Agricultural Drainage Practices in Ireland

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ABSTRACT / Agricultural drainage practices are reviewed under two main headings: arterial drainage of river catchments by developing main channels, and field drainage of smaller parcels of land using pipes and open trenches. The use of cost/benefit analysis on the arterial drainage program is considered and the inherent errors are discussed. Conservation of the environment is described as it applies to landscaping, fisheries, and wildlife, and the drainage authorities are shown to have an enlightened attitude to proper preservation of the world around us.

Introduction

Ireland is basically saucer-shaped, with a rim of mountains and a flat central lowland. Rivers rising inland must circumvent the mountains to reach the sea. Most of the rivers in Ireland do not flow directly to the sea. For example the Shannon rises near Lough Allen, 30 km from the coast but flows south and west 240 km to reach its tidal estuary. Likewise, the river Slaney rises west of Wicklow Mountains 30 km from the sea, but travels 90 km to its outfall at Wexford. Such conditions give rise to poor gradients and poor channel development (Lynn, 1980). Flooding and high water-table levels result in consequent hardship and financial loss. According to Gardiner and Radford (1980) wet mineral lowland soils cover 21% of the country or 27% of the agricultural land. This land is inhibited by surplus water and requires drainage in one form or another to achieve its full potential.

Two organizations in Ireland are principally responsible for promoting improvements to drainage conditions. The Office of Public Works carries out improvements to arterial drainage systems (rivers and large collection drains), while the Farm Development Service, a branch of the Department of Agriculture, administers field drainage operations.

Arterial Drainage

History

The history of arterial drainage is described by the Office of Public Works (OPW) in their account of the cost–benefit analysis for the River Maigue Drainage Scheme. The OPW first became associated with arterial drainage with the Drainage Act of 1842. It was made responsible for the design and execution of drainage works. It was the intention of this first act that the cost of the works would be borne by the landholders, but the famine years 1846 and 1847 intervened and much of the work done then and later was relief work. The Drainage Act of 1863 transferred responsibility for design and execution of schemes to the owners of affected lands, the function of the OPW being to examine the merits of proposals, to consider objections to schemes, and to advance the money required. Further drainage acts were passed in 1925, 1926, and 1927. During all this time, 229 schemes were completed benefiting 198,000 ha. Most of these schemes were heavily subsidized by the state although in the period 1863–1925 the state contributed less than 7% of the cost of arterial drainage.

In 1938 a drainage commission was set up which recommended two fundamental and far-reaching changes as follows: First, the entire river catchment should be used as the basis for the design and execution of schemes; second, the initiative for undertaking schemes should be vested in a central drainage authority, the OPW, which would meet the full cost of design and execution of schemes. The 1945 Arterial Drainage Act gave effect to the recommendations and also conferred on the OPW responsibility for maintenance of completed schemes, with the cost of maintenance to be borne by the county councils. The provisions of the act meant the end of piecemeal drainage, which often led to the transfer of a flooding problem from one area to another, and protected the capital investment in drainage by ensuring that maintenance would be carried out on a regular basis and to adequate standards. Maintenance work is essential if channels are not to revert quickly to their original conditions. Under the 1945 act, 9 major catchments and 25 small catchments have been drained. Schemes currently in progress include the Boyne, Maigue, Corrib-Mask, Boyle, and Bonet (Fig. *1*).

Under the early acts completed schemes were constituted as drainage districts, with responsibility for maintenance being vested in drainage trustees or boards. The cost of maintenance was to be levied on

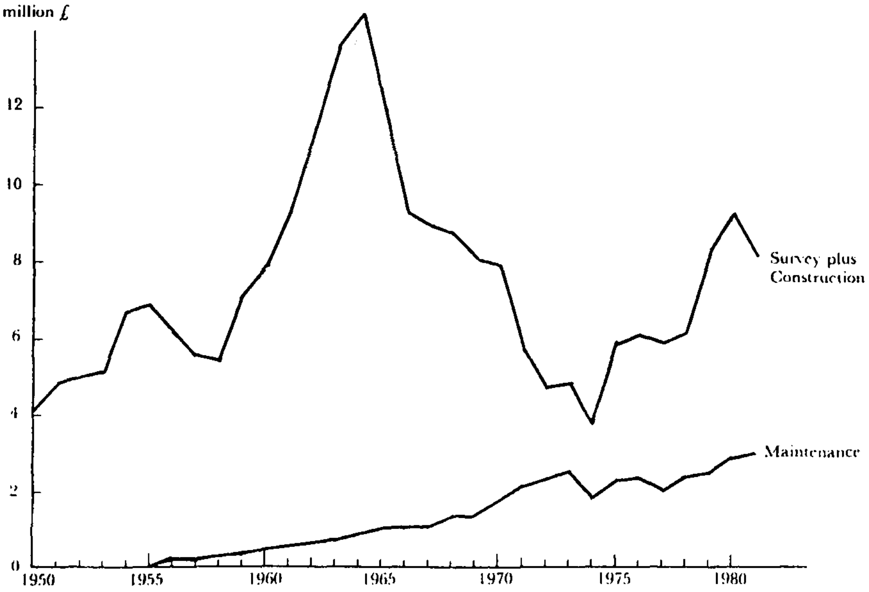


Figure 1. Expenditure on arterial drainage has fluctuated substantially over the last 30 years when measured in real terms. Following government cutbacks in the late 1950s, the economic boom of the 1960s caused expenditure to double until the Department of Finance intervened in 1964. Membership of the EEC made further funds available and activity increased once more from 1974 onwards.

the benefiting owners. This method of organization was for the most part a failure. Under the 1924 act, the OPW was empowered to carry out maintenance works on its own initiative. State grants of up to 50% of the cost were made available, the rest of the cost to be borne by the benefiting owners. The act was ineffective, however, because many of the drainage districts had fallen into such a state of disrepair that complete redrainage rather than maintenance was required. In subsequent drainage acts responsibility for financing maintenace work was transferred progressively to the county councils.

Design and Construction

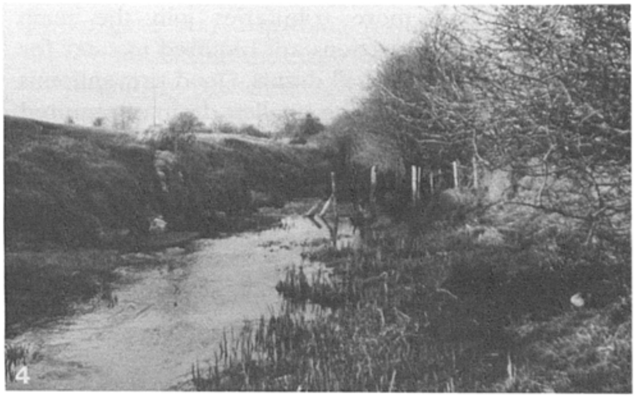
During famine times, arterial drainage work was done by hand and it employed about 40,000 people at peak (Bruton and Convery, 1982). Now the process has become highly merchanized using dragline excavators and floating dredgers for excavation, and specialized equipment for drilling and blasting rock (Fig. 2). Less than 1,000 people are currently employed on the schemes.

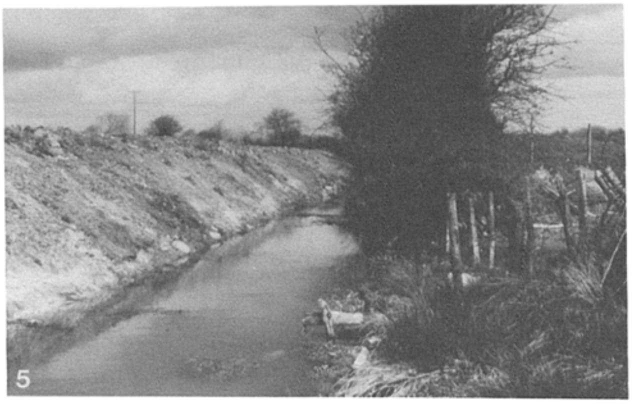
Almost all of the arterial work has consisted of deepening and widening river channels to accommodate existing river flows (Fig. 3). Other forms of improvement, such as channel diversions and provision of storage reservoirs have been rarely used.

The preliminary stage to design of open channels constituting a scheme is to survey the levels and the discharges in the catchment. Bed levels of the channels and the levels of the benefiting lands are determined to provide a basis for the design levels of the finished scheme (Figs. 4, 5, 6).

Flow measurement may be performed by fixed structures, such as flumes, weirs, and orifices, or without fixed structures and using a calibrated section of streambed. For the latter system, a calibration curve relating water level to flowrate must be built up by measuring flowrate for different water levels in the

Figure 2. Excavator.





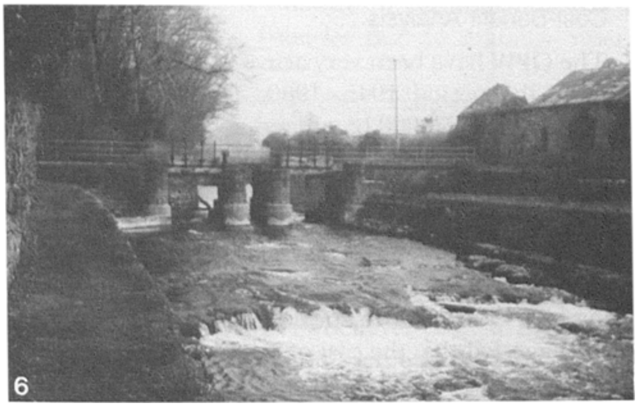


Figure 3. Design for flashfloods. A larger cross-section allows a greater increase in flow for a given increase in head.
Figure 4. River before drainage.
Figure 5. River after drainage, showing stripping of vegetation and canalization of the stream.
Figure 6. Where the channel underneath a bridge or other structure is deepened, the structure is sometimes strengthened by underpinning to overcome damage to the foundation. In this view, new concrete is visible at the base of two old sluice gates where the river Robe has been deepened by about 1.0 m.

river. There are several methods for measuring water flow in this situation. The OPW use a currentmeter placed at certain points in the water, e.g. at 0.2 and 0.8 of the depth below the surface. Flow is measured like this at several points across a section. The values are used to calculate a weighted average which when multiplied by the cross-sectional area of the river yields the flow through that section. This process is repeated on several different occasions with several different flow rates until a full staging curve can be drawn. Water level at this point is measured regularly, enabling a good record of flows to be built up. The OPW have 200 such gauging stations around the country, over half of which have records extending over 30 years. The information on flow thus gathered is used to predict the magnitude and frequency of floods.

The information on water flows is used to determine the 3-year flood, and this is normally used as the design criterion. This standard is considered capable of reducing the incidence of flooding during the cropping period considerably (probably up to once in 15 years) and would make possible the more or less full development of agricultural potential of the improved lands and reduce overall flood damage to relatively small proportions (OPW, 1984).

Bed levels in streams and rivers are determined by taking into account both dry weather flow and peak discharge (3-year flood), and must permit drawdown of the water table to at least 0.75 m below the surface in benefiting lands (Howard, 1980). The procedure starts with the smallest drain and levels, and cross-sections are computed downstream to suit soil conditions at as many places as is economically viable. Bed levels allow for a gradient of 1:300 in incoming field drains at peak discharge in the stream. Channel cross-sections for a given flow and gradient are generally obtained from the formula of Manning:

$$Q = K_m R^{2/3} I^{1/2} A$$

where Q = Discharge rate
R = Hydraulic radius
I = Hydraulic gradient
A = Wet cross section area
K_m = Roughness coefficient

As more and more tributaries join the main channel larger cross-sections are required to cater for the 3-year flood. For small drains, flood prevention is not normally an issue as the smallest drain of required depth that can be excavated using modern machinery will have excess capacity for flood flows.

Up to recently the OPW deposited spoil from rivers and streams on the banks thereof. However, due to pressure from the public and due also to the finding in the cost/benefit analysis that the cost of burying spoil was offset by the saving in land, this practice has now been discontinued on agricultural land.

Cost-Benefit Analysis

The OPW have been very active in arterial drainage work in the period 1945–1980. They have drained approximately 250,000 ha of land and spent £238 million (at 1980 prices) on survey and construction work in that period. On average, expenditure amounts to 1.5% of the Public Capital Program and 12.5% of state capital spending on agriculture (Bruton and Convery, 1982). In the 1960s expenditure was particularly high, giving rise to disquiet in the Department of Finance. They suggested that the cost of drainage exceeded the improved market value of land and consequently insisted on a full cost–benefit appraisal of the merits of proposed schemes before work proceeded. This appraisal was initiated by the OPW in 1970. Cost–benefit analyses were carried out on four catchments to date:

Maigue, Co. Limerick
Corrib-Mask, Co. Galway and Mayo
Boyle, Co. Roscommon
Bonet, Co. Leitrim

The results of the analyses, while conclusive for the purpose of ranking, are inconclusive for the purpose of project appraisal. This will be clear later.

Convention. The procedure adopted by the OPW is as follows (Howard, 1980):

1. All costs and benefits, both primary and secondary, are enumerated and compared.
2. Benefits and costs are measured up to a cutoff point of 50 years after the completion of the arterial drainage scheme. This is an arbitrary figure usually adopted for such projects.
3. Costs and benefits are evaluated at constant prices.
4. No distinction is made between direct and indirect benefits and costs.
5. Both the benefit to cost ratio and the internal rate of return are calculated. In calculating the benefit to cost ratio, a discount rate of 3.5% is used.
6. Costs incurred throughout any year are assigned to the start of the year, and benefits accruing through the year are assigned to the end of the year. This reflects actual cash flows in agriculture.

Benefits and costs. The benefits of arterial drainage are listed by Howard (1980). They include the following:

1. Increase in landholders' income. This is calculated on the basis that farmers have no opportunity costs and that the time they spend working on the land could not be gainfully spent any other way.
2. Additional employment given by the product.
3. Training of personnel employed.
4. Reduced flooding in built-up areas and on public roads.
5. Provision of new bridges and culverts.
6. Savings in discontinued maintenance of incorporated earlier schemes.

The costs of arterial drainage are listed below (Howard, 1980):

1. Arterial drainage construction costs.
2. Arterial drainage maintenance costs—to continue for an indefinite period.
3. Field drainage construction and maintenance.
4. Landholders' investment: livestock, building, extra fertilizer.
5. Losses due to widening of channels and spoil deposition.
5. Disruption of fishing.
7. Losses incurred in areas of scientific and recreational value.

The principal benefit by far is listed as number 1. Bruton and Convery (1982) argue that a preferable measure of the benefit to the farming community of arterial drainage is the increase in the market value of land after drainage. This reflects the extra income that a farmer expects to derive from the land over a number of years and as such is an indication of the benefit to farmers of arterial drainage. The OPW has not accepted this view.

The principal costs here are listed as 1, 2, and 3. Losses in areas of scientific and recreational value are very difficult to evaluate. Little precise information is available on numbers and distribution of birds and on the nature and distribution of wild plants. Furthermore, the value of such areas is highly subjective and no satisfactory method is available to evaluate it. This uncertainty compares unfavorably with the clear-cut economic values associated with agriculture.

Table 1 shows first, that the results are highly sensitive to the base year used in the analysis.

Table 1. Discrepancy between improved market value of land and PDV[a] of future net income as ratios.

	Improved land value / PDV of net income	Improved land value / Drainage costs	PDV / Drainage costs
At constant 1972 prices	0.102	0.329	3.220
At constant 1979 prices	0.180	0.543	3.022
At constant 1980 prices	0.274	0.494	1.801

[a] PDV denotes present discounted value.

Second, it illustrates the very large discrepancy between improved market value of land and PDV of future net income. Column 1 illustrates how PDV of net income can show a return up to 10 times that of the improved land value. This is especially surprising as the two systems of analysis should indicate the same return. Columns 2 and 3 show the cost/benefit ratio for each method. Using the improved land value method, the four projects assessed were nonviable. However, according to the PDV of net incomes, the arterial drainage projects would repay handsomely. There is no way of knowing which method is more accurate in the absence of factual information regarding the response of farmers to arterial drainage. Such information has not been gathered to date.

The discrepancy between the two methods is not as important as it might appear. While the cost/benefit analyses were instigated to determine whether or not drainage projects should proceed, in practice the results are used simply to rank schemes in order of priority (Walsh, 1984). The decision to proceed is a political one.

Fisheries

There has been prolonged conflict between people with fishery interests and those involved in arterial drainage, with the result that drainage has a bad name in fishery circles. This attitude has not always been justified as in some cases drainage has improved fish stocks rather than reduced them. The Bunree River, a tributary of the river Moy, is a case in point. Prior to drainage much of the riverbed was covered in peat silt. Drainage operations removed the silt and exposed the boulder clay underneath to provide excellent spawning ground. The recovery of salmon stocks after drainage was remarkably good (McCarthy, 1980). However, fishery studies pre and post drainage on the Boyne gave very disturbing results. The recovery of salmon stocks after drainage was very poor. Stoneloach, the dominant post-drainage species and a predator of salmon fry, can tolerate silt conditions. They also have a preference for fast-flowing shallow water, the condition of most drained streams. They flourished under post-drainage conditions, preventing a proper recovery of the salmon stocks (McCarthy, 1980).

A major problem for fisheries is the need to maintain channels on a six- or a nine-year cycle. This disturbs spawning grounds and removes cover on a recurring basis. Whelan as quoted by Bruton and Convery (1982) gives a number of recommendations to reduce damage to fisheries due to drainage operations.

1. Minimize interference, removing only points (sills).
2. Retain and replace as much vegetation on the banks as possible.
3. Replace gravel.
4. Dig pools at intervals.
5. Drain in a stepwise manner so as to provide short riffle areas whenever possible to break up the suface film and thereby increase aeration.

At the request of the Department of Fisheries and Forestry, sections of streambed are now covered with gravel to act as spawning grounds. In certain areas, such as Lough Mask, fish are restocked at the expense of the scheme.

Wildlife

Arterial drainage has serious effects on certain aspects of flora and fauna, above water level (see Figs. 4 and 5). Otters suffer a loss of potential breeding holts when stream banks are stripped of vegetation. The natterjack toad, found in North West Kerry is so threatened by loss of spawning pools through drainage that Merne (1980) suggests that active conservation measures may need to be taken. Almost a third of the more common birds found in Ireland are wetland birds, and most of these are threatened in some way by drainage. Conservationists accuse the OPW of having scant regard for wildlife. The OPW counter this by pointing out the lack of scientific information regarding distribution of species and site priorities. The Forest and Wildlife Service is responding by surveying wetlands with a view to drawing up an inventory which can be used in defense of our wildlife. "It is hoped that co-operation and liaison between conservation and drainage authorities will result in modification of drainage plans to accommodate wildlife conservation interests (Merne, 1980).

Figure 7. Shows the number of acres improved each year and the grant cost per acre. In 1966, the maximum permissible grant per acre was relaxed giving a sudden increase in activity. Further surges in field drainage occurred in 1974 with the introduction of the Farm Modernisation Scheme and in 1979 with the commencement of the Western Drainage Scheme.

Table 2. The percentage rate of grant assistance available under the Farm Modernization and Western Drainage schemes.

	Type of farmer			
Type of investment	Commercial farmers	Development farmers	Other farmers	All western farmers
Drainage and reclamation	35	45	45	70
Buildings & fixed assets	15	25	25	40
Mobile equipment				
Purchases of extra stock		10		
Fertilizers				

Field Drainage

History

The state has been involved in field drainage since 1931, when grants were first introduced for this purpose. Only 56,000 ha benefited in the first 20 years. After the Second World War, arterial drainage started up once more providing more outfalls for field drainage. At the same time more specialized machinery became available. The Department of Agriculture responded by setting up in 1949 the Land Project, which was a major scheme of land reclamation and field drainage. A survey made about this time was used to show that approximately 2.4 million ha of land, or 50% of the total agricultural area, were in need of improvement. Of this, 2 million ha were in need of drainage. Through the Land Project some 1.2 million ha of land were improved at a cost of £600 million, (at 1980 prices), of which 58% was borne by the state (Fig. 7).

Under the Land Project, farmers had the option of (1) carrying out the work themselves and receiving two-thirds of the cost in grant aid up to a maximum level of assistance per acre, or (2) letting the state contractor do the work and paying a two-fifths share of the cost up to a maximum payment per acre. Farmers quickly realized that option 2 was cheaper for them on difficult jobs and exploited this fact, so that option 2 was more than twice as expensive per hectare for the government. Consequently, this option was withdrawn in 1958.

In 1974, the Land Project was superseded by the Farm Modernisation Scheme (FMS). This brought field drainage into conformity with EEC directives. The FMS was later augmented by the Western Drainage Scheme (WDS) in 1979. Both these schemes are operated by the Farm Development Service (FDS) of the Department of Agriculture. Grant levels associated with the schemes are listed in Table 2.

The Western Drainage Scheme was programed to drain 130,000 ha of land. The response to the scheme was good, but in September 1981, the decision was taken to accept no more applications, as all funds were allocated.

The officers of the FDS are responsible for the design of schemes and the administration of grants. Because of this, they can control the use to which the money is put and help avoid waste.

In 1968, a survey team of the Land Project carried out an economic appraisal of 70 field drainage schemes. They found that for all the schemes taken together, the discounted cash flow, income/expenditure, over the entire life of the schemes (36 years) was 2.32. This shows that on average field drainage is well worthwhile.

Field Drainage Design

There are four main types of problem in field drainage. Their distribution is shown by Galvin (1961) and they are listed below.

High Water Table. This is the condition normally dealt with in part by arterial drainage. It is the result of moderately permeable subsoils over poorly permeable rock. It is typically found in flat areas, like cutaway raised bogs.

Seepage and Spring. Seepage and springs occur on low-lying ground adjacent to higher land. It is typical of undulating topography, especially where sands and gravels occur underground, such as Newcastle West, Co. Limerick.

Impervious Layer. Where an impervious layer occurs it is normally due to sedimentation or to a chemical process of pan formation in situ. This applies to the iron pans of North Mayo.

Impervious Subsoil. This is the most difficult problem to deal with. It can only be solved if the soil properties are altered. Impervious subsoil problems are well represented by the heavy clays of the Leitrim drumlin landforms.

Site Investigation

Field drainage sites in Ireland tend to be small, that is, less than 10 ha, and the physical properties of Irish soils are highly variable, so proper site investigation is generally a difficult and expensive operation. The ideal procedure is outlined below.

First, the designer should walk the land, noting (1) topography, to decide where drains should go, (2) vegetation, to get an idea of average water table levels, and (3) soil surface condition, to determine the performance of the field in its present state under agricultural use. The designer should now have an idea of the extent of the problem facing him and some thoughts as to drain layout.

The next step is to examine the soil profile. This is best done using test pits 2–4 m in depth dug by hydraulic excavators. Soil texture and structure and the sequence of layers are noted through the profile. Layers having exceptionally poor permeability are identified, as are layers with exceptionally high permeability. The water-table level is recorded if visible, and the rate of flow of water into the hole is also observed. This procedure is repeated at 5 to 10 locations until the designer has an accurate impression of the nature of the soil. Finally, soil permeability measurements are made to provide a permeability value for use in the design equations for drain spacing.

This approach is adequate for use on peat and alluvium soils. However, the bulk of Irish soils are glacial till of one type or another, which are noted for stoniness and the high degree of variation in soil physical properties (Fig. 8). This means that permeability measurements are difficult to perform and that very large numbers of measurements are frequently required. A recent study using the ring infiltrometer test and the auger hole test on a sample of 10 soils in the west of Ireland showed that up to 250 tests, each taking approximately 2 h may be required to determine with adequate precision the permeability of the soil on one site (Ryan, 1984) (Fig. 9). At this intensity of measurement, the cost of permeability determination could well exceed the construction costs for the entire project! Evidently, a cheaper method is required, and soon, if land drainage design on Irish soils is to be placed on a proper scientific footing capable of providing economic plans for agriculture.

In the absence of permeability measurements alternative methods of assessing permeability must be used. One such method is estimation of the permeability of the soil from its textural class. This is subject to a high degree of error as the permeability of soils in one textural class can vary substantially (that is, to the order of 10 fold). Alternatively the designer observes drains already on site or in an adjacent field with similar topography, provided they are installed for at least a year, and thus decides the maximum drain spacing which will provide the level of control of the water table required on the site in question.

Procedure in practice differs from that outlined above in that the Farm Development Service (FDS) do not generally use test pits. Instead, after the first site visits, the designer lays out the open drains (Fig. 10). These are excavated and inspected to provide information on the soil profile for use in the subsequent pipe drainage design. While open drains do act as test pits, they are often not quite deep enough to explain the occurrence of the drainage problem. If we take a site requiring drains at 20 m centers, then drainage

Figure 8. Permeability measurement can be difficult and tedious. This photo shows an 8-cm Dutch auger and an example of stony glacial till. The stones hamper augering and typically 3 out of 4 attempts to bore a hole to 1.2 m will fail on this type of soil.

Figure 9. The infiltrometer ring is relatively easy to use where a suitable pit can be excavated by hydraulic excavator. However, a 10-cm ring as illustrated will normally give more variable figures than the auger-hole test, due to the smaller amount of soil tested.

theory demands information on the soil to 5 m below the drains. For practical purposes information down to 2 m below the drains is adequate. This requires test-pits down to 3 m depth—somewhat deeper than an open drain extending to perhaps 1.2 m. Furthermore, on a site showing seepage or springs, the sands, gravels, or rock aquifer causing the problem must be located. It is very likely that open drains around the field perimeter will not intercept the aquifer. Test-pits would be better suited to this task.

Drainage Solutions

There are a number of relatively straightforward solutions that can be applied to field drainage problems once the problem is understood and quantified.

High Water Table. The solution to this problem consists of installing piped drains at spacings ranging from 10 to 50 m. The piped drains are generally shallow, 0.75 m, and discharge into an open drain. Frequently, in this situation open drains are provided all around the field. This seems something of a waste, as generally only one open drain is required. The other trenches are either redundant or should be replaced by piped drains.

Seepage and Spring. These conditions are difficult to handle and require very careful consideration. Seepage rates can vary enormously and are very difficult to measure. Stisen and Mortensen (1981) in Denmark, where topography is similar to that in Ireland, quote normal rates of 2–6 mm/d and one case of 500 mm/d. Normal design discharge rates for drains catering for rainfall only lie in the range 10–12 mm/d. Thus we see the significance of seepage in drainage design. The usual method of measuring seepage rates is to measure groundwater pressures using piezometers. These are combined with permeability measurements to give seepage rate (q) using the expression:

$$q = Ki$$

where q = seepage rate (mm/d)
K = permeability (mm/d)
i = hydraulic gradient (dimensionless)

This method can seldom be used in practical drainage design due to the large number of expensive measurements required to make one determination of seepage rate. This makes it difficult to apply theory to the design of drains in the seepage situation. However, if the sand, gravel, or rock aquifer acting as the source of seepage can be located and tapped, then the pressure can be relieved in the aquifer and the upward flow of water reduced or eliminated.

Springs are a particular case of seepage where rising water appears in spots. General practice is to excavate a spring, tap the hole, and back fill with gravel.

Figure 10. Aging of a drainage system is inevitable as nature tends to level both humps and hollows. The drain shown above is at a gentle gradient. The accumulation of weeds will reduce water velocity allowing deposition of silt. The drain will need to be cleaned using a hydraulic machine every 5–10 years.

This method does not always work as the spring sometimes moves elsewhere. The best solution is to find the aquifer and to tap it with a pipe.

Impervious Layer. This is found most frequently on iron pan formed close to the surface of the soil. Subsoiling or ripping will solve the problem where the layer is shallow. Where the layer is deep it can be treated as the impermeable layer for design purposes and drains installed over it.

Impervious Subsoil. These soils are the most difficult to deal with. They cannot be drained economically unless the permeability is improved. The two principal techniques in use on impervious soils are mole drainage and gravel mole drainage. Mole drainage involves drawing a bullet-shaped mole, 75 mm diameter followed by an expander, 100 mm diameter, through the ground at a depth of 0.5–0.6 m. This has the effect of forming a channel in the ground while shattering the soil above the mole to increase the soil's permeability. This method is cheap, so it can be applied at close spacings (1 m–2 m). However, it only works for soils that have a high clay content, i.e, greater than 30–50%.

Gravel mole drainage must be used on impervious soils with low clay contents where ordinary moles collapse. Gravel moles are essentially the same as ordinary moles but contain a core of gravel which supports the roof and walls of the mole. Galvin (1981) reports on comparative trials between gravel and ordinary moles and shows that gravel moles outlast ordinary moles on certain soils. Surface drainage is sometimes used, as for example by Bord na Mona, on peatland where the soil surface is shaped to make the water flow over the surface into drains. This is not sufficient on its own to drain the soil so supplementary drainage is required.

Benefits of Drainage

Drainage is basic to agriculture in Ireland, where rainfall varies between 800 mm in the east and 1400 mm in the west, while evapotranspiration from grass is only about 450 mm–580 mm. The ideal soil for agriculture has 50% pore volume, and 50% of this is occupied by water. Departure from this ideal through excess of water gives rise to the following problems:

Poor Trafficability. Excess water in the soil adversely affects its workability. When wet, the soil cannot be worked without causing smearing, loss of structure, compaction. With poor drainage, the soil can remain wet and unworkable for long periods. Farm operations are held up, giving rise to late sowing or fertilizer spreading and harvesting difficulties. Stock can't be put out on the land for fear of damaging the soil and grass sward thus increasing the requirements for conserved feed.

Lower Soil Temperatures. Due to the high specific heat of water, wet soils have lower temperatures (4°C–8°C lower) than comparable well-drained ones (Van Beers, 1979). This retards the commencement of growth in spring and reduces output during the growing season.

Parasites. Wet soil conditions and surface ponds encourage certain parasites, such as liver fluke, to such an extent that drainage is seen as an effective method of parasite control.

Waterlogging. In waterlogged soils the pores are mostly filled with water, leaving very little room for gas exchange. Oxygen flow from the air to the soil is restricted, inhibiting respiration in the rootzone. Carbon dioxide flow from the rootzone to the atmosphere is restricted, causing CO_2 toxicity. Root growth is reduced, as also is the root's ability to absorb nutrients. Anaerobic conditions in the soil may also lead to toxic concentrations of reduced iron and manganese compounds, sulphides, and organic gases (Smedema and Roycroft, 1983).

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