A MANUAL

OF

PRACTICAL DRAINING.

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PRACTICAL DRAINING.

BY

HENRY STEPHENS, F.R.S.E.

AUTHOR OF "THE BOOK OF THE FARM."

In grounds by art laid dry, the aqueous bane
That marr'd the wholesome herbs is turn'd to use;
And drains, while drawing noxious moisture off,
Serve also to diffuse a due supply.

GRAHAM.

THIRD EDITION.

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ADVERTISEMENT TO THE THIRD EDITION.

Another edition of this little work being wanted, I have endeavoured to make the instructions contained in it in conformity with the experience of draining up to the present moment. So busily and generally has draining been conducted in the last few months, that scarcely a day passes but what gives birth to some new suggestion, or modification of old practice. Profiting by what is going on, I have not hesitated to modify some of the particulars of practice I have hitherto followed; and it is possible that we shall all be obliged to modify still more the views hitherto entertained on many points of thorough-draining, and especially on the depth and distance of drains in soils of various qualities.

The amended Drainage Act, as was expected, includes the payment of trenching and fencing waste ground that has been drained; and another and later Act provides for proper outfalls for drains from any property.

THE AUTHOR.

REDBRAE COTTAGE, EDINBURGH,
March 1848.

PREFACE.

When the portions of the Book of the Farm treating of Draining appeared, it was suggested to me to publish the article in a separate form, because, as my friends alleged, so important a subject as Draining would make a popular book. However good the idea, or flattering the suggestion, my time was too much occupied with the bringing out of my systematic work, to avail myself of it.

Changes, however, have of late been made by the Legislature, which will ere long, as I conceive, necessitate the practice of draining in every part of the kingdom: For, I suppose, even the most ardent promoter of free-trade is not disposed to deny, that the entire abolition of protective duties will place the produce of our own land in a position much more unfavourable than that of the foreigner, by both being brought into direct competition in our own market. Nor, on the other hand, can it be gainsaid by the strictest protectionist of native agriculture, that a very large proportion of the land of this kingdom is still much in want of draining, and that draining is the first and most efficient step towards exciting the natural, and increasing the acquired fertility of the soil. To compete, therefore, with the foreigner, there exists with the agriculturists of this country the most powerful incentive for increasing the permanent fertility of the soil, if that be practicable; and its practicability is known by the agriculturists themselves to be in their own hands, by pursuing a substantial system of draining.

I acknowledge that the attempt to foretell, at the present moment, the ultimate effect of the direct competition of foreign grain on our arable agriculture would be rash; but the mind cannot elude the conviction, that our farmers will henceforward receive a lower price for their grain than they have hitherto received. At the same time, it would be equally rash to assert that the soil of the kingdom is inadequate to raise sufficient food for its inhabitants, while as yet draining has not been efficiently and universally practised.

Hitherto draining, as a promoter of fertility, has not been neglected in this country, for large sums have been expended, and much trouble bestowed upon it. Through a long series of years, and until a recent period, draining was confined to the practice of Elkington's system, which inculcates the penetrating of deep wide cuts into the seats of springs of water; and its prosecution, with this particular object in view, has been attended with much success. It was, however, at length discovered, that spring-water making its appearance at the surface was not the only, but the smallest, source of injury to the land; the mould operated on by the plough evidently deriving much greater injury from the pestilential influence of rain-water and melted snow, remaining in a state of stagnation upon the retentive subsoil immediately under it, than from spring-water. Various devices have been suggested for getting quit of this stagnant water, but the most rational one consisted of making numerous covered drains under the surface of the cultivated land, into which the rain, on falling, might immediately subside, through the porous mould and fissured subsoil, and find a channel along their bottom, to any receptacle fit to receive it. This method is known by the name of Thorough-Draining, and was first introduced to public notice by Mr Smith, when at Deanston, and has since obtained the approval of all practical farmers, though some of them had quietly drained portions of their farms on that system for several years previous to his announcement of it.

Like most subjects of public utility, however, the best method of applying thorough-draining to particular circumstances has occasioned considerable difference of opinion amongst its most active promoters. What at present causes most controversy, is regarding the depth and position of the drain that will most quickly and effectually convey away surface water. Mr Smith insists that surface water is most quickly and effectually removed by drains placed at short intervals, and most economically so when the drains are not cut too deep. Mr Parkes, Consulting-Engineer of the English Agricultural Society, maintains, on the other hand, that the surface water is most effectually and economically absorbed by deep drains placed at wide intervals. These two points constitute the whole difference in practice respectively advocated by these opponents, though I am aware that much difference of theoretical opinion also exists between them.

Many present at the discussion on draining, at Newcastle, on the occasion of the meeting of the English Agricultural Society in July 1846, might conclude, that the views taken by the opposite parties who conducted the controversy were irreconcilable; but, as I understood the merits of the controversy, the conclusion arrived at by both parties was right, when the state of the subsoil was suited to the particular view of each; but that both were wrong in applying his particular view to every state of the subsoil. Were subsoils all alike, similar depths and distances of drains — whether deep or shallow, wide asunder or near — would, of course, suit them all; but as subsoils are known to differ very much in their quality of permitting water to percolate through them, that is judicious draining which suits itself to the nature of the subsoil, and, by a parity of reasoning, that injudicious which recommends the same depth and distance of drain in every kind of subsoil. Should examination ascertain that drains of four feet in depth are required to reach the part of the subsoil through which the water percolates most copiously, then, of course, the drains ought to reach that depth before they can either receive all the rain that descends from the surface, or present channels for the conveyance of the water stagnating there. It is no objection to such a common-sense-like proceeding, that this is no other than Elkington's method, and not the improved or thorough system of draining, because, wherever land *cannot* be thoroughly drained but by the assistance of Elkington's method, its *principle* ought to be applied to gain the end in view; and this is as capable of being adapted to parallel and furrow draining as to the ramified form recommended by Elkington, and practised by his followers. It was the great error of Elkington's disciples to apply his ramified form of drainage to every state of wet soil; and it would be to commit a similar error in the present day to apply any system of *fixed* rules to every condition of subsoil. There should, therefore, be no controversy on the practice of draining; since every drainer ought to be right in his own case, and every judicious drainer will reject all dogmatic rules on the subject, and judge for himself in reference to the circumstances in which he is placed.

These are my views of the principles upon which draining should be practised, and I have endeavoured to illustrate and reduce them to practical rules for the use of drainers, with reference to the very various subsoils that exist under the soils of this country. The extent of my observations enables me to say, that too many drains, especially in England, have of late years been executed irrespective of those principles, or of any other, but solely on the desire to expend as little money in their construction as possible,—a resolution erroneously regarded by many farmers as evincing the very spirit of economy. Time will demonstrate whether or not inefficient drains are economical; and though they may answer the temporary purpose of a tenant—whose regard for the soil is apt to be measured by the duration of the tenure by which he occupies it—they will eventually do harm, by becoming ready-formed receptacles for stagnant water, which will require greater cost to remove than the original wetness of the ground. Yet, as long as landlords stand aloof, and view with inward satisfaction the short-sighted though industrial efforts of their tenants to improve their land, and express no desire to assist them, it is not surprising that tenants should hesitate to spend larger sums than they conceive they are likely to be repaid from the land during the course of a lease: and the ultimate injurious effects which the parsimony of the tenants inflicts upon the land seem but a just punishment on landlords for indifference to the improvement of their own property. To remove a temptation like this from tenants, whose means are generally limited, landlords should co-operate with them in draining, and thereby acquire a right to construct such drains as shall most effectually and permanently answer the purpose.

Should these remarks urge any tenant to request the assistance of his landlord; or should any landlord be induced by them to volunteer assistance to his tenants with a fair proportion of the expense of draining his own land in the most efficient manner; or should they, moreover, demonstrate to both landlord and tenant that their interests are mutually involved in the joint prosecution of thorough-draining the land, which supports them both, I shall feel gratified at having directed their attention to results so happy.

There is another subject connected with draining, which, although involving no controversy, is encountered with so much prejudice in Scotland that I cannot refrain referring to it, with the view, if possible, of correcting the erroneous notions entertained regarding it. I mean the prejudice against the use of tile-machines and pipe-tiles.

Tile-machines are objected to, on the general grounds urged against the use of all machinery, that of throwing tile-makers out of work. In England, many forms of tile-machines are in use, and if they have a necessary tendency to interfere with manual labour, they would there interfere with it to a much greater extent than in Scotland; and yet in that country not only no prejudice exists against them, but they are regarded, by labourers as well as farmers, as a very superior instrument to the human hand, in making a good and cheap tile. A tile machine requires four hands to work it, and fewer cannot work it with advantage, and these do not interfere with those employed in preparing the clay and attending on the kiln. Thus, as many hands are engaged in a tile-work in which a machine is employed, as in one where no such tool would be allowed to be used. Whence, then, it may be asked, is the economy of using a tile-machine? Simply because common labourers make superior tiles with a machine, to the most experienced moulders with the hand. Labourers' wages vary from 9s. to 12s. a-week, according to the season of the year, and the demand for labour; and at the present time, 1848, they are at the highest rate, on account of the inordinate demand for labour in the formation of the numerous railways constructing in the kingdom. The wages of expert moulders are at all times from 15s. to 18s. a-week. Six shillings a-week additional to several hands considerably enhance the cost of making tiles, and as a tile-work only yields a return in summer, economy is a paramount consideration in tile-making. Notwithstanding the present feeling in Scotland against tile-machines, I have no doubt that the superior and cheaper tiles they make will secure to them ere long not only a fair trial, but a decided preference for them over the cleverest moulder that ever formed a tile. The tile-machines have thus the effect of producing superior articles from the hands of men who have not, in the first instance, to undergo the drudgery of apprenticeship.

The prejudice therefore, against tile-machines, I expect to see soon at an end; but that against the use of *pipe-tiles* will not be so easily removed, as it will require some time to show their efficacy in draining to be equal to that with common tiles and soles. The prejudice too, against pipe-tiles, is entertained by farmers and farm-stewards, who are men of a higher class than tile-moulders, and are, therefore, more difficult to be disabused of prejudice. Nothing but the conviction of actual experience will satisfy them. Fortunately, however, two very cogent reasons exist with landlords to insist on their tenants using pipe-tiles instead of the common tiles and soles. One is, that, as pipe-tiles can be made at much less cost than common tiles and soles, the landlord, who has to purchase or supply them, has a direct interest in procuring the cheaper article, provided it is suitable, which they undeniably are; and the other reason is, that pipe-tiles secure in all circumstances every advantage derivable from common tiles and soles. This fact, coupled with the lower price, should overcome even the strong temptation tenants feel, to use common tiles without soles. Pipe-tiles can be made at less cost than common tiles, and 50 per cent less than tiles and soles. This pecuniary argument, one would think, should go far to give the preference to them.

The principal objection against the use of pipe-tiles arises, I believe, from the idea, that their close form must necessarily prevent the water finding its way into them quick enough for the purpose of draining the land. There is no way, it is triumphantly asserted, for water to get into pipe-tiles but by the joints between them, when placed one at the end of the other; and how can such small joints, it is demanded, admit so large a quantity of water as usually occupies a drain? This objection, be it remembered, is entirely founded on conjecture, and not on the experience of those who urge it; and it must be admitted that an inch pipe-tile is a very small duct. Let us test the validity of this objection by a practical analysis. In the first place, there is no necessity for using a pipe-tile of only 1 inch in diameter, and of thus going to the minimum extreme. The use of inch pipe-tiles in draining, is like administering the infinitesimal dozes of homœopathic medicines to the human frame. Suppose that egg-shaped pipe-tiles are used, and this is now regarded as the best form of pipe-tile, and the best size of them for common drains is 2 inches wide, and $2\frac{3}{4}$ inches high in the bore. The thickness of the clay of such a pipe, after being burnt, is $\frac{5}{8}$ inch. Now these dimensions give a circumference to the pipe of ten inches. Pipe-tiles cannot be placed closer to each other in the drain than to form a joint of $\frac{1}{8}$ of an inch in width; so the length of this joint around the circumference of the ends of two pipes comprises an area of $1\frac{1}{4}$ square inch. Suppose that a drain is 200 yards in length, which is a fair enough length for an ordinary ridge. In such a drain, 480 pipe-tiles of as long as 15 inches each are required. Now the joints between this number of pipe-tiles will afford openings for water to enter the pipes to the extent altogether of exactly 600 square inches, or 4 square feet and 24 square inches. Here, then, is an opening of more than 4 square feet to receive all the water that can flow in a drain of 200 yards in length. Does any one doubt that an opening of 4 square feet and upwards would easily contain all the water that can issue from a common covered drain of 200 yards in length? Nay, were an opening of only 1 foot square placed at the end of such a drain, no one would doubt of its capacity to receive all the water from it, and yet that would only be one-fourth of the area of the openings with which every drain is furnished. Pipe-tiles of shorter length than 15 inches will, of course, afford proportionally more numerous joinings for the admission of water into them in the given length of drain.

I conclude with this reflection, that the same subject will appear very differently, when contemplated in different aspects. Vague and cursory glances tempt to insecure conclusions; but, by taking premises such as the above, the results amount to something like demonstration. The hasty observer sees a pipe-tile, and, from some notions floating in his own mind, pronounces it unfit for the purpose intended; while he who regards it more narrowly, and carefully ascertains its properties, as I have done, will, I doubt not, agree with me in opinion as to its utility and value.

CONTENTS.

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The Symptoms exhibited by Land requiring Drainage.

DRAINING may be defined the art of rendering land not only so free of moisture as that no superfluous water shall permanently remain *upon* it, but that none shall remain so long *in* it as to injure or even retard the healthy growth of the plants cultivated upon it for the use of man and the domesticated animals.

On considering this definition, it may reasonably be inquired why water in the soil should injure the growth of useful plants, since botanical physiologists tell us that the food of plants, derived from the soil, must all be conveyed to the spongioles of the roots in a state of solution in water. In what way such injury should arise, is certainly not apparent; though observation has shown that *stagnant* water, whether upon or under the surface, does injure the growth of all useful plants. It perhaps prevents, or at least checks, all useful perspiration or circulation; or affects the chemical state of substances which largely supply the food of plants. Be this as it may, experience assures us that draining prevents all these bad effects.

It is quite conceivable that an obvious excess of water might injure useful plants, since that is usually indicated by the presence, in number and luxuriance, of sub-aquatic plants, as rushes, (*Juncus acutiflorus* and *J. effusus*), &c. which only flourish where water is too abundant for other kinds of plants; and it may be supposed that damp dark spots in the soil, may contain so much water as to prevent plants attaining full maturity; but it is not so evident why land *apparently* dry should require draining. It is also conceivable that land, though not containing a superabundance of water, may nevertheless prevent or retard the luxuriant growth of useful plants, by a cold damp state, almost as much as land decidedly wet. The truth is, the deficiency of crops frequently attributed to unskilful husbandry, on apparently dry land, arises from the baleful influence of *concealed* stagnant water; and want of skill is here shown, not so much in the mismanagement of arable culture, as in the neglect to remove this concealed moisture; for, let the culture be ever so skilfully conducted, there never will be produced so great and good crops from damp land as from that naturally dry or thoroughly drained. Indeed, my opinion is,—and it has been forced upon me by long and extensive observation of the state of the soil over the greater portion of the kingdom,—that the neglect of draining is the *true cause of most of the bad farming to be seen*, and that *not a single farm* exists, not already thoroughly drained, which would *not be much the better for draining.* Entertaining this opinion, it is not surprising that I should urge the practice of draining with much earnestness.

By the experienced eye, the particular parts of a field most affected by superfluous water are easily detected. They may be so by the peculiar state of the crop the field bears at the time. Want of vigour in growth—a sickly hue of colour—and none of the parts sufficiently developed, are strong indications of the presence of water; while the soil that supports such a condition of vegetation always feels unelastic under the foot. There is no doubt about these symptoms. They are more obviously exhibited by grain and green crops than by the sown grasses; and in *old* pasture, the coarse, hard, uninviting herbage is quite a sufficient index of a moist state of the soil.

But moist land is easily detected in other ways, especially in March after being ploughed, when the air is dry and keen. Then, large belts of dark-coloured soil may be observed near the top of acclivities, whilst the rest of the field *seems* quite dry, of a light-brown colour; or with only small dark spots here and there; or only the flat and hollow parts are covered with dark soil. All these palpable hints of water lurking below cannot be mistaken; and they may disappear, or be much contracted in dry, or much extended in rainy weather. When these disappear on the approach of summer, it is erroneously concluded that they can do no harm to cultivated plants, and the land *requires no draining*; but it is the water *remaining in the soil all winter* which injures the crops in summer. The *wetness* which disappears partially in spring, and altogether in summer, would not injure growing crops, as it would all be absorbed, and more, in the wants of active vegetation; but when it remains stagnant, and occupies the pores of the soil and subsoil all winter, it renders the soil so damp, that most of the summer's heat is required to evaporate it, and, in this process, the heat is dissipated that would have advanced the crops. In regard to the abstraction of heat, there is no doubt that, even after the soil and subsoil have been drained, the winter rain passing through them takes some of their heat, and conveys it away in the drains; but though such an abstraction makes them somewhat colder, it cannot render them either wet or sour, and having now free access to the air, they necessarily assume its temperature. In these circumstances, the heat of spring and summer have only to push forward the growth of the crops, to fill them fully, to make them of fine quality, and to bring them to maturity. Where the symptoms of wetness are obvious to the senses in summer, there is no doubt of the land requiring draining; but even favourable symptoms of dryness may not indicate in it the true state of the subsoil, for water may be lurking. And that it does so lurk to a very great extent in this country, and will continue so to lurk, until vents are made for its egress, is a melancholy truth; and even any dry soil around it becomes injured by imbibing stagnant water by capillary attraction.

The occurrence of damp spots in fields can be easily explained. The surface of the ground being permeable to water, where it rests on beds of different depth, of various length and breadth, and of different consistency, the water derived from rain or melted snow proceeds downwards until it is intercepted by retentive beds, and becomes accumulated in the pervious ones in a larger or smaller quantity, according to their nature and capacity, until, at length, becoming there superfluous, it pours itself from the surcharged strata, and, meeting with other retentive beds, it flows over them and finds its way to the surface-soil, at a somewhat lower level from its origin, in the form of land-springs. Springs are either concentrated in one place, or diffused over a large or small extent of ground, according as the retentive beds are extensive or otherwise. Deep draining is generally required to remove springs, and it is done by cutting through alternate beds of retentive and pervious matter, until the seats of the springs are reached.

In cases, however, where the soil and subsoil are retentive alike, the water, not being able to penetrate further, finds only a passage between the impervious subsoil and the soil made loose by the plough; and should the subsoil be uniformly and extensively retentive, the water remains upon it, and, becoming stagnant, injures the plants growing upon the surface. To remove the water from such a situation, deep drains are generally not required, but rather plenty of them, to afford it opportunities to escape.

Where the soil and subsoil are both porous, the water passes quickly through them, and no draining is required to assist it in passing through a thick subsoil, as itself constitutes an extensive and uniform drain. In soils of this nature, water is only retained by capillary attraction, and what is not so supported sinks through the porous subsoil by its own gravity.

The capillary force is quite capable of supporting, and bringing as much water through a permeable soil and subsoil, from below, as is needful for vegetation, except under the extraordinary occurrence of excessive drought, and through a porous subsoil of great depth; and of all conditions of water which capillary attraction supplies, that from springs is the coldest, most injurious to useful plants, and most permanent in its effects; and hence it is that the abstraction of spring water by draining from soil otherwise dry, does not interfere with the beneficial effects of rain-water as a supporter of plants, a meliorator of the soil, a menstruum for the food of, and a regulator of temperature to, plants. To take away, therefore, spring water from the soil by draining, and to supply it with recent rain-water by drains, is an excellent means of promoting the health of plants.

The different Methods of Draining.

These distinctions in the states of soil determine the method of draining them. One method draws off large bodies of water from isolated portions of ground, by *deep draining*. Another kind absorbs, by means of numerous drains, the water spread over extensive pieces of ground immediately under the surface, and it is called *shallow draining*. These two kinds embrace all the varieties of draining in existence; but this distinction exists betwixt them, —deep draining admits of no modification of plan and structure, in any soil, while shallow draining is modified to suit the nature of the soil.

Shallow draining subdivides itself into two kinds, one consisting of small open channels formed by the spade upon the surface of the ground, in various directions, for the reception of water while flowing upon the land; the other consists of covered drains at different depths, at short intervals, into which the water as it falls upon the surface finds its way by its gravity through the loose soil and porous parts of the subsoil, and is discharged by a convenient outlet. When these covered drains occupy the furrows of ridges, it is called *furrow-draining*, though drains are not indispensable to occupy the furrows. It has also been called *frequent-draining*, from the circumstance of the water finding frequent opportunities of escape; but this name, though the original one, is objectionable, inasmuch as the word may imply that land requires to be drained frequently, which it certainly does not. From the parallelism of the lines of the drains, it has been denominated *parallel-draining;* and yet all the drains in the same field do not require to be placed parallel to one another. As the land by this kind of draining is effectually drained, it has most appropriately been called *thorough-draining;* which term, as a name, has the advantage of not committing the drainer to the adoption of any particular form or position of drain, but admits of every form or position which renders land thoroughly dry. The other names given to this kind of draining only indicate the mode in which the materials are placed in the drains, such as *shoulder-draining*, *wedge-draining*, *plug-draining*, *mole-draining*, &c.

Draining by Open Ditches.

Mere *surface*-draining is effected by *water-furrows*, and *open cuts* and *ditches*, into which the surface-water flows, and is carried to a distance to some lake or river. This mode does not profess to interfere with the water which finds its way below the surface of the ground, beyond what percolates through the ploughed surface into the open furrows of the ridges. The ridges being ploughed in a rounded form, the water finds its way into the open furrows, which are made suitable channels for conveying it, by being cleared out with the plough and with the spade, at the junction of the open furrows, after the crop is sown. Open spade cuts are also carefully made across the ridges, through every natural hollow of the ground, however slight, into the open furrows. These cuts are continued along the open furrow of the lowest head-ridge, and across its hollowest parts into the adjacent open ditch. This recipient ditch forms an important part in the system of surface-drainage, while conveying away the collected waters of the field of which it forms the boundary; and for which purpose it is made from 3 to 4 feet in depth, with a proportionate width. It is always connected with a larger open ditch, which discharges its accumulated waters, from a number of such recipient ditches, into a river or lake. This large ditch is from 5 to 8 feet in depth, and of proportionate width, and when conveying its fill of water in winter, appears like a small canal.

This is evidently a system of mere *surface*-drainage, which is only applicable to very tenacious clay-soils, that retain water for a long time upon their surface; and, accordingly, it has long been extensively practised in such districts as the Carse of Gowrie. The ploughmen of the Carse are accustomed to the spade, and are yearly employed, in the proper season, in scouring out the smaller ditches; the larger ones being only scoured occasionally: and whenever a heavy fall of rain occurs in winter or spring, they are employed in clearing out the spade-cuts, and directing the water as fast as possible along them into the furrows and ditches. This is their necessary occupation in wet weather, and as clay land cannot then be ploughed, it is executed by the men with no loss of horse-labour. This, however, constitutes a very imperfect system of drainage, and sacrifices a large extent of good surface-soil. It would be better, I think, if the Carse farmers were to use plenty of covered drains, which would more quickly absorb the surface-water than the open ditches, while they would save much trouble in scouring these, and make the soil into a fitter state to be worked at any season than can be done under the present system.

I am aware that many Carse farmers will smile at this recommendation, and imagine that I have never seen the heavy, wet, slippery, cloggy clay of the Carse, else I would never recommend draining it with covered drains. I have often seen the Carse clay in its very wettest state in winter, and as often under summer-fallow in summer, when it was as dry as dust, and hard as bricks, and inclods so large that the harrows and roller — such, at least, as are used in the Carse—could make little impression upon them. Now, how became the slippery, cloggy clay so dry and hard? Simply by being made dry by evaporation. If other means, then, than evaporation were offered at all seasons to keep it dry, what should prevent its losing its slippery and cloggy character in winter? Would not numerous drains afford those means? If not, I ask, wherefore? since in summer, evaporation causes clay to assume a very different character from what it seems in winter. Now, no means are so ready of depriving clay of rain as it falls as numerous drains; and these would dry it better, because more slowly than evaporation, and thus time would be afforded to pulverise the ground before it hardened into large clods. When I see Mr Mechi of Triptree, in Essex, draining clay land dry, as strong and heavy and wet as that in the Carse of Gowrie, I cannot doubt the efficacy of covered drains in the latter district. No doubt, the soil cannot be drained but at considerable cost, but where shall we find soil that will repay so large an expenditure on its improvement as the clay of our Carses?

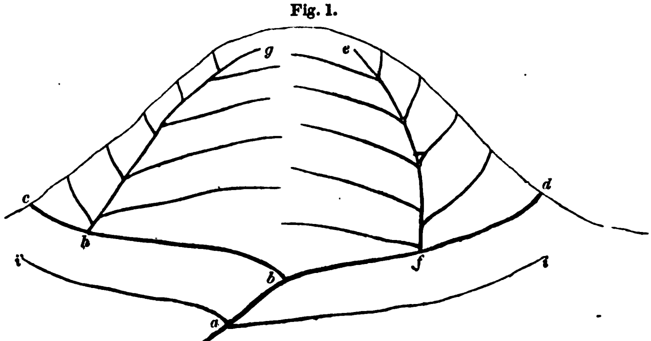
Sheep-Drains in Hill Pasture.

The wet surface of pastoral hills composed of impervious clay, may be dried on the principle of surface-draining; that is, a number of transverse open cuts may be made across the faces of the hills, and the water received from them in open ditches into large drains; but where the ground is under the plough, covered drains are requisite. Indeed, covered drains, when properly formed, are best adapted even for sheep pasture, as being not only secure from external damage, but permanent in their structure; and there is no sort of drain better adapted for the use of pipe-tiles. They keep the surface unbroken; no manure would be apt to be washed away in open cuts; the ground would be rendered permanently dry; and, I think, much cheaper than by any form of drain at present known.

Though I recommend covered drains in hill pasture, yet, as open ones are most frequently in use, it is necessary to describe the best forms of these.

Open surface-drains in permanent pasture exhibit the form represented in fig. 1, where the leaders *e f* and *g h* are cut the more nearly down the face of the hill the less steep the acclivity is, and the feeders are cut across the face nearly in parallel lines, into their respective leaders. In this way, the water is entirely intercepted by the feeders in its passage down the hill. Where one

Fig. 1.



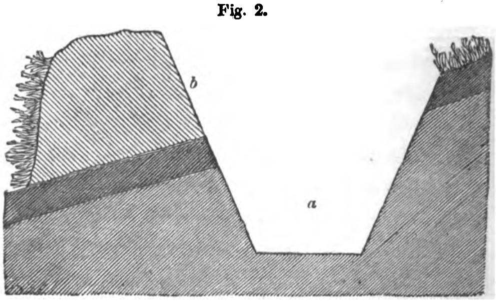
A PLAN OF SHEEP-DRAINS ON A HILL OF IMPERVIOUS SUBSOIL.

drain enters another, the line of junction should never be at right angles, but at an acute angle with the line of the flow of water, as in the drain from *g* to *h*; and where small drains enter a large, from opposite sides, they should enter at alternate points, as shown by the three drains above *f*, and not as represented by the three pairs of drains above these towards *e*. The large drain *c b d* may be left open or covered. Should it form the line of separation between arable ground and permanent pasture, it may be left open, and serve as an assistant to the fence of the hill-pasture; but should the entire hill be under the plough, this, as also the main drain *a b*, and all the lateral ones, including *a i*, *a i*, should be covered.

There are various ways of making drains in grass. One is to turn a furrow-slice down the hill with the plough, and trim the furrow afterwards with the spade. When the grass is smooth and the soil pretty deep, this is an economical mode of making an open *sheep-drain*. Every line should be previously marked off with poles when the plough is to be used. Such a drain would not cost a halfpenny per rood of 6 yards. But where the grass is rough and strong, and swampy places intervene, the plough is apt to choke, and come out of the ground by the long grass accumulating between the coulter and beam, and this makes at best very rough work; while the horses are apt to strain themselves in the swampy ground, and its cost would be considerably enhanced.

A better, though more expensive mode, is to form them altogether with the spade. Let *a*, fig. 2, be a cut thrown out by the spade, 9 inches wide at bottom, 16 inches of a slope in the high side, and 10 on the low, with a width of 20 inches at top along the slope of the ground. A large thick turf *b* is removed by the spade, and laid with its grassy side down the slope, thus preserving the grass on the lowest side of the cut, the shovellings being thrown upon its top to finish the bank neatly. Such a drain catches all the water descending the surface between it and the drain above, and leads it to the sub-main drains, as *e f* or *g h*, fig. 1., which are of similar

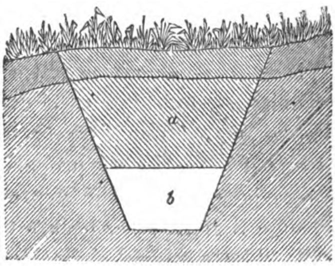
Fig. 2.



AN OPEN SHEEP-DRAIN IN GRASS.

construction, but of larger dimensions, with their lower end joining the large main drains *b c* and *b d* at the top of the arable land. This is an open drain, and might be formed for about twopence per rood of 6 yards, provided many obstructions, such as brushwood and rank heather, do not encumber the surface.

Fig. 3.



A COVERED SHEEP-DRAIN IN GRASS.

The following, in fig. 3, is a covered sheep-drain. A cut is first made 6 inches wide at bottom, 16 inches deep, and 18 inches wide at top. The upper turf *a* is taken out whole across the cut, as deep and large as the spade can make it. Two men will take out such a turf better than one. It is laid for a time on its grassy face upon the higher side of the drain, and the earth pared from the other side with the spade, leaving the turf of a trapezoidal shape. While one man is doing this, the other is casting out with a narrow spade the bottom *b* of the drain; and the earth and shovellings are spread over the ground. The large turf *a* is then replaced in its natural position, and tramped down, and an open space *b* is thus left below it for the water to pass along. This is not so permanent a form of sheep-drain as the last, nor can it be so easily kept clear; and it is unsuited to pasture for cattle, as they would inevitably tramp the turf to the bottom of the drain. It also affords an open space for moles to run along; and when any obstruction by them or other burrowing animals occurs, the part obstructed cannot be detected until the water is seen to overflow the lower side of the drain, where the turfs must be raised, and the obstruction removed. It forms, however, a neat drain, possessing the advantage of retaining the surface whole where sheep alone are grazed;* but it could not be formed for less than fourpence per rood of 6 yards; and when it is determined to expend so much in making sheep-drains it would be better to employ pipe-tiles at once, which would require a comparatively narrow cut. The pipe-drains could be made for little more than the original cost of the tiles, and their carriage.

* Figs 2 and 3 are drawn on a scale of ⅛ inch to 2 inches.

Drains for Ground to be planted with Forest Trees.

Another species of open draining is that which should be practised in ground intended to be planted with forest trees.

It is surprising how little desire seems to be evinced by landed proprietors, to prepare the ground by draining for the reception of plantations. The fencing of young plantations is scrupulously attended to, and very properly, because young trees cannot defend themselves against the depredations of man and beast; but it is strange that it never occurs to the planter, that young trees are as little able to defend themselves against the chilling and suffocating influence of water about their roots, as their stems and tops can withstand the gnawings and croppings of animals. The deleterious effects of water in the case of every large plantation that does not form an important portion of a domain may be explained,—in the freezing of the ground in winter in one mass around the roots of the trees, as long as they are young,—in obstructing the sun's heat entering the soil, and finding its way to the roots, in the early part of every year,—in preventing the passage of the air to the roots of the trees, the presence of air being essential to their good health,—and the particular effects produced by all these causes may be witnessed in every tree becoming the victim of lichens and mosses, or other parasitic plants, or of being evidently stinted in its growth, or diseased in the interior of the trunk. The consequences are, the trees are a very long time of reaching to a state of usefulness as timber or shelter, and can never realise the price of those grown on dry soils. It is not enough to place young trees in ground that does not become a plashy swamp in the worst winter weather, because rough ground will retain as much moisture in its vegetable covering and spongy mould, as will injure the roots of the young plants constantly remaining in it. There is no alternative therefore left, but to drain the ground before it is converted into a plantation, if it is desired by the planter to have his trees attain maturity and usefulness; and the system of drainage suited for such ground is neither intricate nor expensive, as I shall proceed to show.

Ground appropriated to the use of trees, should be drained by open drains upon the surface only, and not with covered drains of any kind; for the roots of the trees will direct their first efforts towards the conduits of covered drains, in search of moisture in the summer season, and their fibres will soon choke up the orifice of the conduits. Now, open drains upon the surface will be quite sufficient to remove all the water that would remain in a stagnant state in winter, and prove injurious to the roots; whilst they would allow as much moisture to remain *under* the roots of the trees, as would prove beneficial to them in summer; and they are not required to be made so large or so deep as to be objected to on the score of expense.

On laying out the drains on such ground, it is requisite to observe the form of the surface, and wherever a hollow trough occurs, with rising ground on both sides, there cut a *main drain* along the bottom of the hollow. This drain should at least be 3 feet in depth, and have a flat bottom of 1 foot in breadth, to allow the spade to pass easily along it in scouring out at any time the earthy and vegetable matter that may have remained in it, and its width should be 1½ foot wide for every foot in depth, allowing, moreover, the 1 foot width at the bottom. Thus, for example, a main drain 3 feet in depth would be 4½ feet in width, but with 1 foot in the bottom, it would be 5½ feet in width in all. The size of the main drain is of course regulated by the probable quantity of water it will have to convey away from the small drains which lead into it. And it should be borne in mind from the first, that main drains and all other sorts should be so formed as to be rather too capacious than too confined, to contain all the water that will ever flow in them.

The *small drains* should not be made along the fall of the ground, as in the case of covered drains in ordinary arable land drainage, because the large body of water which they at times will collect at once from the surface, would then be apt to run holes into their sides and bottoms. They should, therefore, be placed with a slope across the inclination of the ground towards the main drains, at such an angle as just to preserve a brisk enough trot in the water to carry off sediment and leaves, but not to injure the sides and bottom. In clay soil, the slope may be made more inclined than in light soil.

The small drains should not be made less than 20 inches in depth in clay soil, with a width, of course, of 30 inches, and with 9 inches at the bottom, making the entire width at the top 39 inches. And on light soils they should not be made less than 14 inches in depth, and 21 inches in width, with 9 inches at bottom, making the entire width 30 inches.

Where slight hollows occur across the surface of a field of small drains, a sub-main drain should be inserted therein, having a communication with a main drain. These sub-main drains should be of less dimensions than main drains, but larger than the small drains, and should be of the same proportions as the other two kinds.

The cost of the 14 inches in depth drain in light soil, requiring a little picking at the bottom, will be about one farthing per running yard; and that of the 20 inches deep drain in clay soil, with extra picking, will be two farthings per running yard. The cost of making the main and sub-main drains will be in proportion to the above prices, according to the quantity of the earth thrown out and requiring to be picked, in the respective kinds of soils mentioned.

The cost of draining per acre will of course depend on the number of the drains, and the number will be determined by the distances fixed on between the drains. This distance must be determined by the judgment of the person who undertakes the drainage, or of the proprietor himself. Perhaps it may be proper to state as a guide between two extremes, that the distance need not be nearer in any place than 5 yards, nor exceeding 40 yards, the distance being closer in clay than in light soils.

Ancient Shallow Covered Drains.

The drains which our forefathers made in loamy soils resting on a retentive bottom, were placed upon the subsoil immediately under the upper soil, where that happened to be deeper than the plough furrow; and as the arable portion of the soil, when it is quite of a different nature from the subsoil, is never very thick, the drains were necessarily placed at very small depths. Experience would soon teach any drainer the impropriety of placing the materials with which he fills drains within reach of the plough. Consequently, such shallow drains were filled with very few stones, often not exceeding three, and those not of large size, one being placed on each side of the drain, and another above them, forming a sort of conduit. These conduits being near the surface, of small area, and not numerous in any one place, a small quantity of water soon carried as much matter into them as to endanger their obstruction, and moles easily forced the soil into them. Obstructed drains operate on the land like springs, by causing the water to burst to the surface at the point of obstruction, and every drain in such a state produces the very mischief it was intended to remedy. Such paltry drains have evidently been formed on the notion that a simple conduit placed betwen a porous soil and retentive subsoil, was all that was requisite to render the surface-soil permanently dry,—a notion, the fallacy of which the drainers of the present day are well aware of. I have met with several such drains in the course of my draining operations; and they were invariably choked up, but on being relieved by the cutting of new drains, clear water flowed from them for a considerable time. They were beyond the reach of the plough, as the land had been ploughed shallow from time immemorial, with a mere skimming of about 4 inches of the soil. The sole of the plough had compressed the black mould into a thin slaty crust, under which the black virgin soil remained untouched, while the ploughed surface had become an effete powder by constant cropping. From what has been said of these shallow drains it may be believed that they in no degree rendered the land dry.

Draining Isolated Hollows and Running Sands.

The draining of isolated hollow spots of ground is often attended with difficulties connected with their peculiar position as well as the nature of the materials which they contain. Wet hollows in winter are caused by water standing in basins of impervious clay, derived entirely from rain, in which case they become dry in summer — or, constantly wet hollows originate from springs at a higher source. Such pools may be dried either by boring holes through the impervious clay into a porous stratum below, or by a deep drain, having its efflux at a lower level.

As a good illustration of draining such pools, I shall give an account of a successful attempt made by myself, at Balmadies in Forfarshire. The pool contained water in winter to the extent of about 2 acres, in the centre of a field of 25 acres; and though none appeared above ground in summer, its site was swampy. It was called the "Duck-mire," wild ducks being in the habit of frequenting it every season. On taking the level of its bottom in summer, it was found that a cut of 10 feet in depth was required through the rising ground around it, to allow a drain of 2½ feet deep through the pool; and its nearest outlet terminated on the top of a clay-bank, about 150 yards off, rising perpendicularly 40 or 50 feet above a small rivulet.

The operation was best performed in summer, when the pool was comparatively dry. The deep cut of 10 feet was first executed, and a conduit of 9 inches in width, by 12 in height, was built and covered with land stones obtained from the field by trench-ploughing. The continuation of this conduit constituted the main drain through the centre of the pool, where it could only be made 30 inches in depth. Another drain, of 3 feet in depth, encircled the area of the pool a little above the water-mark, and was let at each end into the main drain. Both the drains were made 9 inches wide at bottom, to contain a coupled duct of 4 inches in width, and filled with small round stones, gathered from the surface of the field, and admirably adapted for the purpose, none exceeding the size of a goose's egg. The stones were blinded with withered wrack, and the earth returned above them, first with the spade and then with the plough. The pool was at once determined to be dried by a drain, as the high bank of clay exposed above the river forbade any attempt at boring for a porous stratum below.

But a difficulty occurred in passing the drain through the centre of the pool, which was not foreseen. A complete quicksand was met with, which extended much below the bottom of the deep cut. To have effectually drained it, the cut should have been at least 13 feet in depth; so that fully 3 feet of quicksand were obliged to be left beneath the drain; and how to construct a lasting drain upon such a foundation, was a puzzling practical problem. It was now evident that, though the subsoil was assuredly a deep bed of clay, I had erred in not ascertaining the state of the pool by pitting or boring, and discovering the existence and depth of the quicksand before making the deep cut. As matters stood I was obliged to form a drain in the quicksand. Thick tough turfs were provided to lay upon the sand, to prevent its rising into the bottom of the drain, and upon these were laid flat stones, to form a foundation upon which to build a conduit of stones of 6 inches square. The back of the conduit, when building, was packed with tough turf, to prevent the sand finding its way through it into the conduit; and the packing was continued as high as the few small stones reached above the cover of the conduit. A thick covering of turf was then laid over these stones, so that the entire stones of the drain were completely encased in turf, before the earth was returned upon them. The filling up was solely executed with the spade, lest the trampling of the horses should have displaced the stones. These extraordinary precautions were only used as far as the quicksand was found to be annoying. After the drains were finished, a large quantity of water flowed by the outlet in the succeeding autumn and winter; but by spring the land had become quite dry, the blue unctuous clay forming the bottom of the pool friable, and on the soil and subsoil being intermixed by deep ploughing, the new and fresh soil, with proper management, ever after bore fine crops of grain and turnips.

The turf completely kept the sand out of the conduit; but where it cannot be procured in quantity the conduit should be built of stone, and lime mortar, which, although the most expensive, is the most effectual preventive of quicksand in drains.

This is an instance of draining quicksand with stones; and while on the subject of quicksands, I may give an instance of a successful method of draining it with tiles by Mr William Linton, Sheriff Hutton, near York :—

"When the first man has got a few feet from the end of the drain," he says, "the second commences taking out the bottom of it; and as soon as he has made way for the laying of stones or four tiles, they are immediately laid by the tile-layer; first laying the bottoms quite close to each other, and upon them the tiles, leaving as little crevice as possible, and immediately covering them with about four inches of the most tenacious soil that can be procured. Clay would be used, but on account of its being in large hard lumps, it cannot be made to bed sufficiently close to keep out the sand. Here I must notice that it is essentially necessary that the drains be cut 3 or 4 inches wider at the bottom than the width of the tile, so as to admit this strong soil down the sides to the very bottom. Much mischief is done by the sand getting in at the bottom part of the joinings of the tiles. Other materials have been used for keeping out the sand, but with bad effect. I prefer clay to any thing else when it can be got sufficiently loose and malleable, so as to bed quite close and firm, and leave no crevice. . . . . .

"After the clay or strong soil is well trodden in and thrust down the sides of the tiles with a common spade, the sand thrown out in the making of the drain is then filled in, and is firmly beat down by treading, and sometimes by running a broad-wheeled cart upon it, in which is put a sufficient weight, in order that the covering of the drain may become as firm as any other part of the field. This is done to prevent the water from descending or finding a channel to the tile in that direction, or it would be almost impossible to keep out the sand.

" . . . . . The pipe tile having been of late introduced into this neighbourhood, I have commenced using them. The drains are cut, and any other part of the work performed in the same way as when the common tiles are used. But on account of the land being but recently drained by them, my observations are not sufficiently matured to justify me in saying that they are in all respects equally good with the common tiles. I find it sometimes difficult to get them to fit close enough to each other, the ends not being quite straight, and some of them curved in the middle; therefore it is necessary to apply clay to most of the joinings. Of these running sands I have drained about 500 acres; and when the plan which has been stated here at large was adopted, which has generally been the case, the average cost per acre was about £5, 5s.; that is to say, 1500 tiles at 26s. per thousand; 3000 bottoms at 11s. per thousand; cutting, £1, 10s.; and incidental expenses, 3s.; total, £5, 5s."*

Clay is almost always the support of *bogs and marshes*, in basin-shaped hollows; and when it is of considerable depth, the only way of draining the bog is to bring a deep cut from the lowest ground and pass it through the basin of clay. But it not unfrequently happens, that gravel or sand exist at no great depth below the clay on which bogs rest; in which case the most economical plan is to bore holes in the first instance through the clay, with an auger 6 inches in diameter; and, should the water subside, to finish the

* *Journal of the Royal Agricultural Society of England*, vol. vii. pp. 117, 118.

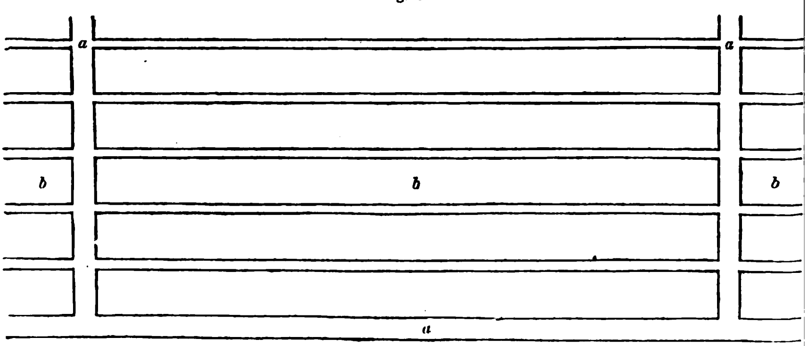
work by sinking wells through the clay, and filling them with small stones to within 2 feet of the top.

I have never seen an instance of the draining of bog by *boring* or by *wells;* but the late Mr George Stephens, land-drainer, related two or three instances of bogs being successfully drained in Sweden by means of bore-holes and wells in connexion with drains; and the late Mr Johnstone adduces in his treatise many successful cases in this country.*

Bog-Draining.

I have seen extensive and successful cases of drying bogs in Ireland, by ordinary drains, especially of Carrick Bog, in the county of Meath, by Mr Featherstone of Castle Rattan. The plan consists of dividing the bog into divisions of 60 yards in breadth, by open ditches of 4 feet in depth and 4 feet wide at top, allowance being thus made for the sliding in of the sides and subsidence of the moss by drying, and which cause considerable diminution in the dimensions of the drains. The open ditches are connected by parallel drains at right angles, 3 feet 3 inches in depth and 18 inches in width. Fig. 4 is a plan of these drains,

Fig. 4.



A PLAN FOR DRAINING BOGS AS PRACTISED IN IRELAND.

where *a* are the large ditches and *b* the small drains. The ditch *a* at the bottom, next the dry land, takes away the water to a river. The fall in the ditches and drains is obtained from the natural upheaving of the moss at its centre above the level of the adja-

* See Stephens' *Practical Irrigator and Drainer*, pp. 169-184, edition of 1834; and Johnstone's *Systematic Treatise on Draining*, 4to edition of 1834, p. 75; both excellent works on deep draining.

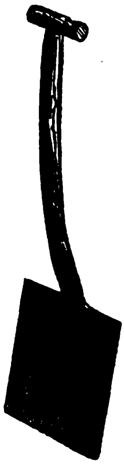
cent ground, and this peculiarity causes all the drainage water of such bogs to flow towards the land.

The small drains *b*, fig. 4, are made in this manner. A garden line is stretched at right angles from one open ditch *a*, to another *a*, 60 yards. The upper rough turf is cut in a perpendicular direction, along the line with the short handled edging-iron, fig. 5. The line is then shifted 18 inches, the width of the top of the drain, where a similar cut is made by the edging-iron. While one man is employed at this, another cuts a moderately thick turf across the drain with a broad-mouthed shovel, fig. 6. The drain is then left 2 months to allow the water to run off, the moss to subside, and the turf to dry.

Fig. 5.

THE EDGING-IRON.

Fig. 6.



THE SQUARE-MOUTHED SHOVEL.

Fig. 7.

THE 3-PRONGED FORK.

At the end of that time a long handled edging-iron, fig. 5, is employed by one man cutting down the sides of the drain in a perpendicular direction 2 feet 3 inches deep; while another man uses the square-mouthed shovel, fig. 6, to cut the moss into large square peats, which being wet, and situate much below the hand, cannot be thrown out with the shovel, but are taken hold of by a third man, with a small three-pronged fork, fig. 7, and thrown upon the surface, where their square form is regained by a few strokes with the back of the shovel, and then left to dry and harden. The work is again left for 2 months more, for the water to drain off, and the moss to subside still further.

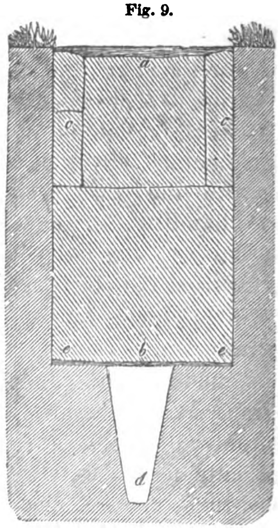
Fig. 8.

THE HORIZONTAL SPADE.

A new spade which I

have named here as the "horizontal spade," fig. 8, because it works in a horizontal direction, has lately been introduced in bog-draining, to cut the under parts of the peats and turfs in making these drains, and assist in casting them out, instead of the small three-pronged fork, fig. 7. In bogs, where footing is found for the workmen, such an instrument will be eminently useful; but in deep bogs, in the drains of which no man can be supported, such a spade is of no use, especially in cutting out the second or lowest turf, which is too much below the hand of the man standing on the surface. The three-pronged fork, fig. 7, is the only tool he can most conveniently use in such cases.

Fig. 9.



THE SHOULDERED BOG-DRAIN.

In the course of the four months the moss subsides about 1 foot, and the turfs and peats become firm. After the two spits of the shovel have been thrown out, the long edging-iron is again employed by one man to cut down both sides of the drain to the depth of about 1 foot, leaving a shoulder *e e*, fig. 9, 5 inches broad, on each side. The scoop, fig. 10, is then employed by another man to cut the moss below and across this last narrow spit, whilst a third man takes out the cut pieces by the small fork, fig. 7. The scoop is employed to polish the narrow bottom of the drain with a few shoves of its back, making the duct *d*, fig. 9, 1 foot deep.

Fig. 10.

THE BOG-DRAIN SCOOP.

The filling of the drain is commenced after this last spit has been removed, and is conducted in this manner. The large turf *b*, fig. 9, taken out by the second spit, being now dry, is lifted by the hand and placed upon the shoulders *e e*. If this turf is replaced too tight in the drain, the moss will have a tendency to collapse from both sides, and choke up or diminish the opening, *d*. The large turf, *a*, first taken out, is then lifted by the hand, and put into the middle of the drain, as in the figure, with the grass face undermost, and the long narrow stripes of turf, *c c*, separated by the scoop from the bottom spit, along with any other broken pieces, are firmly packed, by means of the fork, fig. 7, along both sides and top of the drain, so that the entire number of turfs just fill up the subsided drain to the top. It is the common practice to put the turf first taken out upon the shoulders of the drain, with the grass face undermost, but as its thick covering of grass is soon converted into mould, which will, of course, then fall into the duct, it is much better to place the second turf upon the shoulders, as, being composed entirely of fibrous moss, it will never be converted into mould.

Fig. 9 represents this drain finished. In its construction it is well suited for drying bog, and possesses the advantage of having all the materials for filling it upon the spot. To resist the action of water with impunity, is a well-known property of dried peat, and the slow mode of making such drains, affords sufficient time for drying the moss into peat; but the time allowed for the moss to subside is a greater advantage to the drain than the mere drying it into peat, which might answer the purpose even in a wet state, though not so well. It is the custom of some bog-drainers to finish the drains at once, but as the moss of *deep* bogs shrinks considerably in drying, I conceive no one can determine beforehand how much the bottom of a bog-drain will have become distorted, or whether it will be so at all, by the time the moss has subsided and been dried into peat. For my part, I prefer the Irish mode as described above. In regard to shallow bogs, where the bottom of the drains rests upon firm ground, the drains may be formed in them at once.

A bog-drain requires no other materials, such as wood or tiles, to fill it, there being no materials so appropriate as the peat itself or more durable—the slightest irregularity in the subsidence of the moss in the bottom of the drain would destroy the continuity of the soles and tiles employed, whether of wood or clay. The cutting of the drains is best effected in summer, when the drought quickly dries the moss, and, by removing a large quantity of the water by evaporation, effects its subsidence.

Elkington's Method of Draining.

Elkington's may still be characterised as the only method of *deep* draining. Although a considerable desire at present exists to return to what is termed *deep* draining, yet the plan only deserves that appellation when compared with the shallow system which has prevailed for some years past, and not when compared with the system of Elkington.

It is not likely that the Elkington method will in future be applied to the drainage of fields, and on that account might have been but slightly noticed; yet, as the construction of its drain is still the best for forming conduits for conveying away large quantities of water from any system of drainage, I shall minutely describe this system of draining.

Before determining the direction in which the lines of drains should run in the field proposed to be drained in Elkington's manner, it has been recommended to sink pits here and there, of such dimensions as to allow a man to work in them easily, varying the depth from 5 to 7 feet, and to expose as much of the subjacent strata as to indicate the part from which the greatest quantity of the water is seen to issue. Prior examination of the underground being requisite, pits will certainly exhibit the arrangement of the substrata to some extent; and had I pitted the bottom of the pool, the drainage of which I have described above, the depth of the quicksand would have been ascertained, and the main drain made commensurate with the circumstances of the case. In preference, however, to sinking pits, I agree with the late Mr Wilson of Cumledge, Berwickshire, that the most satisfactory mode of obtaining an enlarged view of the disposition of the substrata, and of determining the depth to which drains should be sunk, is to cut a few drains from the bottom to the top of the field.* Pits are of no use afterwards, but such lines of drains will form part of the system of drains.

Having thus ascertained the nature of the underground, the main drains should be marked off, and it is not improbable but that these trial drains may form appropriate main drains. The small drains should branch off from the main drains; and their direction may be marked off by drawing a furrow-slice along each line; but a neater plan, and one which will not spend the time

* *Prize Essays of the Highland and Agricultural Society*, vol. vii. p. 243.

of horses at all, is to set off the lines by means of pins driven into the ground, or, when the field is in grass, by small holes made in the ground with three notches of the spade, the inverted sod being left beside each hole.

It is very desirable that the stones for building the conduit of drains should be laid along the lines of the drains before these are cut, to have them at hand to fill in, and thereby save the labour of throwing out earth that may have fallen in, and of procuring additional stones for filling up the gaps thus formed, and the horses much trouble in backing the cart to the side of the opened drains, where the space is necessarily much confined. The stones should be laid on the higher side of the ground, when there is one, that the earth from the drain may be thrown upon the lower side, this being easiest for the men. When tiles and soles are used, they should be placed in a continuous row where the stones are directed to be laid down.

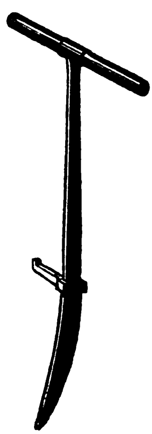
Suppose that previous examination of the substrata has determined that the drains shall be 6 feet deep, 30 inches width at top, and 18 inches at bottom, will give sufficient room for men to work in easily. The room requisite for the men should always be kept in view when cutting drains; as any space beyond this, however small, is unnecessary, and makes a considerable addition to the earth to be thrown out, and of course to the stones for filling the drain. A simple calculation will at once show the great difference in capacity between a wide and narrow drain. One of the above dimensions, namely, 6 feet deep, 2½ feet wide at top, and 1½ foot at bottom, gives an area of vertical section of 12 square feet, and, in a rood of 6 yards in length, a capacity of 216 cubic feet; whereas a drain of 6 feet deep, 3 feet wide at top, and 2 feet wide at bottom, the size recommended in a particular instance by the late Mr Stephens,* would give a vertical section of 15 square feet, and a capacity of 270 cubic feet, creating 54 cubic feet more of cutting in every rood, without at all increasing the efficiency of the drain. When special room is required for a particular size of conduit, then of course it must be afforded. But, on the other hand, too confined a space for the men to work in, will cause them to make bad work. The simple rule for the width of a drain is to give the men no more room than to work with ease at the *bottom*; and, indeed, men working by the piece, and drainage work being always measured lineally, they will invariably prefer narrow to wide drains.

* *Prize Essays of the Highland and Agricultural Society*, vol. vii. p. 222.

The cutting of drains should always be contracted for by the piece. The size I have specified above, may be cut for from 1s. 6d. to 2s. per rood, of 6 yards, according to the hardness or other difficulties of removing the subsoil. Where clay is very hard and dry, or spongy, tough, and wet, or where many boulders interfere, the larger sum is not too much; but where the subsoil can be loosened with ordinary picking, and is mixed with small sand veins and stones, the smaller sum will suffice. In every contract, it should be provided that the contractor re-fill the first portion of the earth into the drain with the spade, and that he furnish himself with all the tools necessary for the work.

The first operation in draining is to stretch the garden line from the lowest side of the field for setting off the width of the top of one of the main drains, which should occupy one of the hollows of the field where there are such. The ground is rutted with the spade along the line, and a rut made at each side of the drain, at the width suppose of 36 inches, it being a main drain and requiring a larger conduit than a small drain. The distance lined off for a division to be cast out at a time, is commonly about 4 roods or 24 yards. Three men are the best number for cutting drains most expeditiously. Whilst the principal workman is rutting off the second side of the top of the drain, the other two dig and shovel out the mould-earth face to face, throwing it upon the side opposite the stones. When the first spit of the spade and shovelling do not remove all the mould, the first man digs and shovels out the remainder when he has finished the rutting and rolled up the line. The mould is thus all quite removed along the division of the drain. Then the picking commences. One man uses the foot-pick, fig. 11, working backwards, another follows him working also backwards with a spade, and digs out the picked subsoil, while the contractor, with his face to the last man, shovels with fig. 12, the loose earth, and trims the sides of the drain. In this way the first spit of the subsoil is removed.

Fig. 11.



THE FOOT-PICK.

Fig. 12.

THE DITCHER'S SHOVEL.

The foot-pick is the most efficient implement where a number of rather large stones are found in the subsoil, and when the subsoil consists of uniformly hard dry clay, that usually rises at a time the breadth of the hand-pick. In all other states of the subsoil the hand-pick, fig. 13, is the implement most in use among drainers. In using it the man works with his face forward, and of course has his back to the man who follows backwards with the spade. The man who uses the hand-pick tramples on the earth he loosens, whilst he who works with the foot-pick does not touch the loosened earth at all, and has therefore a firmer footing to work upon. Besides, the foot-pick permits the man to use the whole weight of his body upon its handle, to loosen the resisting earth or the impeding stone; and when the earth is firm, a large lump is thus raised by it with one leverage, while the hand-pick throws the whole strain upon the arms.

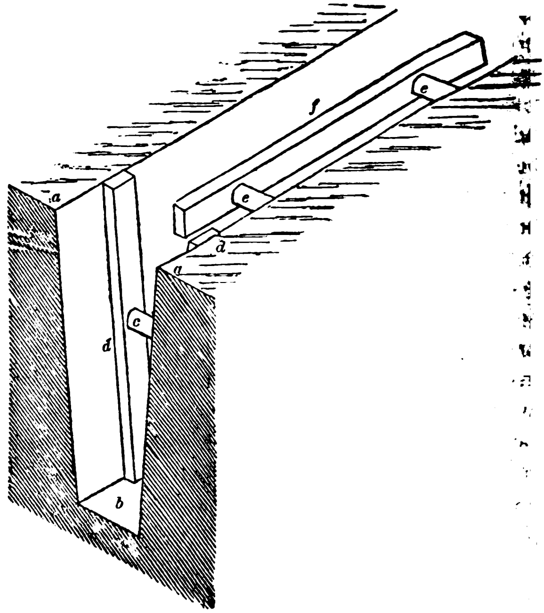
Fig. 13.

THE HAND-PICK.

Should the drain prove very wet, and danger be apprehended of the sides falling in, the whole division should be taken out to the bottom without stopping, in order to have the stones put into the drain as quickly as possible. Should the earth have a tendency to fall in before the bottom is reached, short thick planks should be provided, and placed against the loose parts of both sides of the drain, in a perpendicular or horizontal position, according to the form of the loose earth, and there kept firm by short stobs acting as props between the planks on both sides of the drain, as in fig. 14, where *a a* are the sides of the drain, *d d* planks placed perpendicularly against them, and kept in their places by the short prop *c*; and where *f* is a plank placed horizontally and kept secure, opposite another plank similarly placed, by the props *e e*. When there is no tendency of the earth to fall in, the drain may only be dug at once to half its depth.

When the earth in the drain is moderately dry and firm, the mould of another division of 4 roods may be taken off the top, and the subsoil removed as low as that in the former division. The men should then fall back on the former division, and clear out all the subsoil to the bottom of the drain. The bottom should be carefully taken out square to the sides, and made smooth on the floor, and the fall previously determined on carefully preserved, before proceeding to line off a third division. The object of this plan is to keep the diggers of the earth separate from the builders of the conduit, and to convert the half dug second division into a stage upon which to receive from and hand down the large stones of the covers of the conduit to the builders in the first division.

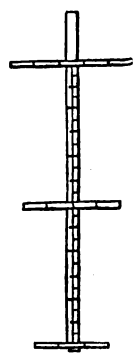
Fig. 14.



THE POSITIONS OF PLANKS AND WEDGES TO PREVENT THE SIDES OF DRAINS FALLING IN.

When a division of the drain has thus been completely cleared out, the farm-steward or overseer should ascertain that the dimensions and fall have been preserved in terms of the contract, before any stones be allowed to be placed on the bottom. I have seen it recommended to employ the builder of the conduit to ascertain these particulars; but it is always an invidious task for one contractor to check the work of another. The duty, therefore, should be performed by the farmer himself, or a neutral person authorised by him.

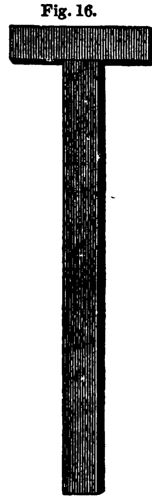
Fig. 15.



THE DRAIN-GAUGE.

Instead of measuring the dimensions of the drain with a tape-line or foot-rule, which are both inconvenient for the purpose, a *rod* of the form of fig. 15, will be found most convenient, most certain, and most quickly applied. The rod, divided into feet and inches, is put down with the arms extending along the drain, to ascertain the depth, and then turned gently round while resting on its end upon the bottom of the drain, until the points of the arms touch the earth on both sides. If the arms cannot come round square to the sides of the drain, it is narrower than was intended, but can do no harm; and if they cannot touch both sides, it is wider than necessary, and involves greater expense to fill with stones, and should be objected to.

Fig. 16.



THE LEVELLING STAFF, FOR TESTING THE UNIFORM FALL OF A DRAIN.

The uniform fall in a drain is best ascertained by means of three levelling staffs, such as fig. 16, two being about 2 feet in length, and the third about 2 feet longer than the depth of the drain, with cross-heads 9 inches long. One of the staffs is held perpendicularly on the ground at the upper end of the drain, where it is cut completely out, and another in a similar position at the lower end; and while the inspector places himself at one end of the drain, and brings his eye on a line with the upper edges of the cross-heads of the two extreme staves, he observes whether the upper edge of the cross-head of the third staff, on being gradually moved from one staff towards the other, by another person, keeps the line of those of the other two. If it does, then the fall of the bottom of the drain is uniform; but where it sinks below the other two, the bottom has been too much scooped out, and if considerable, should be filled up with earth; and where it is elevated above them, the bottom has been left too high, and must be as much cut down. When such staves are painted each of a contrasting colour, such as white, red, blue, they are easily distinguished in use.

All deep drains should be furnished with *built conduits*, to let the water have a free passage in all circumstances, and thereby save subsequent expense in re-lifting and re-building. The re-lifting of a *blown* drain, that is, one from which the water is forced to the surface of the ground, in consequence of a deposition of mud amongst the stones preventing its passage among them, is a dirty and disagreeable business for work-people, and an expensive one for their employer, as it costs at least 9d., and the filling in of the earth 1d. more per rood of 6 yards;* besides, additional

* Stephens' *Practical Irrigator and Drainer*, p. 105.

stones are required to fill the enlarged space occasioned by the unavoidable removal of wet earth along with the stones.

The building of the conduit should be contracted for as a separate operation from the cutting of the drains. If both are undertaken by the same party, there is a risk of the two sorts of work being so carried on together, to suit the convenience of the contractor and his men, as to deceive even the inspector; whereas, if one sort of work is inspected and approved before another is allowed to be commenced, both may be executed in a satisfactory manner. The building of the conduit will cost from 1d. to 2d. per rood, according to the adaptation of the stones for the purpose.* Flat handy stones can be built firmly and quickly, whereas round-shaped ones will require dressing with the hammer to bring them into proper shape, and much pinning to give them stability. The stones are furnished to the builder, and a labourer is usually provided to supply the stones as required. But circumstances may occur in which it will be more convenient to oblige the builder to quarry the stones, and supply himself with a labourer, the carriage of the stones only being furnished by the employer. A builder of dry-stone walls is better at building conduits for drains than a common mason, as he does not depend upon mortar but pinnings of small stones only, to give steadiness to the stones.

Should the ground be firm, the drain cut in summer, the length of the drain not very great, and the weather propitious, the conduit is most uniformly constructed after the drain is entirely cut, and built from the top to the bottom of the line of drain; and the uniform fall of the ground is then also best ascertained. But in ground liable to fall in, or in winter, or when the weather cannot be reckoned favourable for two days together, or when the drain extends to a great length, the safest plan is to build the conduit immediately after the earth is taken out to the bottom; and it is best built from the upper to the lower end of the division of the drain.

A convenient article in the building of the conduit is a plank of 5 inches in breadth, and from 6 to 9 feet in length, to place in the middle of the bottom of the drain, for a dry and firm footing to the builder, and one of that size answers as a gauge for the breadth of the small conduit, a space of ½ inch on each side of the plank giving it a breadth of 6 inches. The plank can easily be pulled from length to length by a short rope-end or chain attached to each end by an iron staple.

Even on ordinary subsoils of clay, the conduit should not be

* *Prize Essays of the Highland and Agricultural Society*, vol. vii. p. 242.

built without a stone sole, as water might carry away the material by degrees, and the flat stones thus laid form a permanent foundation to build the walls of the conduit upon. Indeed, in every case where a *run* of water is expected in a drain, the bottom ought first to be laid with flat stones.

Supposing the plank set down in the middle of the upper end of the cut, the stones are handed down to the builder from the surface, and it is most economical to employ a woman to do so. The conduit is 9 inches in width, and 9 inches in depth, when in a main drain, and after the building is finished to the length of the plank, the plank is pulled by the ropes another length down the drain, and so on, length after length, until the entire length of the drain, or of the next division, as the case may be, is reached. The mouth of the conduit is formed of good and selected stones; and should be protected from the inroads of vermin by close iron gratings.

But before the entire length of the conduit is built, it is covered over with flat stones, and in order that the sole of the conduit may be free of all obstructions, the builder clears it of all loose earth, stones, and other matter, with a narrow hand-draw-hoe. Immediately after this, he receives the flat covers, 2 or 3 inches in thickness, from the labourer, from the adjoining half-cast-out division of the drain, and, working backwards, lays them, extending at least 3 inches upon the walls of the conduit. The open spaces between the meetings of the covers, which will probably not be square in the ends, should be covered with flat stones, and the space between the ends of the covers and the sides of the drain should be neatly packed with small stones. The builder, in like manner, covers the conduit in successive divisions of the drain. To keep the finished conduit, on the lower division, clear of all impediments, the builder takes a firm wisp of wheat or oat straw, and shuts up its end, and which, while permitting water to pass through, seethes it of its earthy impurities.

Should the labourer have spare time from supplying the builder with materials, she throws in stones promiscuously upon the covers, until they reach a height of 2 feet above the bottom of the drain, where they are levelled to a plain surface. They have been recommended to reach the height of 4 feet, to give the water plenty of room to find its way through them; but more than 2 feet seems unnecessary, unless where water is more than usually abundant, in which case the conduit should rather be made larger, that is, deeper and broader, than the loose stones raised higher. It has also been recommended to break the upper stones as small as road-metal;* but in deep draining with large conduits there seems no good reason for such labour, which greatly enhances the cost. Ordinary land stones or quarry rubbish are quite suitable for the purpose, and the larger stones can be broken with a sledge-hammer. The builder might be employed in breaking such stones, which he will do more easily than the labourer, and the extra work included in his contract. Should all the stones be of the size required, and they had not been previously laid down, the process of putting them into the drain would be greatly expedited were they emptied at once out of the cart. This may be done by backing the cart to the edge of the drain, and letting its tilt-body rise gently, so as to pour out the stones by degrees. To save the lip of the drain, and break the fall of the stones, a strong broad board, a little longer than the breadth of the cart, should be laid along it, with its edge projecting so far over the drain as to cause the stones to fall into the middle. A short log of wood placed in front of the board will prevent the wheels of the cart going too far back. To save the covers from injury, especially when they are thin, the stones should not be allowed to fall from the cart directly upon *them*, but *upon the end of the stones previously poured in*, from which point most of the stones will roll down of themselves upon the covers without force, and the remainder are levelled by the hand before the next cart-load is emptied. Provided this mode of filling be cautiously done, it saves considerable expense, compared with the usual one of laying down the stones when the drain is ready to receive them, and then throwing them in singly by the hand. Were it determined to lay down *all* the stones before the drain is cut, this mode of filling would, of course, be inapplicable, as they would have to be thrown in singly by hand. I am aware that this mode of filling drains from the cart has been objected to by a competent authority in such matters, the late Mr Stephens, as being a dangerous practice for the safety of the drain, especially as stones carry much earth along with them.† But in deep and conduited drains I am sure no danger can arise from the practice, as I have experienced myself to a large extent with perfect impunity, and can vouch for its expedition, economy, and safeness; and as to earth being amongst the stones, as much care may be taken to avoid it when the stones are thrown or shovelled into the cart, as when thrown into the drain.

After all, when the conduit is made large enough to contain more water than will ever pass through it, there seems no use of

* *Prize Essays of the Highland and Agricultural Society*, vol. vii., p. 233.
† *Quarterly Journal of Agriculture*, vol. iii. p. 286, note.

incurring the additional expense of providing the small stones to place above the covers of the conduit.

The levelled surface of the stones is commonly covered with some *dry material* before the earth is put over them. The best substance, beyond doubt, for the purpose, when any is used, is tough turf, though it is expensive to prepare and carry from a distance; but should the field be in old grass when drained, the turf removed from the top of the drain should be laid aside by the drainers, and used for covering the stones. Other materials are also used, such as withered wrack, dried leaves, coarse grass, moss, spent tanners' bark, or straw. I much dislike to see good straw wasted for such a purpose, when manure is usually too scanty upon a farm. The object of placing any thing upon the stones is to prevent loose earth finding its way amongst them; and though any of the substances recommended will keep out earth, and continue for a time undecomposed, they will at length be converted into fine mould, except the tanners' spent bark, and probably carried down with the water when it seeks its way into the drain more easily than the subsoil itself. When the covers of the conduit are well packed about with stones, there seems no use for any dry material to put over them.

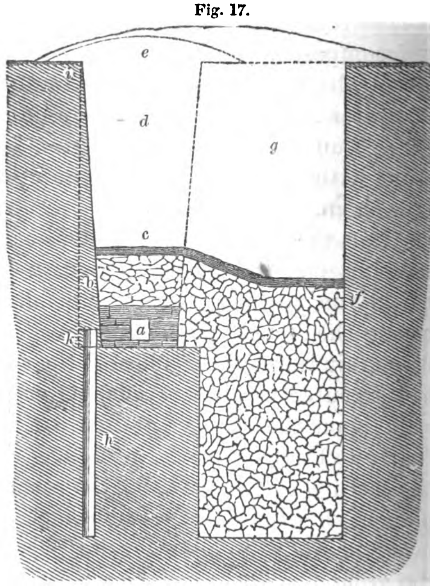
After the drain has been sufficiently filled with stones, and a covering put upon them, the earth should be returned into it as quickly as possible, in case rain fall and wash it down the sides among the stones. The filling in of the first part of the earth of a deep drain is usually included in the contract made with the drainer, and executed with the spade, because it is not safe for a horse to walk upon the edge of a deep drain until the earth is filled in nearly to the level of the ground. The men may either put in all the earth with the spade, or the remainder may be put in with the plough; but in any case a little mound of earth is left immediately over the drain, to allow for its subsidence to the original level of the ground. There will be much less earth left over the filling of a drain than would be imagined from seeing the quantity thrown out, and the space occupied by the stones; and in every case the mound soon subsides, especially in rainy weather.

These are all the remarks requisite to the formation of main drains, and these will be found useful as tail-drains to convey away large bodies of water from any system of draining that may be adopted.

The small drains are set off as branches from both sides of the main drains at all angles that may suit the inclination of the ground; but the steeper the acclivity is, the drains are set off in a more horizontal direction; but whatever be the position of the small drains, they should enter the main drains at a smaller angle than a right angle in the direction of the run of the water. The small drains are lined off immediately above the dark lines seen on the ground from the issuing of spring water to the surface, and are formed as deep as all the water it is conceived will be carried off by them. The conduits of small drains are made 6 inches square, and constructed exactly in the same manner as those described for the main drains. As it is highly improbable that such drains will now be employed for the ordinary drainage of land, it is unnecessary to allude to them farther; but other expedients for removing water in connexion with them may be mentioned.

The section of a small drain, 6 feet deep, is seen in fig. 17, where *a* is the opening of the conduit 6 inches square, built with dry masonry, on a basement of flat stones, and covered with a flat stone at least 2 inches thick; and above it is a stratum of loose round stones, *b*, 12 or 14 inches in thickness. The covering above the stone is *c*, and the earth returned into the drain is *d*, with the portion, *e*, raised mound-wise a few inches above the ordinary level of the ground.

Fig. 17.



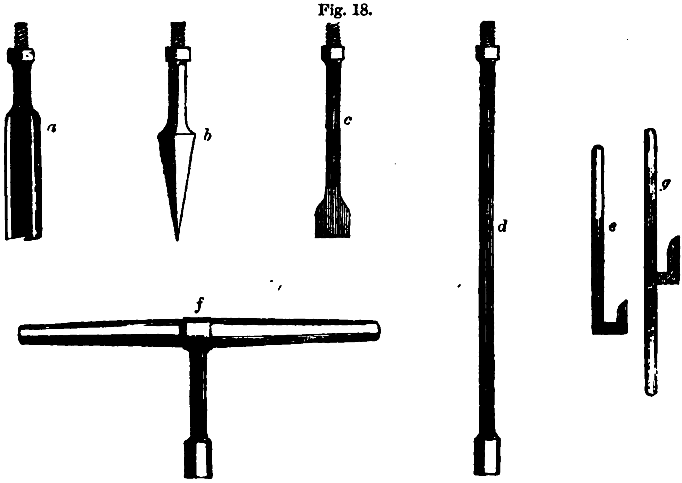
THE DEEP CONDUITED DRAIN, WITH WELL AND AUGER BORE.

Should water be supposed or known to exist in *quantity* below the reach of even a 6 feet drain, means may be used to abstract it, and these means are, sinking wells or boring holes into the substrata beside the conduit. A *well* is made as represented by a part of fig. 17, where a pit *g* of the requisite depth is cast out on one side of the drain *d*. A circular or square opening, of 3 feet, will suffice for a man to work down several feet by the side of the drain *d*, and when the stratum which supplies the water is reached, the well should be filled with small stones to about the height of those in the drain, to *f*, and covered with dry substances as from *f* to *c*, and the earth filled in again above all, to *g* and *e*. In making such a well, a small scarcement of solid ground should be left between it and the conduit, that its foundation may run no risk of being shaken by the operations connected with the making of the well. I fear this precaution is not so much attended to in the making of drain-wells as it ought to be.

The *auger* may be used instead of the well for the same purpose, by boring through a retentive stratum into a porous, whereby the confined water may be brought up by altitudinal pressure into the bottom of the drain and escape; or free water run down the bore and be absorbed by the porous stratum below. In the first case, the water has to be discovered; and in the second, it is seen and got rid of by running down the bore from the drain. The boring the bottom of a drain should be made at one side and not in the middle, as the sediment would be carried by the current of the water into the bore and probably choke it, when the water went in or came up with a small force. In preparing to make the bore at the side, let a cut, *i k*, fig. 17, be made down the side of the drain, terminating at a little higher level than its bottom; let the bore be made through the solid ground, in the direction of *k h*, as far as necessary; and let an opening be left in the building opposite the top of the bore, to allow the water to flow easily into or from the drain.

The *boring-irons* useful for finding water in a field, or for drain-

Fig. 18.



THE INSTRUMENTS FOR BORING THE SUBSTRATA OF DEEP DRAINS.

ing or ascertaining the depth and contents of a bog, are the following:—The *auger*, *a*, fig. 18, is from 2¼ to 3½ inches in diameter, and about 16 inches in length in the shell, the sides of which are brought pretty close together. It is used for drilling a hole in the ground, and bringing up the drilled earth. When harder substances than earth are met with, such as compact gravel or thin soft rock, a pyramidal *punch*, *b*, is used, to penetrate into, and make an opening for the auger. When rock intervenes, then the chisel or jumper, *c*, is used to cut through it; and its face should be of greater breadth than the diameter of the auger to be afterwards used. There are *rods* of iron, *d*, each 3 feet long, and 1 inch square, unless at the joints, which are 1½ inch in diameter, with a male screw at one end, and a female at the other, for screwing into any of the above instruments, or into one another, to make a long rod, to allow the descent of these instruments. The short iron *key*, *e*, is used for screwing and unscrewing the rods from the instruments and from one another. A *cross-handle* of wood, *f*, having a piece of rod attached to it, with a screw to fasten it to the top of the uppermost rod, is used for the purpose of wrenching round the rods and auger, and for lifting up and letting fall the rods and jumper, when these are used respectively. The long iron key, *g*, is used to support the rods and instruments as they are let down and taken up, while the rods are screwed on or off with the short key, *e*. Three men are as many as can conveniently work at the operation of boring a drain.

As I have never witnessed the use of the auger in draining, though I have on a large scale in mining, and the formation of Artesian wells, I will give a description of the manner of using it in draining, from a competent authority. "Two men," says Mr Johnstone, "stand above, one on each side of the drain, who turn the auger round by means of the wooden handle; and when the auger is full of earth they draw it out, and the man in the bottom of the drain clears out the earth, assists in pulling it out, and directing it into the hole. The workmen should be cautious, in boring, not to go deeper at a time, without drawing, than the exact depth that will fill the shell of the auger, otherwise the earth, through which it is boring, after the shell is full, makes it more difficult to pull out. For this purpose, the exact length of the auger should be regularly marked on the rods from the bottom upward. Two flat boards, with a hole cut into the side of one of them, and laid alongside of one another over the drain, in time of boring, are very useful for directing the rods in going down perpendicularly, for keeping them steady in boring, and for the men standing on when performing the operation." *

Thus it appears that Elkington's method may still be applied to the making of large tail-drains, to convey away quantities of water from any system of drainage, and to the drainage of deep bogs by boring and the sinking of wells. In all these cases it will be attended with complete success.

I have, however, made many drains along the lines of spouts of water and across the sloping faces of fields, to the depth of even 6 feet, and never less than 4, without drying more land than their own breadth. In these cases, I considered the cost of making them thrown away; whilst in other cases, 4-feet drains have completely removed the spouts, though the subsoil was apparently the same in both cases. It is possible that small veins of sand, in the unsuccessful cases, may have dipped away from the line of drain, and the water had ceased to flow towards them, while, in the successful ones, the sand veins may have been intersected with a favourable inclination for discharging water into the drain. Whatever difference may have existed on the component parts of the substrata in these opposite cases, the results were obviously indicated upon the surface; and such results call loudly upon us to make minute investigations of the substrata, before prosecuting draining to a large extent; and they instruct us to look for some other mode than Elkington's for the general drainage of our fields.

The *principles* of Elkington's mode seem to depend on three alleged facts. 1. That water from springs is the principal cause of the wetness of land, and if it be not removed, nothing effectual in draining can be accomplished. 2. That the bearings of springs to one another must be ascertained before it can be determined where the lines of drains should be opened; and by the bearings of springs is meant that line which would pass through the seats of *true* springs in any given locality. Springs are characterised as true ones when they continue to flow and retain their places at all seasons; and temporary springs consist of bursts of water, occasioned by heavy rains, appearing at the surface, at a *higher* level than permanent springs, and they are also occasioned by true springs leaking water, which always appears at a *lower* level than the true springs themselves. Without due consideration, the appearances assumed by temporary springs may easily be mistaken for those of true ones. It is evident that drains formed through mere *bursts* of water cannot effectually drain land, which can only be

* Johnstone on *Elkington's Mode of Draining*, p. 111, 8vo edition.

accomplished by their passing through the lines of true springs. 3. That tapping the spring with the auger is a necessary expedient, when the spring is too deep for a drain to reach it.* From these statements, it appears that true springs are to be found neither at the top nor at the base of a rising ground, but that temporary springs may be found at both; that the more extensive the acclivity, the more numerous the springs, whether true or temporary; that true springs on the side of a rising ground may be removed by branch drains; and that at the base of rising ground the leakage of true springs may originate bogs or swamps. Hence, Elkington's mode is adapted only to these peculiar cases. It has been very extensively, and, I must add, successfully practised in Scotland, for the removal of true springs. The system would have ample scope in Ireland, where bog still exists to an incredible extent; and in England also, where the regularity of alluvial deposits in many of the western and southern counties might give employment to the auger to great advantage, in removing quantities of concealed water; but in Scotland, where irregular superficial deposits abound, the system of tapping is inapplicable, though, of course, it might prove successful in bogs resting on alluvial strata.

Stagnant Water is the greatest Source of Injury to Land.

Whatever may have been the case formerly, the soil of Scotland is *not now most injured by springs.* Such injuries have long been removed by the application of Elkington's mode of draining. As experience indicated that injury was sustained by land from water other than from springs, a modification was introduced into that system; but being in direct opposition to its principles, no surprise need have been excited when it ended in failure; though the failures had the effect of bringing an otherwise excellent and efficient mode of draining into disrepute. The modification I allude to, consisted in cutting *deep* drains in all directions, irrespective of the arrangement of the subjacent strata, and filling them nearly to the top with stones of any size, and in any order. Much cost was incurred by this thoughtless practice, and when it proved unsatisfactory in its results, disappointment ensued, and that blame was imputed to a system which ought to have been borne by those who abused it.

The chief injury now sustained by the soil is caused by the

* Johnstone on *Elkington's Mode of Draining*, p. 11, 8vo edition.

stagnation of rain-water upon an impervious subsoil. Most of the soil of Scotland consists of loam, of different consistence, resting on tenacious clay, of unequal depth. Where the soil is shallowest, it is injured by the stagnant water remaining constantly beneath it; and where deepest, it is injured by chilly exhalations.

The injury done to soil by stagnant water, may be estimated by these effects. Manure, whether putrescent or caustic, imparts no fertility to it; the plough, the harrow, and even the roller, cannot pulverise it into fine mould. The new grass contains little nourishment for live stock; and in old, the finer sorts disappear, and are succeeded by coarse sub-aquatic plants. The stock never receive a hearty meal of grass, hay, or straw, being always hungry and dissatisfied, and, of course, in low condition. Trees acquire a hard bark and stiffened branches, and become a prey to parasitic plants. The roads are constantly soft, and apt to become rutted; whilst ditches and furrows are either plashy, or, like a wrung sponge, ready to absorb water. The air always feels damp and chilly, and, from early autumn to late in spring, the hoar-frost meets the face like a damp cloth. In winter the slightest frost encrusts every furrow with ice, not strong enough to bear one's weight, but just weak enough to give way at every step, while snow lies long lurking in shady corners and crevices. In summer, musquitoes, green-flies, midges, gnats, and gadflies, torment the cattle, and the ploughman and his horses, from morning to night. In autumn, the sheep get scalded heads, and are eaten into by the maggots of the green and carrion flies, during hot blinks of sunshine. These are no exaggerated statements, but such as I have observed in numerous situations—in hill, valley, and plain; and wherever any of these phenomena occur, it may safely be concluded that stagnant water lurks beneath the soil.

The only way of draining the stagnant water which produces such effects is to allow it to pass away through moderately deep and numerous drains; for Elkington's deeper drains cannot take it away at the distances they are usually made. This mode is now generally named *thorough-draining.*

The Particulars which determine the Minimum Depth of Drains.

It is sufficiently obvious that *depth* is a more effective condition of a drain for drying the soil than width, but what should be the exact depth in every case of thorough-draining is not so easy to determine. It would be one step towards the solution of this practical problem were the *minimum* depth of drains determined in every class of soils, which I shall now endeavour to ascertain.

A drain is not a mere ditch for the conveyance of water; were it only so, its size would be determined by simply ascertaining the quantity of water to be conveyed away in a given time; just as a pipe is chosen of the size wanted to carry a given quantity of fluid to a given point. The principal function of a *drain*, as its very name implies, is to *draw* water towards it through the soil from every direction; and its subsidiary purpose is to serve as a ditch to convey it away when collected. This is the popular notion of the functions of a drain, but the mode in which a drain *draws* the water towards it is not distinctly understood. It does not draw the water to it as a horse pulls a boat along a canal by traction, or as the mouth draws water into it by suction, or as water is forced up an artesian bore by altitudinal pressure, but simply in this way: by removing the obstacles which prevented the water descending to a lower level, the force of gravity is allowed to act freely on the water, and without their removal gravity would remain dormant, and the water stagnant. These being the necessary functions of a drain, it follows, in theory, that the larger the area the sides of a drain present to the materials out of which the water is to descend into it, every other particular remaining the same, it should produce the greater effect; but in practice it is found, that the larger extent of area, even in the same locality, does not always afford a larger supply of water. So that the depth of each drain should be determined from the condition of the particulars amongst which it is to be placed.

Now, what are the ordinary circumstances in practice which determine the *minimum depth* of drains? In the first place, the culture of the ground determines it; for were land never ploughed, and in perpetual pasture, very little more soil than would support the pasture grasses would suffice to cover a drain, and this need not exceed a few inches in thickness. The plough, however, requires more room; for the ordinary depth of a furrow-slice is seldom less than 7 inches, and in cross-ploughing 9 inches are reached, and 3 inches more, or 12 inches in all, exclusive of the space occupied by the materials which fill the drain, may suffice to give room to the plough in ordinary use; but, in many instances, land is ploughed with 4 horses instead of 2, when the furrow will reach 12 inches in depth; and should the four-horse plough follow in the furrow of the common plough, the depth reached will be 16 inches, so that 19 inches of soil are required in such a case above the materials of a drain to place them beyond the reach of a plough. Further, subsoil ploughing is sometimes practised, and it may penetrate 16 inches below the ordinary furrow of 7 inches, so that 26 inches of earth are required on the upper part of a drain, to place the materials filling it beyond the risk of being disturbed by the plough. The *minimum* depth of 26 inches above the materials is thus determined by practice alone; but as the ploughed part of the ground at all times admits water easily, by mere absorption, it ought not to be regarded as a part of the drain about to be formed, so that the effective part of every drain lies entirely below the ploughed surface, which in Scotland is generally 7 inches in depth. The *shallowest* drain above the materials ought thus to be 19 inches below the furrow-slice, or 27 inches below the surface of the soil.

The depth of the ploughed surface, the height of the materials filling the drain, and the 3 inches above these, always remaining the same, the question is, what data do we possess, to determine how much deeper a drain should be cut than any ploughing can stir the subsoil, to produce no more than the *minimum* degree of effect? In the first place, we know that subsoils possess very different degrees of porosity, always assuming that no subsoil exists but what permits the passage of water through it at some time and in some degree; and we also know that a really porous subsoil, when intersected, will exhaust all its water in a much shorter time than one of an opposite character. Judging from observation alone, not from experiment, I should say, that 1 inch thick of porous materials will discharge as much water in a given time as 10 inches of tilly, and 18 inches of truly tenacious clay.

These proportions are doubtless arbitrary; but I think every observant drainer will own, that the comparative discharging effect of a truly porous and really tenacious subsoil, is not stated at an exaggerated ratio at 18 : 1. So far is this proportion from being likely regarded as extravagant, most people would at once believe that 1 inch of sand or gravel would part with its water much faster than 18 inches of clay, and such I have no doubt is really the fact, in as far as the element of *time* is concerned; because gravity has liberty at once to act on the water when a stratum of porous subsoil is cut through, whereas tenacious clay requires some time, even to begin to discharge, though gravity will make the water to pass through clay as well as gravel; but the fact is, that time is an element which should not be considered in treating on the art of draining, for plenty of time will be afforded them to discharge all the water that can possibly reach them.

The conclusions to which this reasoning would at once conduct us to determine the *minimum* depth of drains in the various kinds of subsoils, are these:—

	Porous subsoil. inches.	Tilly subsoil. inches.	Clay subsoil. inches.
Ploughed surface, . . .	7	7	7
Depth for subsoiling, &c., . .	16	16	16
Thickness of earth above the filling materials, .	3	3	3
Height of tiles and soles, say . .	6	6	6
Depth of discharging effect of subsoils, . .	1	10	18
Hence the *Minimum* depth of drains in porous subsoils, is	33		
" " tilly " .		42	
" " clay " .			50

When stones are used for the filling materials, perhaps 6 inches more should be added, making a porous *minimum* drain 39 inches deep, a tilly *minimum* 48 inches, and a clay *minimum* 56 inches.

Reasoning such as this has led us to an opposite conclusion to the opinion generally entertained of clay subsoils. It is conceived useless to form any other than shallow drains in clay subsoils, since water cannot pass through them. This, we see, is a great error. On the contrary, water will find its way through clay, both by gravitation and evaporation, as effectually as through sand or gravel. Witness the state of the surface-soil in the Carse of Gowrie in a dry season, how dusty and hard it becomes; and every one who has cut a drain in hard dry clay, and left it open for a few days, knows that water will certainly make its appearance on the bottom in even very dry weather; and, on close inspection, the sides of the drain may be seen to ooze out water. Clay, no doubt, possesses a strong affinity for water, and as long as they remain in contact, the clay will retain its retentive property, but *make* the water leave it, and it assumes a different character by shrinking, which, causing numerous cracks, gravity *makes* the water descend through them. Every one, I presume, has seen the form which the pulpy starch of wheat assumes on being dried in pans in ovens in the manufacture of starch for domestic use. The bits of starch assume a columnar form, not unlike that presented by basalt columns, and their position in the pan is always perpendicular, though not extending to its whole depth. In like manner clay, in drying, assumes a similar columnar form, a phenomenon which may be seen every year, on a great scale, in active operation at the mouths of the rivers in Northern Africa, as mentioned by Shaw in his travels in Barbary. The clay in our subsoils, in drying, assumes the same columnar form and perpendicular position, and the columns are more or less perfect in form, according to the presence or absence of disturbing causes; but, between the most imperfect form, there is no difficulty in detecting innumerable fissures. Indeed clay, in thus assuming a form, is only following the great law of molecular action, which arranges molecules in that particular form which distinguishes the crystallisation of every species of mineral. The fissures are just spaces left by the irregular molecular arrangement of the clay, and constitute innumerable ducts down which the water descends by the force of gravity. Notwithstanding these illustrations, should a difficulty occur to the mind of any one in regard to the manner in which clay parts with water, let him be assured that, whenever a drain is formed in clay, gravity will impel the water to move towards the lowest point, that is, to the bottom of the drain. Indeed, it would be beyond the power of man to prevent water finding its way through the most tenacious clay into a drain.

It is thus consonant with reason to give the greater depth to a drain in a subsoil that permeates water slowly, whilst a smaller depth in one that permeates freely, will be equally efficient. Keeping these important distinctions in view, the drainer will soon learn the use to be made of them in the construction of efficient drains. I guard myself by saying *efficient* drains; for drains can be ill made, though planned on the most correct principle. The correct principle is to fix the minimum depth of the drain, according to the nature of the subsoil, and make it as much deeper as circumstances will permit. Until this principle is adopted by drainers as an immutable rule, I am of the opinion that the greatest proportion of the shallow drains now forming in this kingdom will prove worthless in the course of a few years.

The results given above must be regarded as the *minimum* depth of drain in each case of subsoil, and in numbers these range from 33 to 50 inches. Whether it would be proper to make deeper drains in the respective subsoils, must depend on the circumstances of expense, the obtaining of suitable materials, and such like. But if an error is likely to be committed in determining the depth of drains, it is better to err on the safe side, by making them deeper than wanted, rather than shallower; for, in the former case, no loss would arise from the effects connected with the drain, but simply from an excess of outlay. No one ever wished he had made his drains shallower, or lamented having over-drained his land; but I believe many may be found who wish they had drained their land more effectually, either by deeper or a greater number of drains.

Open Ducts for Drains.

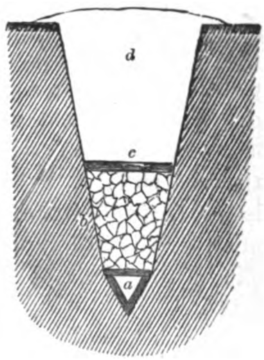
Viewing drains as mere *channels for the conveyance of water*, the more quickly they promote its emission without injuring themselves or the land, they act the more characteristically; so that an open duct should be preferred to loose stones, however well broken for the purpose, because of its affording a freer passage for water; and this point being conceded, it follows as a corollary, that a drain provided with an open duct will act most efficiently. Viewing drains as a *gravitator* of water, the deeper the drain the more water will be brought towards it; and the more porous, and the greater the thickness of the materials of the subsoil, they will allow the water an easier passage through them. So that, as a gravitator as well as a conveyer of water, a drain should have an open duct for the water to pass quickly through it. I crave particular attention to this mode of reasoning in support of the use of open ducts, as I believe very erroneous notions prevail amongst farmers regarding their utility; but those notions have been formed most probably more on account of the cost of ducts, than of any valid objection against their usefulness.

Various substances are employed as ducts, 1*st*, dry stones, built as seen at *a*, in fig. 17,; 2*d*, a coupling of flat stones set up against each other as a triangle, or, in a more rude way, two round stones set one on each side of the drain, with a flat one, or a large round one, to cover them; 3*d*, clay tiles, arched and in pipes; 4*th*, wooden tubes. One and all of these forms of ducts answer the purpose, and should be selected according to the facility of obtaining them.

Ducts of *stone* are formed in various ways, the strongest being built with masonry and covered with strong flat stones, as in fig. 17, *a*.

Two flat stones placed against each other at the bottom of the drain, either resting upon or covered by another stone, and the three making an equilateral triangle, of 6 inches in the side, make a tolerable duct. The latter may be seen in fig. 19, where *a* is the equilateral duct, *b* the small stones above it, gathered from the land or broken for the purpose, to a height of twelve inches, then covered with turf or other dry substance, *c*, and the earth, *d*, returned above the whole. This form of duct requires the drain to be 18 inches wide at top, to allow the drainer room to work while standing on the narrow angular bottom. Placing the apex of the triangular duct undermost, allows the water to sweep away the sediment and prevent it lodging along its bottom; but it has the disadvantage of letting the water pass by its own gravity through the joining of the stones to the subsoil, and so to soften it into a pulp. It is besides possible for an angled stone to get jammed in the narrow gutter, and form a damming against the water.

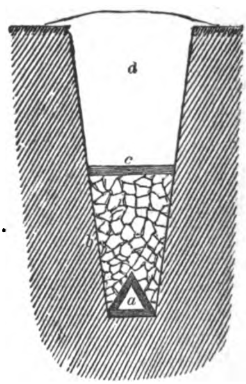
Fig. 19.



THE TRIANGULAR STONE DUCT.

Another triangular duct, also of 6 inches in the side, may be seen in fig. 20, at *a*. This form encourages a deposition of sediment upon the flat sole, but prevents the descent of water under the sole to any dangerous extent. Having a flat bottom, the drain may easily be cast out with a width at top of only 15 inches. The sloping stones of the duct are held in their position by stones placed as wedges between them and the earth, and the drain is finished by 12 inches of small stones, *b*, covered with turf, *c*, and the earth, *d*, returned above them.

Fig. 20.

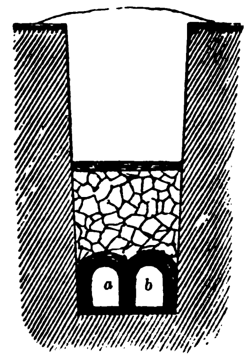


THE COUPLED STONE DUCT.

A more perfect duct than either of these is made by a tile and sole. A tile 2½ inches wide and 3 inches high, will contain a large body of water, but should one be insufficient for the purpose, 2 may be placed side by side, as represented by *a* and *b* in fig. 21. Should a still larger duct be required, a sole might be placed upon these, and one or two tiles set upon it. Stones may be placed or not upon such a duct. Or, a tile may be inverted on the ground upon its circular top, as *a*, fig. 22, bearing a sole, *c*, upon its open side, and the sole supporting another tile, *b*, in the ordinary position.

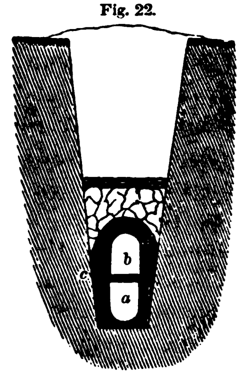
In this form, it is rather difficult to make the undermost tile, *a*, stand steadily on its top, unless the earth is taken out of a rounded form, or the tile carefully wedged into the desired position. A greater difficulty still is felt in making the uppermost tile, *b*, stand in that position upon the edges of the inverted one, without a sole, as recommended by some writers on draining, and practised, I observe, by some drainers. It is evident that the least displacement of either tile will cause the upper one to slip off the edges of the under, and fall into it.

Fig. 21.



A DOUBLE TILED DUCT.

Fig. 22.



AN INVERTED DOUBLE TILED DUCT.

A pipe-tile duct is seen in fig. 55, and should one pipe be insufficient to convey away the water, two may be placed side by side, as in fig. 21, and even a third above them. All the ducts I have described are suited both for main and small drains, the stones and tiles of the former requiring to be larger, but the relative proportions between the ducts and the depths of the drains are not attempted to be given in the figures.

Necessity of Using Soles for Ducts.

It is maintained by geologists that water has no abrading effect on any kind of rock, and it seems a prevalent opinion amongst farmers, that hard clay may withstand, for any length of time, the action of water in a drain. It cannot be denied, however, that water will soften clay, dissolve saline substances, and even suspend and carry along with it, at a high velocity, mineral substances, which by friction will polish the hardest rocks.

Farmers, judging of the hardness of clay from its state when the drain is cut, erroneously imagine that it will always remain so; and the common practice of dispensing with the use of soles evinces the strength of the opinion. Yet it is marvellous how such an opinion should be held by those who have daily opportunities of observing the operations of nature; for every farmer knows that clay is softened by rain at the surface of the ground, and when drains are formed in clay for no other purpose than to conduct water along their bottom, they should know that water will soften clay as easily at the bottom as at the top of a drain. *Why* it should *not* produce the same effect in both places, it is for sceptics to explain. The idea of economy, however, I suspect, is allowed to overpower the force of reason in this case. It is cheaper, in fact, to use an arched tile alone, than an arched tile and sole. Such an indisputable pecuniary argument will soon convince the minds of some to neglect the sole.

The usual effects on clay subsoils becoming soft by water are seen by the lower stratum of stones, and the edges of tiles becoming imbedded in it to so considerable a depth, as to form dams which prevent the flow of the water, and cause it to burst up through the soil. When drains so burst, they are said to have *blown*, and many cases of blowing have occurred in Ayrshire wholly from the want of soles. In softer subsoils, the sandy particles are carried along with the water, and deposited in heaps in the curves and joinings of drains; and where subsoils are more sandy still, the foundation supporting the building or tile gives way, and when the materials are displaced, they form obstructions that render the upper part of the drain almost useless. There is less risk of such obstructions being formed with pipe-tiles than with common tiles or stones, since there is less chance of the bore of the pipe being filled up than either of the other two. Water also carries sand down the sides of a drain, and where no ducts are used, deposits it among the lowest stratum of stones. Thus many chances of derangement occur in a drain, where no soles are used to keep the subsoil clear. For these reasons, I am a strenuous advocate for drain-soles in *all* cases; and where even such a precaution may prove of little service, I would rather use too many than too few expedients in draining, as with the most perfect workmanship, we cannot tell what change may take place in the interior of a drain, which we are never permitted, and have no desire again to see.

Natural materials for filling drains are usually scanty upon a farm. They consist only, 1*st*, Of small stones gathered by hand from the surface of the land; 2*d*, Small stones prepared in a quarry; and, 3*d*, Gravel, obtained from the bed of a river, the sea-beach, or screened from a gravelly knoll.

Estimation of the Quantity of Water to be conveyed by Ducts.

It is of consequence to ascertain the quantity of rain that falls in every locality, before breaking ground for thorough drainage, in order to provide the number, and determine the size of the ducts to convey away the water, and the quantity depends upon the climatic character of the locality. More rain falls on the west than the east coast of this kingdom, and the ratio is as 8 : 5 ; the quantity of rain falling at Edinburgh being 26, and at Greenock 40 inches in the year. It does not follow, from this ratio, that double the number or capacity of drains are required to keep the soil in the same state of dryness on the western as on the eastern coast ; but that the drains in the west will have nearly twice as much water to convey in the course of the year as those in the east. Nor does it follow that the quantity of water to be conveyed in the drain, is to be measured by the absolute depth of rain that falls in any place ; because as a drainer observes, "the water which flows from a drain is considerably less at any one time than what formerly ran on the surface ;" and this is an anticipated result, as evaporation and vegetation combined must dissipate and assimilate a large proportion of the water that falls on the ground before it passes into the sub-soil.

To obtain somewhat accurate data on this subject, the late Mr James Carmichael, Raploch Farm, Stirlingshire, a midland county, and therefore experiencing an average fall of rain in Scotland, ascertained that

a length of 200 yards, and the distance from drain to drain 18 feet, where the *square feet of surface* receiving rain-water for each drain amount to 10,800, at 2 inches of rain in 24 hours, will give 1800 cubic feet of rain-water ; and taking the sectional area of the smallest tile of 2½ by 3 inches at 7·5 inches, and the water moving in this aperture at the rate of 1 mile per hour, the number of cubic feet discharged by the drain in 24 hours will be 6,600 or nearly four times as much as is necessary to carry off so great a fall of rain as 2 inches in 24 hours;

and this besides what was taken away by evaporation and vegetation. The late Mr Stirling of Glenbervie has also given similar testimony of his experience in Stirlingshire in regard to the quantity of water conveyed by drains.

I have only three sets of drains, he says, in which I know the exact fall in the mains near the mouths and the area drained. The land is mostly stiff clay, having in some places a fall of 1 in 6, and for 60 yards from the mouths of the mains only 1 in 140 ; is drained at 15 feet ; the main tiles are 2¾ by 3½ inches, and the rain which falls on 5 superficial roods is discharged at each mouth. I find the tiles nearly

$\frac{3}{4}$ full after very heavy rain; therefore that size of tile would, with the same declivity, pass the rain which falls on nearly two acres; and if the fall in the side drains were less, the water would never stand so high in the mains.*

In both these cases the quantities of water passed through drains in *stiff clay*, a substance erroneously believed preventive of the passage of water through it; and, besides the dispersion by evaporation and vegetation, it may reasonably be supposed that much of the rain ran off the surface of the clay, and consequently, by a porous soil much more of it would have been absorbed. Drains in clay subsoils thus require smaller ducts than those in porous. It is obvious that a small orifice will suffice to carry off much more water than can possibly fall from the heavens in these latitudes at any time; and that in ordinary rains the drains will be no more than wetted. Still *all drains should be capacious enough to carry off the largest quantity of rain that ever fell in the locality.* Drains intersecting true springs will always contain a run of water; and spring water may be distinguished when issuing from a drain from any other, in summer by its low temperature, and in winter in sharp frost, by vapour hovering above the mouths of the drains. The explanation is that spring water is colder than the air in summer and warmer in winter.

The inquiry into the discharge of water through the soil being an interesting one, it may be prosecuted a little farther. If we suppose the rain falling on the surface of an imperial acre of land in the year to be $26\frac{6}{10}$ inches in perpendicular depth, it would amount to 96,563 cubic feet=2711 tons, which, spread over a twelvemonth, gives an average of $264\frac{1}{2}$ cubic feet = $7\frac{4}{10}$ tons a-day per acre. As 1 inch of rain in depth amounts to 101·91 tons per acre, the above daily average fall is about $\frac{7}{100}$ths of an inch in depth. By a set of careful experiments in the county of Hertford, near King's Langley, in the years 1836 to 1843 inclusive, by the eminent paper-maker, Mr Dickenson, of Abbots' Hill, instituted to ascertain the quantity of rain that falls and is filtered through the earth, as indicated by the common rain-gauge and Dalton's gauge, it appears that, of the whole annual rain, about $42\frac{1}{2}$ per cent., or $11\frac{17}{100}$ inches out of $26\frac{6}{10}$ inches, filter through the soil, and the annual evaporative force is only equal to the removal of about $57\frac{1}{2}$ per cent. of the average rain which falls. As might be expected, only about 25 per cent., of the rain which falls from October to March inclusive, passes back to the atmosphere by evaporation; whereas, from April to September inclusive, about 93 per cent. is

* *Prize Essays of the Highland and Agricultural Society,* vol. xii. pp. 94 and 100.

evaporated. During the six coldest months, from October to March inclusive, it also appears that the mean excess of rain-water to be disposed of by some other process than evaporation amounts to no less a weight than about 1050 tons per acre. *This* amount of water, if not *drained off* by the natural porousness of the soil, or by artificial drains, must remain stagnant upon retentive subsoils; but these figures, it should be remembered, apply to Hertfordshire, not to Scotland.

Now, let us consider whether ordinary drains could convey such a body of water.

I am able to demonstrate by simple arithmetical computation, says Mr Parkes, how very small is the quantity of water required to enter the crevice formed by the imperfect junction of two pipes. The rain-gauge informs us that $\frac{48}{100}$ths of an inch in depth of rain fell upon each square foot of surface on the 7th and 8th November, 1843, in the observed time of 12 hours. This quantity is equivalent to $69\frac{1}{10}$ cubic inches or $2\frac{1}{2}$ lbs., which, divided by 12 hours, gives little more than $\frac{2}{10}$ths of a pound per square foot of surface per hour for the weight of the rain.

The drains are 24 feet asunder, and each pipe 1 foot in length, so that each lineal foot had to receive the water falling on 24 square feet of surface, equal to 60 lbs. or 6 gallons; and, as the time which this quantity occupied in descending through the soil and disappearing was about 48 hours, it results that $1\frac{1}{4}$ lb., or 1 pint per hour, entered the drain through the crevice existing between each pair of pipes. Every one knows, without having recourse to direct experiment, how very small a hole will let a pint of water pass through it in an hour, being only one-third of an ounce per minute, or about twice the contents of a lady's thimble.

The weight of rain per acre which fell during the 12 hours amounted to 108,900 lbs., or 48 $\frac{6}{10}$ tons, which, on the whole piece of 9 acres, is equal to 437 $\frac{4}{10}$ tons; and each drain discharged 19 tons, equal to about $\frac{4}{10}$ths of a ton per hour in the mean of 48 hours; but, when the flow was at the greatest, I find that such drain must have discharged at the rate of five times this quantity per hour, which affords proof of the facility of *inch-bore* pipes to receive and carry off a fall of rain equal to $2\frac{1}{2}$ inches in 12 hours, instead of half-an-inch, a fall which is quite unknown in this climate. Half-an-inch of rain in 12 hours is a very heavy rain. I learn from Mr Dickenson that his rain-gauge has never indicated so great a fall as $1\frac{1}{2}$ inch in 24 hours; and from Dr Ick, the curator of the Birmingham Philosophical Institution, that only on five occasions has the rain there exceeded 1 inch in 24 hours, during the same period of 8 years, the greatest quantity having been $1\frac{6}{10}$ inch on 4th December 1841.*

The conclusion which Mr Parkes would wish to enforce from these facts is this:—"We may, therefore, consider the fact of the sufficiency of inch-bore pipes for agricultural drainage to be fully demonstrated both by experience and experiment;"† and certainly, if inch-bore pipes can effect such a result, no apprehension need be entertained of the capability of any other material commonly used

* On Monday and Tuesday, the 22d and 23d of June 1846, $2\frac{8}{10}$ths inches of rain fell in Edinburgh in the course of 36 hours, as indicated by the rain-gauge of Messrs Adie and Son, the eminent opticians.

† *Journal of the Royal Agricultural Society of England*, vol. v. p. 153.

in conveying away the water; but farther observations are required to confirm the results of those experiments; for in the great rain referred to by Mr Parkes, the "greatest stream at the outfall of each drain amounted to about the half-bore of the inch-pipes," in drains at 24 feet apart; whereas, Mr Stirling found "the tiles nearly $\frac{2}{3}$ full after very heavy rain," his tiles being mains of $3\frac{1}{2}$ by $2\frac{3}{4}$ inches, in drains in clay land at only 15 feet apart, and commanding the discharge of 5 superficial roods of land. The great discrepancy between these two cases, in probably similar subsoils, I should like to see cleared up.

Fields should be Drained in succession.

Having ascertained the greatest quantity of rain that may fall in the locality, the next step is to drain every field in succession, and the field to commence with should occupy the lowest part of the farm. As drains are most conveniently made at one member of the rotation of crops, it may happen that the field which comes next in succession for drainage is not the lowest one. Notwithstanding, it should be selected for commencing the drainage; and care must be taken not to let the water from it make the field below wetter. The best period in the rotation is when grass land is about to be broken up for a crop, as all the operations are then most easily and neatly performed.

It may seem an indiscriminate advice to recommend the draining of every field, as it is possible that many may have parts so dry as not to require it; but it is scarcely possible that no part of any field does not require it. Be this as it may, a system of thorough drainage requires every field to be examined in regard to its *state of wetness throughout the year*. Land which retains water in winter is in a bad state, though it should be burnt up in summer; and burning requires draining to cure it, for drains supply moisture to burning land in summer, while they take it away from soaking land in winter. I have myself cured burning land by draining, and the effect need excite no surprise. Lands burn when naturally light, thin, and on retentive subsoil. Being thin, they are easily saturated with rain in winter, and being light, the water in them is soon evaporated in summer, and when drought continues, the crop is soon burnt up. Now, draining is the best preventive against all these effects, for drains serve as reservoirs for moisture, to be taken up to the plants by capillary attraction through the dry soil in summer, and they act as ducts for the conveyance of superfluous water in winter.

Should the farm be pretty level, it matters not at what side the draining commences ; but when it has a decided inclination one way, the lowest part should be first drained, to afford the water at all times an outlet, and, when the inclination occurs in more than one direction, each plane of inclination should have a system of drains for itself, commencing at the lowest one and at the lowest point of each.

Period of the Rotation at which Draining should be executed.

The period of the rotation of crops in which draining should be executed, deserves consideration. I believe it is now generally believed that draining is best performed when the ground is in grass, and just before it is ploughed up. There are advantages attending this period over every other. 1. Turf can be procured at hand for covering stones ; and, although one year's grass cannot afford good turf for the purpose, yet, if carefully raised by the spade, set aside—not heaped upon one another to rot, but singly in a row with the grass side up—and gently handled, it will answer. In 2 or 3 years' old grass, the turf is better ; and in old pasture or meadow ground, it is as good as can be procured any where. At whatever age the turf is used, it should not be too rough or too thick, as it will not lie closely over the stones. Sheep are the best stock for eating down grass, and preparing it for turf.* A few years ago turfs were used to lap over tiles in drains ; but it is now found of no use, and, being expensive, its discontinuance reduces the expense of draining. 2. Another advantage grass land possesses is the firm surface it presents to the cartage of materials, whether stones or tiles. If stones are put in with the screen, fig. 31, the cart and barrow will easily pass along the side of the drain ; and when tiles are used, grass makes clean ground for them to

* Judging from the usual treatment which it receives, turf seems to be very little valued, being crumpled up, thrown down, and kicked about, until it becomes much broken and bruised, when it is not nearly so fit for covering stones as when raised from the ground ; and yet good turf is an expensive article, and not to be obtained every where. A man will cast from 4 to 6 cart-loads, of 1 ton each, per day, according to the smoothness and softness of the ground. Its usual thickness is about 3 inches, when 1 square yard will weigh about 54 lbs., and, of course, 1 ton will cover about 40 square yards, or 40 roods of 6 yards with turfs of 12 by 18 inches. In the country carriage is the heaviest charge against turf ; in town its cost is from 8s. to 20s. a ton.

be laid down upon. 3. In grass, the filling-in of the earth with the spade makes neat work.

When it is determined to drain land while in grass, the *season* for opening the drains is thereby determined. It would not be prudent to sacrifice the entire pasturage of summer, and, as no stock should be allowed to roam in a field while being drained, both on account of injuring themselves by slipping into, and of breaking down the edges, fracturing the tiles, or displacing the stones of, the drains, the grass should be consumed; but, that the draining may commence soon in autumn, the grass should be eaten down by that time. Whether or not more than one set of men are engaged in cutting the drains, they should all be employed in the same field together, as loss of time is incurred in driving materials to different fields; whereas, with concentrated work, one field after another is drained and ploughed, and such a course permits the eating down of the grass regularly, field by field, as the draining proceeds, so as not to sacrifice the aftermath. These precautions being taken, and the materials laid down, the operations may be carried on through the winter, and as far into spring as to give time to plough the land for the seed.

When the grass field is not intended to be ploughed up, such as a small field in front of the farm-house, or the lawn around a mansion-house, the turf should be neatly re-laid over the drains, and somewhat above the level of the ground, and a heavy roller made to press it down. The turf must be re-laid and rolled in fresh weather; or even in damp or wet weather, provided the grass is dry when rolled.

The divisions as occupied by oats after lea should be drained every year, until the whole farm is dried; but a greater extent of land may be drained in any year, if desired; such as a portion of the fallow-break if bare-fallowed for wheat, or prepared for turnips. Indeed, some farmers prefer draining in summer to any other season, as the land can then be carted on with freedom; the days are long, and a good day's work may be done, whilst all other work is in a state of cessation. These are cogent reasons for summer draining; but unless the entire fallow-break is bare-fallowed, so large a break of the fallow as of lea cannot be drained; and if a larger extent is not drained, the operation will occupy as many years as there are members in the rotations. There is no time in spring to drain the part of the fallow-break to be occupied by potatoes, and certainly not the whole of the part intended for turnips; and it is inconvenient for sowing the wheat seed in autumn to drain after the potatoes and turnips have been removed from the ground. No advantage would thus be derived by draining in spring and autumn instead of in summer; besides its being so very slovenly a practice to poach the ground in autumn with draining after it had been dunged in the fallow-break, and prepared to serve a whole rotation. A few short drains in a particular spot may be executed after the potatoes are lifted in autumn, or after the turnips are eaten off in spring, but to no farther extent. The lea ground, therefore, presents the largest extent of surface for drainage, with the least interference with growing crops and prepared ground, and the space may be enlarged by the part devoted to bare-fallow for wheat.

Position of Main Drains.

The field being fixed upon, the first consideration is the position of the main drain as a recipient of water from the small ones. In all cases mains should be provided with a *duct*, and the ducts formed of stone or tile;—of stone when perhaps the material is abundant on the farm, and of tile where stone cannot be easily procured; but tiles should be procured from a distance rather than ducts be wanting. The best forms of ducts may be seen in figs. 17, 20, 21, and 55.

As main drains are only intended to lead away water from other drains, they should *occupy all the lowest parts of a field*, whether along the bottom, the sides, or through the middle. If the field is so flat as to have very little fall, the water is directed towards the main drains by making them deeper than the other drains, and as deep as the fall of the outlet will allow. If the field has a uniform declivity one way, one main drain along the bottom will answer the purpose. If it has an undulated surface, every hollow of any extent, and every *deep* hollow of however limited extent, should be furnished with a main drain. No main drain should be placed nearer than 5 yards to any tree that may possibly push its roots into it. The ditch of a hedge should not be converted into a main drain, though the roots of the hedge lie in the opposite direction, and though the ditch merely receive surface water from the field, but should be cut out of the solid ground, and not be nearer than 3 yards to the ditch lip, or 5 yards to the hedge; and the ditch, now no longer required to collect surface water, should be converted into a small drain, and filled up with earth from the head-ridge.

As main drains occupy the lowest parts of fields, *the fall along them* cannot generally be so great as in other parts of the field, but it should be made sufficient for drainage. In the case of a level field the fall may entirely depend on cutting them deeper at the outlet than at other places; but whenever the fall is so small, the duct should be constructed considerably larger; as the same bulk of water will require a longer time to flow away. Should the fall vary in the course of the drain, the least rapid parts should be provided with the largest sized or greatest number of tiles; and I would recommend an increase of fall along the last few yards towards the outlet, to expedite the egress of the water, and promote an accelerated speed along the whole length of the drain, unless the fall is rapid enough throughout, and then no increase of acceleration at the termination is required. It is surprising what a small descent suffices for water to flow in a well-constructed duct.

People frequently complain, says Mr Smith, that they cannot find a sufficient fall or *level*, as they sometimes term it, to carry off the water from their drains. There are few situations where a sufficient fall cannot be found if due pains are exercised. It has been found in practice that a water-course 30 feet wide and 6 feet deep, giving a transverse sectional area of 180 square feet, will discharge 300 cubic yards of water per minute, and will flow at the rate of 1 mile per hour, with a fall of no more than 6 *inches per mile*.*

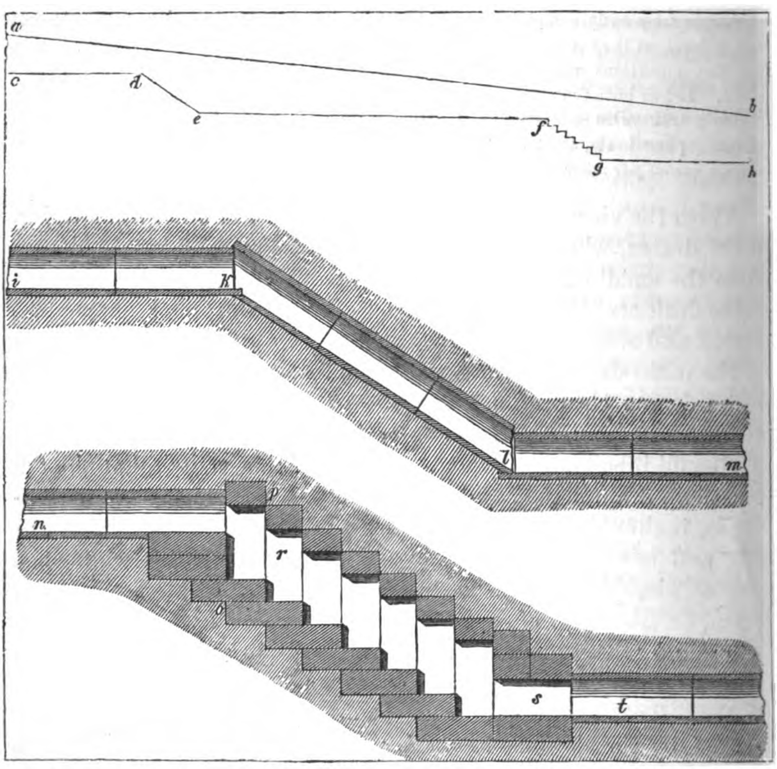
With the view of accelerating the speed of the water from drains, main drains, where practicable, should be made 6 inches deeper than the small ones which fall into them. This is objected to by some drainers, Mr Parkes amongst others, who prefer having the mains and small drains on the same level. But the greater depth of the main drain has the advantage of keeping the outfalls of the small drains clear of any substance that might otherwise lodge there, and also of any back-water from the main.

Should it so happen, from the nature of the ground, that the fall in a main drain is too rapid for the safety of the materials constructing it, it should be divided into lengths, and each have a proper fall, and joined to the next by an inclined plane. The inclined planes should be furnished with ducts built of brick or stone, plain, or like steps of stairs. Fig. 23 illustrates this contrivance, where *a b* represents the fall on a main drain at 1 in 10, which is more than it should have to convey a considerable quantity of water. To lessen this fall, let the drain be cut in the form represented by the devious line, *c h*, which consists of, first, a nearly

* Smith's *Remarks on Thorough-Draining*, p. 6. *note*.

level part at the highest end, *c d;* then an inclined plane, *d e;* again a nearly level part, *e f;* again an inclined plane, *f g;* and, lastly, of a less level part, *g h*, to allow the water to flow rapidly away at the outlet. The inclined parts may be filled in various ways. One with tiles, as from *k* to *l*, where they must be so broken at the end as to fit those on the level at *k* and *l*. In using tiles in such an inclination, it is absolutely necessary to protect the ground with soles, which should be prevented from sliding away at the lowest end *l* by resting against a strong stone imbedded in the ground. The best plan is to line the inclined plane with troughs of hewn stone. Conduits of dry stones would be stronger than tiles, and cheaper than hewn stones. Or it may be protected with brick, built dry, and laid like tile-soles, or in a series of steps, by setting 2 side by side lengthwise on bed, to form

Fig. 23.



THE DIFFERENT FORMS OF DUCTS ON THE INCLINED PLANES OF DRAINS.

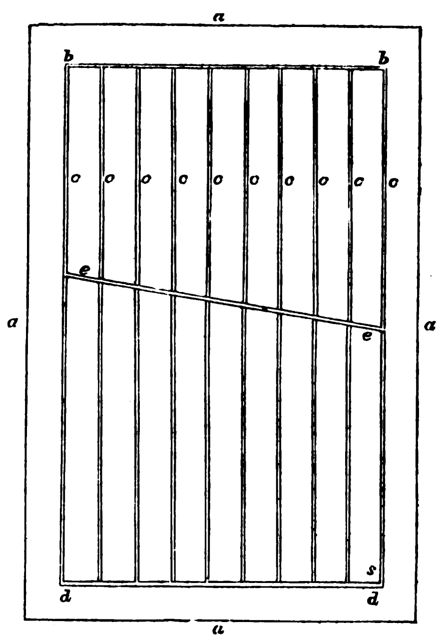
one step, as at *o;* 1 upon each end of these to form the sides, as at *r;* and 1 lengthwise, across upon the 2 upright ones, for the cover, as at *p*. Tiles upon the level part connect themselves easily with bricks, as at *n* and *t*. The step form is preferable to the smooth in breaking the fall and impeding the velocity of water, especially towards the lower part of a drain, where it might acquire too much momentum. It would be imprudent to build these steps with lime mortar, which is easily washed away; and would cause masonry with stones to be less firmly compacted than in dry building with pinnings of small stones.

It is seldom that such structures are required in drains, but they may be so in certain cases.

Position of Small Drains in reference to the Inclination of the Surface.

The position of the main drains being determined, the next thing is to settle that of the *small drains*, which should be placed and constructed with an easy descent towards the main drain into which they discharge their waters. They are usually placed in parallel lines up the inclination of the ground; not that all in the same field shall be parallel to one another, but only those in the same plane, whatever number of planes the field may present. In a field of one plane, whether nearly level or with a descent, they should all be parallel to one another, and terminate in the same main drain. Thus, in fig. 24, *a a a a* are the fences of the field; *d d* the main drain, and *s* its outlet. The

Fig. 24.

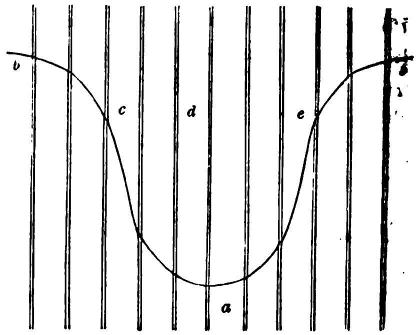


PARALLEL DRAINS IN THE SAME PLANE OF INCLINATION OF THE GROUND.

drains, *c c c*, &c., all run parallel to one another, from the lower end, *d d*, to the upper, *b b*.

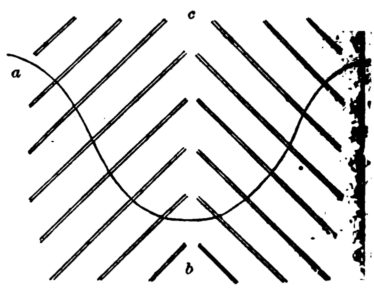
When the field has an undulated surface, the same principle of parallelism is differently arranged. The main drain is carried up the hollowest part, and the small ones are brought to it in parallels down the inclinations. This favourable arrangement for the speedy riddance of water is not enough attended to. Thus the common practice is to run all the small drains, *b c d e b*, fig. 25, parallel to one another, through the length of a field, even over undulations; and should these occur, as represented by the curved line *b a b*, the parallel drains *c*, on both sides of the hollow, *d*, would run along the declivitous faces, in a horizontal instead of a vertical direction. The probable effect of this would be to miss the drainage of both sides; for where any vein of sand dipped out at the surface of the declivitous ground, the drain might run parallel with and just below it and miss it, instead of dividing it along the dip, as it should do; and though it were not entirely missed, but bisected along its length, and across the dip, the sand might be brought down from the upper part of the ground into the drain, enter the duct in quantity, and render it inoperative.

Fig. 25.



DRAINS IMPROPERLY MADE PARALLEL IRRESPECTIVE OF THE SLOPE OF THE GROUND.

Fig. 26.



DRAINS MADE PARALLEL IN ACCORDANCE WITH THE SLOPE OF THE GROUND.

Such a form of ground should have the drains placed as in fig. 26, at *a a*, to run right up and down the declivitous faces towards the main drain which should occupy the line, *b c*. This circumstantial plan is just as easily executed as the other indiscriminate one of treating all parts of a field alike.

Wherever small drains are placed, they should run *nearly at right angles to the main drains.* Excepting in confined hollows, having steep ascents on both sides, such as in fig. 26, the drains should run parallel with the ridges. Drains should be carried continuously through each plane of a field, irrespective of the wet or dry appearances of the surface, uniform and complete dryness being the object aimed at by draining; and portions of land, seemingly dry at one time, may be wet at another, and may even always appear dry on the surface, though in a state of injurious wetness below.

As regards the direction in which drains should run in reference to the surface, so as to dry the land most effectually, much diversity of opinion at one time existed; but I believe most farmers are now convinced that it should follow the inclination of the ground. The late Mr Stephens expressed his opinion practically on this subject in these words:—

Drains winding across the slope or declivity of a field, whatever their number or depth may be, their effect upon tenacious or impervious substrata will be much greater than if they were made straight up and down the slope; and when the soil is mixed with thin strata of fine sand, which is the case nine times out of ten, the effect will be increased in proportion; and, accordingly, a much less number will answer the purpose, the expense will be greatly lessened, and the land and occupier much more benefited in every respect.*

This statement does not convince my mind. Mr Smith wholly denies it; and, what is remarkable, employs the same reasons to refute it.

Drains, he observes, drawn across a steep, cut the strata or layers of subsoil transversely, and as the stratification generally lies in sheets at an angle to the surface, (see fig. 29,) the water passing in or between the strata, immediately below the bottom of one drain, nearly comes to the surface before reaching the next lower drain. But as water seeks the lowest level in all directions, if the strata be cut at right angles by a drain directed down the steep, the bottom of which cuts each stratum to the same distance from the surface, the water will flow into the drain at the intersecting point of each sheet or layer, on a level with the bottom of the drain, leaving one uniform depth of dry soil.†

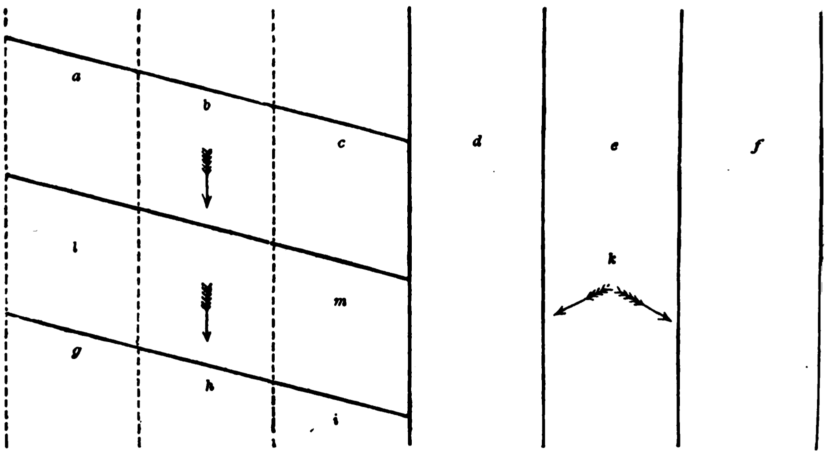
Without assuming more than one law of hydraulics, that water seeks the lowest level in all directions, I shall prove the accuracy of Mr Smith's conclusions, by referring to fig. 27, which represents two portions of a field supposed to have the same acclivity, and laid off in 6 equal ridges, *a*, *b*, *c*, and *d*, *e*, *f*, down the slope, three of which, *a*, *b*, *c*, having the drains oblique, and three, *d*, *e*, *f*, parallel, and every drain at the same distance from the other. Now,

* Stephens' *Practical Irrigator and Drainer*, p. 103.

† Smith's *Remarks on Thorough-Draining*, p. 9.

when rain falls on, and is absorbed by the ridges, *a*, *b*, *c*, *d*, *e*, *f*, it naturally makes its way to the lowest level, and as the ground has

Fig. 27.

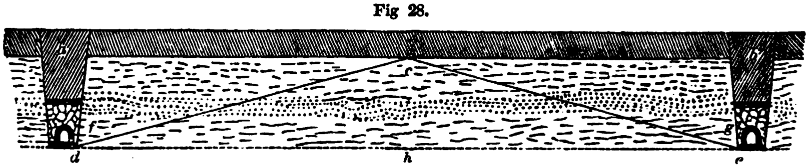


THE COMPARATIVE EFFICACY OF DRAINS ACROSS AND ALONG RIDGES ON A DECLIVITY.

the same declivity, it will reach the bottom of the drains, sooner or later, as the circumstances presented by the two systems of drains may accelerate or retard its motion. Let us see how these circumstances should operate:—

On the ridges *d*, *e*, *f*, the water will take a course on each towards the bottom of the drains, as indicated by the deflected arrows at *k*; and as ground has seldom only one plane of declination, but more commonly one to the right hand, and another to the left, from *a* to *f* or from *f* to *a*, it follows that the lower side of a ridge thus situated, will be sooner drained than the upper; but both sides will soon be drained, as may be seen by reference to fig. 28, where *a* and *b* are vertical sections of drains,

Fig 28.



THE DESCENT OF WATER ON A RIDGE INTO A DRAIN ON EACH SIDE.

and *c* 1 foot of mould, in which the rain is absorbed as fast as it falls upon the ridge, 15 feet broad, betwixt *a* and *b*. On being absorbed, the rain, seeking the lowest level by gravity, will hasten at first perpendicularly towards the line *d e*, and, in doing so, will find it easier to move towards the open ducts *d* and *e* than the close ground at *h*. In thus moving, the water will always remain at a higher level at *h* than at *d* or *e*, and, by its accumulation there, cause a constant lateral pressure towards *d* and *e*, and this the more powerfully the greater the supply of water from above. It is a common belief that water finds its way from the surface of a ridge to the drain on either side along the imaginary inclined planes *c d* and *c e*; but no force exists at *c* to cause it to take so decidedly a diagonal course, in counteraction to the force of gravity which carries it directly from *c* towards *h*. The fissures in drained retentive subsoil, having a perpendicular direction, conduct the water downwards with increased velocity to the assistance of gravity; and the assistance which the water finds in its way laterally into the drains *d* and *e* from the centre space at *h*, is afforded by the fractures formed by shrinkage in the columnar masses of the subsoil.

On the ridges *a b c*, on the other hand, the water will have to traverse in the direction of the arrows *b* and *h*, fig. 27, the entire distance across the drains *a* and *l* or *l* and *g*, instead of half the distance on *d*, *e*, *f*; for both sets of drains are supposed to be equidistant. So that the water should take double the time to reach the drains at *a*, *l*, and *g*, as at *d*, *e*, and *f*. Take the superficial view, and suppose that *d*, *e*, *f*, and *a*, *l*, *g*, are open furrows, the water will only have to move 7½ feet, as indicated by the arrows at *k*, to reach the open furrows *d*, *e*, and *f*; whereas on the ridge *a c*, *l m*, or *g i*, it will have to move across the entire breadth of 15 feet, just double the distance of the other, before it can reach the open furrows, *a*, *l*, *g*.

Trace the passage of water under the surface, through the substrata. Mr Thomson, Hangingside, Linlithgowshire, drained 150 acres of land having an inclination varying from 1 in 10 to 1 in 30. Portions of 3 fields had drains cut in them in 1828, 1829, and 1830, in the oblique direction, and, finding them less successful than the rest of the fields, he put them in the direction of the slope.

In order, says he, to ascertain the cause of these failures, a cut was made in the field first referred to, entering at a given point, and carrying forward a level to a considerable depth, when it was clearly seen that the substrata, instead of taking in any degree the inclination of the surface, lay horizontally, as represented in fig. 29. It is therefore obvious, he justly concludes, that, in making drains *across* a sloping surface, unless they are put in at the precise point where the substrata crop out (and these are exceedingly irregular in point of thickness), they may in a great measure prove nugatory; because, although one drain is near another, from the rise of the ground, none of them may reach the point sought; whereas, in carrying a drain right up the direction of a slope, it is impossible to miss the extremity of *every* substratum passed through.*

Fig. 29.

THE USUAL POSITION OF SUBSTRATA IN REFERENCE TO THE SURFACE SOIL.

And although drains in the oblique direction should cut through a vein of sand as from *f* to *g*, fig. 28, and thereby carry off the water it contains, the drains along the inclination would also cut through the same vein and carry off the water as well. So that oblique drains present no advantage over those on the inclination, while they are attended with many disadvantages. This experiment of Mr Thomson's strongly supports my recommendation in the two following sections, of making experimental cuts before determining the depth and distance of drains.

Particulars which serve to determine the Proper Depth of Drains.

The next step is to fix the *depth* of drain best suited to drain the particular field; and that can only be done by acquiring a thorough knowledge of its subsoil. I have already afforded data for fixing the minimum depth of drains in different kinds of subsoil; but as the reasoning employed there is only to establish the principle, it is not sufficient to determine practically the proper depth of drains in every case.

When a field presents a uniform surface, but inclining, and does not exceed ten acres, let at least two exploratory drains be cut from the part at the bottom, where the main drain should be placed, to the top. In larger fields one such exploratory drain for every 5 acres, may perhaps suffice. Whatever be the nature of the subsoil, let the cut be made at once 3 feet deep without hesitation; and on proceeding up the rise of the ground, let it be increased to 4 feet; and let portions of each drain be cut 1 foot and 2 feet deeper. Where small undulations exist, these cuts should pass right through both the flat and rising ground. In very flat ground, no considerable increase of depth is practicable, farther than to preserve the fall. The exposure of the

* *Prize Essays of the Highland and Agricultural Society*, vol. xiii. p. 295.

substrata afforded by the experimental drains, will supply data to fix the proper depth of the drains of the field.

Should the subsoil be pretty similar in all the experimental drains, it may reasonably be concluded that it is so over the whole field; but should it prove otherwise in different parts, then the nature of the difference should be strictly observed. A correct judgment of the true nature of the subsoil, cannot be formed immediately on the opening of these drains; for time must be allowed the water from the adjoining ridges to find its way into them, and even several days may elapse ere the water show itself. When it is believed the drains have received as much water as they can, the part which supplies the most should be observed whether it is nearer the top or the bottom. If rainy weather occur during the experiment, let its effects be observed. It is so much the better that parts of the sides of the drains fall in during the dry or wet weather, for the new fractured ground affords much better indications of the natural structure of the subsoil, than when newly cut by the spade. Whatever may be the facts observed, it should be borne in mind, that the durability of drains depends upon their standing on impervious matter, as it prevents the escape of water by any other channel than the duct; and such matter should therefore be sought for in the experiment.

Now, let us see how these facts should regulate our practice. If it is found that a depth of 3 feet affords as much water as 4, or more, it is unnecessary to incur the expense of cutting the additional depth, unless it afford some other advantage; and all the parts of the field containing the same kind of subsoil should have the drains cut of the same depth. If a porous and tenacious part of the subsoil afford the same results, the drain should be cut of the same depth in both. On the other hand, if 4 feet evidently afford more water from the same kind of subsoil than 3, a 4-feet drain should be preferred without hesitation, because we do not know but that the larger quantity of water is required to be extracted from the land to dry it thoroughly, while the extraction of the smaller quantity may effect very little good. On comparing the nature of porous and retentive subsoils, if it is found that 3 feet and less of porous matter afford more water than 4 feet of retentive, whatever less depth than 3 feet the porous drain may be made, the 4 feet tenacious one should be made still deeper, until it is seen whether the quantity of water is increased, and if it be not increased by 1 or 2 feet of additional depth of drain, it is inexpedient to go beyond the 4 feet.

On making the comparison between porous and retentive subsoils, *the point from which the water issues* is an important element in determining the depth of drains. If it is found that the porous subsoil affords all its water at not more than 2½ feet, where it rests upon retentive matter, it is unnecessary to take it deeper, as far as the supply of water is concerned, than will just afford a trough for the tile in the retentive matter, and this is about 6 inches more, making the entire depth 36 inches. Now, by referring to the inquiry which was made on the particulars which determine the depth of drains, at p. 38 it will be seen that the minimum depth of drains in a porous subsoil was fixed at not less than 33 inches, to afford room for the proper culture of the soil. So that, although the whole water of a drain is supplied at 2 feet, its depth must still be carried to *at least* 33 inches. If the retentive subsoil parts with its water uniformly down its whole depth of 6 feet, then that depth should be adopted; but when all the water is afforded at 4 feet, it is inexpedient to go deeper than the minimum depth for retentive subsoils, which was estimated at 50 inches. If, on the other hand, a retentive subsoil gives out its water freely, by some sand-vein, at 3 feet, and continues retentive at a much lower depth, it seems inexpedient to go deeper than the 3 feet, except 6 inches more to afford a proper trough for the tile. In such a case, if porous materials are found at the lowest depth tried, it would be proper, while keeping the drain at 3 feet, to make cuts here and there through the bottom of each drain into the porous matter below.

Besides the effects in the interior of the drains, the changes upon the surface must be simultaneously observed. If 4 feet evidently dries a larger surface over the same sort of subsoil than 3 feet, while the quantity of water in both is equal, the 4-feet depth should be preferred without hesitation. Attention should also be directed to the particular places where the drains were cut deeper; and if they exhibit greater effects on the surface, while the supply of water is the same, the greater depth should be preferred. Wherever all the varieties of subsoils are found, the drains should be cut of the depth specified for the particular variety, even in the same field.

This experimental method is not usually adopted, the common practice being, on knowing the subsoil of the field to be retentive, to cut the drains of a depth predetermined by the cost willing to be expended on the operation. Such an empirical mode of proceeding is too common in all agricultural operations, whereas the considerate plan I have recommended is founded on principle—on observation of facts—and incurs no unnecessary expense, as the experimental drains will serve the purpose of small drains; and, though they should cost more in repairs than ordinary drains of the same length, the information they afford much more than compensates for the additional expense. It may happen that the experimental results coincide with those of the empirical, still it is satisfactory to have the support of reason and principle, for our guidance, rather than parsimony and caprice.

The adoption of the most proper depth of drain is a more important step in draining than many farmers, to judge from their practice, seem aware of. By grudging to cut ½ a foot, nay, perhaps only 3 inches deeper, the largest amount of benefit may be unattained; for it is perfectly true—what the late Mr Stephens said,—that "land may be filled full of small drains, so that the *surface* will appear to be dry; but the land thus attempted to be drained will never produce a crop, either in quality or quantity, equal to land that has been *perfectly* drained,"* which can only be obtained by drains at depths best suited to the nature of the subsoil, and which is best ascertained by direct experiment.

Much diversity of opinion exists on the depth drains should be cut to *thorough* drain the land. The common-sense view of the matter seems to be, that the deeper drains give the greatest chance of cutting through the larger number of minute striæ, by which water is always seen to issue from the subsoil into drains, and from a well-known law in hydrostatics, the water issues with greater force from the deeper striæ, than from those nearest the top of the drain. On this principle the Rev. J. C. Clutterbuck has illustrated the rationale of the particular effects of deep drains.

If a drain be dug, he observes, the water-level upon a retentive subsoil will assume an inclination, the angle at which it declines being greater or less, in proportion as the soil is pervious to, or retentive of water; in this, as in other cases of subterraneous water flowing to a vent, the inclination which its surface assumes will represent the amount of friction or resistance which the water encounters in its passage through the soil. . . . . It is with reference to the amount of this angle of inclination, that all draining operations must be conducted. If, for instance, a soil is uniformly porous to the depth of 5 feet, it is obvious that a drain to that depth would drain it more effectually, and to greater distance, than one of 4, 3, or less than these, and that the subterranean level would settle to a surface declining uniformly towards the drain. But as all clay soils are, from the action of the air, and their perforation by the roots of plants, more porous at the surface than below, the angle at which various drains will act, and the extent of soil they will drain, will vary as they sink lower into the soil, though the deepest drain will *invariably* command the greatest

* *Quarterly Journal of Agriculture*, vol. iii. p. 290.

amount of soil. Thus, if a soil becomes less porous in proportion to its depth, 5 feet, say in three degrees, then if 3 drains be cut 20, 40, and 60 inches deep, their draught or action on the soil will be indicated by three lines of different inclinations. The 20 inch drain will drain *on the surface* a greater distance in *proportion* than the 40, and the 40 than the 60 ; but the 40 will command not only a portion of the subsoil, but also of the surface not affected by the 20, and the 60 will act in a similar manner, with reference to the subsoil, more than the 40, showing that deep drains must be most effective ; but to *ensure* this effect really, adds Mr Clutterbuck, the drains should be filled with some substance through which water can percolate freely throughout their depth.*

The observations of Mr Parkes on the subject of deep drains, have a practical bearing. After stating a fact that had been observed by Mr Hammond, of a drain 4 feet deep running 8 pints of water in the same time (February 17, 1844) that another 3 feet deep ran 5 pints, although placed at equal distances, he draws these conclusions, and makes the following remarks on deep draining:—

Hence, he concludes, we have two phenomena very satisfactorily disclosed; 1*st*, That the deepest drain received the most water ; 2*d*, That it discharged the greatest quantity of water in a given time,—the superficial area of supply being the same in both drains. It would appear, then, he continues, either that the deeper drain had the power of drawing water from a horizontal distance, greater, by the ratio of 8 to 5, than the shallower drain, or that the perpendicular descent of the water was more rapid into the 4 feet drain, or that its increased discharge was owing to both these causes combined. The phenomena of a deep drain drawing water out of soil from a greater distance than a shallower one, is consistent with the laws of hydraulics, and is corroborated by numberless observations on the action of wells, &c.; but the cause of the deeper drain discharging more water *in a given time* is not so obvious. An opposite result, as to time, would rather be expected, from the fact of water falling on the surface having to penetrate a greater mass of earth, both perpendicularly and horizontally, in order to reach the deep drain.

Mr Parkes explains this phenomenon on the well-known property of the great shrinking of clay when deprived of water.

A natural agricultural bed of porous soil resembles an artificial filter ; and it is unquestionable that the greater the depth of matter composing such filter, the slower is the passage of water through it. In stiff clays and loams, however, but more particularly as regards the latter earth, the resemblance ceases, as these soils can permit free egress and ingress to rain water, only after the establishment of that thorough net-work of cracks and fissures, which is occasioned in them by the shrinkage of the mass from the joint action of drains and superficial evaporation. These fissures seem to stand in the stead of porosity in such soils, and seem to conduct water to drains rapidly after it has trickled through the cracked bed ; it is probable too, that in deeply drained clays of certain texture, the fissures may be wider, or more numerous, in consequence of the contraction of a greater bulk of earth than where such soil is drained to a less depth. However this may be, it is asserted by several respectable and intelligent farmers in Kent, who have laid drains very deeply in clays and stiff soils, that the flow from the deepest drains invariably commences and ceases sooner than from shallower drains after rain. . . . . . . The consideration of the depth of

* *Journal of the Royal Agricultural Society of England*, vol. vi. pp. 490, 491.

drains, adds Mr Parkes, with great force and truth, has been too generally limited to the mere exigencies of culture and implements, combined with the natural desire to restrict expense also, the materials used were dear, and the cost of earth-work great. These adventitious circumstances have certainly tended to obscure from view the true principles on which drainage should be founded, and on which the utmost benefits to be derived from it depend. The question of distance between drains is important on the score of expense, and it will be *wise to err on the right side, and keep within safe limits;* but insufficiency of depth can only be remedied by a new outlay. So far as experience can illuminate the subject, we know that many agriculturists have, a second time, drained their fields to a greater depth; it may, however, be doubted whether any one has taken up *deep* drains, and placed them nearer the surface, or nearer together.

There is another effect which I fear is little regarded, when the depth of drains is determined on, namely, the bulk of earth relieved of its surplus water.

This I conceive, says Mr Parkes, to be the true expression of the work done, as a mere statement of the cost of drainage per acre of surface conveys but an imperfect, indeed, a very erroneous idea of the substantive and useful expenditure in any particular system.

Taking the cost of 2 feet drains, in stiff clays, 24 feet apart, at £3, 4s. 3d. per acre; of 3 feet drains, in porous soils, 33½ feet asunder, at £2, 5s. 2d. per acre; and of 4 feet drains, in soils of varied texture, 50 feet apart, at £2, 5s. per acre, the following table will give the cost in cubic yards as to the depth, and in square yards as to the surface, drained for one penny, at the above mentioned prices, depths, and distances:—

Depth of the drains in feet.	Distance between the drains in feet.	Mass of soil drained per Acre in cubic yards.	Mass of soil drained for 1d. per cubic yard.	Surface of soil drained for 1d. in square yards.
2	24	3226½	4·1	6·27
3	33½	4840	8·93	8·93
4	50	6153	12·00	8·96

The results are, generally, that double the depth of drain has effect on about three times the cubical contents of the earth, and about half more in extent of surface;* and, particularly, although 3 and 4 feet in depth drain about the same extent of surface, the deeper drain one-half more of the ground in cubical contents. Such a mode of reasoning holds as good in regard to the draining as to the ploughing of land. The neat, small, sharp-crested, notched-

* *Journal of the Royal Agricultural Society of England,* vol. v., pp. 154-6.

sole furrow made by Wilkie's plough, does not constitute the best ploughed land, though the work exhibited on the surface is beautiful, but the deep, square, level-bottomed furrow made by the East Lothian plough, which stirs the greatest quantity of earth under the same area of surface, is what affords the true criterion of good ploughing.

Particulars which seem to determine the proper Distance between Drains.

The investigations in which we have so long been engaged, have now brought us to a very important inquiry, namely, the most proper *distance* to be left between the drains. It is evident this particular can only be determined after the depths of the drains have been fixed upon, as drains which collect water from a distance, need not be placed so close as where the subsoil is retentive; and as subsoils may vary in the same field, so may drains be placed at different distances. It is a common practice to occupy the open furrow with a drain, perhaps because its hollow saves a little cutting, though this is a trifle compared to the advantage of selecting the best parts of the ground for drains, but, more probably, because water runs most quickly to the open furrow. The open furrow has no greater claim for a drain than any other part of a ridge, especially as most of the water is received by the drain from the subsoil, and not directly from the surface. On this subject, Mr Smith has these remarks :—

When the ridges of the field have been formerly much raised, it suits very well to run a drain up every furrow, which saves some depth of cutting. The feering being thereafter made over the drains, the hollow is filled up, and the general surface, ultimately becomes level.

This is very well for the purpose of levelling the ground, but mark the consequences if what follows as a recommendation were adopted.

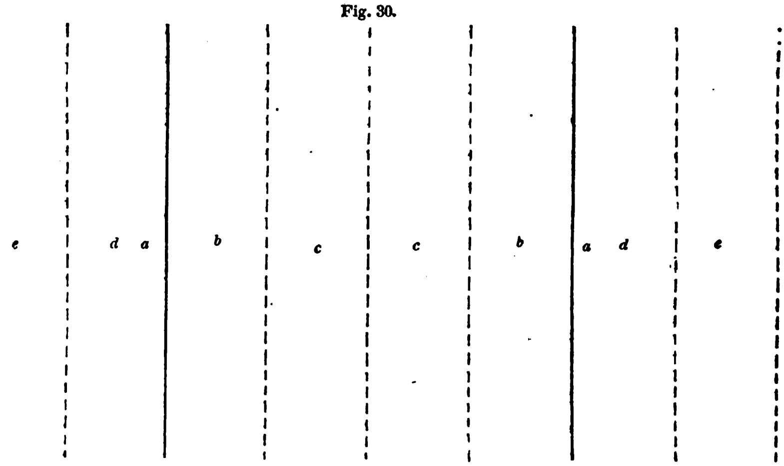
When the field is again ridged, the drains may be kept in the crowns or middle of the ridges ; but if it be intended to work the field so as to alternate the crowns and furrows, then the ridges should be of a breadth equal to *double* the distance from drain to drain ; and by setting off the furrows in the middle betwixt two drains, the crowns will be in the same position ; so that when the furrows take the places of the crowns, they will still be in the middle betwixt two drains, which will prevent the risk of surface-water getting access to the drain from the water-furrows by any direct opening.*

* Smith's *Remarks on Thorough-Draining*, pp. 7, 8, 4th edition.

No doubt, it is easy to transpose furrows into crowns, and crowns into furrows; but how can the transposition be effected after the drains have been made in each former furrow, and the subsequent proposal followed to make the crowns of the ridges between the drains, without committing the unfarmerlike blunder of leaving a half ridge at each side of a finished field?

The distance at which 4-feet drains will *not* dry a retentive subsoil is not left to conjecture, but has been partially determined by experiment. Conceiving that a drain in every furrow, in a tilly subsoil, would be attended with more expense than the anticipated return, a farmer in East Lothian put a drain in every *fourth* furrow; and that they might collect water from that distance, he caused them to be cut 4 feet deep. A figure will best illustrate the results,

Fig. 30.



THE BAD EFFECTS OF TOO GREAT A DISTANCE BETWIXT DRAINS.

where the black lines *a a*, fig. 30, are the drains between every fourth furrow, and the dotted lines the intermediate undrained furrows, and where it is evident, that each drain, *a*, has to dry 2 ridges on each side, *b* and *c* on the one hand, and *d* and *e* on the other. On looking at the arrangement of these ridges, we would expect that the two, *b* and *d*, being nearest *a*, should be more dried, in the same time, than the two farther off, *c* and *e*, and the result agrees with the expectation. The 2 ridges, *b* and *d*, nearest *a*, produced 9 bushels of corn more per acre than the 2 more distant ridges, *c* and *e*, which is a great difference of produce from adjoining ridges under the same treatment and crop; and yet it does not show the entire advantage which may be obtained by thorough drained over undrained land, because possibly the drain, *a*, had partially drained even the distant ridges, *c* and *e*; and such being possible, together with the circumstance that none of the ridges had a drain on each side, and all being incumbent on tilly subsoil could not have been thoroughly drained—the absolute or comparative drying power of 4-feet drains was not ascertained by this experiment.* It may be conceived, however, that had the drains been put into every other instead of every fourth, furrow, the produce of all the ridges would have been alike; inasmuch as every one would have been placed in the same position in regard to a drain; and the expectation seems so reasonable, that the practice of many farmers, from what I observe, is founded upon it. But the expectation does not comprehend the greatest benefit derivable from thorough drainage; for although the ridges did produce alike with a drain on one side only, the produce would be no criterion of what it might be with a drain on both sides. This experiment, then, only demonstrates that a deep drain, for a 4-foot one cannot be termed a shallow one, will collect water in a retentive subsoil more certainly across one than two ridges; and the value of the demonstration consists in directing caution against imitating the practice of those who seem to believe that a drain cannot have too much to do.

Still, instances can be adduced from practice, where drains of moderate depth, though placed at considerable distance, have dried land. Ridges vary from 12 to 18 feet in breadth; and as in the case related above, the distance between the drains might be from 48 to 72 feet, which may reasonably be regarded as too far asunder. Yet Mr Thomas Hammond, near Penhurst, in Kent, has dried uniform clay land, with drains from 3½ to 4 feet deep, at 40 feet apart; and clay land containing some stones, he has dried with 4-feet drains at 50 feet apart. Nay, Mr Kepping, Hudlow, in Kent, has dried soil of various quality, having clay, gravel, and sandy loam, with 4-feet drains at 66 feet apart. And even with stone drains, of from only 2½ to 3 feet deep at 30 feet apart, Mr Bartlett, Butleigh, in Somersetshire, has drained clay and stiff loam for the upper soil with stones in the subsoil.† Mr Mechi renders strong clay land dry with 5-feet drains in the rising ground, averaging nearly 4 feet all over the field, at 40 feet distance; while lighter and more porous soils he drains with 6 and 7-feet deep

* *Quarterly Journal of Agriculture*, vol. viii. p. 539.

† *Journal of the Royal Agricultural Society of England*, vol. vi. p. 126.

drains, at intervals varying from 70 to 90 feet.* A farmer in the east of Fife, within the last twenty years, sunk a shaft in one of his fields with a view to working coal, but after descending about 40 feet he was obliged to relinquish his intention, on account of being overpowered with water. The shaft was filled up, and a conduited drain, of about 5 feet deep, formed from it to the sea-side, discharges a very large quantity of water to this day. He had intended to drain the field, which consists of porous soil resting on clay and rock, but soon discovered that the shaft had effectually dried it, to the extent of at least 16 acres.

The conclusion to be drawn from all these instances is, not that the experiment of wide draining in East Lothian was ill conducted, but that subsoils of various qualities require drains of various depths and at various distances. It is therefore unwise in a farmer to fix the distance and depth of drains before he has ascertained the nature of the subsoil.

My opinion is, that in a partially impervious subsoil, such as is most common in Scotland, 3-feet drains cannot be expected to dry more than 15 or 16 feet ridges, but that 4-feet ones will dry as effectually a distance not exceeding 24 feet. In porous subsoils 3-feet drains may dry 20 feet spaces with as great if not greater effect than these; and in deep hazel loam resting on impervious subsoil,—a not uncommon combination of soil and subsoil in the turnip-districts of Scotland,—4-feet drains will dry, I have no doubt, a distance of 30 feet. I would feel exceedingly reluctant to recommend drains at more than 30 feet distance, unless the arrangement of the subsoil was peculiar, such as a porous subsoil of considerable depth, subdivided into beds by bands of clay, through the whole of which, 4 or 5 feet drains at even double that distance, might dry the soil. I have ventured to fix the minimum depth of drains, in carse clay at 50 inches; and as experience has not yet explicitly fixed their distance apart, I do not feel warranted in recommending a wider distance than 20 feet with that depth. It seems to me somewhat inconsistent in those who believe that water should not enter by the top of a drain, and that strong clay on being dried becomes fissured, to recommend shallow drains of 24 to 30 inches in strong clay, since it is evident the greater the depth clay is dried, the larger, more numerous and more connected will the fissures in it be found, and the more readily will the water be brought by them to the duct. It should be borne in mind in

* Mechi's *Experience in Drainage*, p. v. Preface.

draining clay that it is not merely the rain that falls upon it that has to be removed, but the water which is naturally in it has to be extracted from it at first, and prevented remaining in it afterwards, and these effects may be obtained to a greater degree by a deep than a shallow drain. Water cannot be retained in porous subsoils, but in clay a depth of drain is requisite to allow gravity to act sensibly on the water, and it is only by that power it is put in motion towards the drain.

With our present experience, however, I do not see the utility of cutting drains so deep as 6 or 8 feet, merely to extend the space between the drains, when, perhaps, the same effect might be obtained by 4½-feet drains at narrower intervals, unless such very deep drains and very wide intervals can be proved more economical.

Whilst entertaining this view of the subject, I cannot advise any one to take the advice of Mr Smith, when he recommends,—"In cases where time or capital are awanting to complete the drainage at once, each alternate drain may be executed in the first instance, and the remainder can be done the next time the field is to be broken up."* I would meet this recommendation in the words of the late Mr Stirling of Glenbervie, that "I think it a *great error* to make at first the half the number of drains required, with the intention of putting one between each at a future period. Let what is drained be done as thoroughly as the farmer's exchequer will allow; the farm will be gone over in as short a time, and much more profitably." The reason Mr Stirling gives for holding this opinion is as practical as it is true; because "a tid (or proper condition of the ground for harrowing) cannot be taken advantage of on the drained furrow until the other is dry, and the benefit of an extended period for performing the various operations of the farm is thus lost."† Every farmer who has studied the influence of soil is ready to allow that wet soil does more injury to the dry in its neighbourhood, than the dry does good to the wet. I would, therefore, under every circumstance of season and soil, prefer having the half of my farm thoroughly, to the whole of it only half drained. On visiting a friend in Dumfriesshire, when he was draining his land by halves, I recommended the complete drainage at once. After a sufficient trial he followed my advice, and thanked me for it.

* Smith's *Remarks on Thorough-Draining*, p. 17, 4th edition.

† *Prize Essays of the Highland and Agricultural Society*, vol. xii. p. 102.

Contracting for Making Drains.

The *experimental cuts* having made us acquainted with the nature of the subsoil, determined the depth of the drains, and fixed the distances between them, and having expatiated at sufficient length on the principles of good draining, it is time to attend to the particulars of practice. As the cutting of drains should be prosecuted with industry, it is best and most satisfactorily done by contracting with an experienced spadesman, at so much per rood or rod of 6 yards.* The rates of cutting drains are generally well understood in every locality. In making a contract, only stout, active, and *skilful* men should be dealt with; for, though men able to do a hard day's work may be found any where, if, nevertheless deficient in skill and experience, inconveniences will ensue, and dissatisfaction be engendered. Unskilled men willingly engage at low rates; but it is wisdom to give such wages to skilful men as will enable them to earn a good livelihood, and the advantages of good work can never be over-estimated.

Method of Cutting Main and Small Drains.

Having detailed the method of making drains on the system of Elkington, and described the formation of efficient drains for drying bog, I shall now detail the particulars of thorough-draining, which is at present the pre-eminent system, and will no doubt continue so until a better one arise. The principal materials used for filling the drains are tiles of various forms, and stones are only employed where very plentiful.

The cutting of thorough drains in a field is commenced at the end of the *main drain*, at the lowest point of the field, which is the outlet. When the drains are to be filled with *stones*, the whole operation is done in the way pointed out in the Elkington method; namely, by the contractor or principal man of the party stretching the garden-line 60 or 70 yards, and rutting off the breadth at the top with the common spade. A second man then removes the top mould with the spade, and places it on the side opposite to the one at which the carts supply the stones. The separation of the

* It would be extremely convenient and highly satisfactory were the lineal measure of the *rood*, in which all country work is estimated, fixed of the same length throughout the kingdom, the great diversities existing in this measure being truly perplexing. I cannot see the utility of a general law on weights and measures, if such vexatious anomalies as this and many others are allowed to exist.

top and bottom soils is unnecessary. The principal man follows, and shovels off the loose mould with the ditcher's shovel, fig. 12, working with his face to the first man. A third man—for each gang of drainers, as I have already said, should consist of 3 men, for expeditious and clear work—loosens the top of the subsoil with a foot-pick, fig. 11, working backwards with the picking, towards the other men, removing the mould along the break or division measured off by the line. Or he uses the hand-pick, fig. 13, as the ground best suits, working forwards. After the second man has dug out the mould he removes the loosened picked subsoil with the common spade, digging with his back to the picker, working backwards; and the leading man follows with the ditcher's shovel, fig. 12, trimming the sides of the drain, and shovelling out the loose subsoil left by the digger.

The implements used in Ireland for draining, and especially the long-handled shovel, are very inefficient, and are used with much loss of time.

Should the drain be very wet, owing to a great fall of rain, or the cut drawing much water from the porosity of the subsoil, it is better to leave off the digging at this stage of the work, and proceed to set off another length of line at the top; and, indeed, in such circumstances, it is expedient to remove the mould from the whole length of the main drain in hand, to allow the water time to run off, and the ground to harden. This precaution is more necessary in digging narrow than deep drains, where there is no room to use planks to support the falling sides, as in fig. 14. When the ground is dry and firm, the digging may be proceeded with to the bottom at once.

To proceed with the digging, the picking is renewed at the lower end of the drain, and another spit of earth thrown out with the common spade. The leading man trims down the sides of the drain with the shovel, fig. 12, and throws out the remaining loose earth, finishing the bottom and sides in a straight, even, square form, and in a neat, clean, workman style. The bottom of the drain will have the width of a common spade, namely, 9 inches.

In very dry weather drains are dug with great labour, and prove an unprofitable speculation to the contractors. In that state of ground, it would be better for the drains themselves to defer cutting them until a shower falls. It is right to cut the drain a little deeper at every sudden though small rise, and a little shallower where a trifling hollow occurs, and not exactly to follow the slight undulations of the surface.

After the drain in hand has been completely cut, its dimensions should be tested by the drain-gauge, fig. 15, and the uniformity of its fall by the levelling-staffs, fig. 16, before any filling be allowed to be put into it.

It is expedient for convenience and clean work to mark off the distances of the small drains, where they are to enter the main drain, that when the cutting of it is proceeded with, the ends of the small ones may be cut at the same time to the depth they are intended to be. The main drain should be 6 inches deeper than the small ones, if the fall of the outlet permit; if not, the 6 inches must be obtained as near as possible to the outlet along the rise of the ground, in the line of the main drain.

After the main drain and the ends of the small ones have thus been cut, it is filled with the ducts, and the ducts of the small drains are connected with those of the main, as the filling proceeds.

The small drains are then cut, commencing with that at the lowest side of the field; and the instructions for cutting the main drain are equally applicable to, and should be explicitly followed in forming the small ones. The soil and subsoil are put to the side next the fence, to give room to the carts on the other side. It is best to cut each drain throughout its length before commencing the filling, and no filling should be allowed to be put into any drain until it has been measured by the drain-gauge, fig. 15, and tested by the levelling-staffs, fig. 16.

The distance between, and depths of, drains have already been discussed at p. 35.

In all cases of thorough-draining a small drain should connect the tops of the others at the upper end of the field; its object being to dry the upper head-ridge, and protect the upper ends of the ridges from any oozings of water that may come from a ditch or rising ground beyond the field. If the ditch convey no water, and there are no hedges or hedge-row trees, this connecting drain may be made in the ditch itself, and the ends of the small drains brought across the head-ridge into it; but should water, or hedge, or trees be connected with the ditch, the drain should be kept on the head-ridge, not nearer than 3 yards from its lip, and be of the same depth as, though not deeper than, the small drains.

When drains accompany very long ridges, exceeding 200 yards, it is recommended to have a *sub-main* drain in an oblique direction across them, as represented by *e e*, fig. 24. The reasons assigned by Mr Carmichael for requiring the assistance of a sub-main at that distance are, "because, if the fall is considerable, the bottom may be endangered by the velocity and volume of water collected during continued rain; or if the declivity be very limited, and the aperture small, the drain is in danger of bursting from an impeded discharge;" but a complete answer to these apprehensions, which are only well-founded when drains are ill-constructed, is found in the very next injunction, namely, "the rule is to apportion the area of all drains to their length, declivity, and distance from each other." * Mr Smith truly remarks on this subject, that "some people are still prone to the practice of throwing in a cross drain, or to branches going off at right angles, which are of no farther avail in drying the land, whilst they increase the length of drain without a proportionate increase of the area drained." †

The want of proper materials for the lower part of drains, where the quantity of water really becomes great, should induce to the making of a sub-main drain, rather than injure the land by insufficiency of the ducts at the lower part. Where a drain is cut across a field, as shown by *e e*, fig. 24, and at the same depth as the other drains, those in the space below should be disjoined from it by a narrow strip of ground in the line of *e* to *e*; but a better plan is to make the sub-main 7 inches deeper than the rest of the drains, where it can be so deepened, as it will intercept the water coming from the drains above it, while the drains are continued over it. In using a sub-main *e e*, where it falls into the small drain *b d*, at the side of the field at *e*, the portion of the latter below *e* to *s* should be converted into a sub-main, and of course made larger than the small drains.

General Rules for Filling Drains.

In *filling* drains, it is a common practice with farmers to put in the materials as the digging of the drain proceeds, which I consider an objectionable proceeding. I think the whole length of the drain in hand should be entirely cleared out to the specified dimensions before the filling commences; because the work should be inspected in the first place, in accordance with the specifications, and inspection implies measurement of the contents in depth and breadth, and ascertainment of the fall of the bottom, whether it be uniform throughout, where the slope of the ground is so, or

* *Prize Essays of the Highland and Agricultural Society*, vol. xii. p. 94.

† Smith's *Remarks on Thorough-Draining*, p. 9.

sufficient, where the general fall of the ground is small, or préserved in all places where the ground happens to be not uniform. These are not trifling considerations, but essential; so much so, indeed, that the efficiency of a drain as a conductor of water entirely depends upon them.

The *fall of the ground* can be ascertained by a simple contrivance. As the bottom of the drain is cleared out, a damming of 3 to 4 inches high will intercept and collect the water seeking its way along the bottom, and the water line will cut the ground as far up as it should do, if the specified fall has been preserved. A succession of such dammings will preserve the fall all the way up the drain. When the drain is dry, a few bucket-fulls of water thrown in will detect the fall; but in such a case it is easier to use the plumb level, fig. 43. It is only, however, on comparatively level ground that such expedients are at all requisite.

An unanswerable reason for filling drains from the upper to the lower end, in flat ground, is the ease of clearing the bottom down the natural declivity of the ground; and on doing so it is at once seen whether the fall has been preserved. In very deep drains, I was once of opinion that they should in all cases be filled as cut, but subsequent observation has convinced me that it is better to risk a little of the sides falling in, than to lose the fall on level ground. As to acclivities they may be filled from either end with impunity.

Filling Drains with Stones.

Stones have hitherto been the most common material employed for filling drains; but now that tiles are so easy to be obtained, they will, I suspect, get out of use. Nevertheless, I should describe how they are employed in filling drains.

Drain stones are usually derived from two sources. 1. From the surface of the land, from the channel of a river, or from the sea-beach, where they are small and round, and when not exceeding the size of a goose's egg, no other material is superior to them for durability in a drain; and, 2. From the quarry, where they must be broken with hammers, like road-metal, to the smallness of from 2½ to 4 inches in diameter, before they are used. It is obviously an absurd practice to mix stones of different sizes promiscuously in a drain, as they can never assort; and nothing is more injurious than to throw in a stone which nearly fills up the bottom of a drain, where it is sure to intercept water and make a dam. Large landstones should therefore be broken into small pieces. Stones broken in the quarry are always angular, and in so far are objectionable in shape, because on fitting together, face to face, they become a more compact body than round stones possibly can. No doubt, the ordinary pressure of a body of earth from 2 to 3 feet deep cannot squeeze small broken stones together so as entirely to compress the spaces between them ; but gravity, continually acting on loose stones, will in time press them nearer; and heavy labour on the surface, and subsidence of water through the earth, assist by their action to produce a similar result; and we all know that macadamization makes a much more compact road than did the old-fashioned round stones.

Stones should never be broken at the side of the drain. I agree with Mr Stirling when he says that—

> I prefer breaking stones in a *bin*. It is more easy to check the size, and it is done cheaper, as otherwise each heap has to be begun on the sward, and many of the stones are forced into the ground, which adds to the difficulty of lifting them. There will be a saving in carting the stones large, but it will be fully balanced by this disadvantage. I would deprecate of all practices that of breaking the stones in the field, and filling by the chain. This may be contracted for at a low rate, but it is easy to guess how the contractor makes wages.*

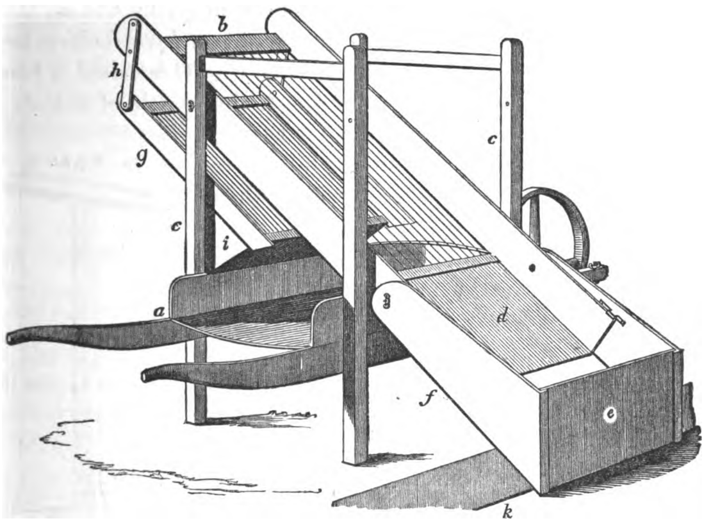
Although I greatly prefer small round stones to angular ones for drains, yet as the places which afford such naturally are limited in number, and draining, if confined to such localities, would be as limited, it is much better to take any sort of quarried stones than leave land undrained; and no doubt every sort of frangible stone forms an efficient and durable filling to a drain if employed in a proper manner.

As I am acquainted with no drainer who has bestowed so much pains on the breaking, preparing, and putting stones into drains as Mr Roberton, Ladyrigg, Roxburghshire, I shall describe his method of managing quarried stones; and first in regard to the implements used by him for the purpose. 1*st*. A portable *screen* or *harp* for riddling and depositing the stones, as seen in fig. 31, which consists of a wheelbarrow *a*, on each side of which are raised two upright posts, such as *c c*, to the height of 3 feet above the barrow. Upon two of these posts is suspended a screen *b*, the lower end of which rests upon the side of the barrow. The screen is furnished with stout wires more or less apart, according to the description of materials intended to be used. To the lower end of the screen is affixed a spout *d*, and at about 10 inches from the lower extremity of the spout is attached a board *e*, by means of two

* *Prize Essays of the Highland and Agricultural Society*, vol. xii. p. 10.

broad arms *f*. Another screen *g*, of one-half the length, and having the wires about half an inch apart, is hung parallel to, and about 10 inches below, the larger one, by means of a small iron bar

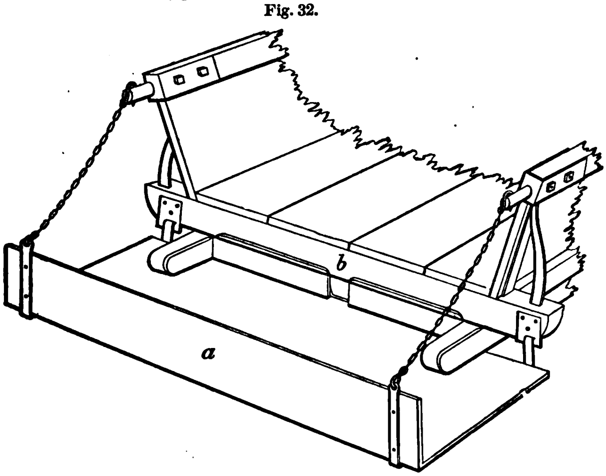
Fig. 31.



THE DRAIN STONE-HARP OR SCREEN.

h from either side of the upper end of the larger screen, and its lower end rests upon a spout *i* sloping outwards upon, and from the side of, the barrow, in an opposite direction to the spout *d*. 2*d*. A movable trough, or, as it is commonly called, *tail-board a*, fig. 32, is attached to the hind part of a cart, for the purpose of receiv-

Fig. 32.



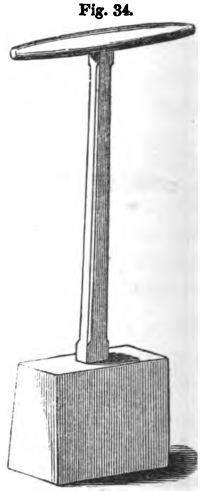
THE TAIL-BOARD, OR TROUGH FOR RECEIVING THE DRAIN-STONES IN THEIR FALL.

ing any stones that may drop while the workmen are shovelling them out of the cart. The portion of the hind part of a cart *b*, as seen in fig. 33, shows the manner in which the tail-board is attached to it. *3d.* Fig. 33, is a small iron *rake* used by the workman in charge of the screen, in giving the surface of the larger stones a uniform height or level before being covered with the smaller. *4th.* Fig 34 is called a *beater*, being a square piece of wood, the width of the drain, with a handle, and used for beating the smaller stones into the interstices of the larger ones, and levelling them into an even surface.*

Fig 33.

THE DRAIN STONE-RAKE.

Fig. 34.



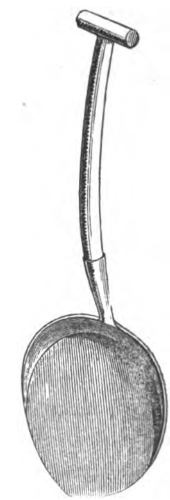
THE DRAIN STONE-BEATER.

The *stones are put* into the drain in this manner. The earth should at first have been put on one side of the drain. The barrow-screen, fig. 32, is placed on the other, so that the board *e*, attached to the lower end of the spout *d*, shall just reach the opposite side of the drain *k*. The cart, with a load of broken stones from the bin, is brought a little in advance of the barrow, and the tail-board *a*, fig. 32, is then attached to the hinder part of it. The carter, on removing the tail-board belonging to the cart, shovels the stones out of the cart, and throws each shovelful over the top of the screen; but in doing this, care is requisite, for if the stones are thrown over the screen with force, they will not alight sooner than half-way down the wires, and then their efficient screening will be impaired. The proper method is to rest the shovel upon the top of the screen, which part should be protected with plate-iron, and merely give the handle of the shovel a slight turn, when the stones will be released; the larger ones, rolling down, strike against the board *e*, fig. 31, and drop into the *middle* of the drain, without disturbing the earth on either side. The smaller stones, at the same time, pass through the upper screen *b*, and falling upon the lower one *g*, roll into the barrow *a*; whilst the rubbish in passing through the lower screen *g*, falls upon the ground on the outside of the barrow farthest from the drain.

* *Prize Essays of the Highland and Agricultural Society*, vol. xiv., p. 37.

The best form of shovel for putting the stones over the top of the screen is what is called the frying-pan or lime shovel, represented by fig. 35, the raised back of which keeps the stones in a collected form until they are emptied over the screen, and its point finds easy access under the stones along the bottom of the cart. Such shovels are much in use for spreading lime upon the land, and shovelling up the bottoms of dunghills in the Border counties of Scotland, and cost 3s. 10d. each, of medium size, ready handled for use.

Fig. 35.



THE FRYING-PAN OR LIME-SHOVEL.

One man takes charge of the filling of the drain. His duties are to move the barrow, fig. 31, forward along its side as the larger stones are filled to the required height; to level them with the rake, fig. 33; to take the smaller stones from the barrow with the shovel, fig. 35, spread them regularly over the top of the larger, and beat them down with the beater, fig. 34, so as to form a close and level surface through which no earth may pass. When the stones are broken in the quarry, so as to pass through a ring, 4 inches in diameter, one-fourth part of them are as small as to pass through the wires of the upper screen *b*, fig. 31, which are 1¾ inch apart, and that quantity is sufficient to give the top of the drain a covering of 2 or 3 inches deep, and on being beaten closely down, the larger stones require neither straw, turf, nor any thing else to cover them.

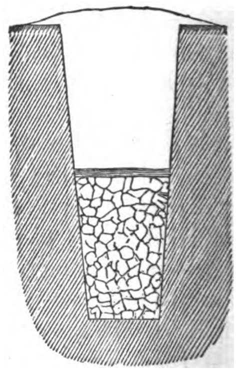
On the expediency of *covering drains with vegetable substances*, Mr Robertson observes with much truth, that—

The only possible use of a covering of straw or turf is to prevent any of the earth, when thrown back into the drain, getting down among the stones; but it is evident that such a covering will soon decay, and then it becomes really injurious; because, being lighter (and finer) than the soil, it will, when decomposed, be easily carried down by any water that may fall directly upon the drain; and if the surface of the stones has been broken so small as to prevent the drain from sustaining any injury in this way, then the covering itself must be altogether superfluous. But farther, it will be found that the effect of this practice, in many cases, is still more injurious. When drains are filled in the usual way, whether with land or quarried stones, a man, or sometimes a woman, is appointed to level the surface and put on the straw or turf; and the person appointed to this duty knows that his master expects him to do a certain number of roods per day, and finding the stones difficult to break, he too frequently contents himself with merely levelling the surface, and by means of the covering the fault is effectually concealed. By the method, however, of separating the small stones from the large, the whole expense of this sort of

breaking is saved, and a covering on which time will produce no change, is given to the drain.*

A drain completed in this manner with stones may be seen in fig. 36. The dimensions given by Mr Roberton are 33 inches deep, 7 inches wide at bottom, and 9 inches wide at the height of the stones, which are 15 inches, and within these dimensions 15 cubic feet of stones will fill a rood of drain of 6 yards. Mr Stirling's drains are 30 inches deep in the furrows, 5 inches wide at bottom, and 8 inches wide at 15 inches from the bottom; making the contents of a rood of 6 yards 12.3 cubic feet. The fig. 36 represents a drain 36 inches deep, 9 inches wide at bottom, 12 inches at the top of the stones, and the stones 18 inches deep. These dimensions give 23½ cubic feet per rood of 6 yards; that is, more than half as many stones more than the drains of Mr Roberton, and, of course, as much more expensive. I own I am partial to the breadth of the common spade as a gauge for the width of the bottom of a drain to be filled with *stones*, because it affords abundance of room for a durable stony filter, which 7 inches can scarcely accommodate, when stones are broken to 4 inches in diameter, and much less can 5 inches, as in Mr Stirling's drains, afford the accommodation, unless the stones are very small.

Fig. 36.



THE SMALL DRAINS FILLED WITH SMALL BROKEN STONES.

I am quite persuaded, however, that the permanence of a drain does not depend so much on the quantity as upon the manner in which the stones are put into it; and I am also persuaded that it is no matter what description of durable materials is used, provided they have sufficient space at the bottom to permit the largest quantity of water the drain can possibly receive to pass, and provided they are so placed as no earth shall get amongst them to form mud, and intercept the flow of water. Yet, as truly observed by Mr Stirling, our experience is not sufficient to prove what is the *smallest* size that a drain might be made to be *permanent*. In this state of uncertainty, the breadth should be sufficient to prevent moles pushing across it. This consideration regarding moles acquires greater importance the more the land is drained, for the deeper the water is confined *under* the ground, and the greater the

* *Prize Essays of the Highland and Agricultural Society*, vol. xiv. p. 40.

facility afforded to the air to descend into drains, the deeper will worms be obliged to go in search of moisture, and they will, if they can find air also, and, of course, the nearer the bottom of the drains will moles be disposed to burrow in search of their natural food. Mr Stirling proposes to make the bottom of the drain 5 inches only, bnt then he directs the stones to be broken to pass through a ring as small as $2\frac{1}{2}$ inches diameter. Such diversity of opinion shows that experience has not yet proved what capacity of stone-drain is the best. One principle, however, we may safely maintain, that, drains being *permanent* works, they ought to be made in the most substantial manner; and as it has not yet been ascertained by experiment what dimensions will afford *sufficient* permanency in given circumstances, it is wisdom, in the mean time, to exceed rather than curtail the dimensions of drains; and though the wisdom may be "dear bought," the consideration of cost is secondary to efficiency and permanency.

As to the *time required for putting the stones into such drains*, Mr Roberton's experience is, that, in drains of the above dimensions, namely, 33 inches deep, 7 inches wide at bottom, 15 inches filled with stones, and 9 inches wide at the top of the stones—the contents being 15 cubic feet per rood of 6 yards—supposing that a set of carts, driven by boys or women, are able to keep one man employed in unloading them, and another man in taking charge of the screen-barrow, from 60 to 70 roods may be filled in a summer day of ten hours; but the lineal extent of work depending on the cubical contents of the drains, that amount of work gives from $3\frac{1}{3}$ to $3\frac{9}{10}$ cubic yards per hour. These data are derived from large pieces of work, such as Mr Roberton contracted for in 1840, for the execution of 4,000 roods, the filling having commenced on the 1st July, and being completed on the 12th August. Two sets of carts and two screens were employed, and the contractors had some stones ready, and part of the drains were half executed by the 1st July. When the filling commenced 66 roods were finished every day, comprising a length of drain of nearly 400 yards; and as the weather proved unfavourable to the work, only 3,300 roods, instead of 4,000, were executed under the contract, in doing which, about 2,000 cubic yards of stones were buried. In 1839, of drains 28 inches deep, having 10 to 12 inches of stones in depth, and about 10 cubic feet contents per rood, 2,100 roods, or from 90 to 110 roods per day, were filled, with 1 set of carts and 1 screen, from 1st July to 5th August.

In Mr Stirling's case of the drains mentioned above, namely, 30 inches deep in the furrow, and 5 inches wide at bottom and 8 inches at the top of the stones, which were 15 inches deep, and their cubical contents 12.3 feet per rood of 6 yards, the distance carted being supposed to be 1 mile,—2 men filled 60 carts of broken stones each day, allowing for loss of time in backing into the bin of stones; one man emptied a cart-load into the drain in 15 minutes, and was ready to return with the cart in two minutes more, the horse being supposed to walk at the rate of 3 miles per hour. In this way, a chain of 22 yards, or 3.66 roods, required 3 carts of stones.

Soles and Tiles.

So much for stone, and now for *tile-draining.* The *dimensions of tile-drains* depend much on the material of which they are to be constructed. If pipes are employed, they may be the narrower; and if nothing else than tile and sole be used, they may be the shallower. If the same rule be followed in regard to them as with stone-drains,—that is, if 26 inches of earth should be retained over the hard materials to give liberty to deep ploughing—then 26 inches, added to the outside diameter of the pipe, will give the *minimum depth* a tile-drain should have; and its *minimum breadth* is determined at once by that diameter of the pipe; but such a rule would by no means secure an efficient tile-drain.

Before proceeding farther, we must again refer to the question, of using soles or not. It seems to be the opinion of many writers and practisers of tile-draining, that, "in hard-bottomed land, the sole-tile is unnecessary;" but why unnecessary, no one has yet proved to *my* satisfaction. On the contrary, I have proved, at p. 39, the necessity of using soles in all cases. If they are objected to solely on account of cost, substitutes may be found. Mr George Bell, Woodhouselees, Dumfriesshire, used Welsh slates instead of tiles, and found them equally efficacious and much cheaper; * and gray slate and pavement quarries, such as abound in Forfarshire, afford abundance of cheap and excellent materials for the soles of drains.

The breadth of the sole determines the width of the bottom of the drain; and should the breadth vary in different parts of the country, the width must in practice be made to suit it; but it is probable that soles will be made to suit the proper breadth of drains, when that point has been determined by experience, and as it has not

* *Prize Essays of the Highland and Agricultural Society,* vol. xiii. p. 509.

yet been determined by experience, and soles are made of sizes most convenient for their manufacture, drains must continue to be made of the breadth of the soles to be used. I observe that the breadth of soles made in the neighbourhood of Kilmarnock, in Ayrshire, at the tile works belonging to the Duke of Portland, as well as by Mr Boyle, tile-maker in Ayr, is 7 inches; and this breadth is made for tiles varying from 4 to 3 inches in width, inside measure. For a 4-inch tile, a narrower sole than 7 inches would not answer; the tile being ¾ of an inch thick, only ¾ of an inch is left outside each side of the tile when placed upon the sole, which is as little space as it can securely stand upon. For the smaller sized tile of 3 inches, the same width of 7 inches is too much; still, it is no disadvantage for a tile to have plenty of room on a sole, as its position may easily be fixed by wedging in stones or clay on each side against it and the walls of the drain. It would be desirable to have soles made to suit each description of tile, and it would be still better, were the sizes of tiles more limited in their range, and more uniformly alike; for at present, such is the great diversity, throughout the country, of the area of the vertical section of tiles, as well as their length, that the prices quoted afford no true criterion of their relative value.

Soles are usually made flat, though some are *curved;* not that they are better, but because they are more easily dried in the shed; but a curved sole is objectionable, inasmuch as it is difficult to form a proper bed for a curved surface to lie upon, and it is more apt to break than a flat one, when it happens to ride along its middle on a hard substance.

As to *arched tiles*, their perfect form is thus well described by Mr Boyle:—

"All tiles should be a *fourth* higher than wide; the top rather quickly turned, and the sides nearly perpendicular. Tiles which are made to spread out at the lower edge and flat on the top, are weak, and bad for conveying water. Some people prefer tiles with flanges instead of soles; but if placed, even in a drain with a considerably hard bottom, the mouldering of the subsoil by the currents of air and water causes them to sink and get deranged."*

Tiles should be smooth on the surface, heavy, firm, and ring like cast iron when struck with the knuckle. They should be so strong when set, as to allow a man not only to stand, but leap upon them without breaking. I have seen drain-tiles so rough, spongy, crooked, and thin, as to be shivered to pieces by a night's frost when laid down beside the drain. The destruction may be

* *Prize Essays of the Highland and Agricultural Society,* vol. xii. p. 20.

caused by insufficient burning, bad slimy clay, or careless preparation.

Clay has long been prepared for tiles by the pug-mill which cuts and compresses it, and the operation greatly increases its tenacity. The use of machinery in making the tiles has caused more clay to be put into them, bulk for bulk; their greater density has caused them to be burnt with a more uniform texture, and they can be handled with less chance of breakage—by all which improvements their cost of manufacture has been much reduced. Although machine-made tiles contain more clay and are denser, they are thinner and much stronger than those moulded by hand. An under-burnt as well as an over-burnt tile is bad; the former being spongy, and ultimately falling down; the latter brittle, apt to break when accidentally struck against any object, and are almost always crooked.

The *length of drain-tiles* varies in different parts of the country. A very common length in England is 12 inches; those from the Marquis of Tweeddale's machine are 14, and the common length by Ainslie's machine is 15 inches, when burnt. When the price is the same per 1000, of course the 15-inch tile is cheaper than the 12-inch. In some respects, such as being handiest in the manufacture, less apt to waste in handling, and twist when in the kiln, and their number being more easily calculated in any given length of drain, the 12-inch tile possesses advantages; but the 15-inch tiles give much less handling in and out of the cart and into the drain, have a steadier position, and are less liable to be displaced in the drain than the shorter.

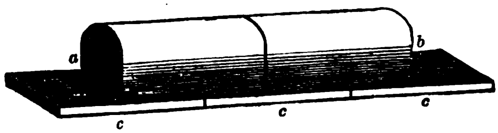
The following table shows the *number* of tiles required for an imperial acre, of different lengths placed at given distances.

	12 in.	13 in.	14 in.	15 in.	
Drains at 12 feet apart require	3630	3316	3111	2904	per acre.
... 15	2904	2681	2489	2323	...
... 18	2420	2234	2074	1936	...
... 21	2074	1914	1777	1659	...
... 24	1815	1675	1556	1452	...
... 27	1613	1480	1383	1291	...
... 30	1452	1340	1245	1162	...
... 33	1320	1218	1131	1056	...
... 36	1210	1117	1037	968	...

Fig. 37 represents well formed drain-tiles, and the best manner of setting them upon the soles, where *a* and *b* are two 15-inch tiles, set upon the soles *c c c*, also 15-inches; being two tiles standing upon parts of three soles, making the joining of the tiles intermediate with those of the soles, thereby giving the greatest steadiness to both.

It is the practice of some drainers to put a half-sole under every joining of 2 tiles, leaving the intermediate space of the bottom without a sole, imagining that the half-soles give sufficient steadiness to tiles on what they call hard clay, whilst it saves half the number of soles. I hope I have said enough on the state of clay when in contact with water to caution the drainer against this questionable practice; for as to the effect of half-soles, I conceive that water would act more partially on clay under them, and cause greater inequalities and displacement of tiles, than if no soles were used at all.

Fig. 37.

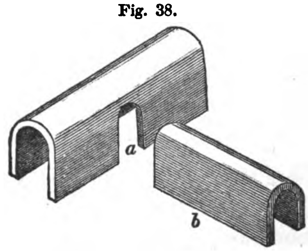


THE DRAIN-TILES PROPERLY SET UPON TILE-SOLES.

There is a mode of joining tiles where drains meet that deserves attention. The usual practice is to break a piece off the corner of 1 or 2 main-drain tiles, where those of the small drains connect with them. Another plan is to set 2 main-drain tiles so far asunder as that the inside width of the small ones shall just occupy the space ; and if the opening on the opposite side is not occupied by small tiles, it is covered up with pieces of broken tiles or stones. A better plan than either is to place the end of the small tile upon the top of the main, when the water will find its way into the latter. This plan implies that the main shall be on a lower level than the small drain. Some drainers object to this, but it is nevertheless useful in preventing back-water in the small drains when the water in ihe main-drain flows high.

Main-tiles are made with an opening in one side for the reception of the end of the small tile ; and to answer this purpose in particular situations, where the small tiles cannot conveniently conjoin with the larger main-tiles, half and quarter lengths of main and small tiles are made, which form a good junction with one another. Fig. 38 represents this mode of joining a small with a main tile, but the small tile *b* is not actually inserted into the opening *a*

Fig. 38.



THE JUNCTION OF A COMMON TILE WITH A MAIN.

of the main tile, the better to show the relative sizes and positions of both.

Besides arched tiles, there are pipe-tiles which possess the combined properties of tile and sole.

Cutting Tile-Drains.

The *cutting* of tile-drains is conducted in precisely the same manner as that of stone-drains, and of Elkington's method. Some of the tools are somewhat different, and the work requires to be very carefully executed.

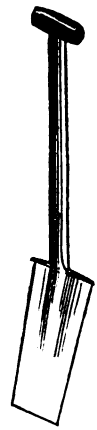
The draining of a field is commenced by the cutting of the principal main drain, which occupies the lowest side of the field, and the lowest end of this main-drain constitutes the outlet from which the entire drainage of the field flows, when all the water of a field is to be led off in one direction.

The position of the principal main-drain is not nearer than 3 yards to the ditch lip, or 5 yards to the fence. Its breadth is set off with the garden line by the first workman, whilst his two assistants dig and shovel out the surface mould upon the side of the drain nearest the fence, with the common spade and pointed shovel, fig. 12.

Whilst the mould is thus being thrown out, the carts should be laying down the tiles and soles or pipes along the open side next the field; or they may be laid down before the drain is begun to be cut, after the line of direction has been fixed. To be certain that the number of tiles and soles are laid down, the tiles should be placed end to end along the whole line, and a sole placed against the side of every tile nearest the drain. A sole though broken in two will do well enough. The main tiles with the opening in the side, along with their conjunctive small tiles, fig. 39, should be laid down at the distances determined on for the small drains entering the main drain. These preliminary arrangements should all be carefully attended to, or much inconvenience may be occasioned in carrying tiles and soles to the person who lays them. The ploughman who carries them in the cart, should be instructed in all these particulars, else some mistake may occur, as few ploughmen reflect on the consequences of what they are doing, and only strive to have their own part of a work as soon off their hands as possible. If, by their inadvertence, more or fewer tiles or soles are laid down than required, part of the time of a yoking of a pair of horses will have been lost in laying them down. and part of another yoking will afterwards be lost in leading away the unused ones to another place, while the tiles, by being so often handled, run the risk of being broken.

When the mould has been removed, the subsoil is loosened by one man, either with the foot-pick, fig. 11, or the hand-pick, fig. 13, according as the ground is stony or otherwise, the foot-pick being best adapted for displacing stones. The pick-loosened earth is removed by another man working backwards, with the narrow spade, fig. 39, with a mouth 6 inches wide, following up the picker, and putting aside the earth upon the formerly cast out mould. The principal workman follows with the pointed shovel, fig. 12, shovelling out the loose earth and trimming the sides of the drain. It may happen that the subsoil requires no picking, in which case the spade and shovel are used at once ; but this rarely is the case with the subsoils of Scotland. It will more likely require another picking in the lower spit, when the first man takes either the foot or hand pick, and loosens the earth in preparation for the principal man throwing out the loosened soil with the same narrow spade fig. 39, with which he trims the sides of the drain, and finishes the bottom neatly.

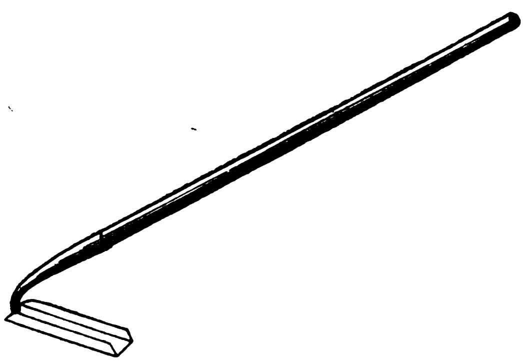
Fig. 39.



THE NARROW DRAIN SPADE.

Should the drain have stood for some days new cut, immediately before the man proceeds to *lay the sole-tiles*, the wet sludgy matter at the bottom should be removed with the draw scoop, fig. 40, and dry earth and small stones with

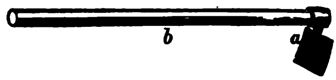
Fig. 40.



THE DRAW EARTH DRAIN-SCOOP.

a narrow draw-hoe, fig. 41, having a 2 feet handle *b*, and mouth *a*, 3 inches in width, costing 1s. The stipulated size of the drain is then ascertained by the drain gauge, fig. 15, and the uniform fall of the bottom by the levelling staff, fig. 16.

Fig. 41.

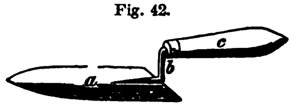


THE NARROW DRAW-HOE FOR DRAINS.

The person intrusted with the laying of the soles and tiles in the drains should be accustomed to the work, and otherwise a good workman, possessing judgment and common sense. If he is not a hired servant, he should be paid by day's wages, that he may have no temptation to execute the work in a slovenly manner; and to enable him to do it well, let him take even more time, especially at first, than is deemed necessary. According to the circumstances of the case, it will soon be ascertained how much work of this kind a man ought to do in a day. This person should remain much at the bottom of the drains; and not having too many particulars to attend to, he is enabled, with an *assistant* to hand him the materials from the ground, to do the work with greater precision and expedition; and the best assistant he can have is a female field-worker. A woman not only receives less wages than a man, but is more dexterous in moving light materials, such as tiles.

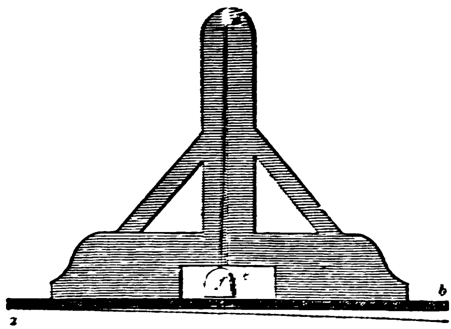
The sole should be firmly laid and imbedded a little in the earth. Should it ride upon any point, such as a small stone or hard lump of earth, this should be removed with a mason's narrow trowel, fig. 42, 7 inches long in the blade, *a*, 5 inches in the handle *c*, and $1\frac{1}{2}$ inch crank at *b*;—a very convenient instrument for this purpose, as also for making the bed for the soles. In cast-steel it costs 2s., in common steel, 1s. 3d. After laying 3 soles in length, he examines if they are straight in the face, and neither rise nor fall more than the fall of the drain. As a safe guide, in cases where the fall is not decidedly cognisable by the sight, a mason's plumb-level, such as fig. 43, is a convenient instrument. A mark at which the plummet line *d f* will subtend an angle with the plumb-line *d e* equal to the angle of the fall of the drain, should be made at the top of the opening *e*, which may be supposed to be where the plumb *f* at present hangs; by which arrangement it is demonstrable that the angle *e d f*, is always equal to the angle *b a e*, which is the

Fig. 42.



THE TROWEL FOR DRAINS.

Fig. 42.



THE DRAINER'S PLUMB-LEVEL.

angle of inclination of the fall. The width of the drain should be the breadth of the sole.

After 3 soles are thus placed, 2 tiles are set upon them, as represented in fig. 37, that is, the tiles *a* and *b* are so placed as that their joinings shall meet on the intermediate spaces *between* those of the soles *c*; and this is done for the obvious reason that, should any commotion disturb one of the soles, neither of the tiles, partially standing upon it, shall be disturbed. In ordinary cases of water in a main drain, a tile of 4 inches wide and 5 inches high inside is a good size; and from this size they vary to 5¾ inches in width and 6½ inches in height. Main pipes are made smaller, 3½ inches wide and 5 inches high, because water flows in pipes with less friction than in tiles with flat soles. Although the size of the tile varies, the width of the main drain sole is always the same, that is, 10 inches. Taking the useful tile of 4 inches in width and 5 inches in height, its thickness being ¾ inch, there will be a space left on each side of 2¼ inches, which is too much. One advantage in using pipes is in being able to fit the width of the drain to them, whereas with tiles and their soles, the width is regulated by the breadth of the sole, which, in some cases, is too wide.

The man who places the tiles takes care not to displace them in the least after being set; and to secure them in their relative places, he puts earth firmly between them and the sides of the drain as high as the top of the tiles, the earth being obtained from the subsoil thrown out.

Preparations for the junction of the main drain with the small drain tiles should be made during the laying of the main drain ones, for if the main tiles are disturbed when the small ones are being laid, to accommodate the latter, they will be displaced, and of course check the current of water which is to run in them. Whichever plan is adopted for letting in the small tiles (p. 83) he should be provided with a 6-feet rod, marked off in feet and inches, to measure the stated distances between the small drains, as near as he can. When the plan of laying the small tiles upon the top of the main ones is adopted, no previous preparation is required while laying the main tiles.

The *mouth of the main drain* at its outlet, whether in a ditch or river, should be protected with masonry, and dry masonry will do. The last sole, which should be of stone, should project as far beyond the mouth as to throw the water either directly upon the bottom, or upon masonry built up the side of the ditch. The masonry should be founded below the bottom of the ditch, and built perpendicularly in the back, with its face having the slope of the ditch. The sloping face can be made straight, which will allow the water to slip quietly into the ditch, or like steps of a stair, over which it will descend with broken force. It is proper to have an iron grating on the end of the outlet, to prevent vermin creeping up the drain; not that they can injure tiles while alive, but in creeping far up, and on dying, their bodies for a time may cause a stagnation of the water in the drain above them.

If the ground fall uniformly towards the main drain over the whole field, the small drains should be proceeded with immediately after the main drain is finished; but should hollows occur in the field, a *sub-main drain* should be made along the lowest part of each, to receive the drainage of the ground around it, and transmit it to the main drain. The size of sub-main drains is determined by the extent of drainage they have to effect, and should any one have as much to do as the main, it should have the same capacity.

Sub-main drains are made in all respects in the same manner as main drains; but this peculiarity may attend them, they may have to receive small drains on both sides, when they will have double the number of joinings. To avoid the deposition of sediment, the small drains should not enter the sub-main directly opposite to each other, but rather alternately, nor should they enter at right angles, but acutely with the flow of water.

The sub-main drain should be as much below the level of the small drains as the main itself, when it receives the small drains directly; and the main should be as much below the level of the sub-main as the latter is below the small ones. The simple way of effecting the latter purpose is, to make the main deeper after the sub-main has joined it.

Every thing is now prepared for the *small drains*. In a field having a uniform surface no difficulty is encountered in bringing the drains directly down the inclined ground into the main drain. Where hollows occur, the drainage belonging to each should be distinctly marked off from the rest, that no interference may arise in the execution of the work; and the markings should be traced along the *water-shed of the ground*—the line from which the water will descend to the sub-main. The markings may be made with pins.

In commencing the small drains from the fence at the lowest side of the field, they may be set off from each other at the distances determined on from the nature of the subsoil. But should it be determined to have a drain for any ridge, it is not necessary to make the drain in the open furrow; it may be made at any part of the ridge.

Small drains may be made much narrower than mains, to save the expense of digging out an unnecessary quantity of earth. To effect this, the narrowest spade, fig. 44, is an appropriate instrument. It is only 4 inches wide at the mouth, and is provided with a stud in front to press the heel upon when the workman is pushing the spade into the subsoil. It serves to throw out some of the earth that had been loosened by the last picking, and to trim the sides of the drain. But the loosened earth at the bottom of a drain is best removed with a scoop. When the earth is dry, the pushing scoop, fig. 10, will answer best, but when wet and sludgy the draw earth scoop, fig. 40 is the best. The scoop finishes the bottom neatly.

Fig. 44.

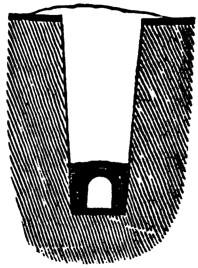
THE NARROWEST DRAIN SPADE.

Small drains, as well as mains and sub-mains, should be completely cast out, gauged, fig. 15, and examined for the fall, fig. 16, before being filled up; and the filling materials should be laid down the same as in the case of mains.

The tiles for small drains are smaller than for mains and sub-mains, being from 2½ to 3 inches wide, and from 3 to 4 inches high, inside measure, the latter being considered a large tile. A substantial tile will last much longer than a slight one, and the probability is, that the larger is the more substantial, but this may not be the case, so it is proper to examine them before purchase. Durability is of more importance than cheapness.

Soles are required for small drains; for give no credence to the absurd assumption, that clay will retain its hardness at the bottom of a drain, because it happened to be so when first laid open by the spade. Soles for small drains are of different breadths, being 5 inches at some places, and 7 inches at others: the former, 5 inches, I should conceive rather narrow for most purposes; for take even the narrowest tiles made, 2½ inches inside—these are moulded at 5-8ths inch thick, and allowing them to shrink 1-8th in the kiln, the thickness of both sides will be 1 inch; the extreme breadth of the tile being thus 3½ inches, leaves only 1½ inch to divide between both sides of the tiles on a 5-inch sole. But as most soles for small drains are made of the same breadth, take a 3-inch tile, and it will be found by the same mode of calculation that only ½ inch on each side of a 5-inch sole will be left, which is little enough space to afford perfect steadiness to the tile; and less than this should not be trusted. In all other respects, the laying of the sole and tile in the small drains is conducted in precisely the same manner as in the mains and sub-mains. A finished drain with tile and sole appears as represented by fig. 45.

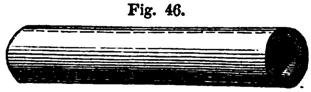
Fig. 45.



THE SMALL TILE-DRAIN.

Of late years the pipe form of tile has been much used in draining. Its adoption has partly arisen from its small cost, compared with sole and tile together, aud partly from its operating both as sole and tile. Its first and simplest form, the cylindrical, is seen in fig. 46, 15 inches in length, 2 inches diameter in the bore, and ⅝ths inch thick. In order to reduce the cost of this form of pipe-tile to the lowest degree, it is made in many parts of England only 12 inches in length, 1 inch in the bore, with a corresponding thinness.

Fig. 46.



THE CYLINDRICAL PIPE-TILE.

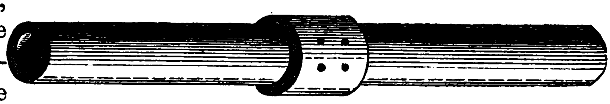
An objection at once occurs to the mind to pipe-tiles, that they cannot permit the water to enter them so freely as sole and tile. The experiments of Mr Parkes, referred to at p. 46, and my own calculations on the subject in the preface, clearly show, that the smallest pipe used is quite sufficient to carry quickly away all the water that will enter the soil after the heaviest rains that ever fall in this country. The experiments of Mr Tweed, near Woolwich, prove besides that water easily permeates through pipe-tiles. Indeed, every one knows that clay dishes would be unable to retain liquids of any kind unless they were glazed. So that in fact it is easier to explain how water gets into clay-pipes, than to devise means how to keep it out.

A good objection may be made to inch pipes, for it does seem a refinement in economy to use so very diminutive a tile as one with only an inch bore, when so very small a space might be choked up with a very small quantity of matter, and when all the water it can convey must flow with but little force.

The cylindrical form, moreover, is practically objectionable, because of the difficulty of placing a number of such pipes on end in a firm position upon the flat surface of the bottom of the drain, to which it is scarcely possible to give a rounded form with the tools in use. No doubt a tool could be contrived of a rounded form, but still the question may arise of what intrinsic value is the cylindrical form? It is evident that, were the slightest depression to take place at either end of a pipe, or were the end of one pipe to be placed a little aside from that of its neighbour, the continuity of the passage for water would be broken, and the drain might prove hurtful to the land. A way has been recommended of securing the continuity in laying small pipes, which is to place each pipe upon a round piece of wood or iron having a shoulder to meet the end of the pipe, and set at right angles to a helve, and with it the pipe is held down in the drain and retained in its place by the pressure of the shoulder until the subsoil earth is firmly packed about it, and then the instrument is withdrawn.

Various devices have been contrived to hold cylindrical pipes straight on end in a drain, without the trouble implied in these directions, and among these are the following:—1. A short cylinder to act as a collar for connecting the ends of pipes as in fig. 47, into which the water is allowed to pass through holes perforated in its sides. The device doubtless answers the purpose, but unless the collars are sunk into the ground to allow the entire length of the pipes to rest with an equal bearing upon the bottom of the

Fig. 47.



CYLINDRICAL PIPE-TILES CONNECTED BY A COLLAR.

Fig. 48.

PIPE-TILES CONNECTED BY LOBES.

drain, the pipes may be broken between the collars by the weight of the earth above it, or other casualty. Collars, besides, incur considerable additional expense and trouble. 2. A much better plan is shown in fig. 48, where the ends of two pipes are held firmly together by giving the end of each pipe a three-lobed form. The waved line in the middle shows the form of meeting of the two pipes. These lobes may be formed by the mould when the tile is made by hand, but if made by a machine, a complicated apparatus is required, which renders this form of pipe expensive. 3. Another device is represented in fig. 49, where a notch of about an inch in length is made at each end of the pipe, as at *a* and *b*,

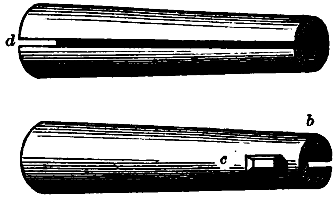
Fig. 49.

PIPE-TILES CONNECTED BY DOWELS.

and on the notches of two ends being placed togther, as at *c*, a small dowel of wood is pushed into both notches, to keep the pipes together, and in the position wanted, until as much subsoil earth is packed about them as will retain them in their places. The dowels will rot in time, but not until they have performed the service required of them. This is a simpler mode than either of the other two; but still the making of notches, and especially of so many small dowels, is attended with considerable trouble, and, of course, expense.

Other forms of pipe, to avoid the cylindrical, have been recommended. One is the conical, as seen in fig. 50. The pipes are connected by slipping the large end of one *a*, upon the small end of the other *b*, until the former reaches the stud *c*, which prevents its going farther. When the pipes are laid in the position seen in the cut, the water easily gets into them by the slits *d d*, along their entire length. It will be seen at once, that this

Fig. 50.



CONICAL PIPE-TILES.

form of pipe is expensive and not easily laid down, because the large end will require to be let into the ground before the body of the pipe can rest upon it.

A much less expensive form of pipe is the sole and tile, combined as seen in fig. 51. The flat sole permits this pipe to be firmly laid upon the ground; but it impedes the water so as to encourage the deposition of mud.

Fig. 51.

CONCRETE PIPE TILE.

A drain-tile of this form was introduced some years ago by Lord James Hay, of Seaton, Aberdeenshire. It was formed of *concrete*, composed of *good* lime, *sharp* sand and gravel, mixed in the proportion of 1 bushel of lime-shells to 2½ bushels of sand and 4 bushels of gravel, which, in swelling, gave 8 bushels of concrete that made 120 tiles. The concrete was run into moulds, in which it soon set firm enough to be placed on boards, and the tiles became in a short time, according to the state of the air, in a sufficiently indurated state to be used. One man, aided by perhaps 4 others to supply the materials, could make 5000 tiles a-day. When the quantity of boarding is taken into consideration, I have great doubts of this process affording a cheap tile; at all events, it can only be made in those localities where *sharp* sand and gravel are found in abundance,—substances which cannot be carried to a distance but at great expense. Another mode of using this concrete was in pouring it into the bottom of the drain, and working it then into a hollow channel by means of a piece of wood about 3 feet long, of a semi-cylindrical shape, and having a long handle set at such an angle as to permit the workman to make the grooved channel while standing upon the ground. This operation, extending from one end of the drain to the other, forms an unbroken channel as long as the drain itself. The obvious objection to this last form of tile is the impossibility of water finding its way into it, until it accumulates in the bottom of the drain so high as to run over the upper edge of the groove, thus keeping the earthy bottom of the drain in a continual soak of water.

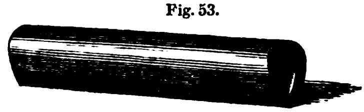
Fig. 52.

HORSE-SHOE PIPE-TILE.

To lessen the breadth of sole, and still retain the capacity of the orifice, the form of fig. 51, was altered into that of a horse-shoe, as in fig. 52, the sole occupying the space between the heels, which is the narrowest part of the shoe, and the upper part rounded off capaciously in the form of the crust of the hoof. The sole is flat enough for the pipe to stand firmly upon the ground. There is no obvious objection to this form.

But the most perfect form of the orifice for a pipe-tile is the egg-shaped, as represented in fig. 53: the narrow end of the egg making a round and narrow sole, the water will run upon it with force, and carry any sediment before it; while the broad end provides a larger space for the water when it rises to the top after heavy rains. The base of this form of tile may be considered too narrow, but it is broad enough for security against sinking, being 1½ inch wide in the bottom, while the bore is 1¼ inch wide aud 2¼ inches high. Tapering broader from the bottom towards the top, from 1½ inch to 2½ inches, a resistance against farther sinking is constantly presented in this form, and unless the force is increased, cannot sink farther, whereas when the broadest part of any tile is at the bottom, there is nothing to prevent such a form sinking altogether when it once begins to sink.

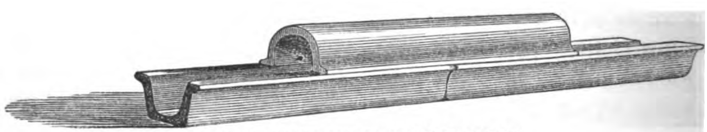
Fig. 53.



EGG-SHAPED PIPE-TILE.

A form of tile combining the properties of the pipe, and tile and sole, is made by the machine invented by Mr William Bullock

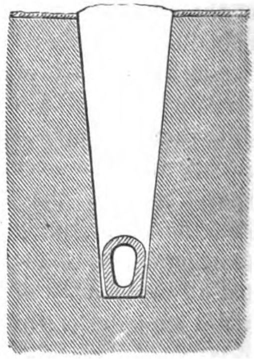
Fig. 54.



TROUGH-SHAPED SOLES WITH ARCHED TILE.

Webster, Houndsdoun, near Southampton. As seen in fig. 54, it consists of a troughed sole presenting to the water the same means of ingress as pipes, while the cover is an arched tile, the whole having the form of a flat-bottomed pipe. Such a combination of tiles will, no doubt, answer the purpose of drainage; but I see no advantage in having to handle so many pieces of tile, when a single one would answer the same purpose.

Fig. 55.

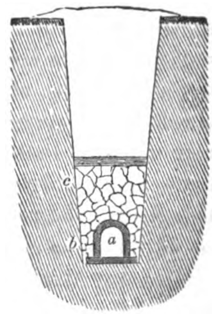


THE SMALL PIPE-TILE DRAIN.

The form of drain with the egg-shaped tile, is represented by fig.

55, the space above the tile being filled with earth ; but the best form of drain in my opinion, is constructed with the egg-shaped tile and small broken stones or clean large gravel, as represented in fig. 56, where a tile *a* is seen to rest on a sole, but where an egg-shaped tile may of course be placed, and around and upon which small stones are packed by the hand until they cover it to *b* ; the remaining small stones *c* being put in by the drain-screen, fig. 31, and covered with the smallest stones, and beaten down with the beater, fig. 34, and the earth returned upon them. The width of the bottom should be 3 inches, to admit a common egg-shaped tile, and the height of the stones 12 inches.

Fig. 56.



THE TILE AND STONE DRAIN.

The stones being packed in while the laying of the tiles proceeds, they should be placed in small heaps, immediately after the tiles have been laid down, as near the drain as possible, and from thence filled into baskets by the assistant, and handed to the man in the drain. Two baskets are required for the purpose, one being filled by the assistant while the other is being emptied by the drainer. The filling with the drain-screen should not commence until as much of the drain is laid with tiles and packed with stones by the hand, as to employ *at least* 2 single-horse carts for one yoking ; and, should the weather seem favourable, not until that number of horses can be employed a whole day, as otherwise the time of the horses will be wasted. If the draining is of such an extent as to keep a pair of horses thus constantly employed, so much the better.

This construction of drain I consider the *ne plus ultra* of the art, though few farmers would adopt it, on account of its expense ; but the consideration of expense should yield to durability and efficiency. It seems to me a perfect piece of work, inasmuch as the pipe-duct forms the smoothest vehicle possible for the water, and is proof against vermin ; while the stones not only secure the duct in its place, but impart durability to the whole structure, and present an extensive area to the permeable capabilities of the subsoil. What properties, then, of a good drain does this one not possess ?

Mr Mechi used to fill drains with broken stones at the bottom, and a pipe-tile above them. What use the pipe could serve in that position, I could never discover, unless that of carrying away the water after the stones became choked.

In small isolated portions of moss in the midst of firm ground, it is inconvenient to follow the plan of draining recommended for bog-draining, at p. 16. Where the moss is not cut through to the hard ground below, instead of making peat-tiles, it will probably suffice to lay a sole-tile for a main-drain, which is 7 inches broad, upon the moss, and place the pipe-tile, fig. 53, upon it. I rather think such a pipe-tile is better for this purpose than even a larger common tile, inasmuch as any sludgy moss that may incline to rise from below, might lodge upon the sole without rising so high as to get into the pipe, and when the pipes and soles are so laid as to break band, as shown in fig. 37, there will be little danger of the pipes being displaced; or, Mr Scott's larch drain tubes, to be described in the sequel, may, perhaps, be successfully used in such cases.

Where quicksands occur, besides using the broad sole and pipe-tile, as in the case of the moss, turfs should be placed along each side of the soles as well as over the joints of the tiles.

Outlets and Levels.

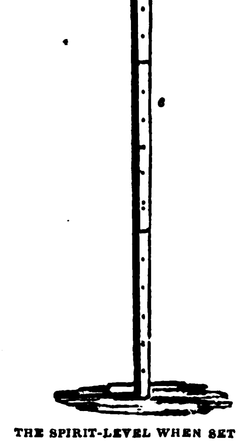
The *outlet* forms the end of the main-drain in tile-draining, as in every other. There should be a decided fall from the outlet, whether effected by natural or artificial means; but it may be as small as from 1 inch in 150 feet to 3 feet in the mile. The open ditch should be kept scoured deep enough for a considerable distance.

It is a frequent charge of neglect against farmers, to allow open ditches almost to fill up before being scoured out, and the ready excuse for the neglect is, that scouring ditches to any extent incurs considerable labour and expense; and no doubt it does, when they are allowed to fill up. But were ditches scoured as they require it, and this every year if necessary for the welfare of stock, fences, and drains, little expense would be incurred at one time. It would be better to incur the expense of converting an open ditch into a covered drain at once, than to neglect the scouring of it when necessary.

Should the fall from the outlet towards a river be too small, the covered drain should be carried as far down by the side of the river as to secure a sufficient fall. Rather incur the expense of carrying the drain *under* a mill-course or rivulet, by means of masonry or a cast-iron pipe, than allow back-water to enter a drain.

In cold countries, such as Russia, Sweden, and Canada, where the frost sometimes penetrates into the ground to the depth of 18 inches, a proper outlet to protect the water from frost as it issues from the drains, is an essential point in every system of drainage. It is evident that shallow drains of 18 or 20 inches, such as are too common in England, will not answer in those countries; the water would freeze in them and derange their structure, and tiles would be burst into pieces. It is equally evident, that if the water were frozen as it issued at the outlets of drains, the ice would cause the water to stand back in the drains in a stagnant state; and although the depth of the drains may place the water beyond the reach of frost, the upper part of the ground, dried by the frost, would be occupied by the stagnant water, by means of the capillary force, and there becoming frozen, materially injure the soil. The only practicable way I can therefore see of retaining the water in a liquid state, as it issues from the outlet, is to place the outlet at such a depth as to be beyond the reach of frost, and to convey the water in a deep and long covered drain. Much foresight will thus be required, and much expense incurred in making drains in countries where frost penetrates to a great depth.

Fig. 57.



THE SPIRIT-LEVEL WHEN SET FOR OBSERVATION.

A *spirit-level*, of the form of fig. 57, I have found a very convenient instrument for ascertaining the fall in apparently level pieces of ground, and generally for taking levels in fields. When in use, it is placed in a frame of brass, a part of which operates as a spring to adjust the instrument by pressure to the level position, *d*, while the large-headed brass screw, *c*, is turned. A perpendicular stud is affixed to the under part of the framing, and pushed firmly into a gimlet-hole in the top of the supporting rod, *e*, which is inserted into the ground, whence the level is desired to be ascertained. There are two eye-sights, *a* and *b*, *a* being in the form of a small hole for the eye to be placed against, and *b*, that of a square opening, furnished with two hair wires crossing it in the middle. I would recommend this instrument being used in all cases of draining level ground, even where the fall of the ground is supposed to be known, for the eye is not a correct judge of the levelness of ground. In one case of my own, I was pretty sure by the eye that the outlet to a division of drains in a field should fall, at some yards off, into an open shallow ditch, which constantly conveyed a current of spring water. The contractor for the drains was of the same opinion. On testing, however, the evidence of the eye with the spirit-level, we found that the outlet was 8 inches below the bottom of the ditch, instead of above it. This being the case, the securing of a proper fall would have occasioned a cutting of 200 yards in a somewhat different direction; so I caused a narrow well to be sunk on the spot, 8 feet deep, through clay, to a bed of gravel below, and on filling it with stones, the gravel absorbed all the water from the drains. I was made aware of the existence of the thick gravel bed below the boulder clay when sinking a well in another part of the field to supply water to stock, when occupying this or an adjoining one. Such a spirit-level costs 15s. When not in use, the brass frame is placed between the eye-sights over the spirit-tube, and both are protected by a movable wooden cover—the whole instrument being only 8 inches in length, 1¾ inches thick, and 1 inch broad, and so light that it can be easily carried in the pocket, whilst the rod may be used as a walking-cane.

It may happen that, on account of the undulations of the ground, more than one outlet will be required to clear a field of water; that is, one division of drains may be let out most easily in one place, and another division most easily in another. In such cases, it is better to have all the outlets separate than to conjoin them, even if practicable.

The Mode of Using the Spirit-Level.

A few directions on the mode of using this spirit-level may be of use to young drainers.

I may mention in the first place, there are other forms of levels in use besides this. There is one mounted on a tripod, accompanied with a small telescope, to show to considerable distances, which is considerably more costly than this, and much used by engineers and surveyors. This one is not intended to level long distances at a stretch, nor is it necessary to use it for such a purpose in the drainage of fields, while it may be used to ascertain levellings of any distance, by taking up a greater number of stations than with the larger instruments. These other forms of levels it is unnecessary to describe here, as the simple one recommended is quite sufficient for every ordinary purpose.

When it is desired to ascertain the fall in a flat piece of ground to be drained, plant the level on its stick about the middle of the piece of ground, and after placing the eye-sights of the level in the direction in which the fall is desired to be ascertained, adjust the instrument until the air-bubble *d*, fig. 57, indicates the level position. An assistant goes to the end of the ground in one direction, having a rod, upon which he marks the level at the point determined by the person using the spirit-level; and he then goes with the rod to the end of the ground in the other direction, and on the level being adjusted and noticed, he marks the point upon the rod. Should both marks coincide, the two ends of the piece of ground are on a level, and the difference between them indicates the fall in the ground from the less to the greater height. For example, if at the first station the mark on the rod measures 3 feet 9 inches above the ground, and at the second 4 feet 8 inches, the difference, namely 11 inches, gives 11 inches as the fall in the ground from the first to the second station.

Take a more difficult case. Suppose that a knoll in the middle of a field renders it difficult to see the direction of the general fall of the ground. Let a point be chosen to place the level, from which the field on both sides of the knoll may be seen at once, and then level, from this point, one or more parts of the ground, first on one side of the knoll and then on the other, and the differences between the sides will show which side is lowest, and of course the one by which the general drainage of the field will have to be effected.

A very little practice with the instrument will show its use in every case of inequality of ground.

In ascertaining the relative heights of different points of a field, the height of the instrument standing above the ground is not taken into the account.

Returning the Soil into the Drain.

The next procedure is the *filling up of the drains with the earth that was thrown out of them*, and this is returned either with the spade or the plough, or with both. When drains are filled with stones, the plough may be altogether used, giving it as much *land* for the first bout or two as it can take in. If the earth has been thrown out on both sides of the drain, a large furrow slice on each side will plough in a considerable quantity of earth; but, as the earth is generally thrown upon only one side, and the plough can then only make it move towards the drain while going in one direction, a more expeditious mode of levelling the ground—which, in the amount of labour of returning the earth into all the small drains of a field, is of some importance—is to cleave down the mound of earth in the first place, and then take in an equal breadth of land on both sides, and gather it up twice or thrice towards the drain, which thus constitutes a prepared feering; after which the harrows make the ground sufficiently level. This laborious plan, however, is only requisite when much earth has been thrown out at a distance from deep drains; but in ordinary thorough-draining, the plough accomplishes the work with much less trouble; the first two furrows loosen the earth along each side of the mouth of the drain and cause it to fall into it, but in doing this the horses are apt to slip a hind foot into the drain, and overstrain themselves; and such an accident, trifling as it may seem, may be attended with serious injury to the animal. The *safest* mode in all cases for the drain and the horses, is to put the first portion of the earth into the drain with the spade; and such a condition should always be made in the agreement with the contractor.

It is an established principle, that all drains, whether furnished with stones or tiles, should receive the water from *below*, and not immediately from above through the soil. Were drains *entirely* filled with loose mould, or other loose materials, it is evident that the rain, in descending directly through them, would arrive at the bottom loaded with as many impurities of the soil as it could carry along with it in its downward course; and as it is a primary object with drainers to prevent impurities getting into the ducts, where in time they might accumulate, or fill up the interstices between the stones—and the smaller the stones are broken, the interstices would fill up the sooner—the only way to prevent such mischances is to return the clayey subsoil into the drain, where it will again soon consolidate, and retard the direct gravity of the rain; for it has been found that mud deposited among the stones of a drain has proved as impervious to water, and formed as favourable a soil for the growth of sub-aquatic plants, as a naturally impervious subsoil. A disposition, however, has been exhibited by some drainers to carry the prevention of water through the returned earth to the duct rather too far, by surrounding even pipe-tiles with the strongest clay afforded by the drain, in a puddled state, and tramping it in. Could this puddled clay be constantly kept in a moist state, it would, of course, resist the passage of water, and prevent it entering the pipes at all; and I can conceive a pipe-tile so luted with wet clay as to be as hermetically sealed by it as the porous nature of the tile will admit. But it is not possible to retain the clay always in a moist state, as the portion immediately above the pipe will be drained by it, become cracked, and the cracks will permit the water to enter the tile *from above.* It being thus impossible to prevent water entering a tile at the bottom of a drain, it seems to be a matter of indifference in what state and with what sort of earth the drain should be filled. Fine sand, however, is a very unfit substance to cover tiles or stones with, for it will certainly insinuate itself into every crevice through which water can pass. The tiles in the drains in Dalmeny Park, belonging to the Earl of Rosebery, were covered with sea-sand and gravel; but the sand soon choked up the tiles and had to be removed, and the tiles re-laid with different materials. Perhaps it would be better to keep the soluble portion of the soil as far from the ducts of a drain as possible, and while thus rejecting the upper mould for a *commencement* to the filling, the subsoil may be returned into the drain in any order or state it may happen to be. The earth should not be returned into tho drains too soon, but time allowed to the subsoil to crack all above the tiles, which it will soon do in dry weather, and of course operate the sooner as a drain after the earth has been filled in; but in wet weather, the rain will wash down the earth into the drains, if they are left long open. So this particular of practice must be guided by the state of the weather.

Conducting Draining Operations.

Serious precautions, in regard to the *mode of conducting* draining operations, require to be given. I have frequently observed in bad weather in winter, great extents of drains cut and left open for an indefinite length of time, without stones or tiles in them, in the intervals of which rain and snow have fallen and brought down parts of the sides into the bottom. The spade-work, too, is often roughly and slovenly executed, whereas it should be neatly and correctly done in every size of drain. I have also observed drains being made to pass round by the side of comparatively small boulder stones, instead of these being removed, and the drains carried forward in a straight line. The most clayey or sandy part of the earth from the bottom of the drain is often placed upon its very edge, where it is apt to slip partly into the drain, instead of being thrown a little distance off. The tiles are frequently laid down in a very careless manner, instead of as near the hand of the person who lays them as possible, on the opposite side of the drain on which the earth is thrown out. Soles of any kind are too frequently neglected to be used. And, to reach the climax of negligence in the whole process, a long time is frequently allowed to elapse before the earth is returned again above the stones or tiles in the wettest weather. Every one of these negligent practices should be scrupulously avoided; and as they entirely originate in neglecting to exercise a strict superintendence over the labourers who have undertaken the work, either on day's wages or by the piece, the farmer himself is blamable for them. Negligence of superintendence is his blame and no one's else. If the same set of men undertake to cut the drains and lay the tiles, which is by much too common a practice, a damp state of weather is more favourable for cutting the solid ground than laying the tiles, and so they go on cutting drains, day after day, as if they had nothing else to do. A large extent of drain is thus left exposed to the weather, which on becoming wetter, much of the sides fall in. If the rain continue, the workmen can neither bottom out the drain nor lay the tiles, and the matter becomes worse daily. Then, should a sudden frost come, it moulders down still more of the earth from both sides, which, absorbing the rain or snow that follows, is converted into sludge that cannot be taken out until it becomes firm. On the other hand, a fine day or two occur, and induce the men to lay the soles and tiles, and they continue laying them, as if certain the dry weather will continue until they are ready to return the earth into the drain. The earth, moreover, is found too wet one day and too hard with frost another, to put into the drain, and so the laid tiles lie exposed to whatever change of weather may happen to come. In all these various states of neglect I have seen drains exposed for weeks together.

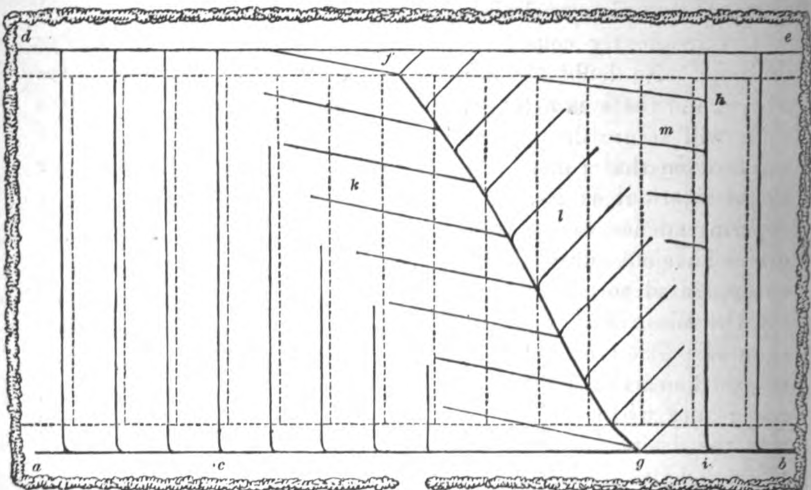
Now, it is certain that all these bad effects would be avoided, were a strict superintendence exercised over the workmen. When left to their own will, they will naturally execute that part of the work most conducive to their own interest when working by the piece, and most pleasant to their feelings, when on day's wages, irrespective of the ultimate consequences to the drains. They have no desire to work badly; but as they cannot predict the weather beyond the present day, they naturally work according to their own convenience. It is thus worse than folly, on the part of the farmer, to neglect the constant superintendence of so permanent an operation as draining. The time of a grieve or steward is too frequently considered thrown away when superintending drainers. No doubt the grieve's time may be fully occupied elsewhere, and there is little fear of men on piece-work working less than will secure them good wages, but it is not the quantity of work done that constitutes the most material consideration for the drainer—it is its *quality* and *efficiency*, and to secure these, superintendence over workmen is absolutely requisite. If the grieve have not sufficient leisure, another competent person should be appointed to superintend, and should he also undertake to lay the tiles, in so far a saving will be effected, whilst his minute inspection will oblige the workmen to cut the drains and return the earth whenever their state is best adapted for the purpose; and when they are not bound to return the whole earth into the drain, he should have the power to direct the steward of the farm to send ploughs to do it when required. With a proper system of superintendence, the whole work may be executed in the fittest time, and in the most satisfactory manner.

Ground Plan of a Thorough-Drained Field.

A general idea of the arrangement of thorough drains, may be gained by a ground plan of a field so drained, such as is represented in fig. 58, where *a b* is the *main-drain* formed in the lowest head-ridge; and when the surface is uniform, the drains run into it parallel to one another from the top to the bottom of the field, as those from *a* to *c*, connected as they should be at the top with the drain *d e* running along the upper head-ridge.

But with inequalities in the ground, an irregular surface cannot be drained in this manner, and must be provided with *sub-main drains*, such as *f g* and *h i*, which are each connected with a system of drains differing in character; *f g* having a large double set of drains, *k* and *l*, connected with it, and *h i* only one set, *m*, connected with it. The sub-main, *f g*, is supposed to run up the lowest part of a pretty deep hollow in the ground, and the drains, *k* and *l*, on either side of it, are made to run down the faces of the acclivities, as nearly at right angles to the sub-main as the nature of the inclination of the ground will allow, so as always to assist the natural tendency of the water to find its way to the hollow. There is also a supposed fall of the ground from

Fig. 58.



GROUND PLAN OF A THOROUGH-DRAINED FIELD.

the height above *l* towards *h*, which causes the drains at *m* to run down and fall into what would be a common drain, *h i*, were it not, from this circumstance, obliged to be converted into a sub-main. The sub-main, *f g*, should be made larger than the main drain, *a b*, above *g*, as it has more to do; but the sub-main, *h i*, should be made as small, and not larger than a common drain from the top of the field, until it reaches the point *h*, where the collateral drains begin to join it. The main drain should be made larger below *g* to *i*, and still larger from *i* to *b*, towards its outlet, than any of the submain drains, as it has there most to do.

It will be observed, that all the *common drains* from *a* to *c*, and at *l* and *m*, have their ends curved, those at *k* not requiring that form, because they enter obliquely into the main, from the slope of the ground.

The dotted lines give the breadth of the upper and lower head-ridges, and the position of the open furrows of the ridges of the field; and it will be observed that the drains are not made in the open furrows—that is, the black lines are not in conjunction with the dotted. This is done with the view of not confounding the open furrows and drains in the figure; but it is a plan which may be practised with propriety, as the absorption of the water towards the drains should be effected from the subsoil as far as it is porous, and not directly from the open furrows. Such a plan of a drained field enables the farmer to go directly to the spot in case of a stoppage or insufficiency occurring in any drain.

Physical benefits derived from Draining.

The existence of moisture in the soil being most easily detected by its injurious effects on the crops, the advantages derived from draining are also best indicated by its good effects upon them. On drained land, the straw of white crops shoots up steadily from a vigorous braird, strong, long, and so stiff as not to be easily lodged with wind or rain. The grain is plump, large, bright-coloured, and thin-skinned. The crop ripens uniformly, is bulky and prolific, more quickly won for stacking in harvest, more easily thrashed, winnowed, and cleaned, and produces fewer small and light grains. The straw also makes better fodder for live stock. Clover grows rank, long, and juicy, and the flowers large and of bright colour. The hay wons easily, and weighs heavy for its bulk. Pasture-grass stools out in every direction, covering the ground with a thick sward, and produces fat and milk of the finest quality. Turnips become large, plump, as if fully grown, juicy, and with a smooth and oily skin. Potatoes push out long and strong stems, with enlarged tubers, having skins easily peeled off, and their substance mealy when boiled. Live stock of every kind thrive, evince good temper, are easily fattened, and of fine quality. Land is less occupied with weeds, the increased luxuriance of all the crops checking their growth. Summer fallow is more easily cleaned, and much less work is required to put the land in proper order for the manure and seed; and all sorts of manures incorporate more quickly and thoroughly with the soil.

Thorough-drained land is easily worked with all the common implements. Being all alike dry, its texture becomes equal, and, in consequence, the plough passes through it with uniform freedom; and even where pretty large stones interpose, the plough easily dislodges them; and moving in freer soil, it is able to raise a deeper furrow-slice, which on its part, though heavy, crumbles down and yields to the pressure and friction of the mould-board, into a friable, mellow, rich-looking mould. The harrows, instead of being held back at times, and starting forward, and oscillating sideways, swim smoothly along, raking the soil into a smooth surface, and entirely obliterating the horses' foot-marks. The roller compresses and renders the surface of the soil even, but leaves the part below in a mellow state for the roots of plants to expand in. All the implements are much easier drawn and held; and hence, all the operations are executed with less labour, and of course more economically and satisfactorily. All these effects of draining I have observed in my own experience.

It is gratifying, says Mr James Black, in reference to the effects of the Elkington mode of draining on the estate of Spottiswoode in Berwickshire, and if such effects were produced by it, so much more sensibly would the results of thorough-draining be felt—it is gratifying to be enabled to state, that the general result of the operations has been such as to bear out the calculations of the engineer, and to justify the most sanguine hopes that could have been formed of a valuable improvement. Bursts and springs, which formerly disfigured entire fields, and which rendered tillage precarious and unprofitable, are now not to be seen; and swamps, which were not only useless in themselves, but which injured all the land around them, have been totally removed. The consequence is, that tillage can now in those parts be carried on without interruption, and with nothing beyond the ordinary expenditure of labour and manure; and a sward of the best grasses, raised and continued on spots which formerly only produced the coarsest and least valued herbage.

Besides those effects, he continues, which were, in a certain degree, to be expected as a consequence of laying land dry, others have resulted, which, it must be confessed, were not at first so clearly contemplated. The hurtful effects of rime or hoar-frost on vegetation, is a circumstance familiar to all who have had experience of cold and elevated districts, or of low lands subject to exhalations, excluded from the influence of the sun and currents of air. The rime, in these swampy hollows, of which mention has been made, was found, even in the warmest seasons, to be productive of serious inconvenience, and injury to the growing crops; and that chiefly at the period when the grain was approaching to its mature state. This evil, it may be said, has been removed, or at least is now so little felt, that the grain produced in these very hollows has, for many years, escaped the smallest perceptible injury from this cause.

Another effect, he adds, which was still less contemplated, and has not less agreeably resulted from the drainage undertaken, has been the improvement of the trees and woodlands in the property. Considerable difficulty was experienced in nursing up the trees in the first stages of their growth; and often individual trees grew up with stunted stems, and covered with parasitical plants, which always indicate unhealthy growth. Latterly this evil has been infinitely less felt, owing, in a material degree certainly, to the superior management of the woods themselves, but obviously also, in a certain degree, to the great dryness of the ground. Since several of the woods have been laid dry by under-drainage, the ground, in many of the hollows, has sunk so much, that the roots of the trees have been left standing up bare above the surface, with the appearance of crows' feet; and parts which were boggy and marshy, and in which sportsmen used to stick fast in hunting, are now perfectly solid, with a good sward of grass, over which they now gallop with freedom.*

All these effects of draining are just the characteristics of a go

* *Prize Essays of the Highland and Agricultural Society*, vol. vii. p. 234-6.

soil, now exchanged for a *bad*; thus proving that draining converts bad land—which is land resting in a natural state on a subsoil retaining surface-water until it stagnates, into good land,—which is land resting in a natural state on a subsoil pervious to surface-water. Draining, in thus curtailing the limits of bad, necessarily extends those of good soil; and it makes rain our friend instead of our enemy—taking all its benefit, and avoiding all its injury.

But draining is found to be beneficial not only to the soil itself—to the processes of labouring it—to the climate in reference to the crops—and to the growth of trees, but also to the health of the labouring population. Dr Charles Wilson, Kelso, when comparing the health of the labouring population of the district of Kelso in two decennial periods, from 1777 to 1787, and from 1829 to 1839, came to this conclusion in regard to the effects of draining, that

> Our attention is here justly attracted by the extraordinary preponderance of cases of ague in the first decennium, where they present an average of $\frac{1}{7}$ of all cases of disease coming under treatment; and a closer examination of the separate years shows this proportion rising more than once to even as high as $\frac{1}{5}$; while, in the second decennium, the average proportion is only $\frac{1}{300}$ of the general mass of disease. Ague, then, as is well known to the older inhabitants of the district, was *at one time regularly endemic amongst us*; affecting every year a varying, but always a considerable portion of the population, and occasionally, in seasons of unusual coldness and moisture, spreading itself extensively as an epidemic, and showing its ordinary tendency, under such circumstances, of passing into a continued and more dangerous type. Ague was not usually in itself a disease of great fatality, the deaths recorded at the dispensary having been only 1·81 per cent of the cases treated,—a sum which denotes its absolute mortality, whilst its relative mortality was 0·26, when viewed in connexion with that from all other diseases. Still, if we keep in view how frequently it was known to degenerate into fevers of a worse form, and how often it terminated in jaundice, "obstruction of the viscera of the abdomen," and consequent dropsies; or even if we take into consideration the frequency of its recurrence, and the lengthened periods during which it racked its victims, we shall see much reason to be thankful that a plague so universal and so pernicious has been almost wholly rooted out from amongst us. Those who recollect what has been stated of the former swampy nature of the soil in our vicinity, and of the *extensive means which have been adopted for its drainage*, will, of course, have no difficulty in understanding why ague was once so prevalent, and under what agency it should now have disappeared; and will gratefully acknowledge the *twofold value of those improvements, which have at once rendered our homes more salubrious, and our fields more fruitful.**

Another physical benefit derived from draining, is the retaining of moisture at the bottom of the drains for the use of plants in very dry weather. Water is so retained, not in a stagnant state, for the surplus will pass off by the ducts of the drain, but in a fresh

* *Quarterly Journal of Agriculture*, vol. xii. p. 328.

state, sufficient to moisten the subsoil and no more; which moisture is ready to be carried off by the ducts when fresh rain falls, and to be elevated to the surface in dry weather by the capillary force. Whenever drought desiccates the surface soil, and consequently forms innumerable fissures in it, the prominent points of soil readily absorb the dew and moisture from the air, while the capillary force brings the water from below to occupy the fissures.

I have heard it stated that moisture rises through soils, not by capillarity but in vapour. But as it is commonly supposed that the diurnal variations of temperature disappear at the depth of 3 feet, I cannot conceive how vapour can arise from water of the mean temperature of 44° Fahrenheit at the bottom of a drain with such a force as to pass through several feet of soil.* Water may easily be converted into vapour for some inches under the surface in summer, but at the depth of 3 feet and beyond vaporisation must act with much diminished force.

Mr Mechi seems to think that "the capillary attraction is stronger than the force of gravity," and that the capillary powers of the soil are strongest at and near the surface.† These views not being quite correct, and as considerable reliance may be placed on them in practice, they are worthy of inquiry. It is found that the height attained by fluids in tubes increases inversely as the diameters of the tubes, so that with a smaller diameter the greater height will be reached by any fluid in any tube. This being the case, capillarity bears no evident ratio to the density or specific gravity of the fluid. But as no tubes are found in the soil, we must regard the fissures caused by drainage as spaces between two surfaces; and in this case, the utmost elevation attained by the fluid is one half of that which would have taken place in tubes having their diameters equal to the distance between the surfaces, and this is always inversely as the distances. It is thus equally evident that between surfaces of fissures capillarity bears no ratio to specific gravity.‡ The capillary force may seem stronger at the surface than lower down, because there the soil is driest by evaporation, and receives the moisture most readily; but inasmuch as the fissures are largest at the surface, there also the moisture will be less minutely diffused through the soil by the capillary attraction than lower down. Hence the capillary force cannot be destroyed by drainage; on the contrary, its sphere of action will be much

* *Transactions of the Royal Society of Edinburgh*, vol. xvi. p. 197.
† *Mechi's Experience in Drainage*, pp. 9, 13.
‡ *Bird's Elements of Natural Philosophy*, pp. 17, 18.

extended by it, on account of the increase and even creation of fissures.

Another physical benefit derived from draining remains to be mentioned, which is the equable supply of water for vegetation and the purposes of machinery. In undrained soil, the water remains constantly in it as in a filled sponge; and a fresh supply of rain finding no room runs off at the surface to the nearest stream, so that heavy falls of rain are succeeded by large inundations of turbid water. By drained soil, on the other hand, the rain is absorbed as it falls, and the deeper the drains are situate, the larger the mass of earth is ready to absorb it. The water is thus retained in the ground for a time after it has fallen, in ordinary cases of rain perhaps 48 hours, and in heavy rains for 24 hours, before it passes off by the drains. So that an inundation is longer of appearing from drained than undrained land, and it continues longer. In heavy rains some of the water runs off even the drained surface in a turbid state, though in ordinary rains it escapes in a comparatively clear state, on account of having been filtered through the soil.

Cost of Draining with Stones.

I come now to a highly important particular regarding draining which is its *cost*. 1. With regard to Elkington's method, as it covers more or less of the surface of the field, its cost is usually not estimated by the *acre*, but by the *rood* of the respective depths of drain executed; and according as the subsoil is more or less difficut to cut.* 2. On the other hand, as thorough-draining occupies a large proportion of the surface of a field, its cost may be ascertained by the *acre*; and fortunately sufficient data exist to satisfy the inquiries of drainers on this point.

The great expense of executing very deep drains has been urged as an objection to the adoption of Elkington's method.

A general answer to this, however, as Mr Black truly says, in his account of the draining of the estate of Spottiswoode in Berwickshire, might be, that the practice which is ineffectual can never be a cheap one. But even in the mere matter of cost, the balance will probably as often be found to turn in favour of the larger as of the smaller drains. If the first be larger in size, the latter must be more numerous; and a single good drain, well laid out, will be often seen to do that which a hundred minor ones would fail to effect. The chief difference of expense is in digging the drains; for, in regard to the materials of filling, it is to be observed that the larger

* *Stephen's Practical Drainer*, p. 105; and *Prize Essays of the Highland and Agricultural Society*, vol. vii. p. 242.

drains are not at all filled in the same proportion to their size as the lesser (this remark is only applicable to drains filled with stones, and not with tiles); which circumstance, combined with the comparative smallness of their number, will, in this particular, generally show the balance of saving in expense to be on their side. The quantity of materials indeed (and this remark is worthy of attention) which has been consumed in these smaller drains, in a few of the earliest improved tillage counties of Scotland, is surprising. Instances are constantly occurring, where new drains are in the course of construction, of their lines intersecting innumerable smaller drains, long since forgotten and choked up, and serving no useful purpose as conductors of water.*

The smaller drains alluded to had been imperfectly formed, and this will ultimately be the fate of *all* drains so constructed.

According to the experience of the late Mr Wilson of Cumledge, the expense of the Elkington method of draining a retentive clay loam upon a retentive clay subsoil, with drains from 5 to 8 feet in depth, is on the average as follows :—

Expense of cutting 6 feet deep drains, 2½ feet wide at top, and 16 inches wide at bottom, per rood of 6 yards,	£0	2	0
... of making the conduit, per rood,	0	0	2
... of quarrying, gathering, and carting 5 loads of stones, per rood, which cost (according to distance of carriage) from 8d. to 1s. 4d., average 1s. the load,	0	5	0
... of filling in small stones, and the earth,	0	0	6
Average cost of rood,	£0	7	8

This sum may be considered a fair charge, by the rood of 6 yards, for the Elkington method of draining.

The cost of thorough-draining with stones, as incurred by Mr Roberton, I shall here give in detail. The drains were placed from 30 to 36 feet apart, as the nature of the subsoil was favourable to drainage; and the average of these distances gives 70 roods, of 6 yards, of drains to the imperial *acre*. In one case there were for

Opening drains 33 inches deep and 7 inches wide at bottom, at 5½d. per rood of 6 yards, for 70 roods,	£1	12	1
Preparing stones 4 inches diameter, at 4d. per ditto,	1	3	4
Carriage of stones, at 4½d. per ditto,	1	6	3½
Unloading carts and moving screen-barrow, at ¾d. per rood of 6 yards,	0	4	4½
Filling in earth, at ¼d. per ditto,	0	1	5½
Extra expense in the main drains,	0	10	0
Per acre of 70 roods,	£4	17	6½
Or per rood of 6 yards,	0	1	4¾

* *Prize Essays of the Highland and Agricultural Society*, vol. vii. p. 239.

In another case, for.

Opening drains 28 inches deep and 7 inches wide at bottom, at 4d. per rood of 6 yards, for 70 roods, ...	£1	3	4
Preparing stones, at 2½d. per ditto, ...	0	14	7
Carriage of stones, at 2¾d. per ditto, ...	0	16	0½
Unloading carts and moving screen-barrow, at ½d. per ditto, . .	0	2	11
Filling in earth at ¼d. per ditto, ...	0	1	5½
Extra expense in the main drains, ...	0	10	0
Per acre of 70 roods, .	£3	8	4½
Or per rood of 6 yards, .	0	0	11¾*

Taking 1s. 1d. per rood of 6 yards as the average of the particulars of the cost of draining with stones in these cases, the following table will show the cost per acre, at the stated distances between the drains, in the different kinds of subsoils of this country, the average depth being 30½ inches.

Subsoils to which the distances are applicable.	Distances between the drains in feet.	Roods per Acre.	Cost per Rood.	Cost per Acre. £ s. d.
Hard till,	10	242	1s. 1d.	13 2 2
	11	220	...	11 18 4
	12	201⅔	...	10 18 6
Stiff clay,	13	186⅙	...	10 1 10
	14	172½	...	9 6 10½
Sandy clay,	15	161⅓	...	8 14 9
	16	151¼	...	8 3 10
	17	142⅓	...	7 14 2
	18	134⅔	...	7 5 11
	19	127 7/19	...	6 18 0
	20	121	...	6 11 1
Free and stony,	21	115¼	...	6 4 10
	22	110	...	5 19 2
	23	105 10/36	...	5 14 1
	24	100⅚	...	5 9 3
	25	96¾	...	5 4 3
	26	93 1/13	...	5 0 10
	27	89⅝	...	4 17 1
	28	86 6/14	...	4 13 7
	29	83⅗	...	4 10 4

* *Prize Essays of the Highland and Agricultural Society*, vol. xiv. p. 43.

Subsoils to which the distances are applicable.	Distances between the drains in feet.	Roods per Acre.	Cost per Rood.	Cost per Acre.		
				£	s.	d.
Open,	30	$80\frac{2}{3}$	1s. 1d.	4	7	5
	31	$78\frac{1}{15}$	...	4	4	7
	32	$75\frac{2}{3}$	...	4	2	0
	33	$73\frac{1}{3}$	...	3	19	5
	34	$71\frac{1}{6}$	...	3	17	1
	35	$68\frac{1}{7}$	...	3	14	11
	36	$67\frac{3}{7}$	...	3	13	0
	37	$65\frac{6}{15}$	...	3	10	10
Irregular beds of gravel or sand, and irregular open rocky strata,	38	$63\frac{2}{3}$	...	3	9	0
	39	$62\frac{3}{4}$	...	3	7	$2\frac{3}{4}$
	40	$60\frac{1}{2}$	...	3	5	$6\frac{1}{2}$

Cost of Draining with Tiles.

The expense of draining with tiles depends on the number of the drains and the cost of the tiles.

About twenty years ago drain-tiles were very scarce and dear. They were made in very few places, and their utility was not generally appreciated. Their price was 60s. per thousand. As the demand for them increased, and tile-works consequently multiplied in number, the price gradually declined to 30s. the thousand, where it remained for a considerable time, and was maintained, notwithstanding the facilities to expeditious manufacture afforded by the invention of tile-machines. The price then fell to 25s. and is now 20s. per thousand, the sole being always one-half the cost of the tiles. The tile-machines execute the common arched tile, and also the pipe-tile—a form difficult of manufacture by hand, and rapidly coming into use on account of its cheapness, and being easily handled and carried about. Pipe-tiles of 14 and 15 inches in length, and 2 inches in diameter, may be obtained at the works at 18s. a thousand, those of $1\frac{1}{2}$ inch diameter, I believe, for 15s, and those of 1 inch bore and 1 foot in length are advertised for sale in some quarters of England as low as 10s. a thousand. Pipe-tiles are as yet scantily manufactured for sale in Scotland, a prejudice existing against them among farmers, stewards, and tile-burners, but I am happy to observe their increase in several parts of the country.

To give a distinct view of the cost of draining with tiles, I have constructed the following tables, the first showing the cost of cutting drains of various depths, from 30 inches to 4 feet, and at various distances; and I need scarcely remark, that the cost per rood of the different depths varies in different parts of the country, and in periods when labour is more or less in demand.

Table showing the Cost of Cutting Drains per Acre.

Distance between the drains in feet.	Roods of 6 yards per acre.	Cost of cutting drains per acre of 2½ feet deep, at 3½d. per rood.	Cost of cutting drains per acre of 3 feet deep, at 5d. per rood.	Cost of cutting drains per acre of 3½ feet deep, at 6½d. per rood.	Cost of cutting drains per acre of 4 feet deep, at 8d. per rood.
		£ s. d.	£ s. d.	£ s. d.	£ s. d.
10	242	3 10 7	5 0 10	6 11 1	8 1 4
11	220	3 4 2	4 11 8	5 19 2	7 6 8
12	201⅔	2 18 8½	4 4 0	5 8 8	6 13 9
13	186⅙	2 14 3	3 17 7	5 0 9	6 4 0
14	172½	2 10 2	3 11 8	4 13 2	5 14 8
15	161⅓	2 6 11½	3 7 2	4 7 2½	5 7 6
16	151¼	2 4 0½	3 2 11	4 1 9½	5 0 8
17	142⅓	2 1 .5	2 19 2	3 16 11	4 14 8
18	134⅔	1 19 1	2 15 10	3 12 7	4 9 4
19	127 7/19	1 17 0½	2 12 11	3 8 9½	4 4 8
20	121	1 15 3½	2 10 5	3 5 6½	4 0 2
21	115¼	1 13 6½	2 7 11	3 2 3½	3 16 8
22	110	1 12 1	2 5 10	2 19 7	3 13 4
23	105 1/3 9/8	1 10 7½	2 2 11	2 16 10½	3 8 8
24	100⅚	1 9 4¼	2 2 0	2 14 4	3 6 10½
25	96¼	1 8 0	2 0 0	2 12 0	3 4 0
26	93 1/13	1 7 1½	1 18 9½	2 10 4½	3 2 0
27	89⅝	1 5 11½	1 17 1	2 8 2½	2 19 4
28	86 6/14	1 5 1	1 15 10	2 6 7	2 17 4
29	83⅜	1 4 2½	1 14 7	2 4 11½	2 15 4
30	80⅔	1 3 5¾	1 13 7	2 3 7¼	2 13 9
31	78 1/15	1 2 9	1 12 6	2 2 3	2 12 0
32	75⅝	1 2 0¼	1 11 5½	2 0 10¾	2 10 4
33	73⅓	1 1 3½	1 10 5	1 19 6½	2 8 8
34	71⅙	1 0 8½	1 9 7	1 18 5½	2 7 4
35	69⅐	1 0 1½	1 8 9	1 17 4½	2 6 0
36	67 2/7	0 19 6½	1 7 11	1 16 3½	2 4 8
37	65 6/15	0 18 11½	1 7 1	1 15 2½	2 3 4
38	63⅔	0 18 6¼	1 6 5½	1 14 4¾	2 2 4
39	62 1/20	0 18 1	1 5 10	1 13 7	2 1 4
40	60½	0 17 7¾	1 5 2½	1 12 9¼	2 0 1

Assuming the price of tiles as given above, and fixing on 15 inches as the most convenient and economical length, the following table shows the number and cost of tiles per acre for drains cut at those various distances, and also the saving effected by using pipe-tiles instead of tiles and soles.

Table showing the Number and Cost of Tiles per Acre.

Distance between the drains in feet.	Roods of 6 yards per acre.	Number of tiles and of soles of 15 inches length each per acre.	Cost per acre of tiles at 20s., and of soles at 10s. per 1000.	Number of pipe-tiles per acre of 15 inches in length.	Cost per acre of pipe-tiles at 18s. per 1000.	Saving per acre by using pipe tiles.
			£ s. d.		£ s. d.	£ s. d.
10	242	3485	5 4 6½	3485	3 2 8¾	2 1 9¾
11	220	3168	4 15 0	3168	2 17 0	1 18 0
12	201⅔	2904	4 7 1¼	2904	2 12 3¼	1 14 10
13	186⅙	2690	4 0 8¼	2690	2 8 5	1 12 3¼
14	172½	2484	3 14 6	2484	2 4 8½	1 9 10½
15	161⅓	2323	3 9 8¼	2323	2 1 9½	1 7 10¾
16	151¼	2180	3 5 4¾	2180	1 19 2¾	1 6 2
17	142⅓	2050	3 1 6	2050	1 16 10¾	1 4 7¼
18	$134\frac{4}{9}$	1936	2 18 0¾	1936	1 14 10	1 3 2¾
19	$127\frac{7}{19}$	1835	2 15 0	1835	1 13 0	1 2 0
20	121	1743	2 12 3½	1743	1 11 3¼	1 1 0¼
21	115¼	1659	2 9 9¼	1659	1 9 10¼	0 19 10¾
22	110	1584	2 7 6	1584	1 8 6	0 19 0
23	$105\frac{10}{46}$	1516	2 5 5½	1516	1 7 3½	0 18 2
24	100⅚	1452	2 3 6½	1452	1 6 1½	0 17 5
25	96⅘	1387	2 1 7¼	1387	1 4 11½	0 16 8¾
26	$93\frac{1}{13}$	1360	2 0 9	1360	1 4 5¾	0 16 4¼
27	89⅝	1291	1 18 8¾	1291	1 3 2¾	0 15 6
28	$86\frac{6}{14}$	1245	1 17 4	1245	1 2 4¾	0 14 11¼
29	83⅜	1202	1 16 0	1202	1 1 7½	0 14 4½
30	80⅔	1162	1 14 10	1162	1 0 10¾	0 13 11¼
31	$78\frac{1}{16}$	1124	1 13 8½	1124	1 0 2¾	0 13 5¾
32	75⅝	1090	1 12 8	1090	0 19 7¼	0 13 0¾
33	73⅓	1056	1 11 8	1056	0 19 0	0 12 8
34	71⅙	1026	1 10 9¼	1026	0 18 5½	0 12 3¾
35	69⅐	996	1 9 10½	996	0 17 11	0 11 11½
36	$67\frac{2}{9}$	968	1 9 0¼	968	0 17 5	0 11 7¼
37	$65\frac{6}{15}$	940	1 8 2	940	0 16 11	0 11 3
38	63⅔	916	1 7 5¾	916	0 16 5¾	0 11 0
39	$62\frac{1}{20}$	895	1 6 10	895	0 16 1	0 10 9
40	60½	872	1 6 1¾	872	0 15 8¼	0 10 5½

These tables contain sufficient data required for showing the cost of cutting drains, and filling them with tiles of different kinds; and from these, other length of tiles, and at other prices, may easily be calculated. As it may prove satisfactory to the drainer to know the comparative saving of draining with tiles instead of stones, the following table affords the information at the prices quoted in the preceding tables on pages 113 and 114.

Table showing the Saving per Acre in using Tiles instead of Stones.

Distance between the drains in feet.	Cost per acre of drains 30 inches deep, with stones.	Cost per acre of drains 30 inches deep, with soles and tiles.	Saving per acre by using tiles and soles instead of stones.	Cost per acre of drains 30 inches deep, with pipe-tiles.	Saving per acre by using pipe-tiles instead of stones.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
10	13 2 2	8 15 1½	4 6 0½	6 13 3¾	6 8 10¼
11	11 18 4	7 19 2	3 19 2	6 1 2	5 17 2
12	10 18 6	7 5 9¾	3 10 8¼	5 10 11¾	5 7 6¼
13	10 1 10	6 14 11¼	3 6 11¾	5 2 8	4 19 2
14	9 6 10½	6 4 8	3 2 2½	4 14 10½	4 12 0
15	8 14 9	5 16 7¾	2 18 1¼	4 8 9	4 6 0
16	8 3 10	5 9 5½	2 14 4½	4 3 3¼	4 0 6¾
17	7 14 2	5 2 11	2 11 3	3 18 3¾	3 15 10¼
18	7 5 11	4 17 1¾	2 8 9¼	3 13 11	3 12 0
19	6 18 0	4 12 0½	2 5 11½	3 10 0½	3 7 11½
20	6 11 1	4 7 7	2 3 6	3 6 6¾	3 4 7¼
21	6 4 10	4 3 3¾	2 1 3¼	3 3 4¾	3 1 5¼
22	5 19 2	3 19 7	1 19 7	3 0 7	2 18 7
23	5 14 1	3 16 1	1 18 0	2 17 11	2 16 2
24	5 9 3	3 12 10¾	1 16 4¼	2 15 5¾	2 13 9¼
25	5 4 8	3 9 7¼	1 14 7¾	2 12 11½	2 11 3½
26	5 0 10	3 7 10½	1 12 11½	2 11 6¾	2 9 3¼
27	4 17 1	3 4 8¼	1 12 4¾	2 9 2¼	2 7 10¾
28	4 13 7	3 2 5	1 11 2	2 7 5¾	2 6 1¼
29	4 10 4	3 0 2½	1 10 1½	2 5 10	2 4 6
30	4 7 5	2 18 3¾	1 9 1¼	2 4 4½	2 3 0½
31	4 4 7	2 16 5½	1 8 1½	2 2 11¾	2 1 7¼
32	4 2 0	2 14 8¼	1 7 3¾	2 1 7½	2 0 4½
33	3 19 5	2 12 11½	1 6 5½	2 0 3½	1 19 1½
34	3 17 1	2 11 5¾	1 5 7¼	1 19 2	1 17 11
35	3 14 11	2 10 0	1 4 11	1 18 0½	1 16 10½
36	3 13 0	2 8 6¾	1 4 6½	1 16 11½	1 16 0½
37	3 10 10	2 7 1½	1 3 8½	1 15 10½	1 14 11½
38	3 9 0	2 6 0	1 3 0	1 15 0	1 14 0
39	3 7 2¾	2 4 11	1 2 3¾	1 14 2	1 13 0¾
40	3 5 6½	2 3 9½	1 1 9	1 13 4	1 12 2½

It is thus seen that very nearly two roods of drain may be made with pipe-tiles for one with stones, at the same cost. Were slates used for soles instead of tiles, the cost of tiles and soles would be somewhat less than shown in the above table ; still the cost of tiles and soles is only ⅔ of that of stones.

But the digging of the ground, and the cost of stones or tiles, do not comprehend the entire cost of draining, there being several other kinds of work connected with the furnishing and finishing of drains. A statement of these particulars of expense was made by Mr George Bell, Woodhouselees, in Dumfriesshire, who drained his entire farm from 1837 to 1847, and it is this :—

Carriage of 38,000 common tiles, at 3s 4d. per 1000, . . .	£6	6	8
... 1,557 main, ... 5s.	0	7	10
31 days' work of man and horse laying down tiles and straw for covering them, at 5s. 6d. per day, ...	8	10	6
Work of women loading and unloading the carts, . . .	2	3	0
30 days' work of a man laying soles and tiles, ...	2	5	0
30 days' work of a woman assisting him, at 8d. per day, . .	1	0	0
3 days' of plough-work, at 10s. per day, ...	1	10	0
Cost for 13 acres, ...	£22	3	0
... 1 acre, of drains 15 feet apart, .	£1	14	1*

So that £1, 14s. 1d. per acre should be added to the cost of tile and sole drains at 15 feet apart, in the preceding table. The cost of loading and unloading, laying down and laying in pipe tiles, is only half of that for tiles and soles ; but how much less the entire particulars should cost I cannot distinctly specify, but should think that £1 per acre would be a fair allowance when using pipe-tiles.

An example of the comparative costs, in full, of the different methods of making drains, may be here given as a standard for reference :—

Drains at 15 feet apart, 30 inches deep, with stones, cost per acre, .				£8	14	9
Similar depth and distance of drains, with soles and tiles, cost per acre, ...	£5	16	7¾			
Add for particular costs, ...	1	14	1			
				7	10	8¾
Similar depth and distance of drains, with pipe-tiles, cost per acre, ...	£4	8	9			
Add for particular cost, ...	1	0	0			
				5	8	9

* *Prize Essays of the Highland and Agricultural Society,* vol. xiii. p. 510.

Still the saving in favour of tiles and soles is £1 4s., and of pipe-tiles £3, 6s. per acre, over stones, in drains 30 inches deep and 15 feet apart, and £2, 2s. per acre in favour of pipe-tiles over tiles and soles.

Mr Mechi gives this statement of the expense draining costs him. "My present cost of effectively draining an acre of strong clay land is as follows:—depth, 5 feet in the rising ground, averaging nearly 4 feet all over the field. Distance, 40 feet between each drain.

64 rods of draining at 6d. per rod of 5½ yards,	£1	12	0
1100 inch pipes, 12 inches long, including 44 for breakage, at 12s. per thousand,	0	14	6
Cartage of pipes from kiln, 4 miles,	0	3	0
	£2	9	6

The cost may vary a few shillings per acre, according to the price of labour and pipes."*

With the exception of the cartage of the tiles, this cost does not include all the particulars enumerated above; still, if we add 17s. per acre for these, £3, 6s. 6d. is a small cost for effectually draining an acre of land.

In regard to the *comparative durability of stone and tile drains*, it is impossible, in the present state of experience, to decide; but I believe it quite possible to make a drain of either material permanent; and this being the case, the only question between them is one of expense, which is greatly dependent on circumstances connected with locality. In some places stones are so plentiful, and tiles distant, that it would be impolitic to neglect the former in order to procure the latter material; and, on the other hand, there are localities where tiles are made on the spot, and stones unobtainable for many miles. But though the two kinds of materials were obtainable at the same distance, tiles are brought at much less cost than stones. In estimating the comparative cost of the carriage of tiles and stones, the late Mr James Carmichael, Raploch, has shown, in the case of a man with a horse and cart being employed to draw the same quantity, say 5 loads a-day, that 1 cartload of tiles and soles, each 14 inches in length, will lay upwards of 100 yards of drain, 6 inches wide, of any depth; whereas 1 cubic yard of stones will only fill 18 yards of drain, 6 inches wide, to a depth of 12 inches—being a saving of carriage

* *Mechi's Experience in Drainage*, Preface, p. iv.

nearly 6 to 1 in favour of the tiles; and as carriage is always great labour, it forms an important particular in undertaking the draining of an entire farm. But in strict fairness the cost of carrying materials in draining should be spread over the saving experienced in working drained land in the succeeding years of the lease, and not on the mere trouble incurred at the time of draining.

Pecuniary Profits derived from Draining.

The most palpable advantage of draining land is the *profit* it returns to the farmer. A few authenticated instances of the profits actually derived from draining will suffice to convince any occupier of land of the benefits to be derived from it.

I am clearly of opinion, says Mr North Dalrymple of Cleland, Lanarkshire, that well-authenticated facts on economical draining, accompanied with details of the expenses, value of succeeding crops, and of the land before and after draining, will be the means of stimulating both landlords and tenants to pursue the most important, judicious, and *remunerating* of all land improvements. The statements below will prove the advantages of furrow-draining; and as to the *profits* to be derived from it, they are *great*, and a farmer has only to drain a 5 acre field to have ocular proof upon the point.*

Without entering into all the details of the statements given by Mr Dalrymple, it will suffice here to exhibit a few general results. 1st. One field containing 54 Scots acres cost L.303, 7s. to drain, or L.5, 12s. per acre. The wheat off a part of it was sold for L.11, and the turnips off the remainder for L.25, 13s. 4d. per acre. The soil was a stiff chattery clay, and let in grass for 20s. per acre; but in 1836, after having been drained, it kept 5 Cheviot ewes, with their lambs, upon the acre. 2d. Another field of 18 acres cost L.5, 9s. the acre to drain. The wheat off one part of it realised L.13, the potatoes off another L.15, 15s., and the turnips off the remainder L.21 per acre. The land was formerly occupied with whins and rushes, and let for 12s. the acre; but when let for pasture after being drained, Mr Dalrymple expected to get 50s. an acre for it. It may be mentioned, that the drains made by Mr Dalrymple were narrow ones, 30 inches in depth, filled 18 inches high with stones or scoriæ from a furnace, and connected with main drains, 36 inches deep, furnished with tiles and soles.†

Mr James Howden, Wintonhill, near Tranent, in East Lothian, found from experience, that although drains should cost as much

* *Quarterly Journal of Agriculture*, vol. viii. p. 319. † *Ib.* vol. viii. p. 320.

as L.7 the acre, on damp heavy land, thorough-draining will repay from 15 to 20 per cent on the outlay. *

These instances will suffice for Scotland. For England, on the estate of Teddisley Hay in Staffordshire, 467 acres, 9 poles, were drained at a cost of L.1508, 17s. 4d.—that is L.3, 7s. 7d. per acre. The former rent was L.254, 10s. 9d. and after the drainage it rose to L.689, 3s. 1d, giving an increase of 28½ per cent on the outlay.† And for Ireland, on the estate of Castle Shane, county Monaghan, belonging to Edward Lucas, Esq., 57 acres, 2 roods, 13 poles were thorough-drained for L.269, 11s. 4d.—yielding an increased value of the land of 30 per cent.‡

I should here remark that, when drains are executed on stubble or lea ground, the first corn crop after draining is not sensibly increased in produce; but after the ground has been fallowed, that is, ploughed, properly wrought and manured, a very sensible increase of crop instantly takes place. Thus, in one instance adduced by Mr Bell, Woodhouselees, in 1839, the increase on oats was only 5 bushels on 2 acres, on the drained over the undrained land; and in the same year, 9 acres drained produced 258 bushels, and 6¾ acres undrained 192 bushels of good oats, being the same amount of produce from the undrained and the drained land. Those products are very much less than from drained land that has been effectually laboured.‖

But although the most remarkable instances of increase and profit are received from drained land, after it has been well wrought, it must not be imagined that the largest ratio of increase will be continued. Effectual draining makes the greatest impression at first on soils most injured by water, whether naturally good or bad; but, naturally, good land possesses more stamina than bad, and will maintain its superiority over bad, even though the latter should exert itself more for a few years after being drained. Although I express myself in these terms, I by no means acquiesce in the opinion entertained by Mr Peter Thomson, Hangingside, Linlithgowshire, on a review of the same subject; yet as his opinion contains much truth, it should be kept in mind, when too sanguine expectations are apt to be entertained by young farmers from recent improvements.

* *Quarterly Journal of Agriculture*, vol. viii. p. 321.

† *Journal of the Royal Agricultural Society of England*, vol. ii. p. 279.

‡ *Transactions of the Royal Agricultural Improvement Society of Ireland*, for 1843, pp. 39 & 44.

‖ *Prize Essays of the Highland and Agricultural Society*, vol. xiii. p. 510-11.

Thorough-draining, like every other improvement, says Mr Thomson, has the best return from good soil. When executed on bad land the outlay will not be repaid, and no little disappointment will be the certain consequence of much that has been already done upon weak soils. Weak land, upon being relieved from an excess of moisture, makes an extraordinary exertion, and in the course of the first rotation of crops yields considerably beyond what it formerly did; but in the course of the second rotation the produce becomes considerably diminished, and when laid down to pasture, the finer description of grasses give way to those indigenous to the soil.

These remarks, I conceive, are more applicable to the abuse than the proper use of draining; and I cannot believe that land, however bad, will not repay the expense of *thorough*-draining, because experience leads my convictions quite the other way. The coarser grasses may predominate on bad land after drainage, but they will do so only in permanent, and not in arable pasture—and it is any thing but good farming to allow land, naturally weak, to remain long in grass, immediately after being drained, and before it has been fertilised by long cultivation. Still the coarsest grasses will be made finer by draining, in the worst classes of soils. In corroboration of the remarks just expressed, I give a table constructed by Mr Thomson himself, which presents the produce from an imperial acre of inferior and good land, before and after being thorough-drained; and the result, it is true, is, that the produce declined from both in the second rotation, and less from the good than the inferior soil; but after all, the inferior soil gives a return of more than 25 per cent from the corn, and 70 per cent from the grass; and surely per-centages of these amounts, from inferior soil, ought to be regarded as highly remunerative.

Kinds of Crops.	From inferior land.			From good land.		
	Before being drained.	After being drained.		Before being drained.	After being drained.	
		In the 1st rotation.	In the 2d rotation.		In the 1st rotation.	In the 2d rotation.
	Bush. Pks.	Bush. Pks.	Bush. Pks.	Bush. Pks.	Bush. Pks.	Bush. Pks.
Barley, .	23 3	33 1	29 1¼	27 3	38 0	36 2
Oats, . .	35 2¾	47 2¼	44 1½	38 0	52 1¼	50 0
	L. S. D.	L. S. D.	L. S. D.	L. S. D.	L. S. D.	L. S. D.
Grass by the acre,	1 3 9	2 11 6	1 19 8	1 11 8½	3 19 3	3 11 4*

It would be of essential service to future drainers were those of the

* *Prize Essays of the Highland and Agricultural Society*, vol. xiii. p. 298.

present day to ascertain the comparative amount of produce received from thorough-drained good and bad land, for a series of rotations of crops, that it may be accurately ascertained whether the smallest profit derived from thorough-draining bad land would repay the cost; and I have no doubt it would.

Draining the Face of Railway Cuttings.

Every one travelling by railroad may have observed, in many of the deeper cuttings, that the earth had slipt in large masses down the face towards the bottom; and, on examining the cause of these slips, it invariably has been found to arise from the action of water upon the subsoil. The subsoil so affected is clay, and it is so affected whether it be of a uniform texture or interstratified with veins of sand. If there was no clay there would be no excess or retention of water, and of course no land-slips. Cuttings of railways may be regarded, therefore, as drains intersecting the substrata to the extent of their depth, and exposing to view the planes of the impervious matter upon which the water naturally travels towards the section, in precisely the same manner, but on a much larger scale, as the water is seen to issue from the intersected strata of the exploratory drains recommended to be made in every field before being drained.

As the clay which retains the water that does the mischief cannot be removed, the only expedient left is to remove the water, by conveying it away in channels, instead of allowing it to take its own course amongst the interstices of the clayey strata; and these channels may consist either of open conduits or covered drains.

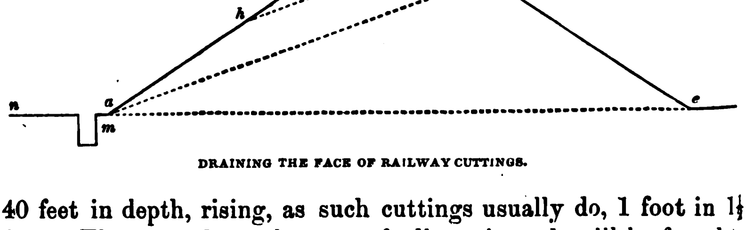
One method in which these channels are usually employed in draining the face of railway cuttings, is to place them in a slanting direction down the face of the cutting, in numerous parallel lines—and when they slant from opposite directions they are sometimes made to empty themselves in a common channel. Where the entire face of the cutting is a uniform mass of tenacious boulder-clay, and the open channels are made so deep as to be imbedded in it through the mould returned upon the surface of the cutting, this method may answer the purpose. In such a case, even, the channels to be efficient should be of large dimensions, and cut deep into the clay—one being placed near the top of the cutting, and sloping to the right and left from its highest point; and only another, perhaps, placed about midway down the face of the cutting, of the same form and size. The water would find its way from the surface into these channels more quickly, were the surface raised into the form of ridges; and as there is always a built drain at the bottom of the cutting, the ridges should be continued below the lowest channel to that drain. But such channels are usually made in the face of the cuttings whether the clay is of uniform texture or otherwise; and the consequence is, that the water, on oozing through the sand-veins, in time carries down both clay and channels in land-slips as it did before.

Another method of draining the cuttings consists in making covered drains of tiles, branching in different directions, in the places where the water is found to burst out to the day; and the success of this plan is as uncertain as the other, because the remedy, in both cases, is applied to remove the effect, not the cause of the evil.

A recent attempt, I observe, has been made to drain the face of these cuttings by means of patented cast-iron pipes, which are so laid down as to convey all the water to the drain at the bottom of the cutting; but this plan seems to me to be founded on no better principle than that of the open channels or covered drains mentioned above, inasmuch as it struggles with the effect only, and not with the true cause of the evil.

I would recommend the following modes of draining such cuttings. In fig. 59, let *a b* be the face of a deep railway cutting, from 20 to

Fig. 59.



DRAINING THE FACE OF RAILWAY CUTTINGS.

40 feet in depth, rising, as such cuttings usually do, 1 foot in 1½ foot. The ground at the top of all cuttings, *b*, will be found to exist in one of three states, namely, sloping upwards, as from *b*

to *c*; or on a level, as from *b* to *d*; or sloping downwards, as much as from *b* to *e*, or only as little as from *b* to *k*, the ground, in this latter case, extending from *k* to *l*.

1. When the ground slopes upwards, as from *b* to *c*, and the subsoil is of uniform clay, the water on the surface will run down from *c* to *b*, and thence down the face of the cutting all the way, from *b* to *a*, washing away some of the soil in its progress. But were an open channel formed in the face a little below *b*, and another about half-way down at *h*, and the face *b a* converted into upright ridges, it is evident that the open channels at *b* and *h* would intercept the water and carry it away, while the ridges would convey it faster into them than could the plain surface.

When the subsoil is not uniform, but veined as from *f* to *g*, it is probable that part of the water may be absorbed by the ground at *g*, and find its way out at the face at *f*; in which case, a covered conduited drain a little way above *b*, as deep as to intersect the dotted stratum *g f*, would prevent the burst of water at *f*, and more effectually remove it than any number of open channels or covered drains on the face at *f* could possibly do. If strata are found as represented by *f g* and *h i*, a drain at *g*, made deep enough to reach *i*, would relieve both the lower burst at *h*, and the upper one at *f*.

2. Where the ground is level, as from *b* to *d*, the water will not run off, but be absorbed, and find its way towards the cutting either by the vein *i h* or *o a*, if there be such, or through the uniform clay in oozings upon the face from *f* to *h*. When the veined structure exists, instead of using expedients to remove the burst of water at *h*, as is commonly done, a drain at *i* would prevent any burst at *h*; and if it were made as deep as to reach the porous stratum *a o*, it would prevent the double bursts at *h* and at *a*. When a burst is only seen at *a*, a drain at *o* will remove it.

3. On the ground sloping downwards, as from *b* to *k*, there need be no fear of any burst of water appearing on the face, from *b* to *h*; and if the ground sloped as far as to *e*, no burst could appear in the face of the deepest cutting. But, as is most commonly the case, the ground may stretch from *k* along the level *k l*; then any stagnation of water at *k*, accompanied with a veined subsoil, would inevitably find its way out at *a*; but instead of using any expedient at *a* to remove it, which is the common way, a drain should be made at *k*, by which the water would be conveyed away elsewhere.

It is clear, from these illustrations, that the ordinary mode of draining the face of railway cuttings is erroneous in principle, and therefore ineffectual in practice. It may be that some of the sites of the drains pointed out above may be beyond the 100 yards reserved for the use of railway operations; but if so, power might be taken in every bill to allow of such a drainage being effected on payment of surface-damage.

It may also be, that some of the drains recommended, such as from *g* to *i*, and from *i* to *k*, may be required of inordinate depth, such as 8 or 10 feet; but much rather incur the cost of such as these, and accomplish the drainage effectually, than be constantly teased by the effects of petty abortive attempts.

The two sides of a cutting will require, most probably, different modes of drainage; indeed, where the clay is interstratified, the strata, while inclining towards the cutting on the one side, will dip away from it on the other, and require no drainage.

The railway is at *n*, and *m* is one of the conduited drains always constructed along the sides of a railway, and forms the great means of keeping the railway dry.

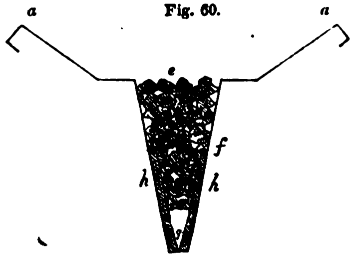
These may be regarded as all the modes of substantial thorough-draining land known; and whichever can be executed with the greatest economy, it should be adopted in preference to every other. But there are other modes of draining land, which, although not so commendable and permanent, may nevertheless be tried in situations of peculiar character, and these I shall now enumerate.

It is perhaps well to have a choice of methods of performing the same operation, that the judgment may adopt the one most advisable in the circumstances of the farm. At the same time, this maxim in agriculture should never be lost sight of—that every operation is most economical in the end, only when executed in the most efficient manner, both as regards materials and workmanship; and the maxim applies to no operation in farming so strongly as to draining, because of its permanent character.

Flat Stone Drains.

In a *tilly subsoil which affords* a little water, situate in a locality in which *flat stones are very plentiful and cheap*, this method of draining may be practised with economy and advantage. Suppose the land, containing ridges of 15 feet in width, has been gathered up from the flat, the drains are made in it in this manner.

Fig. 60.



THE FLAT STONE DRAIN.

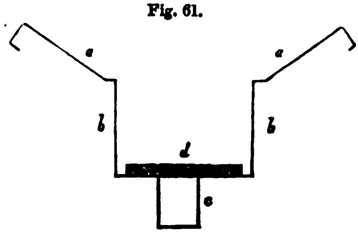
Gather up the land twice with a strong furrow, by splitting out a feering in the crown of each ridge. Should the 4-horse plough have been used for the purpose, the open furrow will be left 16 inches wide at bottom; and if the furrow is turned over 12 inches in depth, and the furrow-slice laid over at the usual angle of 45°, the tops of the furrow-slices on the furrow-brow will be 32 inches apart, as from *a* to *a*, fig. 60. After this ploughing, the spade takes out a trench from the bottom of the open-furrow, 8 inches wide at top *e*, 16 inches deep from *e* to *g*, and 4 inches wide at bottom *g*. The bottom spit of this drain may be taken out with the narrowest spade, fig. 44. The depth of the drain will thus be 32 inches in all below the crowns of the gathered-up ridges. The drain is filled by two flat stones *h h*, 1½ inch thick, each being set up against a side, and meeting at the bottom *g*; and they are kept asunder by a large stone of any shape, as a wedge, but large enough to be prevented descending farther than will leave a conduit *g* for the water. The remainder of the drain along *f* is filled to *e* with small riddled stones with Mr Roberton's drain-screen, fig. 31, or with clean gravel. The stones are covered with turf, or with small stones, beaten down firmly. The expense of this method of draining is small: the spade-work may be executed at 1d. the rood of 6 yards; and for an imperial acre, containing 161⅓ of such roods, the cutting will cost 13s. 5¾d. The flat stones at 1½ inch thick and 6 inches broad, will weigh 22½ tons per acre, and, at 4d. the ton, will cost 7s. 6d. more. The broken stones, to fill 9 cubic feet in the rood of 6 yards, at 2¼d. per rood, will cost £1, 10s. 3½d. more; making in all about £2, 11s. 3¼d. the acre, exclusive of carriage and ploughing, which, though estimated and added, will yet make this a cheap mode of draining land, though executed as close as 15 feet apart.*

A plan similar to this is practised on *strong clay land.* The open-furrow is formed in the same manner with the plough, and being left 16 inches in width, the spade-work is conducted in this way. Leave a scarcement of 1 inch on each side of the open-furrow

* *Quarterly Journal of Agriculture,* vol. vii. p. 245.

left by the plough, as seen near *a a*, fig. 61, and cut out the subsoil, 14 inches wide, perpendicularly, 10 inches deep, as at *b b*. Then cast out from the bottom of this trench, with a spade 3 or 4 inches wide, such as the narrowest spade fig. 44, a cut 5 inches or more in depth *c*, leaving a scarcement of 5 inches on each side of the bottom of the trench *b b*. The bottom of the cut *c* will be found to be 32 inches below the crowns of the ridges, when twice gathered up with a strong furrow. The drain is filled up in this way: take flag-stones of 2 or 3 inches in thickness, as *d*, and place them across the opening of *c* upon the 5-inch scarcements left by the narrow spade; they need not be dressed at the joints, as one stone may overlap the edges of the two adjoining, and thus form the top of a conduit of strong clay, in which the water is to flow. As the water is made to flow immediately upon the clay, it is clear that this form of drain cannot be regarded as permanent; though a flag or tile sole, or still better, an arched tile laid on its back on the bottom of the cut *c*, would render it much more durable. The cutting of this form of drain, the workmen having to shift from one tool to another, will cost 1½d. the rood of 6 yards, which at 15 feet apart is 20s. 2d. the acre. The flags for the cover will weigh 60 tons, at 12 inches broad and 2 inches thick, and at 4d. per ton, will cost 20s. more, in all 40s. 2d.; but with 10 tons of flag soles the cost will be 3s. 4d. more, or 43s. 6d. the acre, exclusive of the carriage of stones and the work of the plough. The earth may be returned into the drain with the plough, without any vegetable covering, but with precaution, and probably with the previous assistance of the spade. But, after all, the great probability is, that no *flat* stones will be easily obtained in the neighbourhood of strong clay; and even where they are abundant, this mode of constructing a drain is not nearly so good as the one last described, fig. 60.*

Fig. 61.



THE CLAY-LAND SHOULDERED DRAIN.

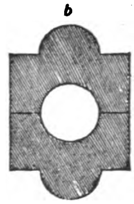
Peat-tile Drain.

The material for draining *light mossy soils where peat is abundant* may be prepared in this way. Peats are manufactured of baked

* *Quarterly Journal of Agriculture*, vol. vii. p. 246.

moss, compressed with a mould into the shape of common drain-tiles, or of the more massive form of fig. 62. One is laid in the drain like a tile-sole *a*, and another placed above it, as *b*, like a drain-tile, leaving a round opening between them for the passage of the water. Such tiles are best cut out of the solid peat, with a spade-tool, fig. 63, contrived some years ago by Mr Hugh Calderwood, Blacklyres, Ayrshire. The spade is easily worked, and forms a peat with one cut, without any waste of materials; that is, the exterior semicircle of *b*, fig. 62, is cut out of the interior semicircle of *a*. A man can cut out from 2000 to 3000 peats a-day with this tool. The peats are dried in the sun in summer, with the hollow part next the ground, and stacked until used; and those used in drains have been found to remain perfectly hard. The invention of this tool tends to make the draining of moorish soils more practicable than heretofore; and this may be done with peat-tiles at one-third or a fourth of the expense of ordinary drain-tiles. The frequent want of clay in upland moory districts renders the manufacture of drain-tiles in such localities impracticable, and distant carriage is always attended with much delay and expense.*

Fig. 62.



THE PEAT-TILE FOR DRAINS.

Fig. 63.

THE CALDERWOOD PEAT-TILE SPADE TOOL.

It is a common property of peat to retain water with great tenacity; but after the water has been thoroughly evaporated, and the peat become dry and firm in texture, it ceases to have affinity for, and will remain in water in an unchanged state. Mr Smith, late of Deanston, immersed a dried peat six months in a boiler, and after that long test it was taken out as firm in texture as when first subjected to the experiment. There is therefore no danger of peats, when thoroughly dried, mouldering away in drains.

Several machines have been contrived to dry comminuted peat by compression. Mr Smith exhibited a peat-tile of the cylindrical form of fig. 46, at the monthly meeting of the Highland and Agricultural Society in April 1847, which was made by a machine, and was quite firm and strong. Mr Anslie, when at Alperton, exhibited a machine for making peat-tiles at the Show of the Society at Inverness in 1846, which possessed a very ingenious

* *Quarterly Journal of Agriculture*, vol. vii. p. 247.

contrivance for preventing the slipping of the wet peat, in the act of being formed into tiles, upon the surface of the rollers; but whether it eventually succeeded in making peat-tiles in an economical manner, I have not learned. Peat-tiles, such as the portions of fig. 62, when placed as a common tile, as *b* is seen to be, upon narrow boards placed as soles in drains formed in moss, would make a good conduit.

Substances which form obstructions in Drains.

Sir Joseph Banks alludes to obstructions being formed in bog-drains that had been executed at great expense at Woburn, by the roots of the mare's-tail, (*Equisetum palustre.*) On examining the plant, Sir Joseph found its "stem under ground a yard or more in length, and in size like a packthread; from this a root of twice the size of the stem runs horizontally in the ground, taking its origin from a lower root, which strikes down perpendicularly to a depth I have not hitherto been able to trace, as thick as a small finger."* I have frequently met with the roots of the mare's-tail under ground, and on being cut by the drains they poured out a full run of water for some time, but on being emptied, and no longer receiving a supply of moisture, withered away. In the case mentioned by Sir Joseph Banks, the roots sent shoots upwards, "along the openings left for the passage of water," which proves that as much moisture had been left in the bog as to support the plant in life; in short, that the bog had been insufficiently drained, otherwise, on the privation of moisture, the vitality of the roots would have been destroyed.

Mr Henry Dixon, Witham, says,—

> I have a curious evidence of the facility with which the roots of trees will destroy drains, *if carelessly placed.* The mass of fibres are the roots of a willow-tree, growing about 5 or 6 feet from the drain, which had been put down only twelve months, and the pipe from which I took it was a 4-inch socketed one.†

The ash and horse-chestnut send strong fibred roots into drains; and it was with the view of avoiding such that I have so frequently in this treatise recommended every sort of drain to be placed at a distance from trees and hedges.

Beside trees, other substances obstruct the passage of water in drains. Incrustations of lime will stop drains whether built with a conduit or filled with small stones, and such are not unfrequent

* *Communications to the Board of Agriculture,* vol. ii. p. 349.

† *Journal of the Royal Agricultural Society of England,* vol. v. p. 603.

in limestone and chalk countries, where they are deposited some inches in thickness, and become quite hard. Common limestone is very difficult of solution in pure water, but when the water contains free carbonic acid, it dissolves it, and converts it into the bi-carbonate of limestone, which readily dissolves in water; but when, from any cause, the carbonic acid is again disengaged, the carbonate is immediately thrown down in thick incrustations.

Depositions of oxide of iron also stop drains. Ochrey water is often seen to issue from drains, especially from bogs. The water holds the protoxide of iron in solution, and whenever it meets the air freely the protoxide is converted into the peroxide, which, being insoluble in water, is immediately thrown down in an ochrey deposit,—which soon forms an obstruction to the water, especially as it is always associated with much vegetable matter.

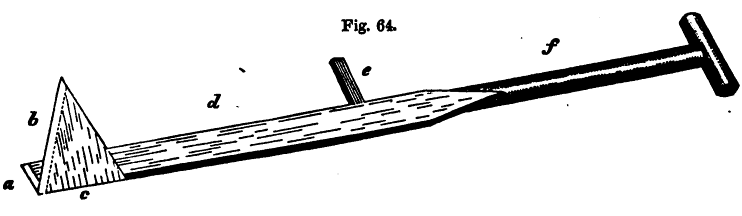
Fine sand occurring in quantity is apt to choke the ducts of drains, and where it so occurs, it would be advisable to employ some vegetable covering upon the tiles. If such a deposit is permitted to accumulate above the outlets of main drains, it will dam back the water in all the drains connected with the main drains; and this is the more likely to occur in boggy ground, which is generally flat, and liable to be much infested with a fine white coloured sand.

Moles cause obstructions in drains by their workings in search of their natural food, the earth-worm. A remarkable instance of this was experienced by Mr Hay, Whiterigg, Roxburghshire, when using soles placed a few inches apart.*

Plug Drain.

This mode of draining requires a very peculiar form of tools. The first remarkable implement used is the *bitting-iron*, represented by fig. 64, where *a* is the mouth, 1¾ inch wide; *b* the bit, 6 inches

Fig. 64.



THE BITTING-IRON IN PLUG-DRAINING.

* *Journal of Agriculture for March* 1848, p. 373.

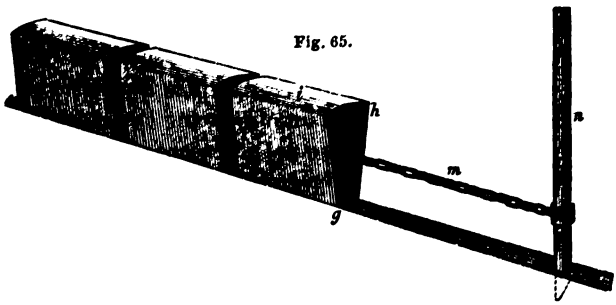
in length; *c*, the width of the bit, 4½ inches. The bit is worked out of the body of the instrument, and laid with the best tempered steel; *e* is the tramp of the implement, placed 18 inches along *d*, from the mouth *a*; it would perhaps strengthen the power of the implement to have the tramp on the same side as the bit *c*; *f* is the helve, which is of the length of that of a common spade.

This species of draining is represented, by those who have practised it, as applicable to all soils of various and uncertain depths of vegetable mould, incumbent on a subsoil of unctuous clay, exceedingly retentive of water, entirely free of stones, and never dry but by evaporation. It is only suited to permanent pasture land; but *tile*-draining should be preferred, even though the tiles are very dear, either from distance of carriage, or cost of manufacture on the spot.

The first process in plug-draining is to remove the surface turf, 12 inches in width, and 6½ inches in depth, with the common spade, and to place it on the right hand side of the workman, with the grass side uppermost. A cut is then made in the clay on each side of the drain, with an edging-iron, as fig. 5; but a common spade will answer the purpose equally well, and it requires both skill and dexterity to remove this second cut properly. The first cut having been made with the spade 12 inches wide, the second should be made at such an angle down both sides of the drain, 9 inches deep, as that the breadth at the bottom shall be the exact width of the top of the plug *h*, fig. 65—that is, 4 inches wide. Carelessness in expert, or blundering in inexperienced workmen, in this part of the operation, has caused this kind of drain to fail. The bitting-iron, fig. 64, then completes the cuttings by taking out the last cut 9 inches deep, and 1¾ inch wide at the bottom. The instrument is used in this manner: The workman gives its shaft such an angle with the ground line, that, when pushed down to the requisite depth, the bit continues the cut made by the spade or edging-iron used previously, on the right hand side of the drain; and he does exactly the same on the left hand side, using a foot in both cases on the tramp *e*, fig. 64. On being forced down on the left side of the drain, the clay, now separated all round by the bit *b*, leans against the stem of the iron, and is easily lifted out, so that each portion of the clay taken out by this instrument will have the form of an oblique parallelopipedon. If this part of the operation be performed inaccurately, the drain cannot succeed; because the angle and depth made by this instrument are of the utmost consequence in forming the bed which is to be occupied by the plug; so that considerable accuracy of hand and eye are requisite, and which cannot well be possessed by workmen without experience, but both may soon be acquired through attention. The clay from the two last cuttings should be placed on the left side of the workman, that is, on the opposite side to that on which the upper turf was laid; and the last cutting being uppermost, it will there come readily to hand when first returned into the drain. Any loose soil that may happen to remain at the bottom should be carefully taken out by a scoop-spade, such as fig. 10, so as to make the drain perfectly clean before any further operation is attempted.

The next implement used is the *suter* or *plug*, fig. 65, which consists of three or more pieces of wood—*i*, of a wedge-shape, 8½ inches in height, 6 inches in length, 4 inches wide at the top, *h*, and 1¾ inch wide at the bottom, *g*, fastened together by means of iron links, *l*, sunk into the sides, to allow the plugs to pass along the drain in a slight curve. A single suter of 18 or 24 inches long would answer the same, or perhaps a better purpose.

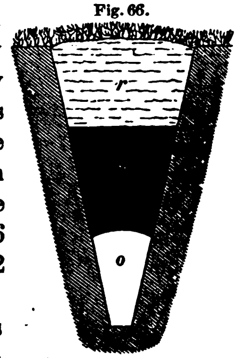
Fig. 65.



THE SUTERS OR PLUGS IN PLUG-DRAINING.

The next step is the placing of the plugs on their narrow edges upon the bottom of the drain, which they will exactly fit, if the drain has been properly cut. The most important part of the process is now to be executed. The oblique regularly-shaped pieces of clay last taken out with the bitting-iron are well rammed down upon the plugs until beaten into one mass; then the smaller pieces are equally well rammed down above the former; and, lastly, the turf is placed in its original position. The whole earth and turf are rammed down along the full length of the plug, with a rammer, such as fig. 34. The operation of ramming being finished, the lever *n*, fig. 65, is then struck into the bottom of the drain, at the length of the chain *m*, which is hooked to a staple in the end of the nearest plug, and the plugs are drawn forward by the repeated action of the lever, till within 8 inches of their entire length. The work of ramming is thus proceeded with, step by step, until the whole drain is completed.

Fig. 66.



THE SECTION OF A PLUG DRAIN.

The finished drain is represented in section by fig. 66, where *o* is the duct left in the clay by the plugs, 8¼ inches high; *p* the clay rammed down above the plugs, 9 inches deep; and *r* the returned turf, with the grassy side uppermost, 6½ inches, which again makes the surface smooth, and finishes the drain at 2 feet in depth. Figures 65 and 66 are drawn to the scale of ⅛ of an inch to 2 inches.

Some particulars in the conducting of this operation should be attended to. 1*st*, Care should be taken to return *all* the earth that was cast out of the drain. This is a criterion of good work; and for this purpose, the ramming being the most laborious part of the operation, workmen are apt to execute it in an insufficient manner. Four men and a boy are the best number of people to carry on the work expeditiously; and only stout people should be employed, as ramming is really a laborious operation. 2*d*, As few main drains should be made as possible, and the open ends of all drains should be protected against vermin; and, what makes the best finish, the lowest end of each drain should be furnished with a pipe-tile of the proper size, or with stone. The main drains, of course, should be made larger than the ordinary ones, and they have to be provided with proportionally larger plugs. The drains should be placed at a distance from each other, in proportion to the drawing nature of the subsoil. 3*d*, No stock should be allowed to enter the field while under this treatment of draining, and even not until the earth over the drains has again become firm. After the drains of a field are all finished, the ground should be rolled with a heavy roller. 4*th*, This sort of drain should not be made in frosty, snowy, or very rainy weather, as the earth to be rammed in will either be too hard, crumbly, or too soft. 5*th*, A strict superintendence of the work is the only guarantee for its efficiency; for as to the expedient of imposing fines upon poor workmen, they cannot be exacted without hardship, and perhaps injustice.

Mr W. S. Evans, of Selkirk House, near Cheltenham, Gloucestershire, executed 300 miles of this kind of drain in 4 years, and is well pleased with its effects upon the land.

It is not so cheap a mode of draining as at first sight may appear, costing 1¼d. the lineal yard, or L.5, 0s. 10d. the acre, according to Mr Evans' practice; but, in another account, the expense is stated as low as 4d. the rood of 6 yards, or L.2, 13s. 9¾d. the acre.*

The principle of this mode of draining is said to have succeeded well on the tops of the Gloucestershire hills, where the bottoms of the drains descend to and are cut through rock, and where the bitting-iron and plug have found a substitute in the pick-axe, the channel formed by which being covered with flat stones, covered with clay rammed down as before described. Such a condition of soil and subsoil would be better suited for the clay land shouldered drain of fig. 61, than for plug-draining, It would be a permanent mode of draining in these circumstances; but in plug-draining in pure clay, I have no doubt that the water will soften the sides of the duct, and cause the rammed wedge of clay to slip downwards; and should it ever reach the water, its lower side will inevitably be dissolved, and its remains form a dam across the duct.

Sod Drain.

An imperfect form of shoulder-draining is practised in some parts of England on strong clay soils, under the name of *sod*-draining. It is executed by removing a thick turf with the common spade, and laying it aside, for the purpose of making it the wedge at a subsequent part of the operation; and the tougher the turf, the sod drain will be the more durable. Another spit is removed with the narrow spade, fig. 39, and the last or undermost one with the narrowest spade, fig. 44, only 4 inches wide at the mouth, leaving a small shoulder on each side of the drain. The drain may be made to any desired depth. The upper turf is then wedged in and beaten down, and rests upon the small shoulders left on the sides of the drain, before it reaches the narrow channel, formed by the last-mentioned spade, fig. 44, and constituting the duct for the water. It is evident that this is a temporary form of drain under any circumstances. Though it may last some time in grass-land, it seems unsuited for arable ground, which is more liable to be affected by falls of rain than grass land; and in any case the clay, when in contact with water, will be softened so as to endanger the existence of the duct. The sod drain is very similar in construction to the covered sheep drain in grass, fig. 3.

* *Quarterly Journal of Agriculture,* vol. iv p. 501, and vol. xi. p. 68.

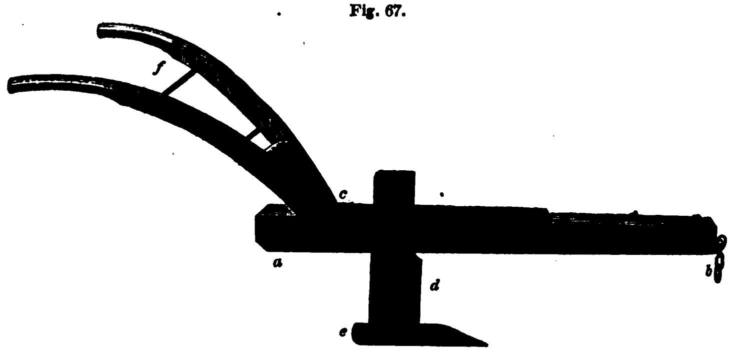
Mole Drain.

Another method of draining is performed on strong clay land by the *mole-plough*. This implement is almost unknown in Scotland, its use being confined to some parts of England, where grass land on a clay subsoil abounds. It was, I believe, first introduced to the notice of Scottish agriculturists by the Duke of Hamilton, at the Highland and Agricultural Show at Glasgow, in 1838. The day after the Show, I saw it in operation on a farm in the neighbourhood of Glasgow, of strong clay land, and it seems best adapted for that kind of soil. Its object is to make a small duct in the soil at a given distance from the surface, in the form of a mole-run, for the water to flow along; hence its name of *mole*-plough. It makes the duct by means of an iron-pointed cone, drawn through the soil by a force considerably greater than that required for the common plough.

The mole-plough as a draining machine can never be of much utility in a country like Scotland, where alluvial deposits, though not deficient in extent, are characterised more by the abundance of stony matter than of clay in the subsoil; and it is only in the few *carses* that such clays occur as would suit the mole-plough. Mole-draining, however, would have but a trifling effect in the carse clay compared to substantial covered tile-drains. In all subsoils where boulders occur, whether large or small, it is inapplicable.

This plough is of extremely simple construction, as appears from fig. 67. It consists of a beam of oak or ash 6½ feet in length,

Fig. 67.



THE MOLE PLOUGH.

being 6 by 5 inches at the butt-end *a*, tapering forward to 4 inches square at the bridle, *b*. As the beam, when in operation, moves close to the ground, and is, indeed, the only means of regulating the depth at which the duct is to be formed, its lower side is sheathed with a plate of iron about ½ inch thick. This plate, at 4 feet 4 inches from the point of the beam, is perforated for the coulter-box, its fore-end being worked into an eye, to serve as a bridle, and it is all along strongly bolted to the beam. At the distance of a foot behind the coulter-box, a strong stub of wood is mortised into the beam at *c*, standing at the rake and spread given to the handles. Another plate of iron, of about 3 feet in length and ½ inch thick, is fixed upon the upper side of the beam, the coulter-box being also formed through this plate, and the hind part is knee'd at *c*, to fit upon and support the stub, to which, as well as to the beam, the plate is firmly bolted. The two handles, *cf*, are simply bolted to the stub, which last is of such breadth as to admit of several bolt-holes, by which the *height* of the handles can be adjusted. That which may be termed the head of the plough is a malleable iron plate, *d*, of about 2 feet in length, and the part of it which passes through the beam and is fastened to it by means of wedges, like the common coulter, is 7 inches broad and ¾ inch thick. The part of *d* below the beam, which acts as a coulter, is 9 inches broad, ¾ inch thick in the back edge, and thinned off to a knife-edge in the front. The share or *mole*, *e*, is of solid malleable iron, welded or riveted to the head, *d*, its length in the sole being 15 inches, and its cross section (which is a triangle with curved sides, considerably blunted on the angles) measures 3 inches broad at the sole, and 3½ inches in height. A cylinder, however, is a better form than a triangle; but, in either case, the fore-part of the share is worked into a conical form, the apex being in the line of the sole, or nearly so. This, while it enables the share to penetrate the earth more freely, prevents the tendency of rising out of the ground. This tendency, however, is not so great as may be supposed, for the centre of motion in this implement being very low, not less than 12 inches under the surface of the ground, and the draught being applied horizontally, there is a strong tendency in the point of the beam and of the share, as in all similar cases of oblique draught, to sink into the ground, the effect of which, if not properly balanced by the effects of *form* in the parts, will give, in the mole-plough, much unnecessary resistance.

In working this plough, the draught-chain is attached to the bridle eye at *b*, and is usually drawn by two horses walking in a circular course, giving motion to a portable horse-capstan, constructed on a small platform movable on low carriage-wheels, and moored by anchors at convenient distances of 50 to 60 yards. The mechanical advantage yielded by the horse-capstan gives out a power of about 10 to 1, or, deducting friction, equal to a force of about 14 horses.

When the plough is entered into the soil and moved forward, the broad coulter, *d*, cuts the soil with its sharp edge, the mole, *e*, makes its way through the clay subsoil by compressing it on all sides, and the tenacity of the clay keeps not only the duct thus formed open, but the slit which is made by the broad coulter permits the water in the soil to find its way directly into the duct. This plough is found to work with the greatest steadiness at 15 inches below the surface. The upper turf is sometimes laid over beforehand by the common plough, when the mole-plough is made to pass along the bottom of its furrow, and the furrow-slice or upper turf is again carefully replaced. This is the preferable mode of working this plough, as it serves to preserve the slit made by the coulter longer open than when it terminates at the surface, where, of course, it is liable to be soon closed up; but the least trouble is incurred when the mole-plough is made to pass through unploughed turf.

To work the whole apparatus efficiently, 2 horses and 3 men are required; and if the common estimate of 8s. a-day for 2 horses and 1 man is taken, and 3s. 6d. for the other 2 men, an acre of ground can be mole-drained for 11s. 6d., exclusive of the first cost of £50 for the apparatus, and its tear and wear.

If the mole-plough is put in motion in soft clay, the slit made by the broad coulter will not remain open even for a single day; and though it may again become open in severe drought, it will close again whenever the clay becomes moist. Pure clay subsoils under old grass may thus partially be drained with comparative economy; and the process being economical, it may be repeated in the course of years in the same ground;* and yet what a lumbering apparatus is thus required to produce so tiny an effect!

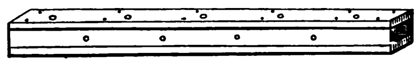
Larch-tube Drain.

It is proposed by Mr Scot of Craigmuie, Stewartry of Kirkcudbright, to substitute tubes made of larch for drain-tiles, in

* See *The Agricultural Surveys of Middlesex and Essex.*

situations where larch is plentiful, and consequently cheap, and drain-tiles dear; and he considers that they would be equally efficient with tiles in many situations, and particularly in mossy soils. Were larch tubes confined to draining mossy soils, I conceive they would answer the purpose well, not only on account of their length maintaining them in their original position in the drain, but of the durable nature of larch in water, as instanced in cases of great antiquity, such as the sound state yet of the piles upon which the city of Venice is founded. The larch tree felled in winter, and allowed to *won* with the bark on, makes much more durable and useful timber for every purpose, and more free of splits and cracks than when cut down in sap, and immediately deprived of its bark for tan.

Fig. 68.



THE LARCH DRAIN-TUBE.

The larch-tube finished, fig. 68, presents a square of 4 inches outside, with a clear water-way of 2 inches. Those who wish to know how this tube is made, I refer to Mr Scot's published description;* but, while doing this, I must remark that the cost of these tubes will exceed that of clay tiles and soles, and, of course, of pipe-tiles. For, take the cost of drain tiles and soles, of 15 inches in length each, at 30s. per 1000, exclusive of carriage, that will make them worth 1½ farthing the lineal foot. Now, a lineal foot of larch tube contains 1 superficial foot of timber at 1 inch thick, which costs for carriage and sawing 1 farthing; the fitting, boring, and pins, other 2 farthings; the timber, at 6d. the cubic foot, increases the cost 2 farthings more; altogether 5 farthings, making the tube more than three times dearer than tiles; and even with the cost of the timber thrown into the bargain, the tubes would still be double the above price of tiles, including, in addition, carriage at 6s. 8d. per 1000; and, as a consequence, the price of larch-tubes would be more than double that of pipe-tiles.

Brushwood Drain.

Many expedients have been devised for filling drains, among the most remarkable of which may be mentioned brushwood, thorns, trees, and even straw-ropes. With the exception of the trunks of small larch trees, which, when laid in wet drains, such as in moss,

* *Prize Essays of the Highland and Agricultural Society*, vol. xiv. pp. 99-109.

will last a considerable time, brushwood of every kind is not durable. Hence the soil over drains filled with such materials soon falls in. It would only be dire necessity that could induce any man to fill drains with straw twisted into ropes; and a similar motive must tempt farmers to fill drains with thorns, even in localities where stones are scarce and drain-tiles dear. No doubt, the astringent nature of thorn-bark may preserve its wood from decay under ground for a considerable time, but the sinking of the ground over such drains, as I have frequently observed, is infallible evidence of the decay of the material occupying them, astringent as it may be. Alders in drains are found in Surrey to remain only 6 or 7 years in clay subsoils. What a mess a drain must be which is "filled up to the height of 8 or 10 inches, either with brushwood stripped of the leaves—oak, ash, or willow twigs being the best—and covered with long wheat-straw twisted into bands, which are put in with the hand, and afterwards forced down with the spade, care being taken,"—the only instance evinced in the whole operation,—"that none of the loose mould is allowed to go along with them! The trench is then entirely filled up with earth, the first layer of which is closely trampled down, and the remainder thrown in loosely."* Yet, such is the method of forming drains in several of the south-eastern and midland counties of England. Need we be surprised to hear of the insufficiency of draining, until we have learned the sort of materials with which the drains are filled?

Brick Drain.

Of the *durability of common brick*, when used in drains, there is a remarkable instance mentioned by Mr George Guthrie, factor to the Earl of Stair, Culhorn, Wigtonshire. On making drains on that estate, some brick-drains were intersected, which emitted water very freely. In documents referring to those drains, it appears that they had been formed by the celebrated Marshal Earl Stair, *upwards of a hundred years ago*. They were found placed between the vegetable mould and the clay upon which it rested, and about 31 inches below the surface. They presented two forms; one consisting of two bricks set asunder on edge, with other 2 laid lengthways across them, making the duct of 4 inches square, but having no sole. Being thick bricks, they had not sunk in the least through the sandy clay bottom upon which

* *British Husbandry*, vol. i. p. 457.

they rested. The other form of duct consisted of 2 bricks laid side by side, as a sole, with two others built on bed on each other at both sides, upon the solid ground, and covered with flat stones, the building being packed on each side of the drain with broken bricks.*

Drain Ploughs.

Various attempts have been made to *lessen the cost of cutting drains.*

An attempt was made to attain this end by Mr Peter M'Ewan, Blackdub, Stirlingshire, by means of the plough. His invention consists of a particular form of plough, certainly displaying much mechanical ingenuity, and performing its work in pure clay with a considerable degree of precision, taking out the subsoil in regular furrow slices. It is, however, not adapted to every variety of subsoil; the most common one, a tilly clay, containing small stones and occasional boulders, presenting insuperable difficulties to its progress. The instrument is thus limited in its application; but a greater objection to it is, that it requires an inordinate power to set it in motion, consisting of not less than 8 to 12 horses. This circumstance still more limits its application, as there are comparatively few farms which employ 6 pairs of horses; and besides, it is almost impossible to yoke 12 horses together, so as to command the entire amount of their power. In fact, it is truly distressing to see horses working with this plough, as I once had the opportunity of witnessing in a field, of even favourable subsoil, in the neighbourhood of Glasgow in 1838, on the occasion of the Highland and Agricultural Society's Show.

Mr Smith, late of Deanston, has given a description of Mr M'Ewan's draining plough, which it is not necessary to particularise here, further than that the horses go in two divisions, one division of 6 horses on each side of the line of draught, yoked to a strong master-tree 10 feet long, arranged so as to have 4 abreast when 8 horses, and 6 abreast when 12 horses are employed.

In regard to the state of the work left by this plough, men must follow with spades, and take out a bed for tiles or broken stones, and make a uniform fall in the bottom. The tiles or stones are then put in in the usual manner, and the earth returned into the drain by the common plough.

This drain-plough is made of two sizes, one weighing 5 cwt.,

* *Prize Essays of the Highland and Agricultural Society*, vol. xvi. p. 45.

costing £11, the other weighing 4 cwt., and costing £8, 8s., and the bars or swing-trees, necessary to mount each plough, are 2 six-horse, 4 three-horse, and a strong chain—the entire mounting costing £4, 4s.

As to the length of drain cut in a day by this plough, Mr Smith estimates the time spent at 2 miles per hour for 8 hours: and allowing one-third of the time to be lost in turnings, the actual quantity of work done in 8 hours he takes at 3126 roods of 6 yards, or about 19½ acres, at 15 feet asunder, the drains being cut from 18 to 22 inches in depth.

The rate of walking taken by Mr Smith, at 2 miles the hour, is too great, as the distance travelled in ploughing 1 imperial acre of ground, in the usual way, in a day of 10 hours, constituting a good day's work of 9⅞ miles, is only 1738 yards per hour, including turnings, or less than 1 mile per hour.

The cost of employing this drain-plough is thus given by Mr Smith:—

12 horses at 4s. a-day each, ...	£2	8	0
8 men at 2s. a-day each, ...	0	16	0
To cover interest of cost, and tear and wear of plough, say 1s. the hour.	0	8	0
	£3	12	0

which is only 1 $\frac{1}{10}$ farthing per rood of 6 yards,* or 3s. 8d. per imperial acre.

Other ploughs have been invented for cutting drains, which have attracted attention, and engaged the advocacy of friends, but their construction is nearly the same as the one I have described, and their use has never extended beyond their own localities; and notwithstanding the efforts that may be made to render such implements perfect, they are quite inapplicable in any subsoil but of pure clay.†

Drain-tile Machines.

Various attempts have also been made to *lessen the cost of making drain-tiles*, by means of machinery.

Even in the most favourable circumstances, hand-made tiles are expensive, their manufacture, though by no means laborious, being slow and tedious; slow, in giving form to the tiles, and placing them one by one on the shelves; and tedious, in waiting for their

* *Smith's Remarks on Thorough Draining*, pp. 26-31.

† See Green *on Underdraining Wet and Cold Land;* Hodges *on the Use and Advantages of Pearson's Draining-Plough; English Agricultural Society's Catalogue of Agricultural Implements*, for 1846, p. 18 and 112.

being sufficiently dry to be packed in the kiln. There are several tools exclusively requisite for hand-made tile manufacture—such as moulding-tables, sand-boxes, benches for horses, and horses and moulding-frames of various sizes.

The making of hand-made tiles costs the following sums, according to estimates calculated at high wages, by practical tile-makers in different parts of Scotland:—

Cost of Operations.	3-inch drain-tiles per 1000.	4-inch drain-tiles per 1000.
	S. D.	S. D.
Casting clay, . . .	0 8	0 10
Grinding clay, and sand, . .	2 6	3 6
Moulding clay, . . .	3 9	5 0
Filling the kiln, . . .	1 2	1 3
Coals 11¼ and 12½ cwt. @ 8s. per ton,	4 6	5 0
Burning, ...	1 6	2 0
Taking out of the kiln, . .	1 0	1 2
	15 1	18 9

At these rates of cost, drain-tiles and soles, which are always half the price of tiles of the respective sizes, are sold at the following prices in different places:—

At Different Places.	Cost of tiles per 1000.	Cost of soles per 1000.	Total cost of tiles and soles per 1000.
	S. D.	S. D.	L. S. D.
2-inch tiles 14 inches long,	14 0	7 0	1 1 0
2½	16 0	8 0	1 4 0
3	18 0	9 0	1 7 0
3 ... 12 ...	18 0	9 0	1 7 0
4	23 0	11 6	1 14 0
6	28 0	14 0	2 2 0

At these prices and sizes, hand-made drain-tiles and soles cannot, therefore, be made in the most economical manner, and in the most favourable circumstances, as to quality of clay and cost of coals, under from 21s. to 42s. per 1000.

The loss from the period of moulding to carting away is calculated at one-fifth of the quantity—that is, a loss of 200 out of every 1000 tiles, which implies an enormous amount of waste, and great negligence.

The drain-tile machines hitherto invented may be divided into two classes:—1st, Those which force out a continuous sheet of clay, by means of smooth rollers, and then mould it into the form of tiles; and, 2*d*, Those which force the clay through moulds that form the tiles at once. The machines of the latter class may be divided into three kinds:—*a*. Those which force the clay with perpendicular or horizontal pistons having alternate motions, through moulds attached to fixed or movable chambers, and which form the tiles at once. *b*. Those which force the clay with smooth rollers through moulds that form the tiles at once. *c*. Those which force the clay with a pug-mill through moulds that form the tiles at once.

Arranging all these machines by the forms of tiles they make, they may be divided into two classes,—1*st*, Those which can form both common drain-tiles and soles, and pipe-tiles; and, 2*d*, Those which can only make common drain-tiles and soles. The machines which do not mould the tile at once, belong to this latter class, while those which do, belong to the former. Hence the latter are more generally useful than the former.

1. The first class of machines was originally invented by the Marquis of Tweeddale, whose machine was the first produced, and that only a few years ago. It deservedly attracted much attention at the time on account of the novelty of its production, as also, no doubt, its ingenious construction, and it is still used by large companies of tile-makers, both in England and Scotland. It has since been rendered more useful for the hand, and more expeditious in its work, by Messrs Boyle and Young of Ayr. It puts out a continuous sheet of clay very smoothly; still, with all the improvements made on the part which moulds the tile, the clay, on being shaped into common drain-tile form, is apt to produce tiles fissured along the back, and this defect can only be remedied by washing the tiles on the back, which renders them very moist, and, of course, difficult to dry. It is an objection to the general use of this machine, that it cannot mould pipe-tiles.

2. The second class contains the names of a numerous band of inventors.

a. For those machines which operate by means of a piston, a great number of names have appeared in competition for public favour, and yet but little ingenuity seems to have been exercised in producing them, as every succeeding one is but a slight modification of its predecessor. One forces first one tile and then another from the same side of the machine, whilst others force from two to seven tiles, first from one side, and then as many from the other. One has its piston moved by a crank-handle on a fly-wheel attached to the shaft of a pinion, whilst another effects the same object by a spoke-wheel attached to the shaft of a similar pinion, and a third works the piston with a lever. All of them can make pipe-tiles as well as common drain-tiles and soles. The names, alphabetically arranged, of the patentees of tile-machines of this description are,—Henry Clayton, Dorset Square, London; Denton and Charnock, Wakefield; John Hatcher, Benenden, Kent; Thomas Scragg, Calvely, Chester; William Bullock Webster, Hounsdown, Southampton; and Richard Weller, Capel, Surrey. All the varieties of piston tile-machines made for these inventors I saw exhibited at the Show of the Royal Agricultural Society of England, at Newcastle-upon-Tyne, in July 1846.

The great objection to all tile-machines operating by means of a piston, is the reciprocating motion, by which time is lost in altering the motion from one impulse to another, whether in the same or in opposite directions. Another objection is, that air is apt to be conveyed into the chamber along with the clay, and, on being expelled by the piston through the moulds with force, it injures the form of the tile. A constant crackling and exploding noise is heard whilst the tiles are being protruded by the piston. Machines having reciprocating pistons, and necessarily so many parts and joints belonging to them, must be much more apt to go out of order than those of simpler construction.

b. The only tile-machine of a simple construction which makes both pipe-tiles and common drain-tiles and soles, with which I am acquainted, is Mr Ainslie's, Alperton, by Acton, in Middlesex. It consists of two rollers, moved by wheel and pinion with a crank-handle on a fly-wheel, taking in a continuous supply of clay, and forcing it through a mould in a stream of tiles or pipes. Its remarkably simple construction renders it very unlikely to go out of working order, and the constant movement of its action in one direction causes it to execute a larger quantity of work, in the same time, than any tile-machine of the same power, with a reciprocating action. It possesses the advantage of the improved Tweeddale machine, in condensing the clay, while it is superior to it in moulding either drain-tiles or pipes, as may be desired. It also possesses the advantage of the piston machines in forming both drain-tiles and pipes; while it is superior to them in moulding tiles and pipes in the most condensed and *dry* state, free from fissures and holes occasioned by the explosive force of confined air. I regard the *dry* state in which a tile or pipe is moulded by a machine as of great moment, inasmuch as the tile requires much less time to become in a fit state for the kiln; and, when as much water is put into the clay of a piston-machine as to expel the air, the tiles are moulded in too soft a state, and are apt to lose their shape on the shelves. For these reasons, I consider the Ainslie tile-machine, in its present form, as the most perfect in principle, as it is without doubt the simplest in construction; and it therefore contains the properties of greater durability than any tile-machine I am acquainted with.

c. A tile-machine, forcing the clay through moulds which form pipe-tiles and common drain-tiles and soles by means of a pug-mill, has lately been presented to public notice by Mr William Benson of Allerwash House, Northumberland. This machine moulds the tiles in a horizontal direction from four points at the bottom of the cylinder of the pug-mill. It is similar in principle to the one invented by Mr Etheredge a few years ago, which moulded the tiles in a perpendicular direction from the cylinder of the pug-mill, elevated at the height of a few feet from the ground, to admit of its conveniently presenting the tiles; and, from the comparative economy with which it was said it could make pipe-tiles, the machine attracted considerable attention at the time, but no one now hears of it. Mr Ainslie's first tile-machine, invented by him while at Redheugh, near Dalkeith, was constructed on the pug-mill principle; but he abandoned it as soon as he got a glimpse of the very superior principle upon which his present machine is constructed. It is, therefore, not improbable that Mr Benson's pug-mill machine will share the fate of its predecessors. I am also satisfied that all the reciprocating machines will be abandoned one after the other, as the progress of draining advances, and the demand for pipe-tiles increases.

As to the cost of making tiles by machine, much of the labour and expense must be the same as in hand-making, such as casting and grinding the clay, the consumption of coal, the filling and emptying of the kiln, and the burning of the tiles; but most of these operations are much modified, and even altered, when performed for a machine. For example: The casting of the clay will be the same in every case, further than, in the case of clay intended for a machine, it should be cast by the *spade* in as *thin* pieces as possible. The grinding should be executed with great care for machine work, as every hard lump of clay and small stone, too large to pass through the orifices of the mould, will cause the tiles to be emitted at unequal velocities, or be rent along the part where the stone is arrested. The grinding, therefore, should cost more for preparing clay to be used by machine than by hand, but as much less clay is required for the machine than the hand, this part of the cost may be regarded as equal. On the other hand, the compressed state of the clay by the machine, together with the uniform thickness of the tile, render the tiles more easily dried in the sheds, which will afford more kilns-full to be burned during the season. The uniform thickness and great dryness of the tiles lessen the consumption of coal, and the burning is also more expeditious and uniform in its effects. The compressed clay and uniform burning, together with the shape of the pipe, render the tiles much less liable to be cracked in the kiln, and broken when handed from the kiln, or from the cart. These are all facilities for making, and means for economising, the cost of tiles by machines.

There are kiln-burners who undertake to make and burn pipe-tiles of 2 inches in width, 3 inches in height, and 15 inches in length in the bore, for 4s. 2d. per 1000, on receiving the use of the machine and kiln, and being provided with coals and prepared clay.

The cost of this size of pipe-tiles should stand as under per 1000:—

	S.	D.		S.	D.
Casting the clay, . .	0	8	Brought up, . . .	4	6
Grinding it, with man and horse,	2	6	2 boys, shelving the pipes, .	0	8
1 man, driving the machine, .	0	8	Filling the kiln, . .	0	6
1 man, feeding-in the clay, .	0	8	Coal, 10 cwt. at 8s. per ton, .	4	0
			Burning, . . .	0	6
	4	6	Emptying the kiln, . .	0	6
Total cost of such pipe-tiles per 1000, . .				10	8

The money cost between making tiles by hand and machine is thus very considerable, and it is much less with the additional number of kilns-full that may be burned in the course of the season. But this statement does not include the salary given to the manager, nor interest on the cost of the erection of the works.

Machines for Preparing Clay.

It is of the utmost importance to the production of a good tile to have the clay in a properly prepared state. Some unctuous clays require little preparation, and may therefore be used in a machine at once, such as that at Cuttlehill, near Dumfermline, in Fife; while the great body of the clay found in this country is unfit for employment in tile-making, either by hand or machine, until it has undergone the long and tedious processes of turning with the spade, and of milling. The machine usually employed in preparing the clay is the common *pug-mill*, which consists of a cylinder, in which is set in motion, upon an upright shaft, commonly by horse power, a number of knives, the faces of which being set at an oblique angle with the line of the upright shaft, cut the clay in pieces, and at the same time force it in a square-shaped stream through the bottom of the cylinder. On considering the action of knives so set and worked, it is evident, that, however well they may be adapted to cut clay in pieces, and however much they may compress the pieces, they cannot incorporate them into a homogeneous mass. The varieties of clays usually found in the diluvial deposits of this country lie in thin parallel layers.

Machines have been contrived to supply this obvious defect in the working of the pug-mill. Those I have seen are Clayton's perforated metallic grating, through which the clay is forced, and by which stones, roots, and other matter are arrested, and W. Bullock Webster's screen for separating stones and other extraneous matters from clay, which it does by pushing the stones to one place and forcing the clay to another. The process of forcing the clay by a piston through gratings, as these machines do, may free the clay from stones and other injurious objects, and it may compress the clay firmer than even a pug-mill, but it cannot incorporate the different varieties of clay any more than a pug-mill. It is, however, a matter of great moment in the manufacture of a good solid tile to have the many varieties of clay found in every clay-pit thoroughly incorporated; for, as it is known that different kinds of clay stand the fire in a different manner—one requiring a much greater heat, and another acquiring a greater hardness—it is obvious, when different kinds of clay happen to be in an unmixed state, in the same tile, each will acquire a hardness by the same heat in the kiln according to its constitutional difference, and, of course, be differently affected when exposed to the air. There is no other way of explaining the cause of the very large proportion of waste, by breakage, experienced at many tile-works, amounting in some cases to 20 per cent. Now, it occurs to me, that a machine of a very different and better principle than the pug-mill alone may be constructed for the preparation of every kind of clay used in the manufacture of drain-tiles. Such a machine should consist of heavy rollers of cast-iron, large in diameter, set on edge on opposite ends of the same axle, to revolve around a common centre, upon the area of a large circular basin of cast-iron, which would bruise and mix together the clays, by the compound action of revolving upon their own axes, and around the centre of the basin, and the clay could be fed to them in a thin stream by a small pug-mill situate between them, in the centre of the basin. With such a treatment, continued for some time, every variety of clay could scarcely fail to be incorporated into a uniform mass, and rendered fit to form a smooth straight tile, that would acquire a uniform hardness and texture by fire.

A machine for preparing clay, somewhat of this construction, was exhibited by Mr Ainslie, Alperton, at the Christmas Show of the Smithfield Club, which was driven by hand; but I know that it has not answered the purpose. I understand that a similar machine for a similar purpose was patented some time ago by some one near Glasgow, but cannot learn the results of its operation.

Whether Landlords ought to undertake any or what part of the Expense of Draining?

I am now arrived at a very important question connected with the draining of land, namely, Whether *landlords should undertake any and what part of the expense?* This question cannot be satisfactorily answered without taking into consideration the object, the effect, and the cost of draining land. The object of draining land is simply to make it dry; but in making it dry, the fertility of the soil is found to be increased, not for one year or two only, or for a rotation of crops, which change might be effected by manure alone, but for a lease of nineteen years, probably for a much longer period, and possibly for an indefinite length of time. Here, then, is an operation capable of making land more fertile, not in a temporary, but a permanent manner; and hence the intrinsic worth of the land should be measured by the increase of the permanent value imparted to it. This being undoubtedly the case, the question of what party ought to drain the land, necessarily resolves itself into one of these: Ought landowners to allow other parties than themselves to increase the permanent value of their land; or, permitting it, ought they to impose a permanent increase of the rent of land, the permanent value of which they have in no way contributed to enhance? The conclusion is obvious, that landlords *cannot in equity refuse at least to assist* in the permanent improvement of their own land, if they exact the highest rent the land is worth, in consequence of those improvements. Improvement arising from judicious draining is acknowledged to be permanent; that by good husbandry only temporary. In the latter case, the landlord is quite entitled to derive all the advantage secured by good farming; because it is in the power of the tenant, if he choose, to remunerate himself before the expiry of his lease; and should he leave the land in any appreciable better state than he found it, he has no cause of complaint after being fully remunerated. On the other hand, in the case of the permanent improvement effected by draining, the tenant cannot secure the entire advantages of it to himself; because the land is left at the end of the lease, or of any other period, in a permanently improved state. This being the practical effect of draining, the landlord in fairness ought to incur the entire expense of it. Nevertheless, there are landlords who refuse to incur any of the expense of draining.

This settles the moral responsibility of the landlord; but there is also a moral question affecting the tenant, namely, ought he in any case to spend his money in rendering his landlord's land permanently better? In fairness to himself, he ought not. What then? shall the land remain unimproved? By no means. When the question of draining is thus plainly placed before the landlord and tenant, the only consideration with the tenant is, whether his outlay will be returned during the lease; and if the return be a bare one, his condition remains unimproved, and he has no inducement to improve the land. Nevertheless there are tenants who drain land at their own cost. I believe the largest proportion of the draining executed in this country in former years was undertaken by the tenant alone, in the hope he would recover the outlay before the expiry of the lease; and the natural consequence was, that it was made as small as possible to secure immunity from loss. Indeed such an outlay is very inconvenient to any tenant, as it absorbs a large proportion of his capital in a scheme which cannot secure him a permanent advantage, while it may return him no advantage at all; for, although little doubt exists that all sorts of land derive benefit in every case of draining, the tenant feels he may nevertheless not have time to receive back all the money he has expended, and be remunerated besides for the trouble of conducting the operation—and to this compensation he is entitled as much as any other man engaged in business; and the apprehension of loss is increased from the circumstance of efficient draining requiring a large sum—from £3 to £8 an acre. It is inconvenient for any tenant to disburse so large a sum of money in draining, or in any other operation but that of cultivating his farm. Can the tenant prudently undertake so expensive an improvement, in a case where the the landlord must ultimately derive most advantage from it? Should he disregard prudence in this matter, the landlord is deprived of the generous motive of offering to participate in it. The tenant, however, has a direct advantage in requesting his assistance; so much so that where the landlord does not assist in the draining, we may reasonably infer the tenant had determined not to request his co-operation; and in such a case, a very high sense of honour and justice alone would prompt a landlord to proffer his services, especially if he cannot afford to incur so great an expense. In every view of the case, it is incumbent on the tenant to request the assistance of the landlord in the first instance, whatever may be the issue of the application.

I have hitherto conducted this argument on the supposition that landlords feel unwilling to incur any of the expense of draining land. Were they, on the other hand, to undertake it, as a matter of course, the proportion which they should disburse is an important preliminary point to be settled; and it should be so, upon fixed principles, before the operation commences. When they undertake it, they are entitled to be relieved from the burden of the advance, unless they receive the farm immediately into their own possession; and they are also entitled to see the draining executed in the most substantial manner. The direct relation of landlord and tenant in draining land not having hitherto been so clearly illustrated as it deserves, I shall endeavour to indicate the true positions of both parties, by proving that draining is more a landlord's than a tenant's business, even in the low view of pecuniary remuneration: and this is probably the most practical way of treating the subject.

Mr Roberton, Ladyrigg, who has drained much, and considered the relation of landlord and tenant in regard to it, expresses himself in these sensible terms. While commenting on the different style of draining executed by the tenant himself, from that undertaken conjointly with the landlord, he observes—

That the immediate effect in both cases is much the same; and to serve merely the temporary purpose of the tenant, I have no doubt that the one will prove as beneficial as the other. To the proprietor, however, the case is very different; because, by the latter method, an improvement is effected which may be guaranteed to endure for several leases. It is very doubtful whether, by the former mode, it can be ensured much beyond the existing lease. That the proprietor should at all times become a party, and thereby secure the permanent improvement of his estate, is now very generally admitted; and yet the plan is not always acted upon. It may, however, be asserted, without much fear of contradiction, that improvements by thorough-draining will never become general, or be made permanent, unless the assistance of the landlord be obtained. When left altogether to the tenant, want of capital, and the shortness of the lease, will tend at all times to limit the extent of the improvement, which will seldom be made permanent ; because the true interest of the tenant is to execute the work only in such a manner as will secure his own temporary purpose. To the proprietor, among the many inducements to improve his estate by draining, the greatest, at least the most satisfactory is, that it yields an immediate and large return. If he has no spare money, he has only to borrow it at 4 per cent, and lend it out at 6 per cent, a per-centage which no tenant will refuse to pay, and upon a security, too, undoubted—that of his own property. No one will deny that a proprietor is as justly entitled to receive a fair return for money laid out in the improvement of his estate, as he is for that laid out on its original purchase. Hence I would assume, as a general principle, that for every penny laid out by a proprietor upon ameliorations of any kind, he shall have an assurance of a return, either immediate or prospective—immediate, in the form of interest ; prospective, in that of additional rent, by which, in after leases, it will repay the present outlay.

Just as these observations are, I would go further, and maintain that the landlord should have the assurance of a return immediate *and* prospective. The immediate return received in the interest ceases with the lease, and the prospective return can only be secured by an additional rent ; for it would be puerile to continue the former interest in a new lease, as its exaction would really be additional rent.

Again, as regards a tenant, Mr Roberton goes on to say, I assume that he makes every improvement the subject of a calculation of profit or loss for *one lease only*, and that he will not lay out any money *merely for the purpose* of making improvements to extend beyond that period ; because, even let him have an assurance of a renewal of his lease, still, before that takes place, a valuation will be made of his farm, which will include the effects of his improvements ; so that, while he originally disbursed the whole expense, he will in reality have to pay the cost over again in the shape of additional rent.

The cost of draining incurred by Mr Roberton varied from £4, 17s. 6d. to £3, 8s. 4d. the acre. In the former case, Mr Roberton informs us that the proprietors of his farm, the Governors of the Merchant Maiden Hospital of Edinburgh, paid the expense of opening the drains, and the work was executed in a manner which, he conceives, will render them of permanent service to the land. In the latter case, the draining was entirely executed at his own expense, upon a lease of only 12 years' duration, and was, therefore, more superficially executed.

In the preceding examples, he proceeds to say, both methods have been tried and both have succeeded ; and the conclusions he draws are worthy of attention, as evolving the point under inquiry—for the difference in the expense of the two methods is very nearly equal to what may be deemed a fair allowance for the landlord ; and when it is taken into consideration that, by the cheaper mode, the improvement of a greater extent of land was completed in a given time, without materially increasing the number of horses upon the farm, it is doubtful whether, in the end, it may not prove the more profitable one for the tenant; and whether, to a tenant of capital, the assistance of the landlord is so essential a matter as to deter him from engaging in an improvement of the kind; because, as a mere speculation, he may embark in it with confidence; and let the prices of produce vary as they may, the money expended in this way will always yield him a fair return.*

In a table of the relative proportions which landlords and tenants should bear in the making of drains, Mr Smith rests his calculations on the assumption that landlords should bear ⅔ds and the tenant ⅓d of the expense,—being the reverse of what the sentiments of Mr Roberton would seem to indicate. †

A statement by Mr George Bell, Woodhouselees, of the cost of tile-draining 13 acres, shows the actual proportions borne by his landlord, the Duke of Buccleuch, and himself, in the draining of his whole farm; and being a specific statement, it is very valuable, as containing particulars that may serve as guides to other drainers. It is this:—

By the landlord—									
Cost of 38,000 3-inch tiles, at 25s.,				£47	10	0			
—— 1,577 4-inch ... 32s.,				2	10	5			
Cutting 2003 roods of 6 yards, at 3d. the rood, . . .				26	0	9			
Slates for soles, . . .				1	5	0			
Total cost to the landlord,				£77	6	2, or, per acre,	£5	18	11
By the tenant—									
The carriage of 38,000 3-inch tiles, at 3s. 4d. per 1000, .	£6	6	8						
The carriage of 1577 4-inch tiles, at 5s. the 1000, . .	0	7	10						
31 days' work of man and horse laying down tiles, straw for covering them, &c., at 5s. 6d. per day,	8	10	6						
Wages of women loading and unloading carts, . .	2	3	0						
31 days of a man setting tiles,	2	5	0						
31 days of a woman assisting him, .	1	0	0						
8 days of a plough, and horses and man,	1	10	0						
Total cost to the tenant,				£22	3	0, or, per acre,	£1	14	1
Total cost to landlord and tenant,				£99	9	2			
Total cost per acre, ...							£7	13	0

* *Prize Essays of the Highland and Agricultural Society*, vol. xiv. pp. 43-5.
† Smith's *Remarks on Thorough-Draining*, p. 16.

Taking Mr Smith's proportion of $\frac{2}{3}$ds for the landlord, the sum which the Duke of Buccleuch should have paid of the total cost of £99, 9s. 2d., is £66, 6s. 1d.; but he actually paid £77, 6s. 2d., which is $\frac{7}{9}$ths, and yet the parts of the work respectively undertaken by the landlord and tenant seem to have been fairly divided.

On looking over the different items of expense contained in this statement, it will be observed, however, that the landlord's share consists entirely of outlay of cash, whilst that of the tenant is greatly augmented by calculating the cost of carriage and other horse labour, at rates paid for them when engaged on hire, and which, of course, include the profit obtained by the hire—a principle of calculation which no tenant is entitled to assume, as he ought not to receive the profit, when he should only charge the cost of labour.

On considering the fairness of this statement, the landlord should, as I think, follow this example, and disburse the expense of cutting the drains and the cost of the materials for filling them; while the tenant should afford the carriages, though the materials be brought from a distance, and pay a specified rate of interest on the landlord's outlay. On these conditions, with the expense, mutually borne, of an experienced man to superintend the execution of the drains, according to specifications previously agreed on, drains might be executed to last for an indefinite period of years. These conditions impose on the landlord $\frac{7}{9}$ths and on the tenant only $\frac{2}{9}$ths of the expenses. It should be borne in mind that the tiles are charged at a high rate at 25s. and 32s. the thousand, and were it 18s., the proportion of expense for the landlord would be much diminished, and it would be still less were pipe-tiles used. Thus, it appears, no fixed rule has yet been established on the proportions of expense landlords and tenants should pay in cases of permanent improvements, though there should be; and let me endeavour to discover one that shall deserve to be established.

Suppose a landlord determines on thorough-draining a farm, takes it into his own hands, and disburses every cost attending the operation. When his purpose has been attained, it is no more than reasonable in him to desire to receive back his disbursements, principal and interest, during the 19 years he is about to dispose of his farm to a tenant; for if the farm will not repay the expense of its improvement in so reasonable a time as 19 years, little advantage will be derived from its improvement. Now, a landlord may receive back all his disbursements, principal and interest, in a 19 years' lease, at 8 per cent on the money expended.

Suppose a tenant disbursed all the expense, he, of course, would be equally reasonable in expecting 8 per cent on his outlay during the lease.

But the positions of landlord and tenant, on expending the same sum in draining a farm, are widely different. The tenant is not only entitled to receive the 8 per cent, but also 15 per cent for his personal trouble in undertaking the draining; because commercial people generally expect that per-centage on their outlays. The tenant, therefore, should receive *at least* 23 per cent for his disbursements, while the landlord should be satisfied with *at most* 8 per cent for his share. For, as regards the tenant, the 19 years is the longest period he can calculate upon to receive back his money, and his case is not made better though the lease should be renewed, as new conditions will be made as if he were a stranger; and these are good reasons for his receiving 23 per cent on his outlay. And when a landlord effects the improvement, he derives the benefit for an indefinite period; and all he can expect in return is the common rate of interest he would receive were he to invest his money in any ordinary security, and this seldom exceeds 5 per cent. But in order to induce him to undertake it, some greater temptation than the ordinary rate of interest should be proffered to him; for although the farm to be drained may be his own property, it is not to be expected he should give himself the trouble to borrow money, and pay the ordinary interest for it, and receive in return no more than immunity from the payment of interest, or to lay out ready money for his successor to reap the fruits of. The interest of money fluctuating from 3½ to 5 per cent, there seems nothing unreasonable in his receiving a greater rate than the greatest one here mentioned.

Thus, then, when a tenant drains a farm thoroughly, he should receive 23 per cent on his outlay; and when a landlord does so, he should receive something more than 5 per cent. Now, what conclusion should be drawn from such premises? Clearly that the landlord should undertake the entire expense upon himself; because his interest in the improvement is permanent—he has the strongest motives for executing it—his demands upon the land are moderate, amounting only to the usual rate of interest—and in disbursing a portion of *his* capital, a smaller portion of the capital of the country is placed in jeopardy than when the tenant undertakes to disburse the landlord's share.

In the preceding suppositions, either the landlord or the tenant is supposed to undertake the entire drainage; but when a mutual understanding exists betwixt them, its conditions should be based on the principle, that both parties should receive their respective rates of interest, namely, the landlord his 8 and the tenant his 23 per cent; nor should the tenant grudge his landlord his 8 per cent, or the landlord exact a greater rent than will enable the farm to repay the tenant, with ordinary skill, 23 per cent; and though both these rates be combined, they will not amount to a large annual exaction upon the land. For example, suppose ⅘ths, or £80 out of every £100, are expended by the landlord, he should receive £6, 8s. a-year as his 8 per cent, and to give the tenant 23 per cent on his ⅕th or £20 he should receive £4, 12s. a-year, both sums together making 11 per cent on the whole outlay, which, if exacted as an annual tribute from the land, would only amount to 4s. 4¾d. the acre on land worth 40s.,—a sum, it is obvious, which its thorough-drainage would easily repay.

A very important measure, named the *Drainage Act*, was passed by Parliament in 1846, and amended in 1847; its object being to grant public money to landlords, for the drainage of their farms, and for the trenching and enclosing of waste land that had been drained under the provisions of the act. Scotland has taken great advantage of this act, and will, no doubt, eventually derive much benefit from it.

Theory of Draining.

My friend, Dr Henry Madden, of Brighton, has favoured me with these general observations on the mechanical effects of water on soils:—

If the mechanical constitution of soil is considered, it will at once be perceived that a soil *in situ* might not inaptly be compared to a porous solid permeated by innumerable tortuous channels, these channels being formed by the interstitial spaces occurring between the various particles composing the soil.

If water is added gradually to soil, the first effect will be doubtless to fill these channels, but from the attraction which the various components of soil have for water, they speedily draw it into their pores, and thus empty the channels; so that even after a considerable addition, the soil, *taken as a whole*, does not lose its porosity, although each particle *has its individual pores* filled with water. This is the healthy condition of soil; it is what I shall call *moist*, in contradistinction to *wet*. Soil in this state can be crumbled down in the hands without making them muddy, although it feels distinctly *damp*, and will lose, when heated to 212° F., from 20 to 50 per cent of water.

If now more water should be added, the channels will be again filled, and as the pores of each particle are already saturated with moisture, they can again be emptied only by one of the two following methods: 1*st*, either very gradually by evaporation from the surface, as in *undrained soil;* or, 2*d*, much more rapidly and effectually by the channels having communication with some larger channel in a relatively lower level, as is the case in *drained soil*. Soil in which all the interstices between its particles are more or less filled with water may be called *wet* soil ; and all such land must be drained before it can be properly and advantageously cultivated.

It will thus be perceived that water does no harm, in fact it is absolutely necessary in soil, so long as it does not alter its mechanical condition ; but whenever it fills up the interstitial channels, it becomes injurious, for the following reasons :—1*st*, it prevents the circulation of air through the soil, as this takes place entirely through the medium of these channels ;—2*d*, it impoverishes the soil by permitting soluble matter to soak through ; because, until these channels are filled, there is no flow of liquid in the soil, except a very gentle current from below upwards, produced by capillary attraction towards the drier particles near the surface.

Again, an excess of water acts most injuriously in soil by reducing its temperature. This is owing to the extremely slight conducting power of water for heat, as compared to earthy matter, assisted also by the cold produced by continued evaporation. According to some experiments which I performed, the diminution of heat produced in this way amounts, in summer, on an average, to 6½ degrees of Fahrenheit, which, according to Sir John Leslie's mode of calculating elevation by the mean temperature, is equivalent to a difference of 1950 feet. When we consider the effects of elevation upon the nature and amount of produce, we shall have good reason to see the baneful effects of such a change as this represents.*

After pointing out the effects of draining in ameliorating the soil and promoting a healthy condition of vegetation, Professor Johnston proceeds to show the effects of water upon clay soil, and confirms by theory what I have deprecated in practice—the danger of using tiles without soles :—

I shall add one important remark, he says, which will readily suggest itself to the geologist who has studied the action of air and water on the various clay-beds that occur here and there as members of the series of stratified rocks. There are *no clays* which do *not* gradually *soften* under the united influence of air and of running water. *It is false economy, therefore, to lay down tiles without soles, however hard and stiff the clay subsoil may appear to be.* In the course of 10 or 15 years, the stiffest clays will soften, so as to allow the tile to sink, and many very much sooner. The passage for the water is thus gradually removed ; and when the tile has sunk a couple of inches, the whole must be taken up. Thousands of miles of drains have been thus laid down, both in the low country of Scotland and in the southern counties of England, which have now become nearly useless ; and yet the system still goes on. It would appear even as if the farmers and proprietors of each district, unwilling to believe in, or to be benefited by, the experience of others, were determined to prove the matter in their own case also, before they will consent to adopt that surer system which, though demanding a slightly greater outlay at first, will return upon the drainer with no after-calls for either time or capital. If my reader, continues the Professor, lives in a district where this practice is now exploded, and if he be inclined to doubt if other counties be further behind the advance of knowledge than his own, I would invite him to spend a week in crossing the county of Durham, where he may find opportunities not only of satisfying his own doubts, but of scattering here and there a few words of useful advice among the more intelligent of our practical farmers.

The effects of water on soils, chemically considered, are thus described by Professor Johnston :—

* *Prize Essays of the Highland and Agricultural Society,* vol. xiii. p. 141.

Vegetable matter becomes of double value in a soil dried and filled with atmospheric air. When drenched with water, this vegetable matter either decomposes very slowly, or produces acid compounds more or less unwholesome to the plant, and even exerts injurious chemical reactions upon the earthy and saline constituents of the soil. In the presence of air, on the contrary, this vegetable matter decomposes rapidly, produces carbonic acid in large quantity, as well as other compounds on which the plant can live, and even renders the inorganic constituents of the soil more fitted to enter the roots, and thus to supply more rapidly what the several parts of the plant require.*

Durability of Drains.

I have more than once been inquired of, whether the tile-drains constructed in the mode I have described in this manual, are intended to be permanent, or only to serve a few years. I own I did not conceive it necessary to state distinctly, whether the drains described possessed a permanent or temporary character; because I did not imagine that any one would incur the expense of making such drains as I have described with the intention of their serving only a temporary purpose. In my opinion, drains, when made at all, should be made with a view to last for ever.

How many years any given drain shall continue to be useful, is a result difficult for any one to predict. Drains, filled with small round stones, as also those with tiles without soles, have been known to become useless in a few years, say twenty. But that substantially constructed tile-drains with pipes, or tiles and soles, of the best form and manufacture, will continue to be useful for many generations, is a result I have not the least doubt of; indeed, as long as the material of tile will retain its consistency—and that is of the nature of stone, (for most of our common stones, and all the laminated ones, are just a composition of clay and sand, indurated by the force of heat,)—it must remain intact in drains placed beyond the reach of frost, for an indefinite length of time. Drains, filled with tiles made in Holland, have been found in this country in an effective state after a lapse of 200 years.

Trenching Rough Ground, preparatory to, and consequent on, Drainage.

Although thorough-drained rough land is still unavailable to the plough, and as it must be made available either by manual or

* Johnston's *Elements of Agricultural Chemistry*, 4th edition, p. 110-13.

animal labour, a few instructions on the trenching of such ground with the spade or the plough, may be regarded, by its improver, as a useful supplement to the preceding pages on draining. It may reasonably be made a question, whether or not rough ground should be drained before being trenched, and the precedence of the two operations should be determined by the state of the surface and subsoil, which should also determine whether the spade or the plough would be the more economically employed in the trenching.

When the ground consists of the site of an old plantation, it is impossible to bring it under the plough but by previous trenching with the spade. The smallest tree-root forms an insurmountable obstacle to the plough; and the destruction of implements, injury to horses, and the time spent in removing obstructions, create more vexation and expense than the cost of trenching with the spade can incommode the farmer.

When it has been ascertained, by the sinking of pits, that the subsoil contains many stones, although the ground may not have been the site of a plantation, it also should be trenched with the spade. In such a subsoil, the plough meets with great opposition from large stones which stop its progress instantaneously; and the shock thus experienced not only endangers the implement, but injures the shoulders of the horses, and shakes their frames so violently, as to render them timid ever afterwards when put to similar work; and when only small stones occur, the plough cannot maintain its hold of the ground, amongst a number of them, and is easily thrown out, so as to make the ploughing of the surface to be very imperfectly executed.

Independently of tree-roots and numerous stones, ground that has grown brushwood—such as hazel, alder, birch, or even large broom and whin—is ploughed with much difficulty. I have tried the ploughing of whinny ground intermixed with bushes of birch, and been glad to relinquish the task; it being truly painful to see the horses stopped every few minutes by sudden jerks, and the furrow-slice irregularly laid over, and, in some places, the surface merely scratched with the point of the sock. Employed in such work, the wind of two valuable horses of my own was completely destroyed. They did not work together, so blame was not attributable to their drivers; but the keen temperament of the willing animals urged them to persevere in a work which was really beyond their strength; and as long as horses have the spirit to work, internal injury is not apprehended until it produces effects beyond the reach of cure.

In all these cases, I would earnestly recommend trenching with the spade, on the score of humanity to horses, of superiority of work, and economy in expense, as regards the immediate use to be made of the surface.

I have found this plan succeed well in trenching the ground. Let the ground be laid off in lots; and let each lot have an equal breadth of five yards. The trench should be at least 16 inches in depth of the solid ground on the average over the surface; and these 16 inches of solid will give a depth of 18 inches in the trenched part of the ground. The trenching should be executed by contract with a man of respectable character, and acknowledged skill. The contractor should be obliged to place all stones and roots, large and small, and every other thing likely to obstruct the future course of the plough, upon the surface of the trenched ground; and where large boulders are found within reach of the plough, they should either be blown to pieces by gunpowder, or further sunk into the ground, whichever is found the more economical plan. Boulders, when broken, may be of use in drains, or, when whole, in the foundation of stone-wall fences.

The trenching is begun at the utmost limit of the rough ground. One lot is appropriated to each man, and he commences work by rutting the surface with the spade some breadths of 12 or 15 inches in width across his lot, and making a trench of the required depth of 16 inches, guaged by a stick kept constantly in his possession to guide him in the depth, that he may have no plea of ignorance to urge in justification of his cupidity. The earth out of the first trench, 16 inches deep and about 15 inches wide, is laid aside beyond the ground to be trenched to fill up the want of the last trench. The upper turfs of the second trench are then put upon their back in the bottom of the first cleared trench; the soil is dug and thrown evenly upon these; and, lastly, the loose earth is shovelled over the surface of that, leaving no inequalities in the bottom of the new trench. In this manner, trench after trench is dug to the end of the lot.

After one set of allotted spaces have been trenched, another should be marked off by the contractor for the men to enter upon as soon as they finish their lots; and the second set of lots should be marked off either along one end or one side of the trenched lots, whichever is found most convenient for removing the trenched-up materials to their destination, in order that an entire piece of ground may be cleared for culture without interfering with the farther progress of the trenching. When the last trench of all the lots has been cast out, the earth laid aside when taken out of the first trench is now brought to fill up and level the last trench.

Trenching may be executed in any season; but to allow time for subsequent operations, it is best and most pleasantly done in the long, dry, warm days of summer, and should be finished by early autumn. The contractor should be bound to spend as much of his time amongst the workmen as possible, taking a lot to himself, and the farmer should have a person to superintend the work in the progress of execution, as some of the men will endeavour to make the *trenched* ground seem as high as it ought to be, although the solid ground may not be dug to the depth it should be. It will be the farmer's own fault in superintendence if the work be ill-executed.

The *expense* of trenching rough ground 16 inches deep—and it should never be shallower to ensure a good plough-furrow ever afterwards—is from 10d. to 1s. per pole, according to the roughness of the ground. I have had very rough ground, consisting of large roots of trees in a scattered wood, with brushwood of birch, alder, whin, and broom, and containing as many stones as would have half-drained the ground, trenched 16 inches deep for £6, 13s. 3d. the imperial acre, which is practically 10d. per pole for the spade work alone—a large sum undoubtedly, independent of draining, clearing away rubbish, and incurring other horse and manual labour; but when the ground was rendered at once from a state of wilderness to one in which manure might be applied and covered with an ordinary plough-furrow of mould, the expense is not inordinate. Though trenching may not be the cheapest mode, in a pecuniary point of view, of rendering land available to the plough, it is, at all events, the most pleasant and satisfactory one for all subsequent operations.

It is evidently more easy for subsequent draining operations to have the ground cleared by trenching of trees and shrubs, and layers of stones, than to cut drains through the roots of trees and the obstruction of innumerable stones. Such obstacles render their cutting very expensive, while having the drains previously cut would in no degree facilitate or economise the trenching of the ground.

On clearing the ground of the trenched-up materials, the roots of every kind of tree must, of course, be entirely removed, or burnt to ashes upon the spot, according to the value of the roots as fuel. The stones, on the other hand, should be used in the drains. If numerous enough to fill the entire drains, as I have seen to be the case in Kincardineshire and the county of Antrim, they should be broken by contract to a specified maximum size, and placed in the drains—the larger and harder ones being reserved for the foundation of fence walls ; and if inadequate to fill all the drains, they should be fully employed as far they go, and the remainder of the drains furnished with tiles. It will be easier to fill the remainder of the drains with tiles, than cart stones for the purpose from the shortest distance, provided the tiles are not very far off.

Even where no obstruction of roots and stones exists, if the surface be rough with coarse herbage, and interspersed with swampy spaces, the ground should be trenched with the spade; but in this case the drains might be cut and filled with tiles before the trenching, and the spaces between the drains would form the lots to be occupied by the workmen, who, in trenching the ground, might easily return the earth into the drains, and level the surface at once for a crop, or for working with the plough. In attempting to plough ground with rank herbage on its surface, the long and strong grass invariably fills up the space between the under side of the beam and the upper front edge of the coulter, and throws the plough out of the ground.

Where the ground is less rough in the herbage, and the turf comparatively smooth, the plough may be employed to trench it; and in executing this sort of trenching, the plough imitates the effect of the spade to a considerable degree, by mingling part of the subsoil with the surface-soil, in descending to an extraordinary depth, perhaps 16 inches. Trench-ploughing is best effected by the common plough with 2 horses, first going and turning over a broad furrow-slice of 6 or 7 inches deep, and by a 4-horse plough, following in the same furrow, and bringing up the soil, whether a surface-soil if so deep, or the subsoil, and turns it over upon the furrow-slice just ploughed. This trench-ploughing is best executed across the ridges or the drains, when either or both exist. It may also be practised with good success in the second rotation of crops after the rough ground had been trenched with the spade, as it will bring up the turf formerly buried and now decomposed into mould, and mix it with the present surface-soil which was the former subsoil, by this time enriched by manure and fertilised by culture.

A method of trenching land has recently been introduced into Scotland by Mr Houston, of Johnstone Castle, Renfrewshire, though known in England, and deserves attention, both on account of its efficacy and cheapness. It consists of marking off lots of rough ground equal in breadth to the future ridges, say 15 feet. A trench of about 3 feet in breadth is then marked off with a line across the breadth of the ridge, and the surface rutted with the spade. The first spit of earth, removed from the surface of the trench to the depth of 10 or 12 inches, is carried off to the side of the field where the trenching will terminate. The trench thus cleared of its upper surface, its subsoil is stirred with *graips*, or forks, as they are called in England, having 3 narrow, broad, strong, slightly bent prongs, 14 or 15 inches in length. The graips are pushed into the ground by the foot in the same manner as the spade; but instead of the earth being lifted up whole, as with the spade, it is broken in pieces by the prongs passing through it, while every stone in the subsoil, to the depth the prongs enter is brought to the surface. Strong dry clay rises in large lumps, which have to be severed by a few thrusts of the prongs of the forks. The earth not being lifted up and turned over, the labour required to stir the subsoil 15 inches deep is not so great as the ordinary delving of the ground. In thus stirring the subsoil with the graip, the 2 or 3 men employed work side by side, and assist each other in breaking the ground when it rises in lumps, and in bringing the entangled stones to the surface. After the trench has been gone over with the graip, the stones are laid along its side and that of the last trenched ridge. Another trench is then lined off and rutted, and the surface is removed with the common spade, and placed with its grassy surface undermost upon the subsoil of the former trench, which has just been stirred and freed of stones by the forks.

The peculiarity of this mode of trenching is apparent, in its keeping the subsoil in its place, while the ground is entirely stirred to the depth of at least 24 inches, and wholly freed of stones; and these are great advantages in new trenched ground. The stones being laid in a row at every breadth of a trench, which may be made at first as broad as is desired to make the future ridge, are ready for the use of the drains that may now be cut. The trouble of collecting the stones will be saved in the cost of the draining, and in most stony soils, as many stones will be obtained as will suffice, when broken, to thorough-drain the land; but if not, they will fill the drains as far as they go, and the remainder may be filled with tiles.

It was stated on the occasion of the show of the Highland and Agricultural Society at Glasgow in 1844, when fork-trenching was exhibited under the direction of Mr Houston, that men undertook to trench the ground with the fork for £2, 8s. the imperial acre—

which is a much cheaper, and far more efficient mode of bringing in *rough* ground, than by any application of the plough; but in an instance tried in 1847, by Mr Milne of Milne Graden, in Berwickshire, the cost of fork-trenching ground 20 inches in depth was £6, 14s. 5d. per acre—which is a nearer approximation to the truth, I suspect, than the other sum. When the ground is very stony, a 2-pronged fork is employed, as meeting with less resistance. The hardest moorband-pan can be penetrated and broken with these forks. Their cost is 5s. each, and they will last for years, with occasional repairs of the points of the prongs; but if made of bad materials, they will easily fracture in the handle or prongs.

Trenching with the fork is as efficient in its effects as subsoil-ploughing, which affects to stir and not remove the subsoil; and it is a much more perfect operation, inasmuch as it exposes the subsoil to view, breaks every portion of it to a greater depth, and frees it of every stone that, from its size, would injure the implements, or present obstacles to the operations of culture.

THE END.

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