, or even more. In the case of pasture-land it may not be necessary to drain so deeply as in arable land, because the weight of engines and heavy agricultural machinery has not to be allowed for ; and no doubt grass can advantageously absorb more moisture than corn crops.

All wet land subsides a little after it has been freed from its excess water, and then the drains will in time become slightly shallower than originally laid. In the case of peats it is well to cut right through the peat if practicable, and to lay the pipes on the soil beneath, so as to minimise the risk of sinking as much as possible. It is well to cut out the open trenches, and then leave the peat twelve months or more to settle before laying the pipes. Mosses are occasionally found to be so soft that it is advisable to cut the trenches by easy stages, with intervals of twelve months between, to allow the mosses to get a little steady before cutting deeper.

As to distances between drains, the drainer has much more left to his discretion than as regards depth, and he must be guided in every case by circumstances and by the character of the soil. In very light land the intervals between the drains may be so wide as twenty yards, and so on through all the various gradations, till in the stiffest clays they need to be so close as 4 yards. Thus, taking depth as criterion as to the width at which it is desirable to lay drains, in porous soils the intervals between drains may be from 10 to 12 times the depth; in light loams, from 8 to 10 times; in loams, from 6 to 8 times; and in retentive clays, from 4 to 6 times the depth. Or taking 3 feet as an average depth, this will be:—

Porous soils	at from 30 to 36	feet intervals.
Light loams	,, 24 to 30	,, ,,
Loams	,, 18 to 24	,, ,,
Clays	,, 12 to 18	,, ,,

Of course the more frequent, though shallower, drains cost more in the first instance than those of greater depth and greater width.

It very frequently happens that drains are placed at wider intervals than the circumstances really justify; but though the result of this is necessarily that of more or less failure, one can readily understand that the small returns from agricultural land at the present time are insufficient of themselves to induce landowners to expend any more capital in improvements than will just suffice to keep their tenants upon the land. One can only suppose that when times were good and corn was high in price it was not worth while to farm well, and now that we have fallen upon evil times it does not pay to do so!

In the case of arable land it is necessary, on account of the need of getting upon it to work and to secure a good seed bed, to drain at closer intervals than in the case of grass land, where a little water lying in the furrows for a few days is not of such great consequence.

Though the widely prevalent idea that pasture-land does not need drainage is, of course, absurd—that after drainage the yield may be temporarily decreased is quite possible, but it is only the moisture-loving plants of little or no feeding value and in due course their place will be better filled.

Furrow Draining.—In the case of lands lying in high-backed ridges, the better plan is to furrow-drain them—that is to say, lay a drain down each furrow—as by so doing not only is the drainage more effective, but by reason of the lesser quantity of digging than would be the case if the high ridges were cut through it is also considerably the cheaper operation.

High and narrow ridges are much to be deprecated, and though, of course, upon wet, undrained land it is the only way in which a farmer can work it at all, it is nevertheless well to avoid them so far as possible on account of the waste of land involved by the frequent furrows, often amounting to a yard on each side, on which the subsoil is exposed, and no mould left good enough for the crop. The danger to stock in the case of grass land is considerable. After drainage these ridges may readily be both flattened and widened, as the necessity for furrows of such frequency and depth will be over, and it will thus be readily seen that in the case of such furrows the drains may be laid comparatively shallow, as by reason of the easing down of the lands their distance below the surface will be materially increased.

Season for Drainage Work.—The best time for drainage is autumn and winter, and commencement should be made so soon after the stubbles are clear as may reasonably be, as the land is usually drier and sounder at that time than it will be later on, and therefore less surface injury is done by carting pipes then. Labour will usually be plentiful immediately after harvest, and the soil to be moved will be found lighter than in spring.

CHAPTER XI

UNDER DRAINAGE

(*Continued*)

"*Lay your land dry before you attempt other improvements ; the first step is cutting deep and large ditches around the wet fields ; thus you gain a requisite fall to take the water clean away from the drains.*"—ARTHUR YOUNG.

TOOLS AND PRICES

Tools used in Draining.—The tools used in the operations of ordinary pipe-draining are as follows :—

A line for marking out the sides of the intended trenches, of a chain or so in length.

A common digging spade, costing 5s. to 5s. 6d., for cutting turf and taking off the top spit, &c.

A common shovel, costing about 3s. 6d., for paring the sides or for filling in after the pipes are laid.

A mattock or pickaxe, at a cost of about 5s. to 6s., for removing stones or breaking hard ground.

A digging fork, costing about 3s. 6d., may be used for filling.

Two "grafts," or narrow clay spades of different widths, the one for use in taking out the spit next under the top spit being about 13 in. deep by 5 in. or 6 in. in width, and the other for use in the bottom being about 20 in. in depth of blade, and tapering from about 5 in. at top to 3 in. or 3½ in. at the mouth. These will cost from 6s. 6d. to 7s. 6d. each, and may, if desired, be furnished with a small stud in front to receive the heel of the workman when pressing the tool into the soil.

A drawing scoop, costing some 4s., with handles of 5 ft. or 6 ft. in length, and blade 14 in. by 3 in., and curved in section. This is used for bottoming and removing the broken earth before the pipes are laid.

A very similar implement, of about the same cost, is the "push scoop," but with somewhat shorter handle.

A "tile-hook," or pipe-laying iron, costing 1s. 6d. or 2s., being composed of a light handle, 4 ft. 6 in. or 5 ft. in length, carrying a round iron arm of 9 in. or 10 in. in length, slightly turned at the extremity to enable the pipes to be

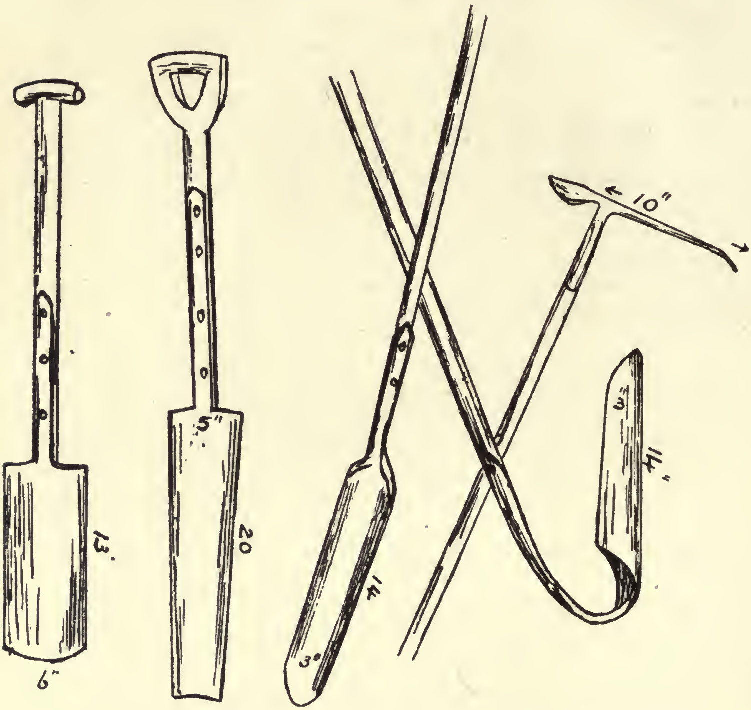

FIG. 6.—THE TOOLS COMMONLY USED IN DRAINAGE

easily handled, and, if necessary, turned in the bottom of the trench. The back of the head may be furnished with a small scoop to remove any trifling inequality in the bottom if desired.

A small tile pick, at a cost of about 1s. 6d., having one side of the head pointed and the other chisel-edged, for the purpose of cutting and making joints in pipes. A set of three ordinary boning-rods or a spirit-level may be used for testing the regularity of fall in a drain.

Prices of Labour.—Besides the special difficulties which may be met with in the execution of any particular work, the cost of drainage labour will vary in accordance with the quantity and weight of earth to be moved (which will depend upon the depth and diameter of the pipes to be employed) and the character of the soil itself. Thus, a loam can be more readily, and therefore cheaply, moved than a clay, and a stiff, even sticky, clay can be dug more easily than one containing a number of stones; the cost per cubic yard ranging from 4d. in the case of sandy or loamy soils, to 8d. or even more for hard, gravelly clay requiring the use of the pick. The number of cubic yards of earth necessary to be moved for any particular length and width of drain may be readily calculated if desired, but the following examples will clearly show how the quantity varies with circumstances:—

NUMBER OF CUBIC YARDS OF EXCAVATION PER ROD (5½ YARDS)

Depth of Trench		Average Width of Trench being— 7 in.	9 in.	12 in.	18 in.
2	6	0·8	1·1	1·5	2·3 cubic yards.
3	0	1·1	1·4	1·8	2·7 „ „
3	6	1·2	1·6	2·1	3·2 „ „
4	0	1·4	1·8	2·4	3·7 „ „
5	0	1·8	2·3	3·0	4·6 „ „

The amount of soil removed cannot be accepted absolutely as criterion of price, because one workman will dig his trench so much wider than another. No one who has witnessed a drainage competition in the Midlands can fail to have been surprised to see some of the more skilful men dig a 3ft. 6 in. drain but little wider at the top than is necessary for the insertion of the pipe.

The following table may be of service as some guide in settling the value of any particular work :—

	Depth in feet		Distance in feet	No. of rods (of 5½ yds.) per acre	No. of pipes of 12 inch length per acre	Cost of cutting and filling— Per rod		Per acre			Cost of mains and outfalls per acre	
Retentive Soils—	ft.	in.				s.	d.	£	s.	d.	s.	d.
Very stiff clay ..	2	6	12	220	3,630	0	4½	4	2	6	4	3
Tenacious gravelly clay	2	6	15	176	2,905	0	5	3	13	4	4	6
Stiff adhesive clay	2	6	16½	160	2,640	0	4½	3	0	0	4	9
Loamy clay ..	2	9	18	147	2,420	0	4½	2	15	2	4	9
Medium Soils—												
Clay loam.. ..	3	0	21	126	2,074	0	5½	2	17	9	5	0
Marl loam ..	3	0	24	110	1,815	0	4½	2	1	3	5	0
Gravel loam ..	3	0	27	98	1,613	0	6½	2	13	1	5	3
Friable loam ..	3	0	30	88	1,452	0	5½	2	0	4	5	6
Free Soils—												
Light gravelly loam	3	3	33	80	1,320	0	7½	2	10	0	5	9
Sand loam ..	3	6	39	68	1,117	0	7	1	19	8	6	0
Sand	3	9	45	59	974	0	6	1	9	6	6	3
Light gravelly sand	4	0	50	53	874	0	9	1	19	9	6	9
Coarse gravelly sand	4	0	60	44	726	1	0	2	4	0	7	0

The cost is naturally less in proportion on a large scale than when executed in a small way.

In calculating the number of rods of minor drain required in a certain acreage the following is the easiest rule :—

Divide 2640 (the number of rods linear at one foot apart per acre) by the intended width between the drains in feet, and the result will be the number of rods of drain per acre at that distance apart. This multiplied by the number of acres will give the figure required.

The number of pipes (each of one-foot length) necessary for the work will be found by multiplying the number of rods by 16½, or the length in chains by 66. To the figure thus obtained a percentage should be added for broken and faulty pipes which cannot be used, and the allowance thus necessary will vary in accordance with the character and size of the pipes, the number of times they are handled, and the amount of shunting to which they are subjected if supplied by rail.

The number of pipes required for mains must be ascertained by measurement either on the ground or upon the estate map.

When the occupier does not execute that portion of the work, it is necessary to add cost of haulage of pipes on to the ground. This will naturally depend upon the distance they must be fetched and the character of the roads and approach to the land to be drained.

The weights of the pipes (when dry) most generally employed are approximately as follows, though they will vary considerably with the density of the clay :—

2 inch	.. .. ..	17 to 19 cwt. per thousand.
2½ ,,	.. .. ..	24 to 46 ,, ,, ,,
3 ,,	.. .. ..	34 to 36 ,, ,, ,,
4 ,,	.. .. ..	45 to 47 ,, ,, ,,
6 ,,	.. .. ..	100 to 102 ,, ,, ,,

The number of pipes which may conveniently be transported in an agricultural waggon is, of 2-inch, 3,000 ; of 3-inch, 1,500 ; of 4-inch, 1,100 : and in an ordinary farm cart, of 2-inch, 800 to 1,000 ; of 3-inch, 400 to 500 ; and of 4-inch, 250 to 300.

Prices of Pipes.—The cost of drain tiles varies considerably in different districts, the chief reason for such variation being the difference in cost of coal and labour, though the one to a certain extent modifies the other, because, as a rule, labour is dearer in colliery districts than in those more remote from fuel.

The following comparison of prices will illustrate this difference :—

COMPARATIVE COST OF DRAIN PIPES IN MIDLANDS AND SOUTH OF ENGLAND

	2in.	2½in.	3in.	4in.	6in. bore of pipes.
Leicestershire, on Midland Railway, conveniently near coalfield	20s.	25s.	35s.	45s.	120s. per thousand (in the manufacturers' yards)
Hampshire, on London and South-Western Railway, remote from coalfields	25s.	—	50s.	65s.	130s. ,,

It will thus be seen that the old rule-of-thumb method of calculating cost of "burying pipes" as being half as much again as the cost of the tiles does not hold good as regards districts remote from coalfields—where, as a matter of fact, the cost of the pipes is practically equal to the expense of laying them. The practice of giving pipes to tenants to lay themselves is rarely satisfactory.

Turfing.—The cost of returfing, building outfalls, and deepening and widening outfall ditches may be taken as from 12s. to 14s. per acre

Chapter XII

UNDER DRAINAGE

(*Continued*)

"The worst laid tile is the measure of the goodness and permanence of the whole drain, just as the weakest link of a chain is the measure of its strength."—Talpa.

Planning and Supervision

Supervision.—Skilled labour should always be employed where it can possibly be obtained, and when it is absolutely necessary to employ some unskilled assistance, it should only be for the purpose of removing the turf and top spit, and never for bottoming or pipe laying. In all cases of under draining good workmanship is of the greatest importance, as the work is all covered and incapable of after alteration, and great care should be taken to lay every pipe perfectly true and to a regular fall, and the workmen should be encouraged and stimulated in every way to do their utmost. The foreman should be made responsible for every detail of the work, and should himself lay every pipe and generally see that his fellow-workmen do their work properly, and the engineer himself should be a frequent visitor to the works, and should, if possible, see every length of pipe before it is covered in. If this by distance or otherwise be impossible, he should at least examine every junction before it is finally filled in, and not be too regular in his appearances in the field.

Filling-in.—As to the filling-in of drains, it should be done by carefully putting the small stuff in on top of the pipes and then filling up with the larger lumps and stones. A covering over the pipes of hedge-trimmings, gorse, &c., may be first put in if desired, and in cases where liability to iron deposits exists, to very good purpose. Do not trample until the trench is nearly full, and do not pitch the soil in anyhow just as it comes upon the top of the pipes. As the surface over drains usually sinks very considerably for some time after laying, the mould may be heaped up on the top of the drain, and the turf laid out temporarily above that, so that upon sinking the level may come as nearly true as may be, and afterwards, if necessary, more soil may be added to fill up before finally laying the turf. The final operation of levelling, laying turf, and making drains tidy will cost from 3d. to 4d. per chain. The occupier is often expected to do this as well as cart the pipes.

In cutting drains commencement should always be made at the lower end in order that any water found may get away freely, and the soil taken out should be laid back far enough from the trench so that none of it shall fall in again. A main should first be cut and piped for its entire length before any of its tributary minors are cut, though it is well to insert the junction for each minor as one proceeds, taking precautions to prevent the entrance of soil through the open ends of the pipes. No drain should be open longer than is really necessary, and the men should be prohibited from cutting long lengths of trench before laying any pipes, as the crumbling down of the sides will prevent the tiles lying true, and the bottom is liable to get soft and muddy. Similarly the filling in should not be delayed, on account of the danger to the pipes by lying open and the probability of the sides of the trench collapsing, or even a heavy rain may wash down particles from the walls to such an extent as to choke an uncovered pipe. The upper extremity of a drain should have a wisp of straw inserted, or be closed by a pipe placed on end or broken piece of tile or stones. During the process of laying, the pipe which is temporarily the upper one should, during a cessation of laying, be protected from wash by another pipe set on end at its mouth.

Regularity of Fall.—Well-laid pipes will run freely at falls of from 1 in 1,000 to 1 in 3,000, but the flow is no doubt impeded at junctions when water enters at a greater velocity. It almost goes without saying that the fall in drains must be true and regular, and must be so cut from the beginning, care being taken that no hollow is formed which has to be afterwards filled up to get the pipes to lie. For the purpose of testing the regularity of fall in drains the ordinary dumpy spirit-level may be used, or it may be accomplished by means of boning-rods, three in number, which, when placed upright upon the various points along the lien of drain which it is desired to test, should, upon looking along their upper surfaces, coincide. Perhaps of the two a sink in a drain is more common than a fracture and quite as disastrous in its consequences. In laying, every pipe should fit well to its neighbours, and should be turned until it fits true and lies well upon the natural bottom, and in cases such as peat veins, where there is a doubt about the pipes keeping their position and true inclination, they should be laid upon slips of board placed in the bottom. The boards should be of elm or other durable wood ½-inch to ¾-inch thick. The cost is very trifling compared to the cost of relaying a drain.

In cases where the soil is entirely, or almost entirely, composed of peat, pipes are bound to sink so soon as the water

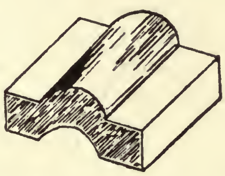

FIG. 7.—PEAT CUT TO SHAPE

in the soil draws off and the peat itself begins to settle, and it is well in these cases to first drain with temporary material, and after settlement has taken place a system of pipe drainage may then be laid. For this temporary purpose the surface of the peat itself affords the readiest material, and may be used in the form of the shoulder drain, or, by means of a special turfing iron, it may be cut into the shape shown in Fig. 7. Two of these placed together will then form a nearly cylindrical channel, and, being of almost the same weight as the surrounding material, will not get choked so readily as may be imagined. The peats should be well dried or baked in the sun before being used.

Tapping Springs.—Where the land to be drained lies somewhat lower than porous land adjoining, it is well to look for indications of springs outcropping in the lower land, as this is quite possibly the only source of wetness, and can they be tapped, it is probable that the expense of a complete system of drains may be avoided. Indications of a spring are often very strongly marked upon the surface, even if it does not appear superficially, by a more or less pronounced patch of rushes and the mossy state of the immediate vicinity. After exceptional rainfall it is probable that springs would show themselves on the surface.

Planning and Measuring up.—In planning a system of drains, whether on a large or small scale, the first endeavour should be to secure a good outfall, and then the lines of the mains should be laid out in the lowest and most convenient places for receiving the discharge from the minors. In most cases the estate map or Ordnance plan of the property will be found to be of great assistance in laying out the general lines of the work. The plan adopted should not be of haphazard character, but must be carefully thought out, both with the plan and on the ground, as a little carefulness in planning will often be the saving of considerable expenditure in execution. Every unnecessary outfall is a source of weakness, but mains should not be too long, and minors should not be longer than about twelve chains, or they will be very apt to choke, and if the fall be great there may be danger of the bursting by the head of water. To prevent minors being too long, submains must be employed. The length of mains may be greater on account of their larger sectional area, but this should be enlarged as the lower end is reached. On flat land, or in cases where the fall is but slight, it will be necessary to give an artificial fall by means of graduating the depth of the drain, so that it will be laid a little shallower at the upper than at the lower end.

In the case of any doubt as to fall, it is well to take a series of levels upon the ground, and for this purpose the ordinary "dumpy" level and staff cannot be beaten. Search should be made by moving the staff to various likely places for the lowest point for outfall, and then the line of the chief main should be staked out, and if thought necessary, by reason of the smallness of the fall which can be obtained or on account of the inexperience of the workmen, level pegs can be driven at regular intervals alongside the intended course of the drain (which can itself be most readily indicated by standing pipes on end), and the labourer can then test his work, as he proceeds, by measuring from the top of the level pegs to his drain bottom, from time to time.

The carting of the pipes, which is almost invariably done by the occupier, should be carried out before any drains are laid, so as to avoid crossing newly-filled trenches with a load, and the pipes should be laid down as nearly as may be in lines parallel to the direction of the proposed drains, so as to lighten labour and to avoid extra handling, so far as possible.

In measuring up work the best instrument to use is the ordinary 100-link chain, preferably rather heavier and stronger than usually employed for survey purposes, and care should be taken to distinguish in the field-book between work at different depths, as, of course, they carry different values. In measuring minor drains the easiest plan is to go up one and down the next, noting in the field-book every change of ten chains, and carrying on the odd lengths from the one drain to the next. When these drains are parallel and the upper ends in a straight line, their measurement may be easily taken by chaining a middle one as an average for the rest. When all is measured, the book should be made up in the field, and the "ganger" or foreman in charge of the work should be told the totals of each depth, or possibly, when he subsequently attends at the estate office to be paid, he will find he has forgotten something, and another journey may be found necessary.

In measuring up work which has to be placed upon a plan a little extra trouble must be taken. The length of each minor should be booked separately, and the positions of the main and other principal drains should be carefully taken by measuring to salient points which can be readily found upon the plan, and a sketch of the arrangement in each field should be made. The minor drains, being usually laid in parallel lines, can be readily placed upon the estate map by means of the parallel ruler, if the outside ones be first laid down, and it is quite unnecessary to take the positions of all of them if the correct number running into each main be marked in the field-book.

In cases where the estate map is upon too small a scale to allow of all details being shown, the course of the mains should be inserted and the positions of the outfalls. The date of execution and sizes of pipes will be found useful, and for easy reference are best marked upon the map.

A special book may be employed if desired, having a plan of each field (enlarged from estate map) on the one side, and an account of cost of pipes, labour, and incidentals, with notes as to the character of the soil, sizes of pipes, depths, and any other information which may be thought worthy of record upon the opposite page.

The outfalls should be watched from time to time to see that they are kept open, and perhaps for this purpose the gamekeeper or water-bailiff is the estate official who can best be made responsible for this work.

A clause should always be inserted in a farm agreement, or lease, obliging the occupier to keep outfalls clear, as well as to clean his ditches out.

Chapter XIII

UNDER DRAINAGE

(*Continued*)

"*It is a sound principle, that all changes which take place in agriculture, if unattended by profit, are wrong, and are not improvements. It must, however, be borne in mind that agricultural improvement is gradual, and progressively increased by time.*"—Mechi.

Cleansing of Deposits, Drainage by Machinery, &c.

Other Materials than Cylindrical Pipes.—At various times many materials have been used for the formation of drains, and of the more permanent of these, stones, either laid loosely or built up to form a conduit, have been most often

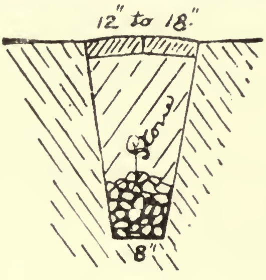

FIG. 8

FIG. 9

employed. Loose stones (Fig. 8) were the material advocated by Smith, of Deanston, and even to this day may with advantage be used in districts where pipes are dear, and stones lie upon the surface of the ground. If stratified stone be upon the spot, it may be utilised to form a drain of lasting character (Fig. 9).

This form of drain has sometimes been termed "a coupled" drain, or if four stones be used to make it square-sided, then it is called a "box" drain.

Drains formed of loose stones are liable to stoppage by the washing of earth into the spaces, and in certain soils by incrustation somewhat similar to that formed in the case of boilers.

Of the more perishable materials which have been used the principal are faggots (still often used by engineers for temporary purposes), turf (in the form of what is known as the "shoulder" drain Figs. 10 and 11), peat, brushwood, &c. In Essex and adjoining counties, a system of drainage by means of such perishable materials as twisted straw ropes, hedge trimmings, furze, &c., which by their decay form a channel for the water, has been in vogue for many years, and has become known as "the Essex system." These drains were usually about 2 feet 6 inches

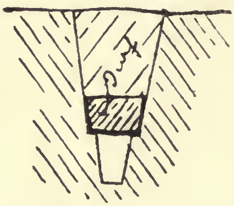

FIG. 10

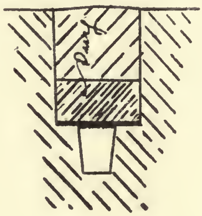

FIG. 11

deep, 10 inches or 12 inches wide at top, and 2 inches at bottom.

The characteristics of this system are shallowness and numerous outlets, regularly arranged down each furrow. These drains, which were filled with any rubbish which might be easily available, were sometimes termed "rumbling drains."

The cost of bush-drainage may be from 30s. to 40s. per acre. I have known a very good and permanent drain formed of old railway sleepers bolted together, and nothing better than a stout wooden trough can be imagined for use under a gateway, where the drainage is shallow, and heavy waggons, &c., pass over.

The system known as "wedge," or plug drainage, was only applied to strong clay, and the operation—generally on pasture—was as follows:—Cut a turf of 12 inches wide and 6 inches deep, followed by other cuts at such an angle down the side of the intended drain as will leave the bottom (at 2 feet deep) with only $1\frac{3}{4}$ inches width. Here the "plug" is inserted. It is exactly fitted to the channel of the drain and formed of several pieces of wood, each 6 feet long and $3\frac{1}{2}$ inches wide at top, and $1\frac{3}{4}$ inches at bottom, connected by iron links and drawn by a chain. Upon this the clay is replaced and rammed down tightly, the "plug" withdrawn, and the operation repeated until the whole length of drain is completed.

Of the many sections of pipe which have been recommended and used at various times, the cylindrical is now the one in general use, and may be said to have attained that position by the action of the law known as the survival of the fittest. The horseshoe tiles so often met with

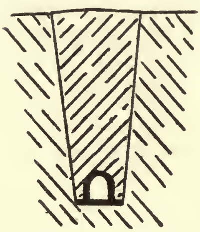

FIG. 12

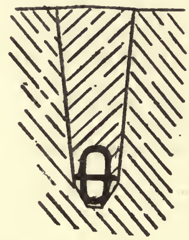

FIG. 13

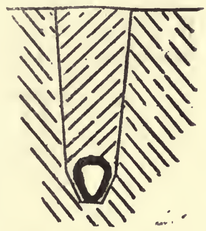

FIG. 14

in old drains, appear to have been much used at one time both singly (Fig. 12) or in pairs (Fig. 13), when they were laid to break joint, and with or without a flat sole, but have now by reason of their liability to breakage and stoppage given place to the lighter, stronger, and more handy circular tile, which, by its contracted channel, can free itself from deposit so much better than the flat-bottomed horseshoe variety.

The oval section (Fig. 14) has been recommended, and is theoretically correct in shape, because when the flow through it increases in volume, its bore correspondingly widens, and when the flow subsides it yet clears itself, because the sectional area of the lower part admits of easy flush by a small quantity of water. In practice, however, this section would be found to be heavy, expensive, and cumbersome to lay, and has not therefore been adopted.

Collar Tiles are made with the collar or socket on the end of the pipe similar in shape to the glazed variety, or a short plain pipe of larger calibre is slipped over the joint of two ordinary pipes, and is quite distinct from them.

Cleansing of Deposits.—In many existing pipe systems, deposits by water, notably of peroxide of iron, are apt to entirely choke or greatly impair their usefulness, and it therefore becomes necessary to free the pipes from this deposit.

The only way to do this is to open the drains at various points, and especially at junctions, in order that cleansing rods or wires may be inserted, and if these be worked up and down, a great deal of the deposit will be washed away by the flow of water through the pipes; if the natural flow be insufficient for this purpose it must be supplemented artificially. One end of a cleansing wire may be furnished

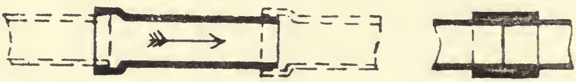

FIG. 15.—COLLAR PIPES

with a brush or piece of sacking, and if two holes are opened the section between may be swept out clean. It is well not to have too tight a fit, but rather to pass the "swab" through more than once, because if jammed it will be necessary to cut out another hole to set it free.

In this way by the exercise of great patience the drainage, if not as good as originally, may be once more made to work; but the process of pipe cleansing is in any case a very tedious and expensive one, and often will cost more than if the whole field were to be redrained. If a drain be stopped up by means of a plug or otherwise at its lower end until it gets full of water, and the plug be then suddenly released, a good deal of deposit will be washed away by the sudden flow. If may even be judicious in certain cases, provided it be not too expensive, to arrange for a means of flushing a drain from a pond or other similar source, so that by means of a valve or penstock the whole drain system may be scoured out periodically.

Redraining.—Where an existing system has become ineffectual, it may be found necessary to redrain land, and in this case, it will usually be found the wisest policy to neglect the very existence of the old drains altogether, except so far as to take precautions to avoid cutting into them.

It is often thought economy to run new drains into an old one, but such a course needs very careful consideration and is not to be recommended, as though the old drain may appear to be working all right, yet its effect may in reality only be to lead away the water to spots where it may, by reason of stoppage, collect and render a considerable area wet, or may even cause a backing up over a wider area still. Old drains may be run into new, but not new ones into old ones.

A few years ago I had occasion to redrain land which had been twice drained before, and save in one place where a spring was run into an old and very deep drain the whole systems have been avoided in every particular, and in fact as there was an old drain down every furrow, the new drains were laid down the centre of the lands. The result has been completely satisfactory.

If this method of making the new system entirely independent of the old be carried out, it will not be necessary to go to the expense of taking up the old drains, unless indeed they be so shallow as to repay the cost of so doing.

Mole Draining.—The plan of mole draining has, in soils stiff enough to retain the impression of the "mole," and free enough from stones to allow of the work being done satisfactorily, been found to be very effective, though of course its effect is not very lasting, and it may require to be repeated, say, in ten or twelve years' time or even less. Its great advantage of cheapness (especially where skilled labour is scarce and dear) renders it especially attractive to a lessee whose interest is more or less co-extensive with the duration of the work, though since the Agricultural Holdings Act of 1883 gave an occupier special powers as regards drainage, this attractiveness is not perhaps so powerful in all cases as it was formerly.

Pasture land may be mole drained at any time during the winter season, but land under the plough should be drained when free from a crop on account of surface damage, or perhaps, better still, it may be drained at that period of the rotation when in seeds.

The operation is briefly thus. The iron mole or borer, which is usually about 3 to 4 inches in diameter and rather oval or triangular in section, is carried by a coulter attached to a wheeled carriage which travels close to the ground, and, is driven by capstan and chain worked by a horse, or by steam power in the same manner as a steam cultivator or plough, the coulter, having been lowered into pits dug above the headlands, cutting through the surface of the soil and drawing the mole behind it by a couple of links of chain, the usual depth of the mole-track being from a foot to 2 feet 6 inches below the surface though of course at the cost of increased traction it may be deeper than this. It will thus be seen that mole draining is most successful where a natural uniform fall exists, as the depth can be modified but slightly, and the result in very uneven ground would likely be disappointing. The mains, which should be 6 or 8 inches below the mole drains, are usually laid with pipes in the usual way, and the lower ends of the mole drains eyed in with pipes, and where there are any low places in the field which the mole drains cross, it will be necessary to lay subsidiary mains up them, and in these cases the expense of pipe connections may be avoided by first laying the main 9 inches or a foot below the proposed level of the mole-tracks ; fill up above that level with gravel or similar porous material, and then, as the mole-tracks will run through the gravel, the water will readily find vent to the main. A very usual width for mole drains is one rod, but this of course depends upon the width of the lands, as this system necessitates a mole drain down every furrow.

A few boulders in the land need not necessarily prevent the execution of mole draining, though they will probably throw the plough out of the ground. These spots should immediately be marked, as well as any pockets of sand (discovered by the rushing of the plough at unusual speed) which may be encountered, in order that the spots may be cut out and pipes inserted to make good. The cost of mole draining ranges from £1 to £2 per acre, varying with the cost of haulage of coal and water and the size and shape of the fields.

It is of but little use attempting to patch mole draining when it once begins to get stopped. Care must be taken to keep down moles and other burrowing vermin.

Cleansing Deposits of Mud.—In cases where the flow is slight, a watercourse, milldam, or pond, &c., may become very much choked by the deposit of mud and the growth of waterweeds, and it is often found necessary to remove this deposit that water space may be enlarged to its original size.

This work is usually done by means of hand labour, barrows, and trestles, when the water is very low or has been diverted artificially. In the case of a watercourse, it is well to clean out one half first in order that the flow may be directed along one side of the channel, and so leave the other side free from water, and allow the mud to "set" a little.

The operation is, however, a very tedious and expensive one when performed by hand, and is liable to stoppage by sudden rains or floods, and to obviate this, dredging apparatus has been devised and worked with very satisfactory results. This invention is in the form of a large iron box or scoop, which is drawn across the river or pond which is to be cleansed by means of chains and wire rope, and propelled by engines such as are ordinarily used for steam cultivation.

This "Patent Sliding Bottom Scoop" can be set to any depth by means of an axle running through its centre, and each time it is pulled to the bank it brings with it a load of mud, sometimes as much as three tons, and when the spot is reached at which it is to deposit its contents it unburdens itself by means of the sliding bottom, after which it is drawn back again by the engine on the opposite bank. Its great merit consists in its rapid action and consequently small cost, as in a working day of twelve hours the scoop will remove from 700 to 1,000 tons of mud, and will thus do the work of about 150 men without any outlay in plant, and without any necessity for altering the bed of the stream, which may still be allowed to flow during the progress of the work. Another form of this useful machine is constructed to empty by turning right over when it reaches the required spot. The mud may either be left to dry and be subsequently removed and used for agricultural purposes, or the banks may be finished off smooth and turfed down.

Chapter XIV

THE MANUFACTURE OF AGRICULTURAL DRAIN PIPES

Character of Clay for Drain Pipes.—The clay used for the manufacture of draining tiles should possess the property of drying in the open air without damage; it must be free from stones and lime, and be plastic and smooth to the touch; it should be capable of being worked without the addition of too much sand, because if a large amount of sand be added the pipe will be weak and will not bear carriage. An open, coarse, gritty, sandy, non-plastic clay will not make good tile—the stronger the clay is, the better.

In summer yards brickmaking usually commences about the beginning of April and continues until early October. The manufacture of pipes may be continued to a later period than that of brick as they dry so much more readily than brick and consequently run less chance of damage by frost.

The usual method of procedure is somewhat as follows, though, of course, details vary according to circumstances and the character of the clay:—

Weathering the Clay.—The clay is dug during the previous winter so as to get well weathered by exposure to frost, rain, and the mellowing action of the atmosphere. It should be dug in thin slices (and not in thick spits as one would naturally dig in getting out a hole) so that air can get into it, and it should be thrown up lightly for the same reason. The heap should be made on a level place and should be built in successive layers so as to get the utmost effect of any frosts which may occur during the digging, and should not be of more than about 5 feet ultimate height. All loose stones should be picked out by hand as the work proceeds.

Tempering.—The clay from the heap is turned and mixed with just sufficient water to make it work properly, and is then passed through a pugmill in a very stiffly plastic condition.

When horse power only is used, the pugmill is much smaller than the similar machine for ordinary brickmaking, as on account of the lesser quantity of water used to temper tile clay and the consequently greater stiffness of the condition in which it is worked, the power required to drive the larger pugmill would be too great for the horse. A very usual size is about 2 feet internal diameter either hexagonal or circular and about 3 feet 6 inches high. It is formed of cast iron in sectional plates bolted together at the flanges and contains four or five knives set alternately (and pressing downwards) on a central vertical spindle which is turned by a pole, of about 9 to 10 feet length, set in a socket at the top of the spindle, the horse drawing by short chains from his collar attached to an iron bow at the further end of the pole and walking over a paved ring about 2 feet 6 inches wide, and of about 22 feet or 24 feet extreme diameter.

The top and bottom knives are usually set at a greater angle than the others, and are termed "force knives," it being their special duty to force the clay to the bottom of the mill. The cost of such a pugmill is about £14 or £15. The clay after being cut and worked about by the various knives during its downward course, exudes either from the bottom or side of the mill by pressure of the bottom knife (which is set for expression) aided by the weight of clay above and the constant downward pressure of the upper knives, is cut off by means of a curved iron instrument with a short handle—commonly termed a "cuckold"—and carried off by boys to the moulding shed. It may be used at once, but is improved by lying in heaps for a day or so, carefully covered with sacking or mats to avoid the too violent effects of rain, wind, or sun.

Making.—The clay from the pugmill is fed into the box of the tile machine by being violently thrown in by hand; the cover of the box is then tightly closed and secured in its position, and by the action of a ram working on a double rack and pinions which are actuated by gearing from the main driving wheel, which is turned by hand, the clay is expressed through iron dies from the face of the machine in a long continuous column, and is received upon the small wooden rollers (about 1¼ inches in diameter) of a cutting-off table about 3 feet 6 inches long and 1 foot 9 inches wide. The rollers are sometimes covered in moleskin or fustian fixed to turn easily and in such lengths as will not impede the cutting-off wires.

The pipes are cut into proper lengths by means of steel wires tightly strained, at the correct distances, in an iron frame which travels from side to side of the cutting-off table and is hinged on a bar below for that purpose.

For general purposes a tile machine of the size of the Bedford Iron Company's No. 3—size of mouth 16½ × 9 inches—will be found most convenient and easy to work.

The catalogue price is £18 including a cutting-off table. but not the dies, which latter cost from 15s. to 20s. each.

A machine of this size is capable of producing about 6,000 2-inch pipes per day of 10 hours and a proportionately smaller number of larger pipes.

Drying and Burning.—The pipes which are thus cut off lie on the table, singly if 6-inch, in pairs if 4-inch, in threes if 3-inch, and perhaps four in a row if 2-inch ; the number, of course, being only limited by the width of the mouth of machine, and the consequent number of orifices in the die. The sizes of the pipes are regulated by the size of the "button" or core of the die, which, of course, depends on the character of the clay ; usually a core of 2¼ inches diameter will produce a pipe of full 2 inches bore when burned. It is not necessary that the dies for pipe making should be lubricated.

Very shortly after the pipes are made they should be rolled—an operation by the way not invariably performed, though undoubtedly one which ensures a truer bore to the pipe.

It consists of the insertion of a wetted wooden roller in each pipe, and the rapid revolution of the pipe by that means upon a sanded wooden table. The roll should be as large as can readily be inserted—if too small, the full benefit of the operation is not obtained. When the pipes are sufficiently advanced in drying to admit of stacking they may be piled up to economise space, and so remain until fit for placing in the kiln, which must not take place until they are quite dry.

Whether burned in an open kiln or in the more modern down draught kiln, they are, on account of their lighter weight, usually burned (as also are roofing tiles and all the lighter goods) in the upper portion of the kiln, and above the bricks, which latter perhaps fill two-thirds or three-quarters of the space. They would, if placed otherwise, be liable to be crushed by the superior weight of the partially molten ware above them. For the sake of economy of space the smaller pipes are "nested," *i.e.*, placed for burning inside those of larger bore, and this is one reason why small bore pipes are usually proportionately so much cheaper than the sizes which are more commonly needed, and of more general utility.

Firing should commence gently (more especially so if some of the tiles are not perfectly "white" dry), or cracking, twisting, or crushing may result.

When all the water-smoke is driven off, firing may become more intense. The kiln when burned off should remain closed for 24 hours, and then opened and allowed to cool very gradually. If cooled too quickly the tiles will crack.

Cost of Manufacture.—When a brickyard is already in existence and equipped with the necessary tempering machinery, shedding and kiln, the only extra capital outlay will be for the tile machine, dies, and cutting-off table, &c.

The cost of labour, calculated on marketable goods only, will run somewhat as follows :—

For 2-inch pipes, @ 10s. 8d., for 3-inch, @ 15s. 4d., and for 4-inch @ 19s. 9d. per thousand.

Interesting articles on the method and cost of establishing a pipe manufactory will be found in the R.A.S.E. Journal for 1845 and 1846, and the earlier article will be found reprinted in Dobson's *Brick and Tile Making*, Weale's Series.

Chapter XV

IMPROVEMENT COMPANIES, &c. AGRICULTURAL HOLDINGS ACT, 1908. COMPENSATION FOR DRAINAGE

Improvement Companies and Facilities for Drainage Execution.—Under the powers of their special Acts several Improvement Companies are in the habit of advancing money to Landowners, with the consent of the Board of Agriculture, for the purpose (*inter alia*) of drainage improvements upon their estates, and by special provisions in the Companies' Acts, limited owners, even such as Mortgagees in possession, Tenants by courtesy, and Lessees for lives or any longer term than fourteen years, are empowered to charge their estates with the repayment of loans for this purpose by means of terminable rent-charges. The usual term for which these are granted varies from twenty to forty years according to the character of the work proposed.

The maximum period for the repayment by terminable rent-charge was 25 years under "The Improvement of Land Act, 1864," "The Limited Owners Residences Act, 1870 and 1871," "The Lands Improvement Company's Act," "The Scottish Drainage and Improvement Company's Act," and the "Land Loan and Enfranchisement Company's Act" [1]; but for the "General Land Drainage and Improvement Company's Act," [1] it was thirty-one years.

By "The Improvement of Land Act, 1899," the powers of these Companies are considerably extended in that they may now undertake all the Improvements authorized by "The Limited Owners' Residences Acts," and by Section 9 of "The Improvement of Land Act, 1864," and not merely Agricultural Improvements as before.

[1] "The Land Loan and Enfranchisement Company" (December 31st, 1897), and "The General Land Drainage and Improvement Company" (March 30th, 1911), are now amalgamated with "The Lands Improvement Company," of 1, Great George Street, Westminster, S.W.

The duration of the terminable rent charge may also be extended to 40 years, the exact term for the loan being decided by the "Board of Agriculture and Fisheries."

The payment of rent charge is constant in amount, although of course during the earlier years it is chiefly composed of interest, and during the latter years is mainly repayment. The rate on which interest is calculated is 4, or possibly 3¾ per cent., unless the expenditure be very large, when special terms may be arranged.

At 4 per cent. the annual Rent Charge will be as follows :—

			£	s.	d.		
To repay in	40	years	4	16	11	for each £100	borrowed.
,,	35	,,	5	3	1	,,	,,
,,	31	,,	5	9	8	,,	,,
,,	25	,,	6	4	0	,,	,,
,,	20	,,	7	3	0	,,	,,

Some of the Companies provide that the rent charges must run their full term and cannot be paid off at an earlier date, unless by special arrangement and with the consent of the Directors ; but one at least of them does allow of the repayment of the remaining portion of the loan at any time by six months' notice upon the part of the borrower.

A Landowner may execute the work himself, or the Company will undertake the whole responsibility of the work, of course charging Landowner with engineer's fees for plans and supervision. In both cases the works must be approved by the Board of Agriculture, and plans and specifications duly passed.

The application to the Board of Agriculture is undertaken by the Company.

No investigation of title is necessary as in the case of a mortgage, but the Company's commission of 5 per cent. upon the amount expended, stamp duty and fees payable to the Board of Agriculture, must be defrayed by the Landowner, and are, together with the interest on any advances made during the progress of the works, usually included in the capital sum which is charged upon the estate by the deed of rent-charge.

It is, however, a question for a Landowner to consider as to whether he should borrow from these Companies, as money having become of recent years very cheap, he can, upon first mortgage of good landed security, borrow money at from 3 to $3\frac{1}{2}$ per cent. very readily, and can form a sinking fund or redeem the mortgage when most convenient; whereas the half-yearly rent-charge payments must be punctually met, though of course they have the advantage that every payment reduces the charge upon the estate.

Another very material advantage of the method of raising money in another way than through the Improvement Company is that an Owner is not then bound to execute the work in any stereotyped fashion, but can do much or little in the way he thinks best.

Under the Settled Land Acts, 1882 and 1890, tenants for life may sell part of their estate for the purpose of permanently improving the remainder, and Drainage is, of course, one of the principal Improvements intended.

Tenant's Powers under Agricultural Holdings Act, 1908 (8 *Edwd. VII., c.* 28).—The Agricultural Holdings Act, 1908, has repealed all the previous Agricultural Holdings Acts and consolidates all previous legislation so far as England and Wales are concerned. By Sections 1 and 3 of the Agricultural Holdings Act, 1908, a Tenant of an Agricultural Holding desiring to secure compensation on quitting for any drainage improvement he wishes to make, may deliver written notice of his intention to execute the said work to his landlord, not more than three months and not less than two months before he intends to commence operations.

He must specify the particular land he intends to drain and the manner in which he proposes to execute the work—*i.e.*, kind of drain, distance and depth, general direction and outfall. Should nothing further transpire, the Tenant upon quitting will be entitled to recover the then present value of the improvement from his landlord; but in order to do so he must be careful to carry out the work at the time and in every detail in accordance with the particulars given in the notice.

Should, however, upon receipt of the notice under Section 3, the Landlord think fit, he may undertake the work himself, not being at all bound by the details given in the Tenant's notice, but executing it in any reasonable and proper manner he thinks fit, and he may charge the Tenant with interest at the rate of 5 per cent. per annum on the outlay, or such annual sum as will repay the outlay in twenty-five years, together with interest at 3 per cent. per annum.

If, however, the Landlord and Tenant come to an agreement even after the Tenant's notice has been delivered, the terms of their arrangement will be substituted for compensation under the Act ; and such agreement is much to be desired, as it is well-nigh an impossible task to assess the value of such an improvement to an Incomer.

For the making of water meadows or for works of irrigation, the making or improvement of water courses, ponds, wells or reservoirs, or of works for the application of water power, or for the supply of water for agricultural or domestic purposes ; warping or weiring of land ; and for embankments and sluices against floods, it is necessary, by Section 2 of the Act, that a Tenant wishing to have legal claim for compensation on quitting, should receive his landlord's written consent to the execution of these works, and such consent may be a conditional one, either as to the method of execution, extent of the works, or amount of future compensation.

By section 6 (2) of the Act "a claim by a tenant for compensation shall not be made unless notice of intention to make the claim has been given before the determination of the tenancy."

Compensation for Drainage Works.—A claim by a quitting Tenant for drainage work may arise in any one of the following ways :—

(*a*) Under the Agricultural Holdings Act.

(*b*) Under the provisions of a lease.

(*c*) In pursuance of a special arrangement.

If under either of the latter heads it is probable that the basis upon which compensation is to be paid will be clearly stated, and no difficulty should arise in fixing the just amount of compensation for the unexhausted value of the improvement.

If the claim arise under the Agricultural Holdings Act, it is necessary, in order that the outgoing Tenant may sustain his claim, that he should prove the giving of the notices previously mentioned, and he must show that the work was carried out in accordance with the original notice.

There are three other points to be noticed under this Act.

(*a*) The claim must be by a *quitting* tenant.

(*b*) The claim must be against the Landlord, the incoming tenant having neither obligation nor *locus standi* in the matter.

(*c*) The compensation must be assessed at "such sum as fairly represents the value of the improvement to an incoming tenant."

The words last quoted were no doubt inserted in the Act as a protection to the Landowner against claims for injudicious expenditure on the Tenant's part or for expenditure incurred for special purposes not adding in reality to the value of the holding; an "improvement" may have cost a large sum, but if badly made or unsuitable to the holding it may be worth little or nothing to any person who is likely to take the farm. Thus a house or building larger than the size of the holding justifies will not enhance the value to an incoming tenant; or again, some special preparation of the land to fit it for some particular kind of crop or industry may have taken place, and yet it may be a failure, or unsuited to the particular circumstances, of the locality.

On the other hand, while it must be admitted that "the value to an incoming tenant" is theoretically the just amount of compensation due, it is yet practically impossible so to fix the amount, because that method affords no tangible foundation upon which to base an award.

There remains but one practical basis upon which compensation can be awarded, and that is the actual cost of the work, or the cost at which it could be equally well executed. Taking this as their basis, valuers have only to determine the actual cost of the particular drainage and the life of the work, having due regard to local circumstances and the character of its execution, and from these data to deduce the still unexhausted value of the improvement.

The rule of one well-known Tenantright Valuers' Association on this subject reads :—

"*Drainage.*—Compensation in no case to exceed the cost at which the improvement could be effected at the time the claim is made. Maximum duration of improvement twenty-five years."

There is no doubt that twenty-five years is a very liberal allowance, and can only apply to works carried out in a first-class manner, from ten to fifteen years being a more generally accepted limit to the improvement for compensation purposes.

Bayldon,[1] in his *Rents and Tillages*, mentions ten years as the period to which a valuation for pipe drainage may extend (that is to say, if it has been executed one year, allow nine-tenths of cost ; if two years, eight-tenths, and so on), and states that in some cases the longer period of twelve years has been accepted. Bush-draining he places upon an eight years principle, giving, however, but trifling compensation in the three last years.

He suggests that even where a Tenant provides pipe drainage upon his farm he will be fully reimbursed for his outlay in from six to ten years, though, of course, the value of the improvement continues in most cases long after the full reimbursement of the cost.

Scott[2] in his *Farm Valuer* names twenty years as the duration of pipe drainage for compensation purposes.

[1] *Bayldon's Rents and Tillages*, by J. Chalmers Morton, 9th edition, 1876. Longmans, Green & Co.

[2] *The Farm Valuer*, by John Scott, 1879. Longmans, Green & Co.

Chapter XVI

ACTS OF PARLIAMENT AFFECTING DRAINAGE

"Act to facilitate the Drainage of Lands in England and Wales, 1874" (10 and 11 Vict., c. 38).—Inclosure Commissioners[1] appointed under "Inclosure Act" of 1846 to carry this Act into execution.

Section 9 gives power of entry on adjoining owner's land for outfall works in conformity with the Commissioners' order given under Section 8, "to widen, straighten, deepen, divert, scour, or cleanse any River, Stream, Ditch, or Drain, Brook, Pool, or Watercourse, and to make, open, and cut any new Watercourse, Side Cut, Ditch or Drain, and to alter or remove any Bank, Sluice, Floodgate, Hatch, Ditch, Drain, Tunnel, or other works necessary or convenient for Drainage, or for warping, and to dam, bar, and stop up with any Weir or Dam any River or Watercourse, and to erect and maintain on such Land Steam and other Engines and Machinery. Provided always that no entry shall be made on any Land, for the purposes aforesaid, except with the Consent of the Proprietors thereof, until the amount of Compensation . . . shall have been agreed upon or ascertained . . . and paid."

Section 10 provides for purchase under compulsory powers, by order of the Inclosure Commissioners, of not more than three acres of land, not being park or pleasure ground, "as the site of any Engine House or for any other Purpose necessary for the Works."

Section 11 provides that the "Land Clauses Consolidation Act, 1845" (8 and 9 Vict., c. 18) shall apply to all works authorised under this Act.

Section 12 protects "the Streams, Reservoirs, and Feeders supplying any ornamental Waters" from interference other than by Agreement and Consent of the Owners.

[1] These powers are now transferred to the Board of Agriculture.

"**The Land Drainage Act, 1861**" (24 and 25 Vict., c. 133), does not apply to Scotland or Ireland, or to the Metropolis.

Part I.—Commissions of Sewers

Section 4 provides for the formation of "Commissions of Sewers" upon the recommendation of the Inclosure Commissioners.

Section 5.—Such a recommendation of the Commissioners may be obtained upon the petition of the Landed Proprietors, after investigation by Inspector sent by the Inclosure Commissioners. Should the Owners of one-third part of the land affected dissent (in writing), the petition must be dismissed.

Sections 6 to 9 define the meaning of the word "Proprietors" and their various powers.

Section 10.—Where no proprietor can be found for any land, such land shall be left out of calculation with reference to dissent under Section 5.

Section 11 gives powers to inspector to require the attendance of any persons he may think right to summon, and to examine them upon oath.

He has also powers to require production of any public surveys, plans, rate-books, or documents, and to take copies.

Reasonable charges of attendance must first be paid or tendered to any witness before his attendance can be compelled.

Section 12.—All expenses incurred will be a charge upon the rates in all cases where a Commission of Sewers is issued, but should the application fail they must be defrayed by the petitioners.

Section 16.—Commissioners' powers shall extend to—

1. "Maintenance of existing Works";
2. "Improvement of existing Works";
3. "Construction of new Works,"

subject to certain limiting provisions.

Sections 17 and 18.—The Commissioners have no power to interfere with any dam, weir, or other obstruction (where the water is used for purposes of profit) until the Owner has given his consent or the questions following have been decided—

(*a*) By two or more Justices in Petty Sessions (if the Owner agree to this method) ; or

(*b*) By Arbitration—viz.,

(1) Is the Removal or Interference necessary ?
(2) Will it cause any Injury to the Owner ?
(3) Is the Injury capable of full Compensation in money ?

Section 19 provides that if such decision is in the negative as regards questions 1 or 3, the Commissioners shall not be entitled to interfere with the obstruction.

If the decision is in the affirmative as regards these two questions, the Commissioners may do the work on paying Compensation.

Section 20.—Compensation to be given in same way as under Land Clauses Consolidation Act.

Sections 21 to 28 provide for the purchase by the Commissioners of land for new works (where it cannot be acquired by agreement), with the sanction of Parliament and of the Inclosure Commissioners.

Section 29.—When new works are projected costing more than £1,000, the Commissioners must give due notice by advertisement for two months, and by notice affixed for three successive Sundays on a Church door, together with list of Proprietors and acreages, and, by section 30, this list must be corrected if any person interested shall prove it to be incorrect.

Section 31.—If within two months the Proprietors of one half the area affected object in writing, the Commissioners cannot proceed with the works, but, if otherwise, they may commence at once and repay the outlay and expenses by rates.

Section 34.—The Commissioners may, with the consent of the Inclosure Commissioners, commute, for a money payment, any obligation lying upon any person to repair any walls, sewers, &c.

Section 35.—Such commutation may be by way of a gross or annual charge upon the lands in respect of which the original obligation arose, and recoverable in the same way as tithe rent-charge.

Section 36.—The record of such charge must be deposited in the office of the Clerk of the Peace of the County.

Section 37.—Subject to such commutation, the liability of any person of " making, completing, altering, amending, or maintaining " any walls or drainage works remains unaltered.

Section 38.—" Rates may be levied by Commissioners of Sewers for defraying all Costs, Charges, and Expenses incurred or to be incurred by them under the Authority of any Act of Parliament, Law or Custom."

As to Incidence of Rates :—Where expenditure for improvements to existing works or for new works exceeds £1,000, it shall be defrayed by a Special Rate, which " shall be deemed to be a Tax on the Owners of Property," but in other cases the rates are to be paid " by the same Persons . . . in the same Manner as they are now by Law payable."

Should an Owner make default in payment of his rates they can be recovered from the Occupier, except that he cannot be compelled to pay more than the amount of rent due from him to the Owner at the time.

The Occupier may deduct this payment from his rent.

Section 39 provides that any person appointed by the Commissioners may inspect, take copies or extracts, from Poor Rate books.

Section 40.—The Commissioners may mortgage the Sewers Rates of all or of a particular part of their district provided.

(1) The Inclosure Commissioners' consent is obtained.

(2) The money may be repaid by equal annual instalments of principal and interest extending over a period not exceeding thirty years.

Clauses 42 to 52 regulate the legal proceedings under the Act, and contain provisions as to Notices and Service, appeal to Quarter Sessions, Arbitration, recovery of Penalties, Costs, &c.

Section 54.—Commissioners, or Drainage Boards, or Private Owners may not interfere with any sewers, drainage, or irrigation works made under Local or Private Act of Parliament, nor with any river, canal, harbour, lock, reservoir, wharves, docks, quays, or basin, so as to injuriously affect the Navigation, where the same are maintained by virtue of Act of Parliament.

They may not interfere with Waterworks " supplying . . . any Town or Place," unless in each case they first obtain formal consent in writing from the Parties affected.

Section 55.—Commissioners may not divert Rivers so as in injure Harbours.

Section 56.—Canal or Dock Companies authorised by Act of Parliament may, at their own expense, and subject to the certificate of the Surveyor to the Drainage Commissioners or Board, divert or alter the level of sewers, drains, culverts, or pipes passing through their land.

Section 57.—Rivers, canals, or inland navigations under the provisions of local or private Acts, are to be exempt from the control of the Commissioners.

Section 58.—No person may, without Commissioners' consent, pass " any filthy or unwholesome Water, or Washings of Manufactories or Mines, or other foul or poisonous Liquid into any Watercourse under penalty of not exceeding £5, and further penalty of Forty shillings for every Day during which the offence is continued ; but this Section shall not apply to any Person having a legal Right to cause such Water, Washings, or Liquid as aforesaid to flow into any existing Watercourse."

Section 59.—Drainage Commissioners or Boards may, with the consent of the Commissioners of adjoining area, execute works within the jurisdiction of the second named Commissioners or Board.

Part II.—Elective Drainage Districts

Section 63.—The Proprietors of not less than one-tenth part the acreage of " any Bog, Moor, or other Area of Land that requires a combined System of Drainage, Warping, or Irrigation may, with the Consent of the Enclosure Commissioners, and subject to the Confirmation of Parliament . . . constitute such Bog, Moor, or other Area a separate Drainage District."

In the case of lands within the limits of any Commission of Sewers, or Borough, or of any District under the management of Local Board or Improvement Commissioners, the consent of this Authority must be obtained.

Section 64.—To obtain the Inclosure Commissioners' sanction a petition signed by the Proprietors, and accompanied by a map and such evidence as the Inclosure Commissioners require, must be presented.

The Commissioners must then send an Inspector to the district, and should they be satisfied with the desirability of so doing, and if the proprietors of two-thirds the acreage are in favour, the Inclosure Commissioners may make "a Provisional Order, declaring the Area in such Order mentioned to be a Drainage District," and notice of such Order shall be published in the *London Gazette* and in some one local newspaper. The due forms having been complied with, it shall be the duty of the Inclosure Commissioners "to take all the proper steps for the confirmation of such Provisional Order by Act of Parliament; . . . but previous to such Confirmation it shall not be of any Validity whatever."

Petitioners must give security for costs, and if the petition be unsuccessful they must pay all costs, including those of the Inclosure Commissioners and their Inspector; but if the Board be constituted, these costs will fall upon the Rates.

Sections 66 to 71 refer to the Constitution and Powers of Drainage Boards, and the Election and Qualification of Members.

Part III.—Power of Private Owners to procure Outfalls

Sections 72 and 73.—"Any Person interested in Land, who is desirous to drain the same, and in order thereto deems it necessary that new Drains should be opened through Lands belonging to another Owner, or that existing Drains in Lands belonging to another Owner should be cleansed, widened, straightened, or otherwise improved," may formally apply in writing to such adjoining Owner, and also serve a copy of the application upon the Occupier for leave to make such drains or improvements. The notice must be accompanied by a map, on which the length, width, and depth of the proposed works must be delineated, and must further state the compensation, if any, which the applicant proposes to pay.

Section 74.—The adjoining Owner may "by Deed under his Hand and Seal assent to such Application, upon such Terms . . . as he may require, and any Assent so given shall be binding on all Parties having any Estate or Interest in the Land, subject to the following provisions":—

1. In case of any adjoining Owner under disability or incapacity, or not having power to assent to such application, two Surveyors must be nominated, one by either party, and each of these Surveyors, if they approve of the

arrangement, must annex to the document containing the same a Declaration to that effect subscribed by them.

2. In such case any compensation paid by the Applicant must " be applied in manner in which the Compensation coming to Parties having limited Interests, or prevented from treating, and not taking Title, is applicable, under 'The Land Clauses Consolidation Act, 1845.' "

3. Any Occupier or Person other than the Owner interested in the lands may claim and be entitled to compensation for Injury sustained by the making of the proposed drains or improvements, but he must claim within twelve months after completion of the work.

In case of dispute the amount of Compensation to be determined in accordance with the " Land Clauses Consolidation Act, 1845."

Section 75.—Applicant to forward to Clerk of the Peace of the District the deed containing the adjoining Owner's consent, " who shall keep the same in his Office as a Record of the Proceedings between the Parties."

Section 76.—Unless adjoining Owner express assent within one month after service of notice of application upon him, he shall be deemed to have dissented.

Unless the adjoining owner within the said month require them to be decided by Arbitration, two or more Justices in Petty Sessions shall decide the following questions :—

1. " Whether the proposed Drains or Improvements in Drains will cause any Injury to the adjoining Owner, or to the Occupier or other Person interested in the Lands."

2. " Whether any Injury that may be caused is or is not of a nature to admit of being fully compensated for by money."

" And the Provisions of the First Part of this Act relating to the Decision of the Questions therein mentioned shall apply to the Decision of the Questions mentioned in this Section."

" The result of any such Decision shall be as follows ; that is to say,

" (1) If the Decision is that no Injury will be caused to the adjoining Owner, to the Occupier, or other Parties interested in the Lands, the Applicant may proceed forthwith to make the proposed Drains, or Improvements in Drains : "

" (2) If the Decision is that Injury will be caused to the adjoining Owner, Occupier, or other Parties interested in the Lands, but that such Injury is of a nature to admit of being fully compensated by money, the Justices or Arbitrators shall proceed to assess such Compensation, and to apportion the same amongst the Parties in their judgment entitled thereto ; and on Payment of the Sum so assessed, the Applicant may proceed to make the proposed Drains or Improvements in Drains : "

" (3) If the Decision is that Injury will be caused to the adjoining Owner, Occupier, or other Parties interested in the Lands, and that such Injury is not of a Nature to admit of being fully compensated by money, the Applicant shall not be entitled to make the proposed Drains or Improvements in Drains."

Section 77.—In cases where compensation under section 76 is payable to " Owner or other Person under Disability or Incapacity, or is not entitled to receive the same for his own Benefit," it must be applied in the manner in which compensation to Limited Owners is applicable under the " Land Clauses Consolidation Act, 1845."

Section 78.—Justices or Arbitrators must certify a correct map of the Drainage Scheme as approved by them, and the Applicant must send it to the Clerk of the Peace for the County, to be kept as a Record in his Office.

Section 79 gives Applicant and his successors perpetual right to enter for " clearing out, scouring, and otherwise maintaining in a state of Efficiency," and should he not do so the Owner or Occupier of the lands through which the drains pass may do the necessary work and recover the expenses, " in a summary manner, from the Applicant, his Heirs or Assigns."

Section 80.—The Owner of the land through which the drains pass has power to " fill up, divert, or otherwise deal with such Drains . . . on condition of first making, and laying down in lieu thereof, Drains equally efficient ; and any dispute as to the Efficiency of Drains so laid down shall be decided by Two or more Justices assembled in Petty Sessions."

Section 81 imposes a Penalty of not exceeding £10 upon any one who wilfully obstructs any person making any drain in pursuance of Part 5 of this Act, and a similar penalty upon any one who wilfully dams up, obstructs, or injures a drain so made.

Section 82.—All reasonable costs incurred by the adjoining owner are to be paid by Applicant.

Section 83.—Where any person wishes to construct a drain which will divert any brook, river, or other natural watercourse into any other brook, river, or natural watercourse, he must publish a copy of the notice under section 73 in one local newspaper for three successive weeks, and must serve a copy of the said notice upon every Owner of land abutting on the natural watercourse into which the diversion is to be made, and situate within four miles of the point of junction, and must deposit a copy of the map accompanying such notice with the Clerk of the Peace of the County.

Any Owner of land "capable of being injured by the proposed Drain" may, within eight weeks after the date of the first advertisement, serve Notice on the proposer of the drain that he apprehends injury, "thereupon such Owner shall be deemed to have dissented, and shall be entitled to the same Rights and Privileges under this Part of the Act as if he were the adjoining Owner."

The Act contains a Schedule, of which the first part consists of the "Rules as to Election of Members of Drainage Boards," and the second of the "Rules as to Proceedings of Drainage Boards."

"**Improvement of Land Act, 1864**" (27 and 28 Vict., c. 114).—An Act passed to consolidate the enactments of the "Private Money Drainage Act, 1849" (repealed by this Act), and the "Public Money Drainage Act, 1846," and includes all the provisions contained in the Acts of incorporation of the various Land Drainage and Improvement Companies. It applies to Great Britain and Ireland.

By Section 33, this Act specifies that when the Inclosure Commissioners shall think it "expedient to obtain or improve an Outfall for draining or warping," that they should "enter and execute any Works upon any Land adjoining." Proceedings may be taken, in the case of England and Wales, either under the provisions of the

" Act to facilitate the Drainage of Lands in England and Wales, 1847," or alternatively under the provisions of the " Land Drainage Act, 1861."

The schedule of Improvements to Land given in this Act is still good as regards Scotland, but as regards England, it has been very much extended by the Settled Land Acts of 1882 and 1890.

Settled Land Act, 1882 (45 and 46 Vict., c. 38), does not apply to Scotland.

Section 3.—A Tenant for Life may sell the settled land, or any part thereof, or any easement, right, or privilege over it, or manor rights, or may make an exchange of land.

Section 4.—Every sale or exchange must be " at the best price that can reasonably be obtained."

Section 15.—The principal mansion " and the demesnes thereof and other lands usually occupied therewith " may not be sold without consent of the trustees of the settlement or an order of the Court.

Section 25.—Capital trust money arising out of the sale of settled estate may be applied, if so desired, in " any of the following works, or of any works for any of the following purposes, and any operation incident to or necessary or proper in the execution of any of those works, or necessary or proper for carrying into effect any of those purposes, or for securing the full benefit of any of those works or purposes :—

" (1) Drainage, including the straightening, widening, or deepening of drains, streams and watercourses.

" (2) Irrigation ; warping.

" (3) Drains, pipes, and machinery for supply and distribution of sewage as manure.

" (4) Embanking or weiring from a river or lake, or from the sea or a tidal water.

" (5) Groynes, seawalls, defences against water.

" (6) Inclosing, straightening of fences, re-division of fields.

" (7) Reclamation, dry warping.

" (8) Farm roads, private roads, roads or streets in villages or towns.

" (9) Clearing, trenching, planting.

" (10) Cottages for labourers, farm servants, and artisans employed on the settled land or not.

" (11) Farmhouses, offices, and outbuildings, and other buildings for farm purposes.

" (12) Saw mills, scutch mills, and other mills, water-wheels, engine houses, and kilns, which will increase the value of the settled land for agricultural purposes, or as woodland or otherwise.

" (13) Reservoirs, tanks, conduits, watercourses, pipes, wells, ponds, shafts, dams, weirs, sluices, and other works, and machinery for supply and distribution of water for agricultural, manufacturing, or other purposes, or for domestic or other consumption.

" (14) Tramways, railways, canals, docks.

" (15) Jetties, piers, and landing-places on rivers, lakes, the sea, or tidal waters, for facilitating transport of persons, and of agricultural stock and produce, and of manure and other things required for agricultural purposes, and of minerals, and of things required for mining purposes.

" (16) Markets and market-places.

" (17) Streets, roads, paths, squares, gardens, or other open spaces for the use, gratuitously or on payment, of the public or of individuals, or for dedication to the public, the same being necessary or proper in connection with the conversion of land into building land.

" (18) Sewers, drains, watercourses, pipe-making, fencing, paving, brickmaking, tilemaking, and other works necessary or proper in connection with any of the objects aforesaid.

" (19) Trial pits for mines and other preliminary works necessary or proper in connexion with development of mines.

" (20) Reconstruction, enlargement, or improvement of any of those works."

Section 26.—An Improvement Scheme having been submitted by a Tenant for life, the Trustees of the settlement may, if they approve, expend capital moneys in payment or part payment of such scheme on—

(1) Certificate of the Land Commissioners certifying that the work has been properly executed.

(2) Certificate of " competent engineer or able practical surveyor nominated by the Trustees and approved by the Commissioners or by the Court."

(3) An order of the Court directing or authorising such payment.

Section 28.—Tenant for life and his successors in title must during such period as the Land Commissioners by certificate prescribe, maintain at their own expense every improvement executed under this Act ; and where a building is in its nature insurable against fire, they must keep the same insured.

The Tenant for life may not cut down, " except in proper thinning," any trees planted as an improvement under this Act.

The Commissioners may require a periodical report as to the condition of the works.

In case a Tenant for life fails " to comply with the requisitions of this section, or does any act in contravention thereof," any person having any estate or interest in the settled land will have right of action ; and the estate of a Tenant for life shall be liable to make good any damages.

Section 48 constitutes the three bodies previously known as the " Inclosure Commissioners for England and Wales," the " Copyhold Commissioners," and the " Tithe Commissioners for England and Wales," into one body, to be styled the " Land Commissioners for England," and gives the new body powers to exercise all the rights and duties of the previous three authorities.

By section 65, among other modifications of this Act, it is provided that the " Commissioners of Public Works in Ireland " shall exercise the same functions as the Land Commissioners in England.

Settled Land Act, 1890 (53 & 54 Vict., c. 69), extends the schedule of Improvements under the 1882 Act to include :—

1. Bridges.

2. Making any additions to or alterations in buildings reasonably necessary or proper to enable the same to be let.

3. Erection of buildings in substitution for buildings within an Urban Sanitary District taken by a local or other public authority, or for buildings taken under compulsory powers, but so that no more money be expended than the amount received for the buildings taken and the site thereof.

4. The rebuilding of the principal mansion house on the settled land ; provided that the sum to be applied under this subsection shall not exceed one half of the annual rental of the settled land.

Improvement of Land Act, 1889 (62 and 63 Vict. c. 46).

Section 1.—" Where under the Improvement of Land Act 1864, or under any special improvement Act, a charge is after the commencement of this Act authorised in respect of the improvement of land, the period for the repayment of the charge shall be such period not exceeding forty years as the Board of Agriculture, having regard in each case to the character and probable duration of the improvement, determine."

The Agricultural Holdings Act, 1908 (8 Edward VII., c. 28), has repealed all the previous Agricultural Holdings Acts and consolidates all previous legislation so far as England and Wales are concerned.

Its enactments are as follows :—

Section 1.—(1) Where a tenant of a holding has made thereon any improvement comprised in the First Schedule to this Act he shall, subject as in this Act mentioned, be entitled, at the determination of a tenancy, on quitting his holding to obtain from the landlord as compensation under this Act for the improvement such sum as fairly represents the value of the improvement to an incoming tenant.

(2) In the ascertainment of the amount of the compensation payable to a tenant under this section there shall be taken into account :—

(*a*) Any benefit which the landlord has given or allowed to the tenant in consideration of the tenant executing the improvement.

. . . . .

(3) Nothing in this section shall prejudice the right of a tenant to claim any compensation to which he may be entitled under custom, agreement, or otherwise, in lieu of any compensation provided by this section.

Section 3 (which refers to Land Drainage only) :—

(1) Compensation under this Act shall not be payable in respect of any improvement comprised in Part II. of the First Schedule hereto, unless the tenant of the holding has, not more than three nor less than two months before beginning to execute the improvement, given to the landlord notice in writing of his intention so to do, and of the manner in which he proposes to do the intended work, and, upon such notice being given, the landlord and the tenant may agree on the terms as to compensation or otherwise on which the improvement is to be executed.

(2) If any such agreement is made, any compensation payable under the agreement shall be substituted for compensation under this Act.

(3) In default of any such agreement the landlord may, unless the notice of the tenant is previously withdrawn, execute the improvement in any reasonable and proper manner which he thinks fit, and recover from the tenant as rent a sum not exceeding five per cent. per annum on the outlay incurred, or not exceeding such annual sum payable for a period of twenty-five years as will repay that outlay in that period, with interest at the rate of three per cent. per annum.

Provided that, if the landlord fails to execute the improvement within a reasonable time, the tenant may execute the improvement, and shall in respect thereof be entitled to compensation under this Act.

(4) The landlord and the tenant may by the contract of tenancy or otherwise agree to dispense with any notice under this section, and any such agreement may provide for anything for which an agreement after notice under this section may provide, and in such case shall be of the same validity and effect as such last-mentioned agreement.

. . . . .

Section 6.—(1) If the tenant of a holding claims to be entitled to compensation, whether under this Act, or under custom or agreement, or otherwise, in respect of any improvement comprised in the First Schedule to this Act, and if the landlord and tenant fail to agree as to the amount and time and mode of payment of the compensation, the difference shall be settled by arbitration.

(2) A claim by the tenant of a holding for compensation under this Act in respect of any improvement comprised in the First Schedule to this Act shall not be made unless notice of intention to make the claim has been given before the determination of the tenancy :—

Provided that, where the claim relates to an improvement executed after the determination of the tenancy but while the tenant lawfully remains in occupation of part of the holding, the notice may be given at any time before the tenant quits that part.

. . . . .

Section 9.—(1) A tenant of a holding shall not be entitled to compensation under this Act in respect of any improvements, other than manuring as defined by this Act, begun by him :—

(*a*) In the case of a tenant from year to year, within one year before he quits the holding, or at any time after he has given or received notice to quit which results in his quitting the holding ; and—

(*b*) In any other case, within one year before the expiration of his contract of tenancy :—

Provided that this section shall not apply in the case of any improvement—

(1) Where the tenant, previously to beginning the improvement, has served notice on his landlord of his intention to begin it, and the landlord has either assented or has failed for a month after the receipt of the notice to object to the making of the improvement ; or—

(2) In the case of a tenant from year to year, where the tenant has begun the improvement during the last year of his tenancy and, in pursuance of a notice to quit thereafter given by the landlord, quits this holding at the expiration of that year.

Chapter XVII

BIBLIOGRAPHY OF LAND DRAINAGE

BLITH, WALTER. "The English Improver"; or a New survey of husbandry, discovering to the kingdom that some land, both arable and pasture, may be advanced double or treble; other land to a five or tenfold, and some to a twentyfold improvement, &c., &c. 8vo. Lond., 1646.

Do. do. 2nd edition 4to. Lond., 1649.

Do. do. 3rd edition. Lond., 1652.

VERMUYDEN, SIR C. Discourse touching the Dreyning the great Fenns lying within the several Counties of Lincoln, Northampton, Huntingdon, Norfolke, Suffolke, Cambridge, and the Isle of Ely. 4to.

DUGDALE, WILLIAM. History of the Imbanking and drayning of Divers Fens and Marshes, both in forrain parts and in this kingdom. fol. Lond., 1662.

Do. 2nd edition, fol., revised by C. N. Cole. Lond., 1772.

DODSON, COLONEL WILLIAM. The design for the perfect Draining of the great Level of the fen called Bedford Level. With maps, &c. 4to. Lond., 1665.

YARRANTON (Andrew). England's Improvement by Sea and Land, to out-do the Dutch without Fighting, to pay Debts without Moneys, to set at Work all the Poor of England with the Growth of their own Lands, &c., first edition, with 8 folding maps. sm. 4to. 1677.

MOORE, SIR JONAS, Kt., F.R.S. History or Narrative of the great Level of the Fens called Bedford Level; with a large map of the said Level, as drained, surveyed, and described. 8vo. 1685.

BRIDGEMAN, CHARLES, Report on the present state of the Bedford Level, &c., folio, 1724.

ARMSTRONG, COLONEL JOHN, Chief Engineer of England. "Answer to the Scheme for Draining the Fens," by Charles

Bridgeman, with map of the Fen Rivers and Survey of the Humber, Ouse and Thames from their spring to Influx.

Do. History of the Ancient and Present State of the Navigation of the Port of King's Lyn, and of Cambridge, and of the rest of the Trading Towns in those parts, and of the Navigable Rivers that have their Course through the Great Level of the Fens, called Bedford Level; also the History of the Draining in that Level, &c., with maps. Folio. 1725.

BRADLEY, R. Complete Body of Husbandry, collected from the practice and experience of the most considerable Farmers in Britain, with the various ways of improving land by hollow ditching, draining, double ploughing, grazing, enclosing, watering, and manuring, with methods of improving ground and trees. Folding plates. 8vo. 1727.

TURNER, NICHOLAS. An Essay on Draining and Improving Peat Bogs. 8vo. Lond., 1784.

ELSTOBB, W. Historical Account of the great Level of the Fens, called Bedford Level, and other Fens, Marshes, and Low Lands, in the Kingdom and other Places. 8vo. Lynn, 1793.

ANDERSON, JAMES, LL.D. A Practical Treatise on Draining Bogs and Swampy Grounds; with cursory Remarks on the Originality of Elkington's mode of Draining. 8vo. Lond., 1794.

JOHNSTONE, JOHN. An account of the most approved mode of Draining Land according to the System practised by the late Mr. Joseph Elkington. 4to. Edin., 1797.

Do. An account of the mode of Draining Land, according to the System practised by Mr. Joseph Elkington. Drawn up for the consideration of the Board of Agriculture. 2nd edition, 8vo. Lond., 1800.

Do. 3rd edition, 8vo. Lond., 1808.

STONE, THOMAS. A Letter on the Drainage of the East, West, and Wild Moor Fens. 8vo. Lond., 1800.

Do. Letter on the intended Drainings and Inclosures of the Moor Fens in the County of Lincoln. 1801.

SMITH, WILLIAM. Observations on the Utility, Form, and Management of Water Meadows, and the Draining and Irrigating Peat Bogs; with an account of Prisley Bog, and other extraordinary Improvements conducted for the Duke of Bedford. 8vo. Lond., 1809.

WALKER, W. An Essay on Draining Land by the Steam Engine. 8vo. Lond., 1813.

WESTERN, C. C., M.P. A few Practical Remarks on the Improvement of Grass Land by means of Irrigation, Winter-flooding, and Drainage ; in a letter to the Owners and Occupiers of Land in the County of Essex. 8vo. Lond., 1824.

STEPHENS, GEORGE. The Practical Irrigator ; being an Account of the Utility, Formation, and Management of Irrigated Meadows, with a particular Account of the Success of Irrigation in Scotland. To which is added a Practical Treatise on straightening Water-courses, protecting River Banks, and embanking Low Lands. 8vo. Edin., 1829.

WELLS, S. History of the Drainage of the great Level of the Fens, called Bedford Level, with the Constitution and Laws of the Bedford Level Corporation. 2 vols., 8vo. Map in separate case. Lond., 1830.

LOUDON, J. C. An Encyclopædia of Agriculture, &c., &c. Book 3, Chap. I. : Draining Watery Lands. Chap. II. : Embanking, &c. 1st edition, 8vo. Lond., 1831. With several subsequent editions.

GRAHAM, RT. HON. SIR JAMES, BART., M.P. On the Deanston frequent Drain System as distinguished from and compared with the Furrow-Draining and Deep-Ploughing of the Midland Counties of England. R.A.S.E. Journal, 1839.

WIGGINS, JOHN. On the mode of making and using Tiles for Under Draining practised on the Stow Hall Estate in Norfolk, &c. R.A.S.E. Journal, 1840.

BURKE, J. FRENCH. On the Drainage of Land. R.A.S.E. Journal, 1841.

BEART, ROBERT. On the Economical Manufacture of Draining-Tiles and Soles. R.A.S.E. Journal, 1841.

PEEL, RT. HON. SIR ROBT., BART. Account of a Field Thorough-drained at Drayton in Staffordshire. R.A.S.E. Journal, 1842.

BROWN, H. H. On the Drainage of Land. R.A.S.E. Journal, 1843.

EVIDENCE of the Antiquity, Cheapness and Efficacy of Thorough-Draining or Land-Ditching, as practised throughout the Counties of Suffolk, Hertford, Essex and Norfolk, collected by Ph. Pusey. With some notice of Improved Machines for Tile-making. R.A.S.E. Journal, 1843.

CHADWICK, E. Sanitary Effects of Land Draining. R.A.S.E. Journal, 1843.

ARKELL, THOMAS. On the Drainage of Land. Prize Essay. R.A.S.E. Journal, 1843.

BEART, ROBERT. On the Proper Materials for Filling up Drains and the mode in which Water enters them. R.A.S.E. Journal, 1843.

PARKES, JOSIAH. Report on Drain-Tiles and Drainage. R.A.S.E. Journal, 1843.

LOW, DAVID. On Landed Property and the Economy of Estates. Chapter vi. 8vo. Lond., 1844.

HUTCHINSON, HENRY. A Treatise on the Practical Drainage of Land. 8vo. Lond., 1844.

PARKES, JOSIAH. On the Influence of Water on the Temperature of Soils, on the Quantity of Rain Water and its Discharge by Drains. R.A.S.E. Journal, 1845.

HODGES, THOMAS LAW, M.P. On the Cheapest Method of Making and Burning Drainage Tiles. R.A.S.E. Journal, 1845.

Do. Account of Use of Temporary Tile Kilns. R.A.S.E. Journal, 1848.

PARKES, JOSIAH. On Reducing the Cost of Permanent Drainage. R.A.S.E. Journal, 1846.

ETHEREDGE, FREDERICK WILLIAM. On the Cheapest and Best Method of Establishing a Tile Yard. Prize Essay. R.A.S.E. Journal, 1846.

CLUTTERBUCK, Rev. J. C. On the Theory of Deep Drainage. R.A.S.E. Journal, 1846.

LINTON, WILLIAM. On the Best Method of Draining Running Sands. Prize Essay. R.A.S.E. Journal, 1847.

PARKES, JOSIAH. On Draining. R.A.S.E. Journal, 1847.

CLARKE, JOHN ALGERNON. On the Great Level of the Fens, including the Fens of South Lincolnshire. R.A.S.E. Journal, 1847.

HUTCHINSON, SIMON. Practical Experiments on the Air Drainage of Land. R.A.S.E. Journal, 1848.

ARBUTHNOT, RT. HON. C. On the Advantage of Deep Drainage. R.A.S.E. Journal, 1849.

CHARNOCK, J. N. On Suiting the Depth of Drainage to the Circumstances of the Soil. R.A.S.E. Journal, 1849.

WOOD, W. BRYAN. On the Improvement to be made in Land by Amending the Channels of Rivers and other Water Courses. R.A.S.E. Journal, 1852.

CLARKE, JOHN ALGERNON. On Trunk Drainage. R.A.S.E. Journal, 1854.

STEPHEN'S Book of the Farm. 8vo. Lond. & Edin., 1855. And three subsequent editions.

WAY, J. THOMAS. On the Composition of the Waters of Land Drainage and of Rain. R.A.S.E. Journal, 1856.

DENTON, J. BAILEY. Hinxworth Drainage. R.A.S.E. Journal, 1859.

WELLS W. The Drainage of Whittlesea Mere. R.A.S.E. Journal, 1860.

DENTON, J. BAILEY. Under-drainage and the Rivers and Arterial Channels. Reprinted from the *Mark Lane Express*. Lond., 1863.

BAYLDON, R. The Art of Valuing Rents and Tillages, as originally written by Mr. Bayldon and Mr. Robert Baker, adapted to the present time, and describing the principle mode of valuing freehold, copyhold, and leasehold estates and land and other property for parochial assessment and enfranchisement of copyhold under the recent Acts of Parliament relating thereto. By J. C. Morton. 8vo. Lond., 5th edition, 1840; 6th edition, 1844; 7th edition, 1856; 8th edition, 1864; 9th edition, 1876.

GRANTHAM, R. B. "Land Drainage Act," 1861: its Provisions, Working, and Results. 8vo. Lond., 1865.

DENTON, J. BAILEY. Water Supply in Connection with Land Drainage. Birmingham, 1866.

Do. On Land Drainage and Improvement Loans from Government or Public Companies. R.A.S.E. Journal, 1868.

WHEELER, W. H. Practical Remarks upon Drainage of Land. 8vo. Lond., 1868.

GRANTHAM, R. B. Drainage of the Leadon Valley, near Gloucester, under the "Land Drainage Act, 1861." 8vo. Lond., 1868.

DEMPSEY, G. D. Rudimentary Treatise on the Drainage of Towns and Buildings, &c., &c., 8vo. Lond. 1867.

Do. Rudimentary Treatise on the Drainage of Districts and Lands. 2nd edition. 8vo. Lond., 1868.

GRANTHAM, R. B. Arterial and Agricultural District Drainage and the Arterial Drainage Act, 1861. Surv. Inst. Trans. Part IV. 1868–9.

Do. Agricultural Pipe Drainage in Connection with

Arterial Drainage and Outfalls. Surv. Inst. Trans. No. 30. Vol. IV. Lond., 1871.

Do. Arterial Agricultural Drainage, and the Laws connected therewith. Surv. Inst. Trans. No. 4. Vol. Lond., 1869.

DEAN, G. A. The Culture, Management, and Improvement of Landed Estates, &c. Chapter xix. 8vo. Lond., 1872.

DENTON, J. BAILEY. Under Drainage of Land: its Development and Maintenance. Lond., 1872.

VOELCKER, DR. AUGUSTUS. On the Composition of Waters of Land Drainage. R.A.S.E. Journal, 1874.

WHEELER, W. H. Arterial Drainage and the Storage of of Water. R.A.S.E. Journal, 1878.

FRENCH, H. F. Farm Drainage; the Principles, Processes, and Effects of Draining Land with Stones, Wood, Plows, and Open Ditches, and especially with Tiles; including Tables of Rainfall, Evaporation, Filtration, Excavation, Capacity of Pipes, Cost and Number to Area of Tiles, &c. 8vo. New York, 1879.

ROLAND, A. The Drainage of Land, Irrigation, and Manures. 8vo. Lond., 1880.

LAWES, J. B., GILBERT, J. H., WARRINGTON, R. On the Amount and Composition of the Rain and Drainage Waters collected at Rothamstead. R.A.S.E. Journal, 1881.

DENTON, J. BAILEY. Agricultural Drainage. A Retrospect of Forty Years' Experience. 8vo. Lond., 1883.

GRANTHAM, R. F. Drainage in the Fens and Marshes of South Lincolnshire. Lond., 1885.

DOBSON, EDWARD. A Rudimentary Treatise on the Manufacture of Bricks and Tiles, &c. Weale's Series. 8th edition. Lond., 1886.

DEMPSEY, G. D. On the Drainage of Lands, Towns, and Buildings. Revised, with additions on the Recent Practice of Drainage Engineering, by D. K. Clark. 8vo. Lond., 3rd edition, 1887; 4th edition, 1900.

WHEELER, W. H. The Drainage of Fens and Low Lands by Gravitation and Steam Power. 8vo. Lond., 1888.

GRANTHAM, R. F. Drainage in the Fens and Marshes of South Lincolnshire. Surv. Inst. Prof. Notes. Vol. II. Lond., 1889.

MURRAY, G. Estate Improvements. Drainage. Surv. Inst. Prof. Notes. Vol. III. Lond., 1890.

GRANTHAM, R. F. Drainage and Irrigation of Land in their Relations to Health. Lond., 1891.

DAVIS, CHARLES THOMAS. A Practical Treatise on the Manufacture of Brick, Tile, and Terra Cotta, &c., &c. 3rd edition. 8vo. Philadelphia and Lond., 1895.

DONALD, JAMES. Land Drainage.

SCOTT, PROF. JOHN. Draining and Embanking. Weale's Rud. Series, Lond.

WRIGHTSON, PROF. JOHN. Agricultural Text-book. Collins' Series. Lond.

KING, F. H. Irrigation and Drainage, Principle and Practice of their Cultural Phases. 8vo. 1899.

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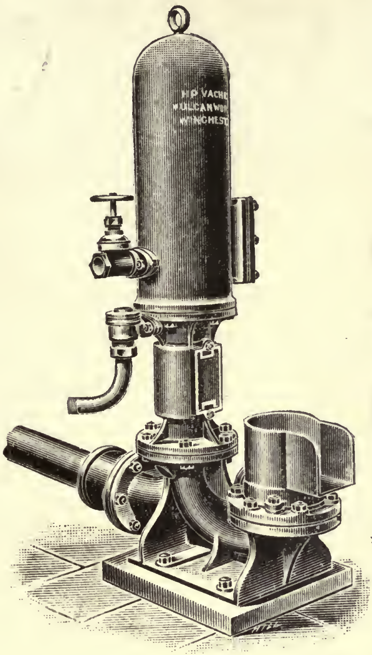

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