Drainage developments in the United Kingdom between 1961-1986

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1 Nature of drainage problems

Due to the combination of soils and climate in the U.K., most areas require some form of artificial drainage for successful agriculture. Rainfall, which is uniformly distributed throughout the year, varies from approximately 600 mm to 1600 mm/year from east to west. This rainfall exceeds evapotranspiration during winter and early spring in the east and for most of the year except for summer in the west.

The majority of soils are medium to fine in texture with the largest proportion being clayey in nature. The predominant drainage problem is one of perched watertables (60-70% approx.) followed by groundwater control (30%), with seepage and spring problems constituting the remainder.

Although drainage practice started in Roman times, the major draining period in history was during the 18th and 19th Centuries. During this period almost the whole of the country, except for the mountainous areas, was drained with subsurface pipe systems and the mole drainage system developed. Drainage practice is therefore very much a case of replacing or intensifying old systems.

A survey by the Ministry of Agriculture in England and Wales in 1968-69, identified an area of approximately 3 million hectares which could repay investment in further drainage works. Drainage activity since then has done little in many areas to correct this need, in most cases, it has simply kept pace with the deterioration of old systems.

2 Area of drainage activity

Drainage activity over the past 25 years has followed closely the most profitable areas of agriculture, which have been the arable and intensive dairy sectors. The arable sector in particular has expanded greatly and drainage has played a major part in this. Governments have tried, by offering larger drainage grants, to encourage drainage in the more marginal farming areas. This unfortunately has not been as successful as was hoped, due to the relatively low profitability of the prevailing cattle and sheep enterprises. Drainage work therefore, although being carried out all over the country, has been concentrated in the predominantly arable areas of the Midlands and South East England and of Eastern Scotland.

The area of land drained in England and Wales over the 25 year period is shown in Figure 1. Installation over the last 5 years has been estimated, due to the lack of exact statistics. The figures show a very rapid expansion in the late 1960s to a peak in the mid '70s of 110 000 ha/year. During this period government grant aid for draina-

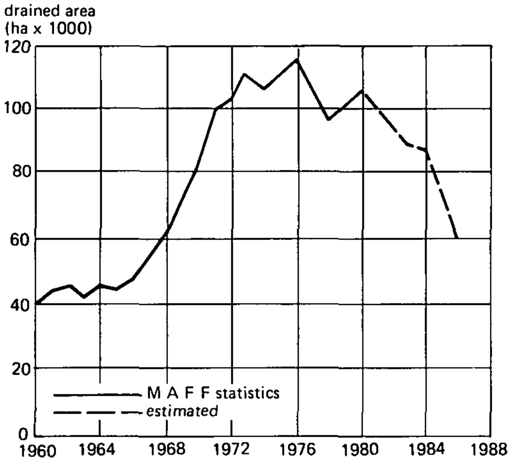

Figure 1 Area drained in England and Wales

age was between 50-60% of total costs. Installations continued at between 90-96000 ha per year in the '80s until 2 years ago after which there has been a rapid downturn. The peaks in the 1970s followed very wet years and the latest downturn is due to greater uncertainty in agriculture as well as to the removal of almost all government support for drainage.

It is not anticipated that there will be any major change in the distribution of drainage schemes around the country in the foreseeable future, but the area to be drained and the nature of future schemes could change markedly. Environmental considerations are now being given much more emphasis and as a result, it is unlikely that any of the remaining marsh and wetland areas will be drained for arable farming purposes. As the profitability of agriculture falls and with moves in some areas to low input/low output systems, the need for cheaper, less intensive drainage systems will increase. Where farmers aim to maintain profitability through greater intensification, drainage as practiced over the last 25 years is likely to continue.

In most environmental circles at the present time, drainage is considered an activity which destroys wildlife habitat. Wildlife habitats, however, require specific water regimes like any agricultural crop. Once this is fully recognized, it is anticipated that drainage will play an important role in the maintenance and creation of specific habitats and in allowing wildlife habitats to coexist alongside profitable agricultural enterprises.

3 Drainage criteria

Drainage scheme design is based largely on past experience, with no use being made of drainage equations. Whilst the equations would be applicable in the groundwater control areas, they are not appropriate for the major problem, namely perched watertables or for mole drainage installations. Nevertheless, estimates of discharge require ments and the water flow characteristics of the soil influencing spacing are still required, together with desired water levels in groundwater areas.

3.1 Discharge

The main requirement for discharge data is for pipe sizing calculations and a standard procedure has been developed by the Ministry of Agriculture over the past 10-15 years, which has proved very successful. The estimates are made on the basis of the climatic data for the critical winter/spring period and the considered acceptable risk for the particular farming system.

Where subsurface pipes only are to be installed, the daily discharge is estimated from the 5-day rainfall input figure for the appropriate return period. In the case of pipe collectors in mole drainage schemes, the 1-day rainfall input value is used, to allow for the higher discharge rates from mole systems.

The return periods considered acceptable are as follows:

1 year	grassland
2 years	cereals
10 years	horticulture

Pipe selection charts derived from laboratory tests and theory have been devised by the Ministry of Agriculture for the different types of pipe on the market.

3.2 Soil permeability/drain spacing

In the 1960s/70s R.H. Miers of the Ministry of Agriculture, devised a method for estimating the drain spacing requirement from a soil profile pit analysis. Soil structure plays a critical role in controlling soil permeability in the medium and fine textured British soils and so this parameter is central in the Miers system. Soil texture, structure and the degree of crack development in winter were assessed in the profile pit and combined using empirical charts to indicate the required drain spacing. The drain spacing estimates represented the recommended subjective values of experienced drainage officers for that particular set of conditions.

This technique proved valuable in the rapid training of new drainage officers over some 15 years. Although the technique is not used directly now, it has increased considerably the awareness of those designing schemes to the importance of structure and macro-porosity of soils in the swollen state, when selecting spacings.

3.3 Heavy soils

Numerous major field experiments executed by the Field Drainage Experimental Unit of the Ministry of Agriculture over the past 25 years, proved conclusively the need for close drain spacings for satisfactory water control on British heavy soils. Spacing requirements are frequently 2-3 m when structure and crack development is poor.

These spacings can only be achieved at an economic cost through the use of mole drains. The mole drains themselves discharge into permanent pipe collector systems through a gravel or stone backfill, placed above the pipe.

The design criteria used in these situations is not related to the spacing of the mole drains themselves, but rather to the spacing of the pipe collectors. Mole drains are very cheap and hence are usually installed at spacings of 1.5-2 m which will allow for some failures. The chosen collector spacing is a function of the moling qualities of the site and the topography of the field. The moling quality of a soil is currently assessed in terms of its texture, structural stability and the presence or absence of silt or sand lenses. Collector spacings vary from 20 m on the poorer moling soils to 80 m on the better soils.

On heavy soils unsuitable for moling, decisions are required as to whether a permeable stone backfill is required above the pipe, to connect the more permeable surface layers to the drain. This decision is taken subjectively on a basis of soil structure macropore development and the likely benefit from subsoiling operations.

Subsoiling as a treatment following pipe installation has increased considerably over the past 25 years, not only to shatter compaction pans, but also to increase the depth of more permeable soil in the surface layers in perched water situations. Permeable backfill over the pipe drains helps connect the subsoiler created fissures directly to the drains. The increase in secondary treatments which includes both moling and subsoiling is shown in Figure 2.

3.4 Future requirements

Before water management practices in wildlife habitat situations can be improved or matched to agricultural requirements there is a need to determine steady and non-steady state watertable requirements, as well as allowable water deficits, for the different plant communities.

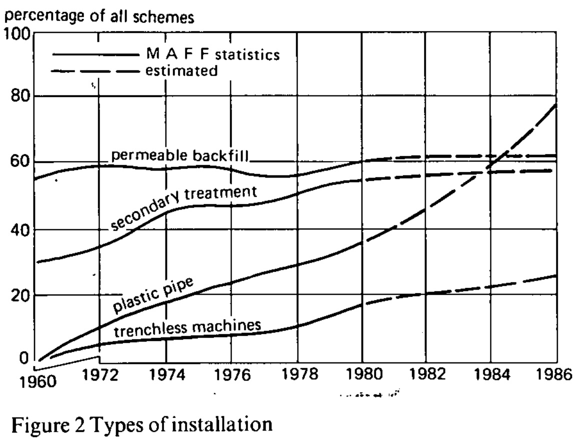

Figure 2 Types of installation

Possible criteria for the use of mole drains as a replacement for the stone backfilled pipe collector in moling systems need further investigation. This system was used on good moling soils prior to the 1950s and offers a way of very significantly reducing drainage costs on heavy soils.

4 Machines and materials

4.1 Machines

Major changes have occurred in both drainage machinery and materials during the 25 year period. The commonest method of pipe installation in the early 60s was to use the wheel trencher. These machines, however, were fairly quickly superseded by the chain type trenchers, which still dominate today. The main changes in the chain trencher have been the increased availability of power and speed, with reductions in the width of trench excavated. A complete range of trenchers from 45-225 kW power is currently available to suit the different sizes of drainage scheme. Trench width is particularly important in the U.K., through its influence on drainage costs in the large number of schemes (60-65%) where permeable backfill is used above the pipe. The wider the trench the greater the amount of expensive backfill consumed. Minimum trench widths of 100 mm are required for moling schemes.

In 1960 the trenchless drainage machine was in the early stages of its development, and was found in two forms, the low output winched and higher output self propelled machines. A major attraction was the narrow trench width and hence backfill saving, to be followed later by higher output and less running and maintenance costs than the equivalent trenching machines. The problems encountered in some other countries, of poorer drain performance after trenchless installation, were not common in the U.K. This was because the machines were mostly used in perched watertable, permeable backfill situations. Research in the U.K. identified the causes of the poorer performance problems and developed techniques for avoiding them.

The smaller winched trenchless machines tend to be used on schemes of up to approximately 8 ha in size, with the larger self propelled machines working on sites usually greater than 15 ha. Problems do arise with trenchless installations in some situations, where old drainage systems have been cut on sloping land and blow-outs occur. Figure 2 shows the rate of increase in the usage of trenchless machines, levelling out at about 20% of all schemes.

V-ploughs were first used in the U.K. in 1983 and there are currently a few operating in the groundwater control problem areas of Eastern England. As yet they have not been modified to place stone above the pipe.

In stony and rocky areas, backacters tend to be used on the smaller schemes up to about 2 ha. They are also used for springline problems and for laying main drains on some of the larger sites of between 2-8 ha.

In areas where gradients are low, laser grade control has displaced boning rods almost completely during the last 10 years. An intermediate stage, developed alongside the trenchless machines, based on interfering light beams or on remote control from a static level, disappeared quickly following the introduction of the laser. Boning rods are still used in other situations, although on steeper regular grades, grade is estimated from the soil surface. Limitations to accurate grade are still controlled by the operator. Wrongly adjusted lasers and excessive installation speeds on undulating ground, particularly with trenchless are the main causes of grade error.

Gravel carts for handling permeable backfill have advanced from what were effectively farm trailers in the 1960s to special purpose power driven or self-propelled vehicles in the 1980s. Most are now effectively tyred or tracked to minimize soil compaction problems and capacities vary from 6 to 15 tonnes.

Changes in mole plough design have taken place over the last 25 years with the introduction of double beam and floating beam ploughs. The floating beam plough has a considerably lower draught (up to 50% less) than the traditional single beam plough. In addition, it is less susceptible to trash blockage with less grade variation when operating on undulating surfaces. A further feature is its ability to install graded mole channels on level surfaces.

4.2 Materials

The major change has been in pipe materials. In 1960, almost all pipes were clayware whereas plastics now completely dominate. The rate of uptake of plastics pipe on a scheme basis is shown in Figure 2. Plastics gained entry initially because the 50 mm pipe had adequate carrying capacity for many schemes and was priced similar to the minimum sized clay tile (75 mm). Lower handling costs and convenience, together with further developments such as the large coil, then took over to displace the tile.

Many materials have been tested as alternatives to stone and gravel as permeable backfill materials, these include products made from power station waste, cement, clinker and plastics. Although some are in use, crushed stone and gravel still dominate despite their weight and cost. Figure 2 shows that the use of permeable backfill has remained fairly constant over the period.

The area of unstable soils in the U.K. is limited and hence the use of envelope materials is not particularly widespread. Thicker envelopes such as coco-fibre have been used where necessary over the whole period, together with thin synthetic envelopes during the last few years.

5 Drainage costs

The gross cost of drainage has risen steadily over the 25 year period as detailed in Figure 3, which presents average costs. Real costs to the farmer have been less than these, due to government drainage grants, and to tax savings on reinvested profits within profitable enterprises. Drainage grants varied between 50-60% of the total cost in the '60s and '70s, falling rapidly after 1980 to approximately 15% or less in 1985. Drainage in the less favoured marginal farming areas has received even more encouragement, with grants remaining at 70% until 1983, thereafter falling to 60% and again to 30% in 1985. Unfortunately profit margins were so low in many of these marginal areas that relatively little drainage was done.

Over the whole 25 year period, there has never been any particular difficulty in justifying drainage economically, in situations where poor drainage was limiting output. This remains the case today even without drainage grants. The greatest returns on drainage investment were achieved, when coupled with good farm management, in the following situations: where it gave a very significant improvement in agricultural potential (almost a reclamation situation), where it allowed a change from poor grass to arable and where it allowed greater intensification of either arable or grass.

The major factor influencing drainage cost is permeable backfill which can constitute up to 60% of the total cost. The clear identification of sites where permeable backfill is unnecessary will, therefore, contribute very significantly in reducing drainage costs. Possible future restrictions on production would necessitate a review of the potential benefits of drainage in some areas.

6 Project organization and management

Resulting from the substantial government aid which has gone into drainage works, the Ministry of Agriculture has played a very important and useful role during the past 25 years in the design, organization and setting of standards of projects. Until 1980, all drainage designs and installations had to be approved by Ministry officials before grants could be paid. After this date standards became the farmers responsibility.

In the 1960s almost all designs were made by the Ministry officers, this input decreased and was passed to contractors and consultants in the 1970s and after 1981 the officers role was mainly an advisory one.

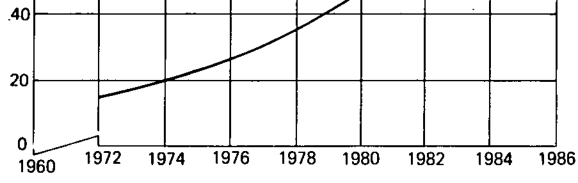

Figure 3 Drainage cost

Ministry drainage officers now offer a commercial consultancy service for farmers requiring drainage. In an attempt to maintain standards of workmanship and to promote drainage, the land drainage contractors have recently formed their own association.

The major drainage season in the 1960s was during autumn and winter. Winter work is now minimal, with much more 'through-crop' drainage being practiced under drier soil moisture conditions.

7 Maintenance of systems

British farmers prefer complete subsurface pipe systems with a minimum of open ditches. Most like to feel that they will never have to maintain any of the pipe systems they install. Evidence collected recently, on silting within pipes installed in the 1970s, suggests that this is a fair assumption on most soils. Except on the few unstable fine sand/silty soils, siltation was minimal where the pipes had been laid satisfactorily. More siltation was found in clay tile than plastic pipe systems, due to soil entering at the joints, and in systems installed using backacters. Flushing machines have been used over the past 5-8 years on some of the unstable soils.

Despite numerous investigations over the past 20 years, no solution has been found for the ochre problem. Cleaning is carried out with either flushing machines or by emptying a tanker of water down the upper end of the pipe system. Poor water entry into plastic pipes in peats has been partly resolved by enlarging the hole area.

Maintenance of farm level open ditches is almost wholly by mechanical means.

8 Acknowledgements

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Field drainage in Scotland

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1 Introduction

Scotland is one of the four countries which make up the United Kingdom. It is a small country with a population of five million and a total land area of 7 715 000 ha occupying the Northern part of the British Isles. Of the total land area approximately 84% or some 6 500 000 ha is classified as agricultural land; the remainder largely being classified as forest, ungrazed uplands and urban areas. Most of the agricultural land is used only for extensive hill or rough grazing with only approximately 25% or 1 650 000 ha being classified as arable or improved grassland. The relative proportion of land in these categories is shown in Table 1.

Table 1 Agricultural land classification

Year	Total improved grass and arable land (1000 ha)	Improved grassland (1000 ha)	(%)	Arable land (1000 ha)	(%)
1963	1722.2	1118.6	65	603.6	35
1973	1645.3	1073.6	65	571.2	35
1983	1686.4	1051.6	62	634.8	38

Table 1 shows that grassland production and associated livestock enterprises form the mainstay of Scottish agriculture. Traditionally most farms were mixed enterprises with a combination of grass and crops. Over the last decade, however, there has been a shift away from traditional rotations in the drier Eastern areas with more emphasis being placed upon arable cropping. This is a reflection of the more favourable economics of arable farming over this period and is a trend that has accelerated since 1983.

In its topography, climate and land use Scotland is a country of marked contrasts. The mountainous nature and high rainfall of much of the Northern and Western parts of the country precludes all but the most extensive forms of agriculture. The arable cropping is concentrated along the drier Eastern coastal fringe where the annual rainfall is less than 900 mm. The main crops grown are barley, wheat, potatoes and oilseed rape. Livestock enterprises predominate in the wetter Western and Northern areas and principally involve dairying, beef cattle and sheep. Because of the adverse winter climate feed must be conserved for overwintered livestock which in the case of diary and beef animals are usually housed during this period. Pigs and poultry products are another important facet of the Scottish agricultural economy with their production mainly being concentrated in intensive housed units.

2 Drainage requirement

Approximately half of the area devoted to improved grassland and arable crops is upon soils that are naturally freely drained. On the remaining area of some 825 000 ha some form of underdrainage is required for the full agricultural potential of the land to be realized. Scottish farmers have long realized the benefits that good drainage confers and there has been a long tradition of drainage improvements on these soils stretching back over the last few centuries. Most of the land in this category has therefore been drained at some time in the past. Unfortunately nothing lasts forever and no matter how well drainage schemes were designed and installed in the first instance, they eventually cease to function and have to be replaced. With an average life expectancy of 50 years, just to maintain the status quo or to ensure that drainage schemes are being replaced at the same rate as they are passing out of commission, the annual Scottish drainage requirement will be somewhere in the order of 16 500 ha. As indicated in Figure 1a, however, the statistics show that since 1955 this annual maintenance target has never been achieved. If the figure of 50 years is an accurate estimate of the life expectancy of drainage schemes it can only be concluded that at best, there

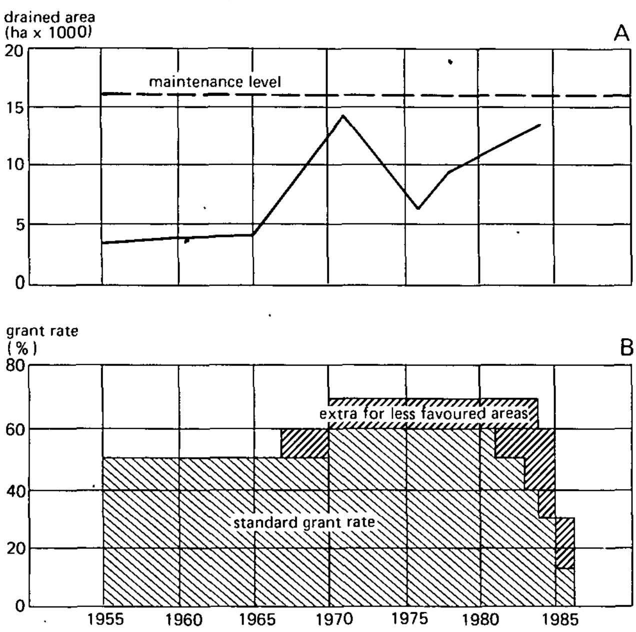

Figure 1 Area drained and grant rate in Scotland

is a substantial area of land where the drains are working at sub-optimum efficiency or at worst, the drains are completely defunct and are making no significant contribution to the drying out of the land.

3 Drainage problems

Most of the drainage effort is on mineral soils with less than 10% of the annual area drained being classified as peat. There are basically three types of drainage problems encountered under Scottish conditions namely surface water, high watertable and springs or seepage lines. Table 2 shows the classification of drainage problems into these categories for 1984.

Table 2 Dominant drainage problems (1984)

Drainage problem	% Area drained
Surface water	65
High watertable	20
Spring/seepage line	15

Although there are regional variations where the relative proportion of these problems differ in response to variations in dominant soil types, the above figures are typical of the overall annual distribution of drainage problems in Scotland.

Accounting as they do for two-third of the area drained, surface water problems are by far the dominant drainage problems under Scottish conditions. This is due to the fact that most of the soils are developed upon dense and slowly permeable glacial tills. The above problems are by no means mutually exclusive and are frequently found in combination.

4 Drainage systems

In all but the most extensive forms of land use in the hill farming and crofting areas field drainage is achieved by pipes. The geological and more recently the glacial and post glacial processes which have formed the Scottish landscape have ensured that there is an adequate network of rivers and streams throughout the country which form the arterial or main drainage outlets. These have been supplemented since the earliest land improvements by a network of man made canals and field ditches to transmit water to the main drainage channels. Another legacy of the natural land forming processes is that the landscape in the main agricultural areas is an undulating one. In most cases therefore drainage can be achieved by a gravity outlet and only in a few cases has recourse to be made to pumping.

5 Drainage criteria

In common with the rest of Britain the most widely used method for the design of piped drainage systems is that advocated by the Ministry of Agriculture, Fisheries and Food (MAFF 1983). In determining daily design rates this system takes account of the incident rainfall, proposed land use and the type of drainage system to be installed. The daily design rate is then used in conjunction with the slope on the land surface, the area served by the pipe and an assessment of soil permeability to calculate the design discharge. From this and the pipe gradient the appropriate size of pipe can be selected.

Because of the large variation in rainfall it would be unwise to adopt a single daily design rate for the whole country. For this and for other agricultural reasons the main agricultural areas have been subdivided into 17 agroclimatic areas (Meteorological Office 1981) for which appropriate meteorological data are available. This includes long-term rainfall data which are used in the determination of the daily design rates for drainage purposes.

6 Drainage materials

Since its introduction in the early 1960's corrugated plastic pipe has had a major impact upon the Scottish drainage scene and currently accounts for 75% of the drainage materials used. Traditional clayware tiles make up most of the remaining 25% with less than 1% being classified as other pipes (mainly concrete).

As indicated earlier the dominant drainage problem encountered in Scotland is the removal of surface water on dense glacial tills which have a slowly permeable subsoil. In response to an increasing number of drain failures and an intensified extension effort the use of permeable infill as a trenchline connection has become increasingly popular on such soils since 1970 and is at present used in 55% of the area drained. In the same context subsoiling and moling are presently practised as permeability aids on 12% and 1% respectively of the area drained.

7 Drainage machinery

Drainage work in Scotland is for the greater part undertaken on a large number of relatively small schemes. The 1984 statistics show that the average project size was 5 ha with the most frequently occurring size falling in the 1-1.9 ha range. This scale of operations limits the use of large capacity drainage machines. Consequently on just over half of the area drained in Scotland the drains are installed by backacting machinery. The remaining area is equally divided between trenchless and continuous trenching machines.

8 Drainage grants

Grants towards field and arterial drainage works were·first introduced in the United Kingdom in 1921. Since then the rate of grant has varied between 15% and 70% but has mostly stood at the 50% level. Today, in an era of surplusses in most of the agricultural commodities within the European Economic Community (EEC) and less emphasis being placed upon home grown food production the rate of grant currently stands at 15% for low ground farms and 30% for farms in areas classified as less favoured (LFA) (Figure 1b). From Figure 1 it can be seen that the rate of grant has a bearing upon the amount of drainage done. There are other factors, however, principally the state of confidence of farming and climate. The records show that periods of high drainage activity have coincided with periods of relative prosperity within the agricultural community when the industry was in a confident mood, or have occurred in response to wet years.

9 Drainage costs

In 1984, without taking account of arterial works or ditch improvements and before grants, Scottish farmers spent £15.2 million on field drainage. In so doing 13 312 ha were drained at an average cost of £1.145 per ha. There were wide variations about this average with the lowest regional cost being £485 per ha and the highest just over 2 000 per ha. This variation is due to the variations in soil type and their associated drainage problems throughout the country and the different types of solutions adopted to combat them.

The development of average drainage costs over the last 25 years together with the corresponding values of the different types of agricultural land is shown in Figure 2. The sharp rise in both land values and drainage costs is in part due to the high inflation rate in the United Kingdom at this time. The continuing steep increase in land values during the 1970's and early 1980's was also due to a confident agricultural industry during this period and the fact that the acquisition of land was perceived by farmers and institutional investors as a good long-term investment and a hedge against inflation. In addition to the inflationary aspects the rise in drainage costs from 1970 is also due to the increasing use of permeable infill in drainage schemes which at current costs can account for more than half the total cost of a scheme.

Until 1984 the graphs show that even before grant if a project was based upon a sound financial footing, drainage and land improvements were an attractive economic proposition especially for arable land. Since then, however, there has been a sharp fall in agricultural land values especially in the more marginal LFA areas while drainage costs have remained constant. As a result the economics of drainage have to be much more carefully assessed before embarking upon major projects.

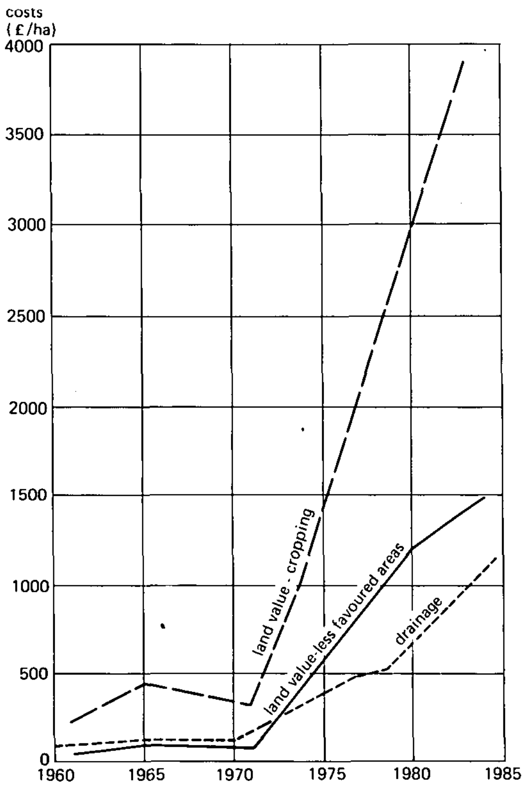

Figure 2 Drainage cost and land value in Scotland

10 Problem areas

In the preceding sections a brief description of the Scottish physical and agricultural background has been given together with an outline of the recent development and current state of the drainage industry. In the following sections attention will be focussed upon the main problem areas confronting the drainage industry in Scotland.

10.1 Standards of design and installation

At least as far as Scotland and indeed the rest of the U.K. is concerned field drainage is an area in which, in the majority of cases, the theory and science of the subject is far in advance of the practice. This is largely due to the structure of the industry and the nature of a large proportion of the servicing contracting industry. Because of the large number of relatively small schemes it is impractical and uneconomic for most of the projects to have a major design input. Consequently in most cases the farmer and his chosen contractor are left to their own judgement and a large proportion of drainage schemes are installed without design guidance and often by untrained and inexperienced contractors. It is not surprising therefore that the final results are often disappointing. This was exemplified in a recent survey into the efficiency of recently installed drainage schemes in S.W. Scotland, carried out by Merrilees & Keer. The results of this survey are shown in Table 3.

Table 3 Farmer and surveyors assessment of drainage efficiency (% of schemes)

	Good	Sub-optimal	Poor	Total
Farmer	58	18	24	100
Surveyor	47	27	26	100

Further detailed investigations of the schemes showed that all the reasons for poor or sub-optimal drainage could and should have been avoided through good design and installation practices.

In an ideal world all drainage contractors should have undergone formal training and be licensed by the administrative authorities. Such a state of affairs is unlikely to occur at least in the forseeable future in Scotland. Under these circumstances the only method of combatting this problem is therefore through a continuing extension and education programme to the wider agricultural community.

10.2 Iron ochre

Almost one third of Scottish drainage schemes have a potential problem due to the presence of iron ochre. In most cases its presence only reduces the efficiency of the drains. In the worst cases, however, it can cause complete drain failure within a few months of installation. Two types of ochre formation have been identified by Kuntze (Kuntze 1982) namely Allochthonous (permanent) and Autochthonous (temporary). Both types are found in Scottish soils with the Allochthonous type presenting the most serious problems.

As yet no satisfactory and environmentally acceptable cure has been found for this problem. Promising work is currently in progress with the use of coniferous bark to absorb the iron from solution. At present, however, the only method of combatting the problem is through design factors to facilitate drain maintenance by rodding or jetting.

10.3 Drainage economics

In a reclamation situation where drainage is a prerequisite to any meaningful agriculture, or where there has been a complete breakdown of an existing system, the benefits of drainage can be easily quantified and justified by economic analysis. For the reasons indicated, however, much of the drainage work undertaken in Scotland does not take place under these categories but is the replacement of sub-optimum drains which are unable to cope with the needs of modern agriculture. Under these conditions drainage economics is much more open to question. This is especially the case under Scottish circumstances where most of the drains are installed to deal with surface water and the drainage need and therefore responses can vary markedly from year to year in accordance with the vagaries of the climate. For U.K. conditions therefore it is a matter of urgency that work is undertaken in this area to allow any drainage improvements to be made on a sound basis.

11 The future

The outlook for the drainage industry in Scotland and the rest of the U.K. will mirror the fortunes of agriculture in general and the emphasis that will be placed upon home grown food production. This in turn will be determined by the priorities of the government of the day and the political sway that the agricultural lobby has with that government. As a member of the EEC any such policies will of course have to comply with the wider interest of the community.

At present both public and political opinion has been coloured by the increasing importance of the environmentalist lobby and the bad publicity targetted at agriculture and fuelled by the high cost of storing the agricultural surplusses produced within the EEC. In this climate it seems unlikely that on a national scale major emphasis will be placed upon increasing or even maintaining current production levels. On the contrary policies being advocated at present would suggest that a decrease in production levels is to be sought. In the future therefore it seems likely that drainage improvements will be concentrated in areas where the interests of the individual farmer are at variance with the national interest of lower production levels.

Against this background it is inevitable that there will be a reduction in the amount of drainage carried out and a corresponding reduction in the capacity of the ancillary industries. In response to this there will be a shift away from single purpose drainage machinery requiring large capital investment and an increasing reliance on the more versatile backacting equipment.

To maintain efficient agricultural production greater emphasis will be placed upon reducing drainage costs without a lowering of standards. The most likely ways of achieving this end for Scottish and U.K. conditions is through alternatives for gravel as permeable infill and the extension of mole drainage to a wider range of soil types. One method of reducing costs which is already gaining in popularity with farmers is 'do-it-yourself' drainage. This trend is likely to increase in importance in the future.

Finally it can only be concluded that within the U.K., agriculture in general and the drainage industry in particular is heading for uncertain times. Many changes will be required while the industry adjusts to the policies of the day and the consequent market pressures. These changes in themselves will produce interesting and stimulating challenges across the whole spectrum of field drainage activities.

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