TEAGASC MANUAL ON DRAINAGE

- and Soil Management

2nd Edition

A Best Practice Manual for Ireland's Farmers

teagasc

Agriculture and Food Development Authority


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2nd Printing

Contents

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Foreword

The Ag Climatise Roadmap for the Agriculture Sector recognises that there are significant opportunities for Irish food products in the new global marketplace that values safe, healthy and environmentally sound products. The opportunities for naturally produced Irish food and drink products are considerable, provided the industry remains competitive and above all, committed to environmentally sustainable food production systems.

In the context of emerging climate change and international food security goals, Ireland's future competitiveness will be influenced by the manner in which it can effectively jointly address and manage both of these challenges. Science based innovation is the key to addressing these challenges.

Enhancing the productivity of land, through prudent and environmentally sensitive drainage, will also play a role. Science and policy have now acknowledged the role of land drainage across the globe needs to change. Drainage of high organic content soils is no longer climate smart. This manual therefore focuses on mineral soils. The future for organic soils will include their role in terms of climate action and how they can contribute to a climate smart economy. In this context, further drainage of high organic content or peat cannot be justified and a significant programme of water table management should be considered on those organic soils that were previously drained. Where land has been drained, or not, careful management of livestock and machinery is vital to protect the soil's health and functionality.

Each drainage project in mineral soils is unique. Its potential financial viability is a matter of fine judgement by the farmer. Direct costs, the potential improvement in output, and the likely increase in revenue from key enterprises must be balanced. The opportunity cost is also important. Would buying land make more sense? Is land available? Is the land to be drained integral to the farm, possibly part of the grazing platform? Unquestionably, drainage projects implemented professionally on appropriate soil types and with careful regard for the environment will improve productivity in most years and they will be a key component of increasing resource efficiency for farmers.

The content, and the way the information has been presented in this updated 2nd edition of the Teagasc Manual on Drainage and Soil Management, is based on feedback from some of the country's leading farmers and scientists. The manual is a guide to best practice and will be particularly useful to farmers who are considering a drainage project on mineral soils. It is also aimed at farmers who are managing soils, which are susceptible to damage due to livestock or machinery traffic in poor weather conditions while a new section focused on soil health seeks to outline the value of soil as a finite resource and how best this resource can be sustained into the future.

The manual is a significant team project which brings together the expertise of front-line advisers, educators, economists and research scientists across Teagasc. Contributions from the Department of Agriculture, Food and the Marine further enhance the publication.

Farmers have seen in recent years how periods of persistent rainfall have played havoc with grazing, silage-making and tillage operations. While the capacity of any drainage system will be limited, drainage systems if appropriately located and designed can alleviate the impact of high rainfall.

It is critically important, however, that any drainage project is climate smart and profit driven and carefully evaluated for financial viability as well as technical feasibility. It is equally vital that any drainage scheme takes into account environmental considerations. Farmers have a profound understanding of sustainability and realise that the optimum drainage project may include leaving some hectares as they are. Location specific management will have to account for the distinctions drawn herein with regard to the management of mineral and organic soils.

We, as an industry, continue to set ambitious goals and while we face significant challenges, I believe that the Teagasc Manual on Drainage and Soil Management can contribute to helping achieve those goals in a manner that satisfies the core principles of sustainability outlined within the Ag Climatise Roadmap for the Agriculture Sector.

Professor Frank O' Mara
Director

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Illustrations and diagrams: Paul Francis Design.

How to use the Teagasc Manual on Drainage and Soil Management

The Teagasc Manual on Drainage and Soil Management is laid out to quickly provide answers for readers seeking information on any aspect of drainage or soil management. Each chapter begins with a brief introduction and a list of the questions addressed within it. The questions are repeated in the chapter to ensure easy 'navigation'.

Readers also have a full listing of the content in the introduction and an index at the end of the manual. All chapters and questions address particular topics and some chapters will refer readers to other sections to provide greater detail.

Soil drainage poses particular challenges in Ireland. The great variety of soils and soil problems means that every drainage challenge on mineral soils is unique. Careful investigation of the site; professional diagnosis; prudent assessment of the costs/benefits; expert implementation of a planned project and due consideration of environmental factors are all essential.

What is Teagasc?

Teagasc is the Irish Agricultural and Food Development Authority. The organisation has three core activities: agriculture and food research; transfer of new knowledge and technologies to farmers, farm businesses and food companies; providing education to farmers through a wide range of full and part-time courses.

Teagasc scientists, advisers and educators work within a national network of offices, research facilities and farms, and horticulture and agricultural colleges.

Teagasc goals are to:

- improve the competitiveness of agriculture, food production and the wider bio-economy;
- support sustainable farming and the environment;
- encourage diversification of the rural economy and enhance the quality of life in rural areas.

Teagasc is led by Director Professor Frank O' Mara and governed by a board consisting of representatives of key stakeholders. Mr Liam Herlihy is the current chairman of Teagasc.

Introduction

A large proportion of farms nationwide are located on land which due to natural limitations related to soil type, topography, relief and climate are poorly drained. Poorly drained soils (mineral or organic), by their nature, typically remain wet for prolonged periods each year and reach saturation during rain events (Section 1). Farms on such soils are subject to lower productivity, profitability and resource efficiency than those on free draining soils. The level of volatility associated with such soils will depend on the proportion of such soils on a given farm and weather in a given year. Generally profitability on such soils is closely related to weather and as such can be extremely volatile (Section 2).

When planning any drainage programme in mineral soils, the potential of the land to be drained needs to be first assessed to determine if the costs incurred will result in an economic return through additional yield and/or utilisation. Some thought is needed in deciding the most appropriate part of the farm to drain. In some circumstances, the installation of land drains can have an excessive environmental impact and as such cannot be justified. We should not consider any fields with high organic content or peat soils for the implementation of land drainage works, as this would be contrary to climate action goals for Ireland. If dealing with vulnerable habitats or wetlands then any benefits yielded will come at too high a cost to the wider environment and cannot be justified. Such works must be avoided. Consider all impacts and seek appropriate advice. Ensure compliance with statutory obligations and always seek to minimise adverse impacts when proceeding with drainage works. If you intend to undertake land drainage works that (a) exceed 15 hectares, (b) the works are to be carried out within (or may effect) an NHA, a proposed NHA, an SAC, an SPA or a nature reserve or (c) the proposed works may have a significant effect on the environment, screening by DAFM is required (Section 3). From a management point of view it is better to drain that land which is nearer to the farmyard and work outwards, however it may be more beneficial to target areas with high potential for improvement (if appropriate from an environmental perspective) to ensure a better return on the investment.

Effective land drainage systems, where appropriate, provide relief of excess water and control the water table on wet mineral soils, thereby improving yields and surface conditions and reducing the volatility associated with periods of adverse weather. The design of land drainage entails the specification and installation of field drains in the soil at such a depth and spacing to control the water table. Effective design requires that the drainage system is tailored to optimise discharge levels from a particular soil (Section 4). A number of drainage systems and techniques have been developed to suit different soil types and conditions with associated drainage characteristics, with this end in mind. These range from groundwater drainage designs, (typically 1.0 - 2.0 m deep) which interact directly with groundwater by virtue of their position in a high permeability soil layer to shallow drainage designs, comprised of shallow (typically < 1.0 m) drains supplemented by mole drainage, gravel mole drainage or sub-soiling at spacings of 1.0 - 2.0 m. The success and lifespan of the system installed will be largely dictated by the quality of its installation and its ongoing maintenance, so due consideration should be given to both (Section 5).

The drainage of mineral soils affects a reduction in greenhouse gas emissions both directly through lower nitrous oxide emissions, which tend to be higher in poorly drained soils, and indirectly through the benefits of extended grazing. However, the drainage of high organic content or peat soils will result in substantial CO_2 emissions to the atmosphere, which would dwarf any non CO_2 benefit. In this context, further drainage of high organic content or peat soils cannot be justified and a significant programme of water table management should be considered on those organic soils that were previously drained. Future iterations of the

Introduction

CAP could see measures targeted to rewetting of organic soils. This would involve proposing suitable locations and liaising with landowners to establish a workable programme of rewetting, and thereafter managing existing drainage features (open and field drains) on selected sites to manipulate the depth of the water table and reduce CO_2 emissions to the atmosphere. This water table management regime will also help prevent the release of sediment, carbon and nutrients, and have benefits for biodiversity.

Performance analysis of drainage systems installed on Teagasc Heavy Soils Programme farms is highlighting how drainage system type, soil type and seasonal variations in soil moisture affect drainage system performance and environmental losses (nitrogen, phosphorus and sediment) to water. Drainage systems reduce the overall period of waterlogging and improve the conditions for both the production and utilisation of the grasslands they drain (Section 6).

However, the implementation of land drainage works is known to affect the dynamics of water movement from drained sites and as such may affect flooding potential downstream, impact on important habitats and/or act as a conduit transporting a percentage of surplus nutrients not being used by the crop system to waters. Teagasc research on nutrient losses from drainage systems shows that ammonium rather than nitrate is being lost to surface waters along with phosphorus and sediment. The amount of nutrient losses varied between shallow and deeper systems. Recent research has looked at methods which reduce potential for nutrient losses, leaving field drains and ditches. Ongoing research is focusing on intercepting the pathway of loss along ditch and pipe networks, thereby breaking connectivity with waters and minimising such losses further in a more controlled manner. Appropriately planning mitigation practices at the outset of drainage works can effectively minimise such impacts and could help reduce the need for retro-fitting mitigation practices further down the line.

Examinations of potential environmental impact of drainage systems shows that both phosphorus and nitrogen attenuation capacity are dependent on surface and subsurface soil chemistry and drainage design specification. In terms of nutrient and sediment losses from land drainage systems; fertiliser inputs, crop type, rainfall, drainage system type (shallow versus deep), soil type and soil chemistry are important factors that distinguish what load of pollutants is to be lost from pipes and ditches to the environment. Shallow drainage systems, for example are more likely to promote high intensity flows which have little interaction with the soil body relative to groundwater systems which promote water movement through the soil. Land drainage system design needs to account for such variability and specify works that identify and negate against impacts on water quality. In Ireland, research has shown that we need to mitigate against dissolved carbon, ammonium, phosphorus and sediment that leave our drainage systems and enter waters. In-ditch mitigation measures (where ditches are connected to surface water directly) will have a role to play in the future management of such losses.

This manual has been prepared to offer guidance on the role of land drainage as a measure to improve poorly drained soils while highlighting the considerations relating to the environmental impacts of such works. There is much potential to improve the outcomes of drainage works by following the guidance within this manual and also advice to outline where land drainage is not a viable option or where measures can be taken to avoid negative impacts while maintaining functionality. The most appropriate actions should always be guided by a full appraisal of landscape and soil conditions, compliance with regulation and due consideration of all impacts of drainage works. As such please seek appropriate advice when planning and implementing land drainage works.

Section 1

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Rainfall, Landscape, Soils

Section 1

chapter 1

Section 1

Rainfall **and Drainage**

by **Owen Fenton, Pat Tuohy**

An update of a previous version written by Tristan Ibrahim, Rachel Creamer, Owen Fenton

Picture courtesy Irish Examiner

Introduction

Rainwater is part of a constant cycle. This chapter describes how water moves in the atmosphere, at the soil surface and in the subsurface, and the typical causes of drainage issues in fields.

1. **Where does rainwater flow to after it reaches the ground?**
2. **What causes drainage problems in a field?**
3. **How much rainfall is there in my area?**

chapter 1

Rainfall
and Drainage

1 Where does rainwater flow to after it reaches the ground?

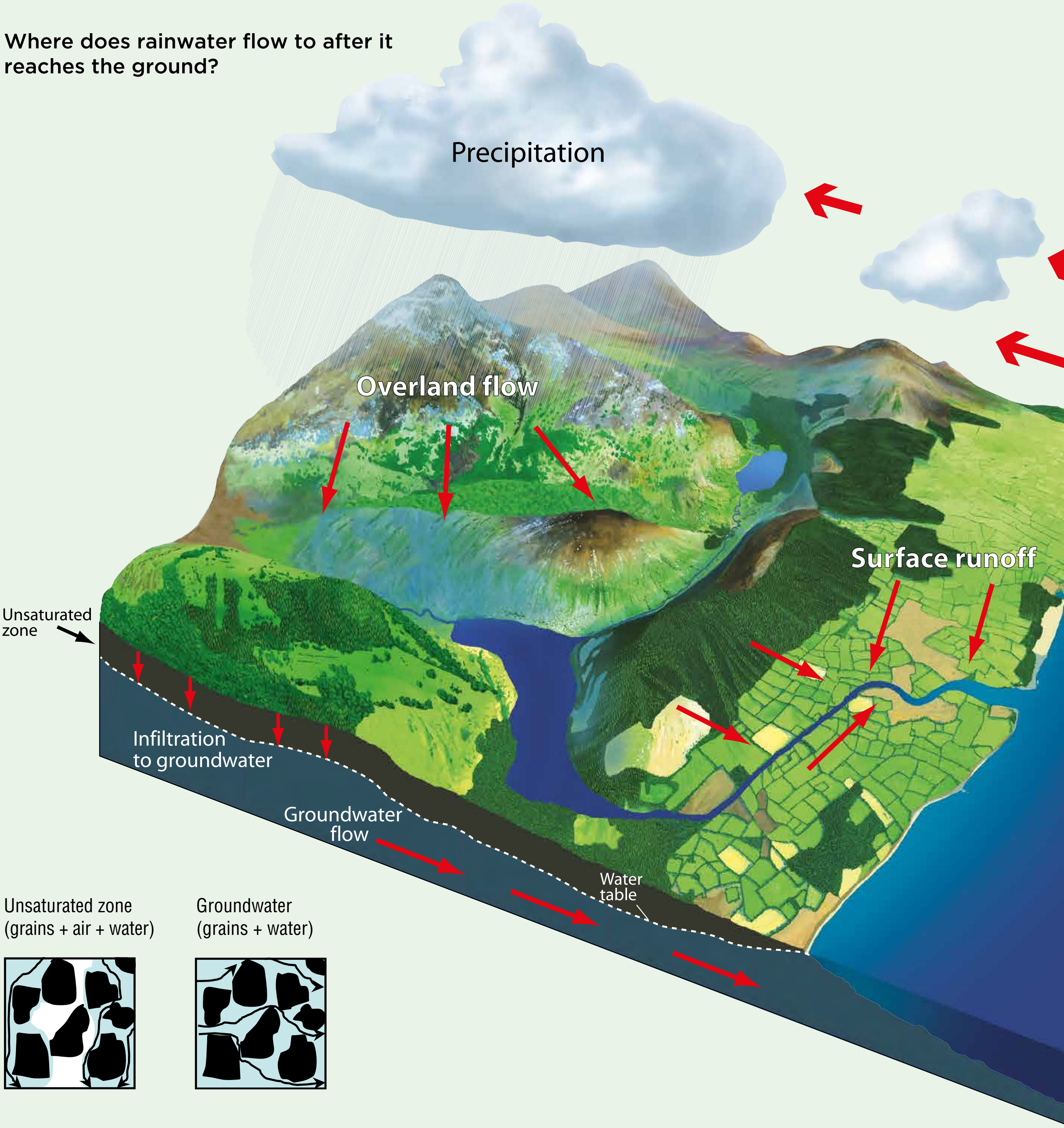
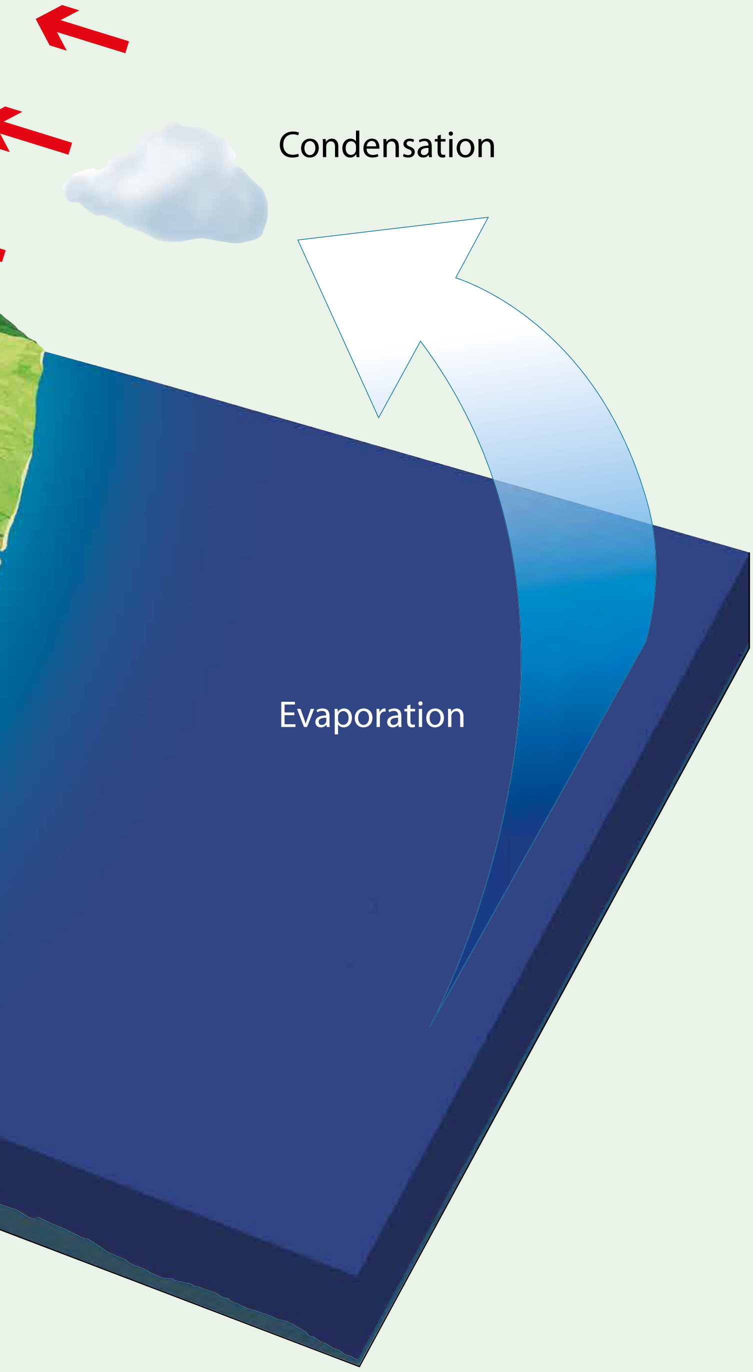


Figure 1. The Water Cycle.

The Water Cycle



- Precipitation, which includes rainwater, can return back to the atmosphere as vapour, either by direct evaporation, especially in areas of standing water such as a lake or the sea, or through transpiration by plants. This process is called evapotranspiration.

- Rainwater can flow along the ground surface. This is called overland flow or where it reaches and enters a river it is called surface runoff. Open drains act as a conduit for runoff to reach a larger water body. The speed of water flowing on the ground and the distance it can reach depends on the steepness of the slope and the extent and the speed with which it can infiltrate through the soil it is passing over.

- Rainwater can infiltrate into the ground and reach the water table. The water table is the upper surface of the groundwater. It is deeper in hills and shallowest near rivers, by the sea and beside open drains. How to identify groundwater in a soil test pit is explained in Section 4.

- Groundwater is found at depth in the subsurface, where all the spaces (pores) between the grains in the sediment or in the rocks are filled with water. Infiltration mainly occurs in what we call the unsaturated zone, this area is where there is both air and water in the sediment pores (see Figure 1).

chapter 1

Rainfall and Drainage

Key fact

Water flow will usually follow the surface topography, from mountains and hills to lowland areas, and finally to the sea.

This rule also applies to the direction of flow of the groundwater. In some lowland areas, rainwater can reach the sea by flowing on the ground surface.

Where rainwater falls a long way from the sea, it is likely to follow a variety of routes during its journey. As an example, Figure 2 shows how rainwater can fall onto the ground and flow along a slope for a distance until it infiltrates (percolates, drains) into the soil, reaches the groundwater and is transferred to a stream.

This stream can then flow to a larger river, to a lake or to the sea. The process of transfer of groundwater to a river, a lake, estuaries or the sea is called groundwater discharge.

In extended dry periods, this discharge maintains the flow of water in many streams and rivers so that fish or aquatic plants can survive and drinking water can still be pumped.

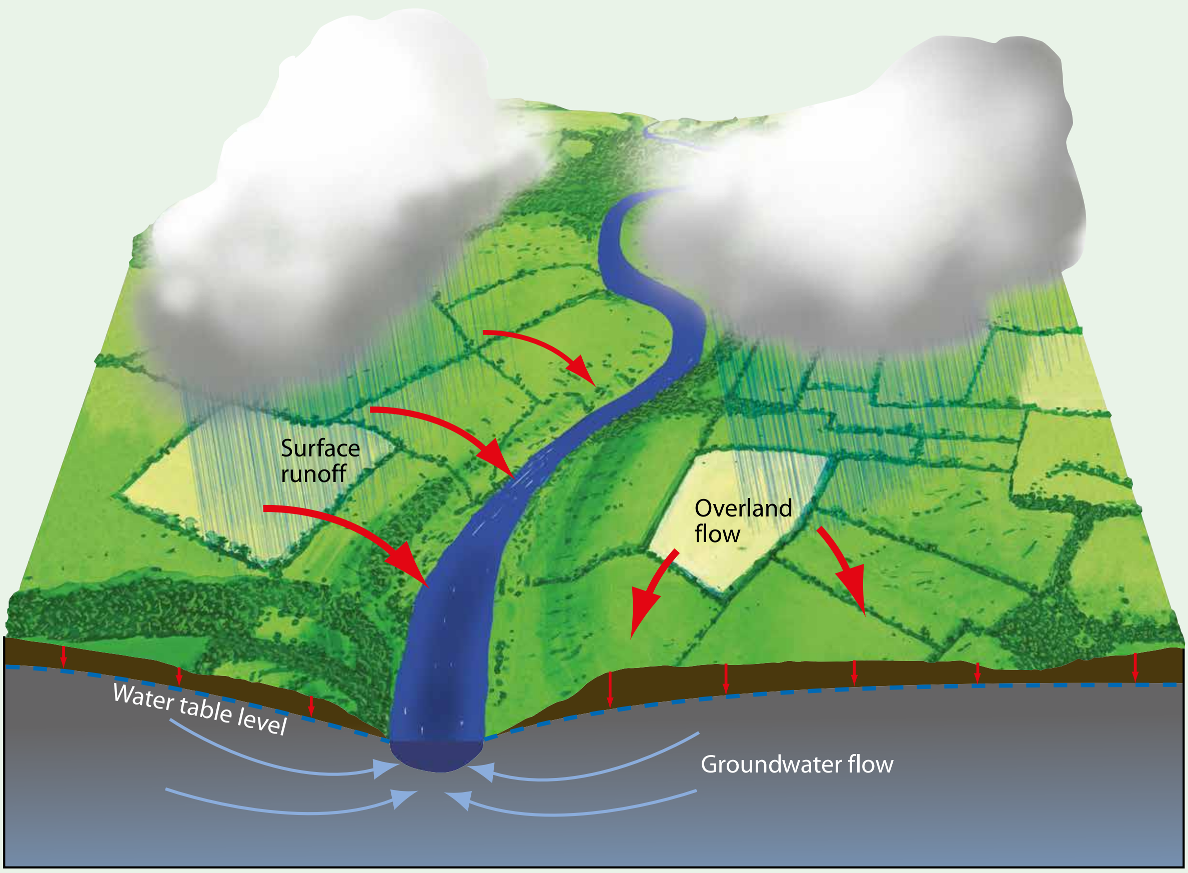


Figure 2. Water flow paths to a river on the soil surface and in groundwater.

2 What causes drainage problems in a field?

In general terms, we recognise three main cases, but remember each site will be different and there may be a combination of reasons for a drainage problem:

- **The presence of a moderately to poorly drained soil.** This is a soil which does not allow the water to infiltrate rapidly from the surface and gets rapidly waterlogged when it rains (Figure 3).

  The capacity of a soil to drain water will decrease with the size of the grains the soil sediment is made of: a soil made of coarse sand will rapidly drain any rainwater, while one made of finer grains (e.g. clay) will be rapidly waterlogged.

  Some soils will have a mix of grain sizes. Where a coarse sand is mixed with a fine clay, the small grains of clay will fill the spaces between the large grains of sand allowing for less water infiltration than for a soil consisting of coarse sand alone.

- **A water table close to the surface.** When rain water infiltrates into the soil, it generally moves vertically downwards until it reaches the water table. In some situations, the water table is very close to the surface. This leaves very little room for the water to infiltrate into the soil, which then quickly becomes waterlogged.

Figure 3. Soil (a) on the left is well drained, soil (b) on the right is poorly drained.

This often happens in lowland areas, in the so-called “floodplain” of the river, a zone where the river regularly floods the nearby fields in wet periods. Another area where the water table is at a shallow depth is where there is a so-called perched water table.

Looking at Figure 4 you can see that if you drill vertically down through the hill side you will find a first water table, sometimes virtually below the soil surface. This water table is called ‘perched’ because of the layer of low permeability which prevents the water from infiltrating deeper. This low permeability layer isolates the perched groundwater from another unsaturated zone and water table further below the surface. An indicator of the layer of low permeability is the presence of a series of springs at roughly the same altitude along the slope.

- **An area of water ponding.** In some fields, shallow ponds will form. Generally, this happens in depressions in the landscape, either man-made (e.g. trenches) or natural. Often there will be a layer of fine sediment at the bottom preventing the water from draining away.

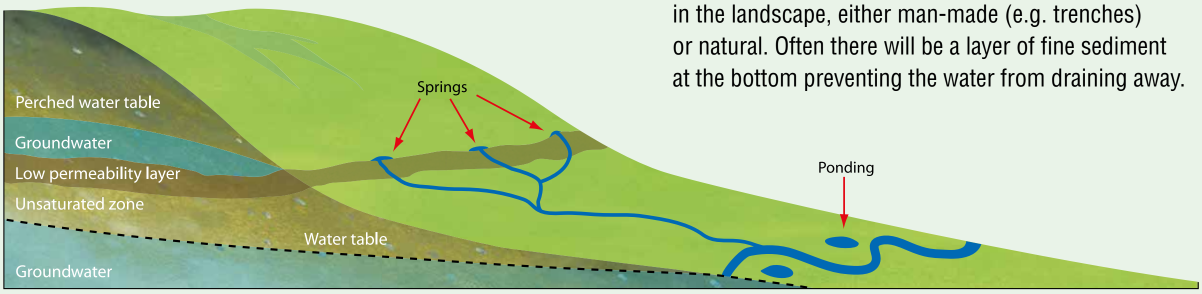


Figure 4. Perched water table (after http://www.physicalgeography.net).

Rainfall and Drainage

These ponds can be filled with groundwater in areas where the water table is higher than the bottom of the pond (Figure 5A). This can either happen close to a river or in an area of perched water table. Where the depression is close to a river, it will fill with river water in wet periods, if the river water floods onto its floodplain (Figure 5B).

When the river water level comes back below the river banks, the pond will gradually lose some water to the subsurface, but this can take some time. In many instances, especially where the pond is located in a floodplain, both mechanisms can be combined (i.e. the pond can be filled with both groundwater AND river water).

In some instances, the pond will be fed with water from a spring (Figure 5C). On the other side of the pond, water will be lost towards the slope when the water level in the pond is higher than its banks.

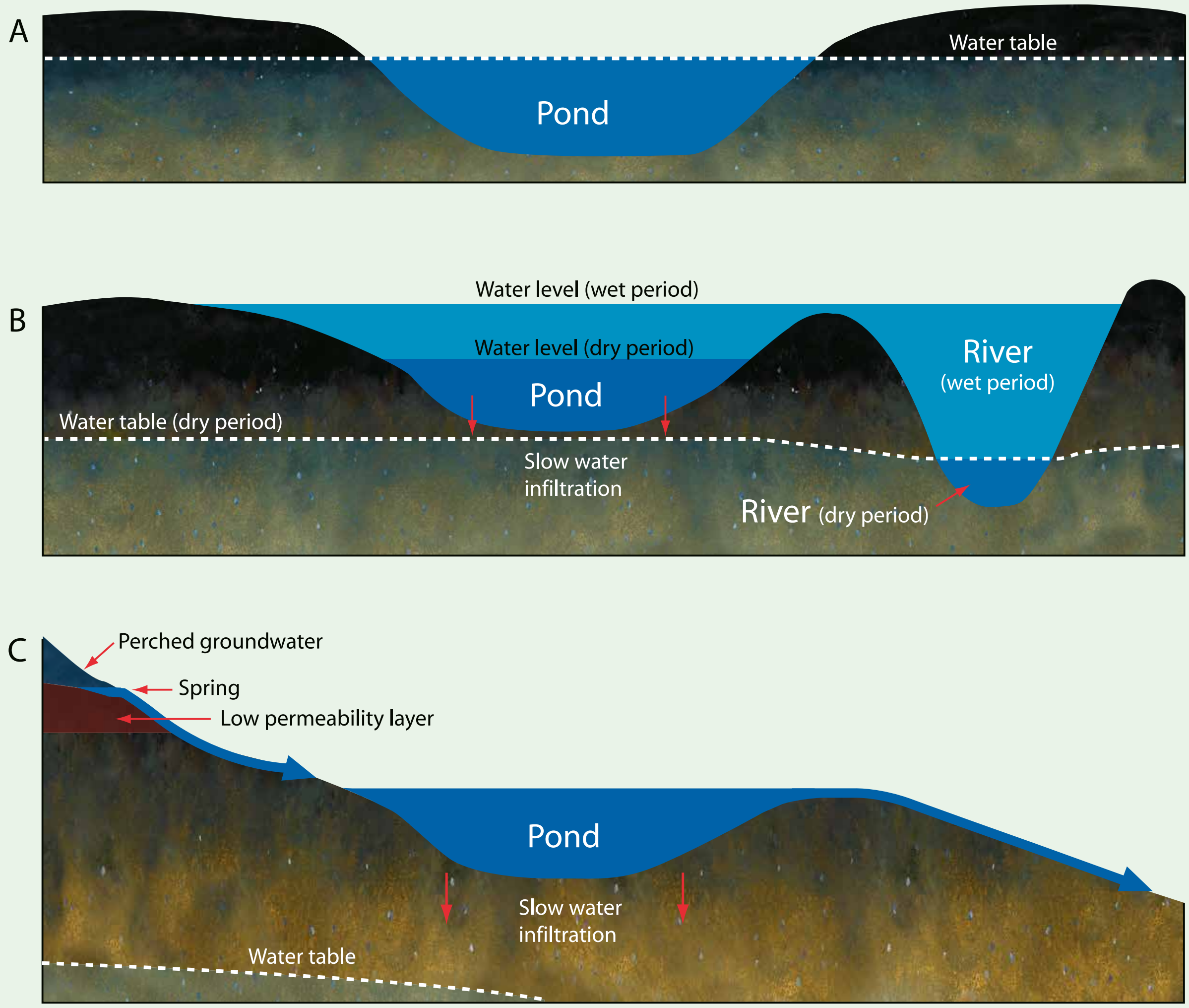


Figure 5. How ponds on the soil surface fill with water.

3 How much rainfall is there in my area?

Ireland receives some of the highest annual rainfall in Europe, with only limited variations between the summer and winter seasons, which means that Irish soils are vulnerable to drainage problems, especially in winter. Over the long term, this high rainfall has resulted in the formation of wetter soils, such as peat (bog) soils. These soils form in areas where there is too much water in the soil to allow the microbes to efficiently decompose dead wood, and leaves. In fact we have the 3rd largest area of peat in Europe (after Finland and Estonia). The drainage of peat soils results in substantial CO_2 emissions to the atmosphere. In this context, further drainage of peat soils cannot be justified and a significant programme of water table management is required on those organic soils that were previously drained. In many European countries, peat soils drained for agriculture are a considerable source of greenhouse gas emissions. Since emissions from this source have high mitigation potential, they will be a focus of the European Union's future climate goals.

Figure 7 (overleaf) summarises the average annual precipitation amounts (mm) for Ireland. Precipitation across the country ranges from as low as 600-1,000 mm per year along the east coast, to over 3,000 mm per year in mountainous areas, particularly along the western sea board, where we find a lot of peat. Evidence of a trend towards increased rainfall has been observed in recent years (Figure 6). Net rainfall (precipitation - actual evapotranspiration) ranges from less than 100 mm in the east to over 2000 mm in the west. As an example, subtracting 500 mm (estimate of your local evapotranspiration) from the annual precipitation gives you a good idea of the amount of water which needs to be drained, either through overland flow or infiltration into the soil.

How to

Calculate the drainage needed.

1. Subtract 500 mm from the precipitation in your area;
2. Work out the size of your field in hectares and multiply this value by 10;
3. Multiply together the numbers found in point 1 and 2. That gives you the average volume of water which needs to be drained in a year in your field in m^3. Multiply this number by 1000 to get a volume in litres.

Example for a field of 2 ha where 1000 mm fall in a year.

1. 1000 - 500 = 500
2. 2 x 10 = 20
3. 20 x 500 = 10,000 m^3 per year or 10,000,000 litres per year

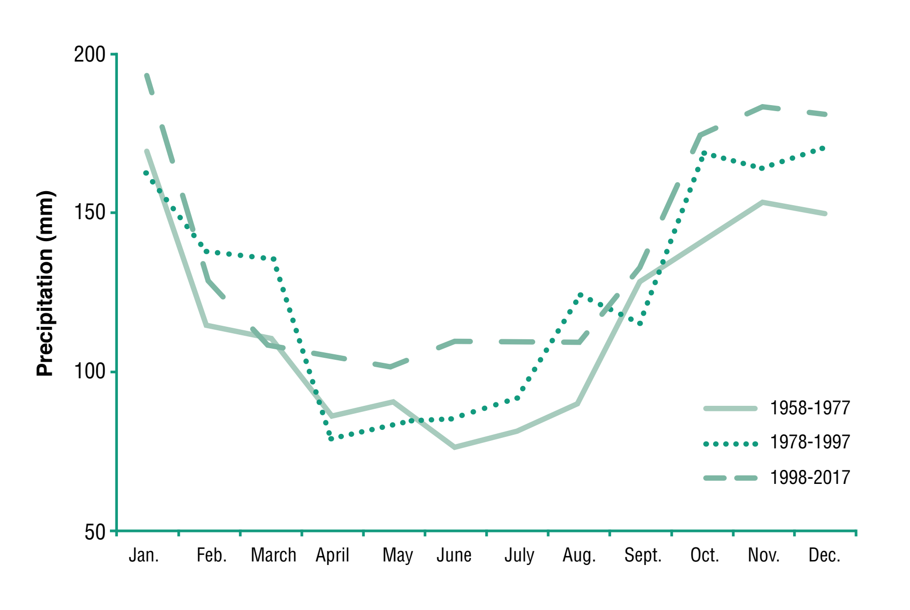


Figure 6. Mean monthly precipitation at Valentia Observatory (met.ie) for three separate 20 year periods, (i) 1958-1977, (ii) 1978-1997 and (iii) 1998-2017, after Tuohy et al. (2018).

chapter 1

Rainfall **and Drainage**

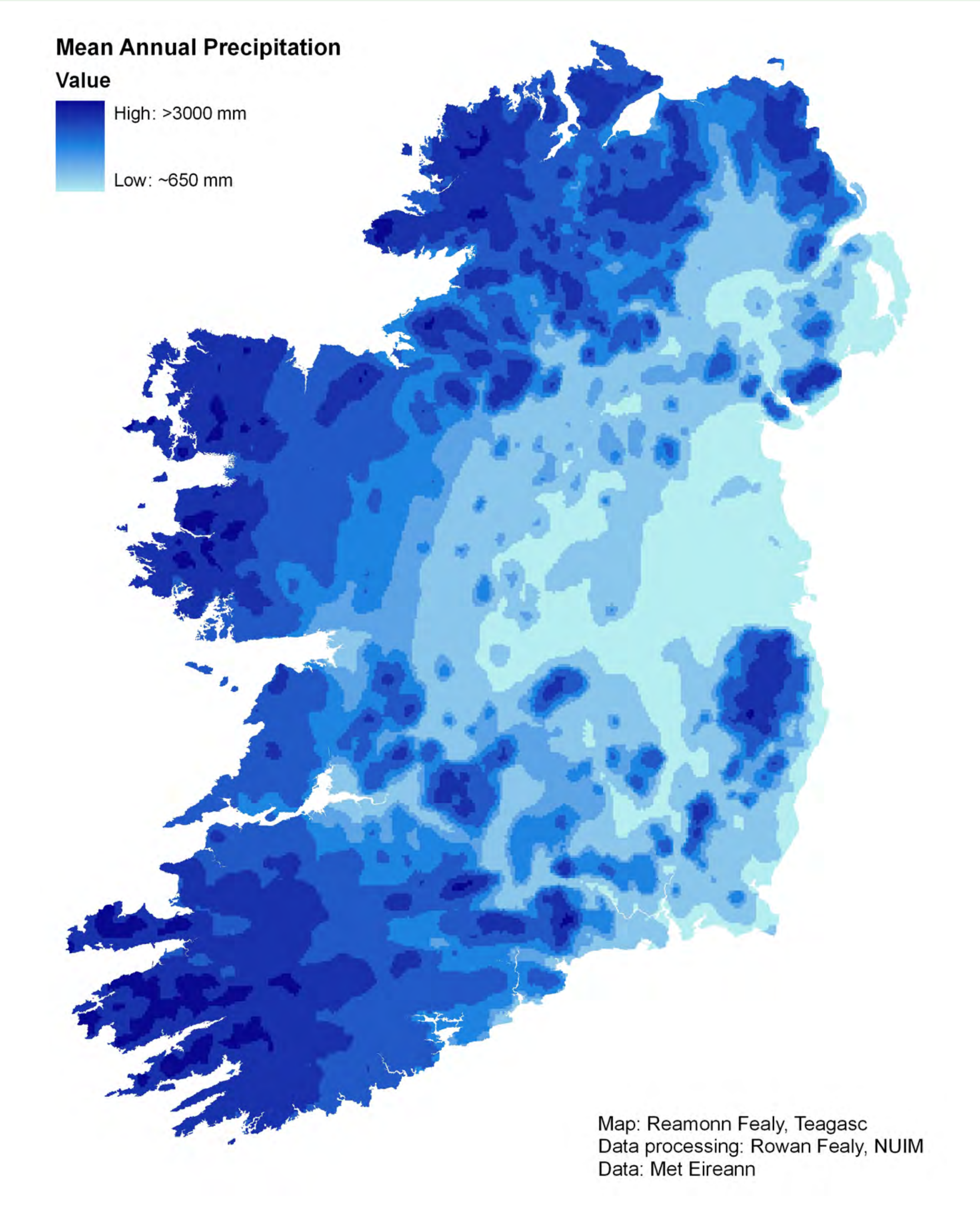


Figure 7. Variations in precipitation across Ireland. Modified from Met-Eireann.

Section 1

Soil and **Drainscapes**

by **Pat Tuohy, Owen Fenton**

An update of a previous version written by Rachel Creamer, Tristan Ibrahim, Owen Fenton

Introduction

Ireland has a diverse range of agricultural activities across the counties: tillage dominates the free-draining soils of the south-east, limestone-rich lowland grasslands predominate in the south and midlands while acid and peat soils are typically associated with extensive grazing and forestry in hills, mountains and along the western seaboard.

1. **Which landscape factors influence farming activities?**
2. **What are the main bedrock, sediment and soil types?**
3. **What are the typical soil and drainage landscapes?**

chapter 2

Soil and **Drainscapes**

① Which landscape factors influence farming activities?

The dominant agricultural activity in any area is primarily influenced by:

1. The main type of rocks (geology) which the soils are formed from,
2. The position in the landscape (see Figure 1) and
3. The climate (see also Chapter 1).

These factors also influence the amount of water that will move through the landscape, whether it is over the surface, or through the soil into the groundwater. Knowing the geology, topography and rainfall for your particular location can help you establish how water flows on your land, and locate likely areas where drainage problems will occur.

② What are the main bedrock, sediment and soil types?

Having a general understanding of the type of geology in your area (rock type/glacial and alluvial deposits) is important. In Ireland, we have soils which form directly over rock material and others which develop in glacial drift deposits (from glaciation) and in alluvial deposits.

It is important to know what type of geology your soils are formed on, as 1) this will strongly influence their drainage capacity and 2) water will move differently in the subsurface according to the bedrock or sediment type. In Ireland, we have a mixture of bedrock and shallow sediment types:

- **Calcareous limestones** are sedimentary deposits largely made of skeletons or shells of marine organisms accumulated under the sea. They cover large areas of the midlands.

- **Sandstones and shales** are more acidic sedimentary deposits made of sediments of different sizes (mainly sands for the sandstones and much finer sediments such as mud for the shales). The largest deposits are found in the south-west.

- **Igneous rocks** (e.g. granite in the Wicklow mountains) originate from magma or lava released when volcanoes were active.

- **Metamorphic rocks** such as gneiss, schist and quartzite are found in areas such as Connemara, West Mayo and Donegal. They are made of sedimentary deposits which have been transformed after their deposition under high temperature and/or pressure conditions.

- **Glacial deposits** originate from a number of glaciation periods, the most recent one occured about 13,000 years ago. These glacial events had a huge effect on the type of soils we find today. Glaciers scoured materials from the tops of mountains and as they moved across the landscape, the material was crushed and ground to produce finer materials of gravels, sands, silts and clays. These finer materials were deposited on the surface of rocks as glacial till and in flat lowland areas or at the bottom of glacial lakes.

- **Alluvial deposits** are shallow deposits made of sediments transported by streams and rivers and which accumulated either under the water (e.g. in slow moving areas of the river) or in a floodplain.

Soil types:

- **Gleys** are grey to grey-blue in colour, which indicates waterlogging conditions for long periods of the year. Sometimes, orange and black mottles (small circles of orange/black) indicate the presence of oxidised iron (i.e. rust) and manganese. Mottles are found where waterlogged soils have been dried out a little and oxygen has reoxidised the iron. Gleys are generally poorly productive in conditions of high rainfall.

  - Groundwater gleys are usually found near to rivers/streams or in lowland areas where the water table is close to the surface. The colours are grey at the bottom of the soil and may improve nearer the surface, depending on how high the water table reaches. The water table will fluctuate depending on the season, it will be highest in winter and lowest in summer.

- Surface water gleys are soils which have a perched water table. This means that there is a layer in the soil which slows down the movement of water. This results in the soil above this layer being grey in colour, but not below. Again, the season affects the extent of the waterlogging. As rainfall increases in winter, the soil is more likely to wet up but in drier conditions this soil may not have a problem.

- **Blanket and basin peats.** Peats are poorly-drained soils developed in very wet areas. They display high quantities of organic matter which accumulates in the top layers because of low concentrations of oxygen in the soil. The drainage of peat soils results in substantial CO_2 emissions to the atmosphere. In this context, further drainage of peat soils cannot be justified and a significant programme of water table management is required on those organic soils that were previously drained. Blanket peats can be from 0.4 m to over 2 m thick and generally occur in the highest areas of the country, where it rains the most.

  Basin peats will generally be found in more lowland areas, often where the water table is very shallow. These soils generally initially form in rivers, or where the water table is at the surface (e.g. nutrient-rich Fen soils). High rainfall can then make the peat more acidic in the long term (e.g. Raised Bogs).

- **Lithosols.** Generally well-drained soils found on steep slopes over acidic bedrock types, such as sandstone, shale, granite, gneiss and schist.

- **Rendzinas.** These shallow soils occur above limestone, hence their high carbonate content.

- **Podzols.** Podzols are soils which had a large quantity of their nutrients washed away by water from the surface layers. This leads to a high acidity and to the accumulation of iron and aluminium in deeper layers, which can, over time, form an iron pan creating a barrier to water movement and roots. This type of soil generally occurs in moderate to high altitudes where access is too difficult to properly enhance their production capacity.

- **Brown podzolics.** These soils generally occur at lower altitudes than the podzols. They have also had some nutrients washed to deeper layers (iron and aluminium in particular), but are not as extreme as podzols. These soils are less prone to form impermeable layers at depth, hence their higher productivity if adequate fertilisation and lime additions are made.

- **Brown earths.** These are considered to be amongst the best soils for cultivation in Ireland, as they generally have good nutrient status and a good drainage capacity.

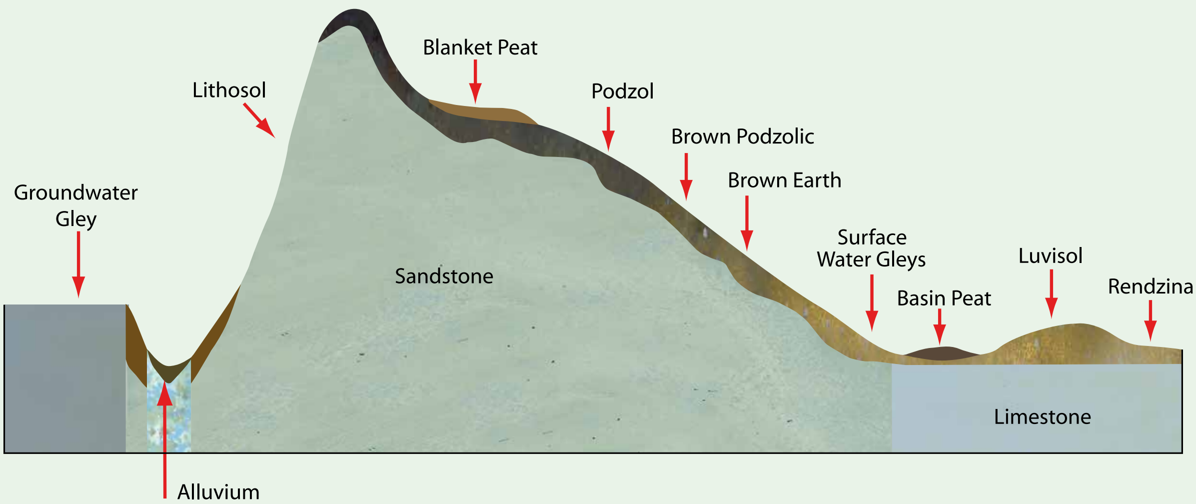


Figure 1. Soil landscapes of Ireland.

Soil and **Drainscapes**

- **Luvisols.** These soils are characterised by a washing of clay from the surface to deeper layers. They generally form over limestone bedrock or in glacial deposits. They can have moderate to imperfect drainage due to the higher clay content in the subsoil. However, these soils can prove to be highly productive where rainfall is not excessive.

3 What are the typical soil and drainage landscapes?

The association of particular bedrock and soil types in different landscape units defines what we call soilscapes and drainscapes. Figure 1 shows the broad distributions of those as found across Ireland.

- **Mountain and Hill soil - and drainscapes** (Figure 2) occur mostly on steep slopes, at an altitude greater than 500m, and mostly on the western seaboard as well as in counties Wicklow, Waterford and Tipperary.

  The soils are mainly shallow and wet. They can be moderately to well-drained lithosols, or more poorly drained, highly organic soils, such as blanket peats and podzols. Water will move quickly downslope, especially in poorly-drained areas, and the water table will be quite deep. For this reason, in the highest parts, water will generally infiltrate from small streams to the groundwater.

Figure 2. Hill and mountain landscape, County Wicklow.

- **Hill soil - and drainscapes** are found at altitudes of 150 to 365 m (Figure 3). These soils develop from shale, sandstone or granite and so are mainly acidic in nature. In these areas, the water table is often shallower than at higher altitude, and groundwater often ends up in local streams, rivers or lakes. Deep wells are often drilled in sandstone to provide a main water supply to industries, farms or towns.

In contrast, shales act more as a barrier for the water to move in the subsurface, while granites contain or transfer only small volumes of water. In some areas, you will observe that the bedrock is fractured. Water can rapidly move through these fractures, unless they are clogged with fine sediments or minerals.

Figure 3. Hill landscape (acidic), County Cork.

Soil and **Drainscapes**

- **Drumlin soil - and drainscapes** (Figure 4) were formed during glacial periods. Drumlins are small oval hills which stand out on a flattish landscape. Drumlins are made from glacial deposits over small rock hills. Generally, glacial deposits can be made up of very fine materials such as clay, which slows water movement, or coarser materials, such as sands and gravels, which allow free to excessive drainage.

Drumlin deposits vary in thickness; thin deposits over rock cores tend to have drier soils on the slopes such as brown earths and brown podzolics, whereas drumlins with thick glacial deposits may have wetter soils on the slopes such as luvisols and surface water gleys. Wet soils can be found at the base of the drumlin (gleys and peats) due to the runoff of water from the slopes. This complex distribution of poorly-drained and well-drained deposits can make it very difficult to predict where water moves on the ground or in the subsurface in this kind of environment.

Figure 4. Drumlin landscape, County Cavan.

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Figure 5. Flat to undulating limestone landscape, County Galway.

- **Flat to undulating lowland soil - and drainscapes** (Figure 5) are found in limestone-dominated areas and give rise to both very shallow soils (e.g. rendzinas in County Clare) and deeper soils found on glacial limestone deposits, such as luvisols and surface water gleys. These soils tend to have moderate to poor drainage. Water travels slowly across intact limestone, but after some time, it can create large fractures (pipes) and cracks in the bedrock through water erosion of the rocks. This phenomenon results in what is called a karst limestone. In this kind of system, water infiltrating into the subsurface can travel very slowly through intact portions of the rock, or very quickly, in the pipe networks and caves often connected to a spring at the base of the slope. On the land surface, large topographical depressions called sinkholes may be found, these are often filled with water, as well as streams ending up in swallow holes.

Soil and **Drainscapes**

Figure 6. Acidic lowland landscape, County Waterford.

- There are also more **acidic soil - and drainscapes** (Figure 6) found on lowland areas which have glacial deposits made up of sandstones and shales, or granite or igneous and metamorphic materials, from surrounding hills and mountains. More acidic soils than in the limestone landscape will be found in these areas (e.g. brown earths and brown podzolics). In areas where there is finer glacial material (i.e. in shale areas), wetter soils such as surface water gleys and groundwater gleys are common.

- **Valley soil - and drainscapes** (Figure 7) are mainly covered in groundwater gleys and organic soils. They are found in small areas all over the country at the base of hills, mountains and in valleys. Shallow wells can be drilled in alluvial deposits to provide large amounts of water by pumping.
  Groundwater will generally move towards the river, but stream water can also infiltrate into these deposits in the vicinity of the stream. These areas are prone to both groundwater and river water-fed ponds in the floodplain, and to spring water-fed ponds at the base of the slopes.

Figure 7. Valley landscape, County Donegal.

Section 2

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Managing and Protecting Soils

Section 2

Section 2

An Introduction to Soil Health

by Fiona Brennan, Giulia Bondi, Owen Fenton, Dermot Forristal, Karen Daly, Lilian O'Sullivan, David Wall

Introduction

Soils are precious finite resources that underpin agriculture in Ireland. Our grass-based animal production and high yielding arable cropping systems rely heavily on the availability of healthy soils to deliver high quality, profitable and sustainable food production on farms. The traditional view of high quality soil, measured by the soils performance for crop production alone, is now considered inadequate, as it does not consider the wider role that managed soils have in the environment and for society. From a food supply point of view, the health status of the soil also extends to food safety, human and animal nutrition and health. In addition to food, feed and fibre production, our managed soils support many other essential soil related services including, the re-cycling of nutrients, sequestration of carbon and regulation of our climate, purification and storage of water and our soils are an important habitat for biodiversity. As an introduction to this topic the following two questions are useful:

1. How do we define soil health?
2. What indicators can be used to assess the health of our managed soils?

chapter 3

An Introduction to Soil Health

① How do we define soil health?

Soil quality (which includes physical, chemical and biological aspects Figure 1) has been described as the soils ability to perform multiple essential functions under changing management and climatic conditions. Recently the concept of 'soil health' has reappeared, with the soil biological community acting as a key driver of soils capacity to deliver these functions. Soil health has been defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans and that can perform a variety of roles which all life on the planet depends upon. In light of this, developing knowledge and understanding of factors affecting soil health and monitoring the trends in soil health over time is required to better manage and protect our agricultural managed soils for future generations.

Figure 1. An examination of the three different aspects of soil quality over time helps build a picture of the health of that soil.

Key point

Soils in agricultural settings have been changed by management over time for e.g. crops growing, cultivation methods, fertilisation etc. The health of a managed soil can be assessed by examining different indicators of soil health applicable to that agricultural system. As with human health it is always good to carry out an initial examination and to follow up with additional assessments where needed. Also the way health is examined will change and progress over time.

Key point

Soil is a finite resource and all aspects of soil health must be managed and balanced for a healthy sustainable soil. No two soils are exactly the same. A healthy soil can facilitate multiple functions at the same time. For example, soil can regulate water supplies, purify water and can act as a habitat for soil organisms.

② What indicators can be used to assess the health of our managed soils?

Not all soil attributes are suitable indicators of soil health. However, certain soil properties play a major role in maintaining soil health, making them suitable indicators. Holistically the health of our soil depends on the interaction and status of the three fundamental characteristics of soils; soil physical, soil chemical and soil biological quality. It should be noted that all of these aspects interact and affect each other e.g. soil organic matter impacts soil structure and also provides food for soil life. Indicators are used during soil examination to assess the quality of each of these characteristics. Moreover, the environment in which soils exist and the management that is exerted on them, impacts on soil health.

Soil Physical Indicators: provide much information about the soil ecosystem and its function. The decline in soil structural quality which leads to soil degradation and compaction is often associated with more intensive management practices. This can also lead to reduced capacity for water to infiltrate and drain through the soil, to store water and to purify water in the landscape. It can also lead to reduced habitat quality for soil biology. Soil structure can be examined in the field with new visual soil assessment methods recently developed for grassland and tillage scenarios. The next two chapters cover how to manage wet and weak soils due to traffic by machines and animals.

Soil Chemical Indicators: provide much information in relation to nutrient cycling, primary production and carbon sequestration functions in soils. In particular soil pH and soil organic matter are identified as key factors, which regulate nutrient availability in soils and the delivery of different soil functions including carbon sequestration and macro/micro nutrient cycling. Soil fertility on farms should be managed by applying fertilisers and organic manures, availing of N fixation opportunities, recycling nutrients, to build up and supply nutrients for production. As soils vary in their fertility, nutrient management planning must be tailored to soil types, and crop offtakes, to achieve the correct nutrient balances. Improving precision would benefit production and the environment.

Linking soil fertility knowledge to soil types and managing soils appropriately will support sustainability and soil heath into the future.

Some farmers might not be aware of soil fertility, soil chemical status or soil nutrient status on each field within their own farm, due to a lack of soil testing, and may overestimate or underestimate the nutrient application rate. Increased farmer awareness and advice is required to address field scale soil fertility issues and to develop a specific suitable fertiliser plan. However, the attention needs to shift from a quantitative approach, based only on the evaluation of chemical features, to a qualitative approach that also considers other factors such as: soil type, aspect and geographical position, hydrogeology and drainage characteristics, management and grass type.

Soil Biological Indicators: provide valuable information on the effects of past and current management on soil health. Soil biology has been described as the "engine of the soil" and soil biodiversity and the soil microbiome is at the centre of soil functioning. Soil organisms play a critical role in nutrient, vitamin and hormone supply to plants, climate regulation and carbon sequestration, maintenance of soil structure, resistance of crops to abiotic stresses, and in defence against pests and diseases. Thus, it is clear that to fully understand our soils, and how to manage them, we need to understand this biological aspect and how it interacts with the soil physical and chemical properties (Figure 2).

Figure 2. Twin Agricultural management practices such as cover cropping can enhance the soil environment for organisms such as earthworms.

An Introduction to Soil Health

Key point

Managing our soils in a way that protects the soil habitat and supports diverse soil biological communities facilitates the functioning, resilience and sustainability of our soils.

Key fact

Soil biology is least well understood aspect of soil health, largely due to historical technological constraints. However, with new tools and increased research efforts in this area this is changing, and a window is being opened on soil biological communities. Soils harbour a staggering diversity and abundance of life from the microscopic to the larger macrofauna making assessment of the biological health of our soils complex. The organisms present differ from soil to soil and from environment to environment so what is healthy for one soil may not be healthy for another, requiring bespoke management and holistic assessment. However, a range of biological indicators are currently being developed which can be utilised to assess soil biological health. Some indicators require sophisticated analysis of soil biological health (Figure 3), which may not always be practical for routine in-field soil health assessments but these are being combined with non-specialist tools that can be employed at farm level for e.g. earthworm counts, physical health visual assessment tools (such as VESS), chemical assessments (such as soil carbon) and biological functioning assessments (such as the capacity of the community to decompose or respire).

Key point

While our knowledge of the soil biology has lagged behind the physical and chemical aspects of soil, new technological advances are offering revolutionary advances in our understanding of the life within soil and the development of new biological indicators.

Figure 3. Molecular approaches are enabling us to understand soil microbial communities in far greater depth than was previously possible.

Section 2

Managing Wet and Weak Soils

by **Dermot Forristal**

Introduction

Whether land is drained or not, appropriate management strategies must be put in place to protect the soil when it is wet. This will ensure that the land will stay productive and that grass can be utilised effectively. The extent of the wet land challenge will depend on: the soil type and drainage status; annual rainfall, seasonal weather variation and the intensity of production.

1. **What problems can arise with animal or machinery traffic on wet soils?**
2. **What machinery strategies will optimise performance on wet land?**
3. **How does compaction harm the soil and affect our crops?**
4. **What options are available to reverse or alleviate compaction?**
5. **When should subsoiling be considered and how should the subsoiling operation be carried out?**

chapter 4

Managing Wet and Weak Soils

① What problems can arise with animal or machinery traffic on wet soils?

When soils are wet, their ability to support animal or machinery traffic is reduced; this causes a number of problems:

- **Trafficability:** The soil can simply be too wet to sustain continuous machinery or animal traffic due to the danger of sinking or excessive surface damage. Trafficability problems can disrupt all operations but impacts on critical tasks like silage harvesting can affect silage quality and mid/late season grass availability. Tillage operations can also be delayed resulting in crop yield losses.

- **Surface damage:** Ruts from wheels and poaching by animals can reduce grass yield and reduce the percentage of productive grasses in the sward. The soil near the surface may be damaged, reducing surface water drainage and grass or crop growth potential in the longer term.

- **Sub-surface damage (compaction):** When soils are wet or moderately wet, animal or machinery traffic can compress or compact the soil which reduces water drainage and impedes grass and crop growth. Sub-surface damage is often not obvious at the surface.

All soils are prone to compaction and trafficability problems. Wet, poorly-drained soils can present problems for much of the season but even free-draining soils will be prone to compaction and trafficability challenges in wet periods. Once caused, compaction is not easily resolved.

Key risks

- Tractors of 120 kw (160 hp) are in common use today and typically weigh 6 t in use with even heavier power units of up to 10 t not uncommon. Silage trailers in excess of 5 t empty, increasing to more than 15 t when laden, are widely used. On tillage farms, a high capacity combine can weigh in excess of 25 t. Tyre sizes are often inadequate for the loads carried.

- Using contractors for machinery operations, while sensible from a cost and labour perspective, reduces control over the timing of machinery operations. This, coupled with the extreme weight of some contractors' equipment, increases the threat to soils.

- Extending the grazing season has resulted in more animal traffic early in spring and late in autumn when ground conditions may be challenging. This places extra pressure on the soil and swards and must be carefully managed.

- Increasing intensity on progressive livestock farms brings with it an increase in stocking rate and consequent extra pressure on the soil.

- The pursuit of economies of scale on tillage farms coupled with more vulnerable low organic matter soils, increases the risk of soil structure damage.

- Reseeding is necessary to increase grass quality and animal performance. Newly established swards are easily compacted and the proportion of higher yielding new grasses in these swards can be rapidly reduced if soils are damaged by animal or machinery traffic.

How to

Improve trafficability to ensure timely field operations and reduce surface damage.

- In some situations, drainage will be an option to improve trafficability, however on many slow-draining soils, trafficability issues will still arise in wet periods.

- Traffic management is hugely important. Restricting both animal and machinery traffic in wet periods can help avoid trafficability problems and improve the bearing capacity of the soils by preventing damage to the sward and soil surface. However, certain machinery traffic operations cannot be delayed without huge potential crop/grass losses.

Key point

Correct wheel/tyre combinations for the loads being used coupled with attention to detail in all areas of machinery selection and use can improve machine performance significantly in difficult conditions.

② What machinery strategies will optimise performance on wet land?

Improving performance involves reducing wheel loads; using bigger tyres; and driving appropriately. All machinery operations can be affected by trafficability issues on grassland but silage harvesting is most critical because of the loads involved and the critical harvesting 'window'. Working on cultivated soils poses the biggest threat on tillage soils.

The strategies discussed here to improve trafficability are the same as those required to deal with preventing compaction (see page 36).

Weight Reduction

- Baled silage systems greatly reduce the axle loads involved compared with pit silage. Limiting trailer size, even if it necessitates an additional tractor and trailer, can make lower ground pressure easier to achieve when making pit silage.

	Weight loaded (t)	Main axle load (t)
Self-propelled forager	13.5	9.5
Loaded 5.5 m trailer	17.0	12.0
Loaded trailer tractor (100 kW)	9.0	7.0
Standard baler with bale	3.8	2.5
Baler/wrapper combination	6.7	5.0

Table 1. Typical axle loads of silage machinery.

- If a contractor has to operate 4 trailers of 4.8 m length instead of 3 of 6.1 m length, it will cost more. This cost may be well worth incurring if it allows timely harvest with reduced soil damage. Correct tyre selection is critical for all.

Tyres and ground pressure

- For a given load, the use of larger tyres will reduce ground pressure and greatly improve performance. Ground pressure is simply the weight carried by the tyre divided by the contact area between the tyre and the ground. The greater the axle load, the bigger the tyre required to reduce ground pressure.

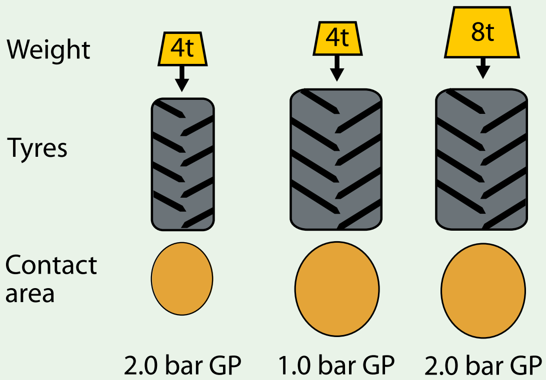

Figure 1. Ground pressure is determined by the weight and the size of its contact area with the ground. For a given load, fitting a larger tyre will increase the contact area and reduce ground pressure. Alternately, if the load is doubled, a larger tyre with twice the contact area will maintain the same ground pressure.

- We can use the required inflation pressure for a tyre to indicate its ground pressure. All tyres have load and inflation pressure tables which indicate the inflation pressure required for a specific wheel load at a particular speed (Table 2). As it's the air within the tyre that supports the load, a big tyre can support a load at a low inflation pressure and consequently low ground pressure (LGP).

How to

Select a tyre.

- Know your axle load (by one-off weighing);
- Know your target ground pressure / inflation pressure;
- Select a suitable tyre that will achieve the target pressure;
- Consider new technology high deflection tyres (VF and IF) which produce larger contact areas and reduced ground pressure;
- Consider other tyre aspects like diameter, tread pattern and carcass flexibility.

Very large axle loads will require large tyres which may be difficult to fit on some trailers or implements.

Managing Wet and Weak Soils

Load carrying capacity (kg/tyre) at various inflation pressures for 4 tractor tyres.

			Load per tyre (kg)			
			Inflation Pressure (bar)			
Size	Circumference (mm)	Volume (litres)	0.6	0.8	1.0	1.6
18.4R38	5258	431	2090	2315	2540	3210
600/65R38	5229	500	2370	2760	3150	4200
650/65R38	5380	602	2650	3090	3530	4740
VF650/65R38	5380	602	3305	3900	4435	5915

Table 2. This load and inflation pressure table clearly shows the effect of tyre size on load carrying capacity or, conversely for a given load, the effect of tyre size on the required inflation pressure. The VF650/65R38 tyre for example can carry 3305 kg at just 0.6 bar inflation pressure compared to the 18.4R38 requiring 1.6 bar for 3210 kg. As it is the air within the tyre which supports the load, when a tyre is inflated to the correct pressure for the load, that inflation pressure value is a good guide to the ground pressure it exerts. ***Low inflation pressure requirement = Low Ground Pressure***.

Tyre selection example:
120kw tractor and 5 furrow plough

1. Check axle load:
- a. Tractor weight: 6.8 t
- b. Plough weight: 2.1 t
- Rear axle load: 7.8 t

2. Target pressure: <1.0 bar

3. Tyre options:
- a. 600/65R38: 1.5 bar
- b. 650/65R38: 1.2 bar
- c. VF 650/65R38: 0.9 bar

4. In this case the VF 650/65R38 tyre is required to meet the target pressures.

Tyre types, diameter and other factors

- VF and IF designated tyres have more flexible carcasses allowing them to run at lower pressures with increased tyre contact area.
- Larger tyre diameters can greatly improve performance in wet conditions by keeping equipment mobile. When a tyre sinks due to rut formation, a large diameter will usually enable the wheel to continue to roll forward and 'climb' out of the rut, greatly reducing rolling resistance and the chances of getting 'stuck' in these situations. However trailer and machine design often restricts the tyre diameter that can be used. Developments like 'recessed wheel' slurry tankers show how simple design changes can accommodate large diameters.
- Tyres with pliable carcasses and in particular flexible sidewalls are most suitable for low ground pressure use. Stiff carcass tyres, designed for high pressure use, generally result in a higher ground pressure than their inflation pressure might indicate. Look for tyres capable of working at low pressures (0.4 to 0.8 bar) as this usually indicates a flexible carcass.
- A traction type tread pattern (but fitted in reverse) will help keep a trailer tyre turning in wet conditions.

Target ground pressures for different operations.

Tyres capable of operating at inflation pressure (bar)	Machines / Operations	Examples
<0.5	**Machines working on extremely weak* soils** *weak structured or weak due to moisture content or looseness	• Early fertiliser spreading on very wet land • Quads / ATVs • Silage harvesting in extremely wet/weak soil conditions • LGP spraying on tillage soils etc.
0.5 - 0.8	**Machines working on very weak soils**	• Early season fertiliser spreading in wet conditions • Slurry application in wet conditions • Silage harvesting on very wet land • All machines working on cultivated soils, e.g. one-pass sowing, cultivation, rolling
0.8 - 1.0	**Machines working on weak soils**	• Silage harvesting on wet land • All operations (fertiliser/slurry etc.) on moderately wet land • Ploughing • Combines in wet conditions
1.0 - 1.5	**Machine operations on dry land over a range of conditions**	• The complete range of operations
>1.5	**Machines fitted with tyres requiring this pressure should only operate when field conditions are very dry and no tyre impression on the soil is being caused**	

Table 3. The lower pressures suggested in this table can be very difficult to achieve with high axle load trailers (e.g. silage trailers). This illustrates how challenging these operations are and the high level of risk of soil structure damage if heavy loads are imposed at high ground pressures on weak soils.

Driving pattern

- Good planning of driving routes, field entrance and exit and careful driving in the field can make a difference to mobility. Before working a wet field examine it and plan carefully. Consider opening additional, well-placed, gateways if helpful. Drive smoothly at all times and be prepared to take action if traction begins to fail. Encourage all drivers, including contractors, to adopt this approach.

Managing Wet and Weak Soils

3 How does compaction harm the soil and affect our crops?

- All soils have a structure which is an arrangement of the soil aggregates and pore spaces between them. The larger pores accommodate root growth, facilitate drainage and allow exchange of gases. Soil aggregates are formed naturally and are made up of soil particles and organic material. While the high organic matter component of grassland soils helps build good aggregate structure, different soil types have different soil structures.

- Where soil aggregates are pressed together reducing the pore space (from >50% to 40% or less) we say compaction has occurred. This 'tighter' soil directly impedes growth, reduces drainage and inhibits gas exchange. Access to nutrients and nutrient cycling are reduced and, in dry periods, the restricted root growth can result in drought stress.

- In Irish conditions, grass yield drops of up to 31% due to compaction have been recorded in Teagasc trials. Tillage crop yields are also affected. While some compaction may have a short-lived effect on yield, compaction typically has a negative effect on yields for 2 to 7 years.

- Compaction can be shallow (<150 mm) or deep (>150 mm) depending on the cause. Heavy machinery compaction will frequently cause deep compaction with axle loads >6 t causing problems at depth. While remedial measures are possible, research shows that 'prevention is better than cure' when it comes to dealing with compaction, as deep soil loosening often leaves the soil at risk of further compaction.

Figure 2. Different axle configurations can help distribute the load on the soil, but the tyres must be large enough to reduce ground pressure.

The effect of conventional, LGP (low ground pressure) and zero silage harvesting traffic on grass yields on a dry site (Oak Park) and a wet site (Kilmaley)

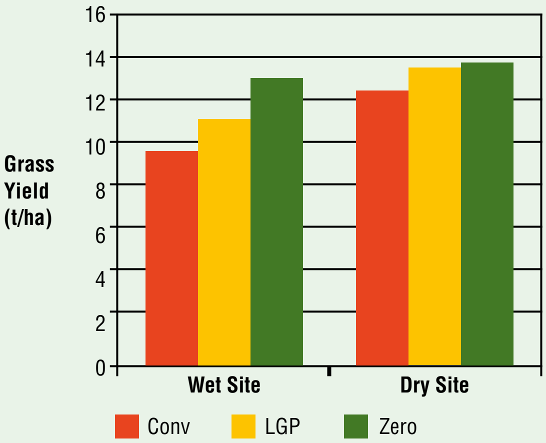

Figure 3. In a detailed field trial, the effect of silage harvesting traffic on grass yield was determined over three years on a wet-land site at Kilmaley, Co. Clare and a dry site at Oak Park, Carlow. Conventional traffic (Standard loads and conventional tyres), Low ground pressure traffic (Standard loads with much larger tyres running at low pressures) and Zero (no wheel traffic on plots) traffic systems were compared. Soil surface damage was avoided. After three seasons there were substantial differences in grass yield, confirming that compaction can have a serious impact on grass yields in our climate.

Checklist

Factors influencing soil damage.

- The most important factor is soil moisture content.
- Very dry soils resist compaction.
- Once soils are wet, they are structurally weak; the aggregates are lubricated and slide easily into a compacted structure.
- The presence of a crop and its root structure help resist compaction while cultivated soils are weakened and vulnerable to compaction.
- Intensive and deep cultivation for potatoes or veg crops can leave the soil particularly vulnerable to structural damage.

How to

Determine whether soils are compacted.

- There are a number of physical measurements which are used in experimental trials. A cone penetrometer and/or shear vane tester both measure soil strength with higher strength values indicating compaction. While these are useful in comparative trials, they are of limited use in a field investigation where soil moisture variation can cause huge strength variations. Other measurements such as bulk density are not easily carried out.
- Visual soil assessment techniques are useful in the field. This typically involves digging out an intact soil 'mini profile' with a spade (the size of the spade) and examining the mini-profile on the spade. A number of assessments should be carried out in areas of the field where compaction may be suspected.

Checklist

Indicators of soil compaction.

- Horizontal type structures or fracture lines can indicate compaction, whereas vertical fissures frequently indicate a good structure through which roots and earthworms can easily move.
- When the soil mass is handled and teased apart (or it can be dropped onto a hard surface), the immediate disintegration into crumb type aggregates indicates good structure, whereas the tendency to break into blocky or plate-like elements with angular faces may indicate compaction.
- Extensive root development through the profile and the presence of earthworms or earthworm casts are evidence of good structure.

Visual soil assessment should be carried out where there are indications of compaction at the surface such as poor growth or yellowed grass/crop in parts of the field that suggest machinery (headlands and/or individual wheel tracks) or animal (congregation areas) compaction. Ponding is another indicator which may suggest soil structure damage.

Managing Wet and Weak Soils

Visual Evaluation of Soil Structure

There are a number of visual evaluation techniques and Teagasc have worked primarily with two of these:
VESS: Used for assessing the structure to a depth of 20-25 cm and developed by Ball (SRUC) and Guimares (Maringa University, Brazil).

DS: Used for assessing structure from 0 to 40 cm, developed by Teagasc (Emmet-Booth, Bondi, Forristal) and UCD (Holden).

The VESS method is a simple test which assesses soil structure based on the appearance and feel of a block of soil dug out with a spade and is described here. The scale of the test ranges from Sq1, good structure, to Sq5, poor structure. The DS technique is similar with more details found at: https://www.teagasc.ie/crops/soil--soil-fertility/soil-quality

Equipment:
Garden spade approx. 20 cm wide, 22-25 cm long. Optional: light-coloured plastic sheet, sack or tray ~50 x 80 cm, small knife, digital camera.

When to sample:
Any time of year, but preferably when the soil is moist. If the soil is too dry or too wet it is difficult to obtain a representative sample. Roots are best seen in an established crop or for some months after harvest.

Where to sample:
Select an area of uniform crop or soil colour or an area where you suspect there may be a problem. Within this area, plan a grid to look at the soil at 10, preferably more, spots. On small experimental plots, it may be necessary to restrict the number to 3 or 5 per plot.

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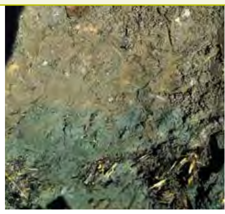
Method of assessment	Step	Option	Procedure
Block extraction and examination	**1.** Extract soil block	Loose soil	Remove a block of soil ~15 cm thick directly to the full depth of the spade and place spade plus soil onto the sheet, tray or the ground.
		Firm soil	Dig out a hole slightly wider and deeper than the spade leaving one side of the hole undisturbed. On the undisturbed side, cut down each side of the block with the spade and remove the block as above.
	2. Examine soil block	Uniform structure	Remove any compacted soil or debris from around the block.
		Two or more horizontal layers of differing structure	Estimate the depth of each layer and prepare to assign scores to each separately.
Block break-up	**3.** Break up block(take a photograph - optional)		Measure block length and look for layers. Gently manipulate the block using both hands to reveal any cohesive layers or clumps of aggregates. If possible separate the soil into natural aggregates and man-made clods. Clods are large, hard, cohesive and rounded aggregates.
	4. Break up of major aggregates to confirm score		Break larger pieces apart and fragment them down to pieces of 1.5 - 2.0 cm. Look to their shape, porosity, roots and ease of break up. Clods can be broken into non-porous aggregates with angular corners and are indicative of poor structure and higher score.
Soil scoring	**5.** Assign score		Match the soil to the pictures category by category to determine which fits best.
	6. Confirm score from:		**Factors increasing score**
		Block extraction	Difficulty in extracting the soil block.
		Aggregate shape and size	Larger, more angular, less porous, presence of large worm holes.
		Roots	Clustering, thickening and deflections.
		Anaerobism	Pockets or layers of grey soil, smelling of sulphur and presence of ferrous ions.
		Aggregate fragmentation	Break up larger aggregates ~ 1.5 - 2.0 cm diameter fragments to reveal their type.
	7. Calculate block scores for two or more layers of differing structure		Multiply the score of each layer by its thickness and divide the product by the overall depth, e.g. for a 25 cm block with 10 cm depth of loose soil (Sq1) over a more compact (Sq3) layer at 10-25 cm depth, the block score is (1 x 10)/25 + (3 x 15)/25 = Sq 2.2.

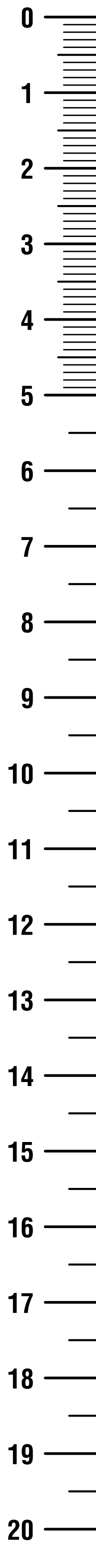
Scoring: Scores may fit between Sq categories if they have the properties of both.
Scores of 1-3 are usually acceptable whereas scores of 4 or 5 require a change of management.

Continues overleaf...

Managing Wet and Weak Soils

Structure quality	Size and appearance of aggregates	Visible porosity and roots	Appearance after break-up: various soils
Sq1 **Friable** Aggregates readily crumble with fingers.	Mostly <6 mm after crumbling.	Highly porous. Roots throughout the soil.	
Sq2 **Intact** Aggregates easy to break with one hand.	A mixture of porous, rounded aggregates from 2 mm - 7 cm. No clods present.	Most aggregates are porous. Roots throughout the soil.	
Sq3 **Firm** Most aggregates break with one hand.	A mixture of porous aggregates from 2 mm - 10 cm; less than 30% are <1 cm. Some angular, non-porous aggregates (clods) may be present.	Macropores and cracks present. Porosity and roots both within aggregates.	
Sq4 **Compact** Requires considerable effort to break aggregates with one hand.	Mostly large >10 cm and sub-angular non-porous; horizontal/platy also possible; less than 30% are <7 cm.	Few macropores and cracks. All roots are clustered in macropores and around aggregates.	
Sq5 **Very compact** Difficult to break up.	Mostly large >10 cm, very few <7 cm, angular and non-porous.	Very low porosity. Macropores may be present. May contain anaerobic zones. Few roots, if any, and restricted to cracks.	

Appearance after break-up: same soil different tillage	Distinguishing feature	Appearance and description of natural or reduced fragment of ~ 1.5 cm diameter	
	 Fine aggregates	1 cm 	The action of breaking the block is enough to reveal them. Large aggregates are composed of smaller ones, held by roots.
	 High aggregate porosity	1 cm 	Aggregates when obtained are rounded, very fragile, crumble very easily and are highly porous.
	 Low aggregate porosity	1 cm 	Aggregate fragments are fairly easy to obtain. They have few visible pores and are rounded. Roots usually grow through the aggregates.
	 Distinct macropores	1 cm 	Aggregate fragments are easy to obtain when soil is wet, in cube shapes which are very sharp-edged and show cracks internally.
	 Grey-blue colour	1 cm 	Aggregate fragments are easy to obtain when soil is wet, although considerable force may be needed. No pores or cracks are visible usually.



Managing Wet and Weak Soils

How to

Prevent compaction by animals/machines.

- The approach is similar to improving performance in difficult trafficability situations. Determine a target ground pressure and select tyres large enough to carry their load at these target pressures. All of the recommendations for tyre selection for trafficability apply in the case of compaction also and you should refer to pages 27 - 29 for solutions.

- The effect of axle load on compaction should not be underestimated. Research shows that even where the same ground pressures can be achieved (i.e. by fitting larger tyres for bigger loads), the effect of a large axle or wheel load is transferred deeper into the soil profile.

Key point

With larger axle loads, the aim should be to have even lower ground pressures than with lighter loads. In practice, this is rarely achieved. Trailers in particular often combine very high axle loads with high ground pressures.

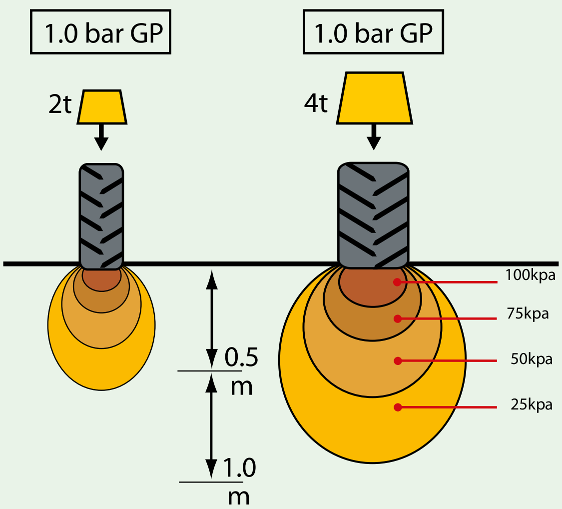


Figure 4. Where the same ground pressure is achieved with a heavy axle load, the effect tends to be transmitted deeper into the soil profile. This means that with bigger axle loads, even lower ground pressures should be sought to minimise the risk of soil structure damage.

How to

Avoid compaction by animals.

Avoiding compaction by animals is mainly controlled by good grazing management. Adequate feed supplies allow a flexible management approach to grazing at all times of the year, but particularly early and late in the season. Paddock design, stand-off areas and active grazing management all have a role to play in minimising animal damage and this is dealt with in Chapter 5.

4 What options are available to reverse or alleviate compaction?

- Leaving the soil to recover may be a viable option where the damage is not too severe. Depending on their clay content, all soils will tend to swell when they get wet and shrink when they dry, resulting in some cracking and re-structuring of the soil. If further damage can be avoided (by managing machine and animal traffic), this may be a practical solution where the damage is not excessive.

- Where compaction is shallow (<150 mm), shallow loosening with spiker/aerator may be an option.

- Where compaction is deeper (>150 mm), deep loosening with a subsoiler or pan buster may be considered, but deep loosening does have its disadvantages.

- Where reseeding is being considered, a range of loosening options may be considered.

How to

Decide if aeration has a role.

- Shallow loosening with spikers or aerators, which have horizontal ground-driven tine rotors, should be considered where shallow compaction is suspected.

- Research indicates that the response from spiking can be very variable. A Teagasc trial series over a range of sites showed little consistent benefit from spiking even where there was known compaction. Where a positive grass growth response is achieved, the effect may be very short term.

- Where there is a shallow, discrete, compacted layer however, there may be a good response to spiking and this has been documented. However, deeper compaction will not be resolved by spiking.

5 When should subsoiling be considered and how should the subsoiling operation be carried out?

- Sub-soiling, pan-busting and deep loosening are all terms used to describe a loosening or cultivation action carried out to a depth of 150 mm or more in grass land, or 300 mm or more in tillage crops. This loosening can relieve compaction, improve root penetration and water infiltration; but it is an expensive operation and it can sometimes create more problems than it solves.

- Deep loosening actions should only be carried out where there is a known compaction problem at depth, which is unlikely to resolve itself over time. Deep loosening can cause a reduction in grass growth due to root damage and temporary drought stress. It can also smear the soil where conditions at depth are not dry enough.

Key risk

A deep-loosened soil is quite prone to re-compaction as the loosened soil is easily damaged by heavy machinery particularly if the soil moisture content at depth is high. In this situation there is a risk that instead of eliminating a problem, sub-soiling can shift the problem deeper into the soil making it more difficult to resolve! Proper management of sub-soiling is critical.

- If there is a known problem and sub-soiling is being considered, it should only be carried out at a depth just beneath the compaction layer, to avoid making the soil vulnerable to re-compaction at greater depths. The leg spacing should be related to the working depth to give an even soil lift and good shatter. For example with a winged sub-soiler, the leg spacing should normally be twice the working depth i.e. if sub-soiling to a depth of 350 mm, the leg spacing should be 700 mm or less. On grassland, a disc in advance of the sub-soiler leg and a roller / packer after the leg should reduce the amount of surface damage caused.

- The soil must be dry to the working depth to get the required shatter to loosen the soil; this usually requires a prolonged spell of dry weather prior to the sub-soiling operation. Typically the end of a dry summer is a good time for sub-soiling as conditions are dry, and the following winter gives time for the soil to settle and for roots to repair.

- Perhaps the most important factor in any sub-soiling operation is the soil management required to avoid re-compaction, particularly over the following season when the soil is prone to re-compaction. Animal and machine traffic must be kept off the land when it is wet, and the density of traffic and tyre equipment on machinery should be adjusted to avoid damage. Remember, sub-soiling is not a cure-all; at best it's a temporary action, with uncertain effectiveness, which may give you a chance to get your soil management in order.

Section 2

Managing Livestock on Heavy Land Soils

by Ger Courtney, John Maher

Introduction

Over 33% of milk production in Ireland is carried out on so-called 'heavy' soils. These soils are restricted by poor drainage capacity. Land is easily compacted when wet and drainage may be impaired. Grass utilisation is difficult as treading by cows' feet damages pasture. Often these soils occur in areas of high annual rainfall.

1. What steps can I take to improve the natural drainage of a field?
2. How do I set up my grazing system to minimise soil damage?
3. What tactical management decisions should I make to minimise soil damage?
4. How do I maintain animal performance during poor weather?
5. What are the grass management targets for a 'Heavy Soil' dairy farm?

Managing Livestock **on Heavy Land Soils**

① What steps can I take to improve the natural drainage of a field?

Key point

Many open drains can become blocked or partially blocked due to a build-up of silt/soil and scrub over time. These provide an essential outlet for excess water to leave a field/paddock and must be regularly maintained (see Chapter 13).

How to

Encourage natural drainage by the sward on heavy soils.

- Soil test, then enhance soil fertility with fertiliser and lime as necessary to encourage productivity.
- Rushes and weed grasses may invade in wet years, reducing the percentage of productive species in the sward. The weather 'windows' to reseed may be fewer and shorter on heavy land but reseeding helps eliminate less productive species and can be hugely beneficial for sward productivity.
- A vigorously growing sward encourages natural drainage in a field as plant roots help overcome compaction and generate new drainage channels down through the soil profile.
- A highly productive sward will naturally draw more moisture from the profile than a less productive one.

Key fact

Annual grass growth will be reduced by up to 50% on heavy soils by poaching depending on the frequency and timing of when it occurs. The impact is greatest when another poaching event happens in a subsequent round of grazing.

② How do I set up my grazing system to minimise soil damage?

- Get a map of the farm with areas for each field/ paddock. Colour code paddocks which, from your experience, are more susceptible to soil damage in wet weather and build this knowledge into your management plan.
- Determine paddock layout - ensure paddocks are square/rectangular. The ideal depth:width ratio is 2:1. Avoid long narrow paddock layouts - they require too much walking over ground to graze the back of the paddock (see Figure 2).

Key goal

Maximum depth of 150 m from Farm Roadway to end of paddock, with a network of spur roads to facilitate access to all areas. Ideally, no grazing area should be more than 50 m from a roadway/spur road.

Grazing Infrastructure

To maximise grass utilisation and minimise damage to pasture on heavy soils it is critical to have:

- A good network of farm roadways;
- A well laid out paddock system;
- Multiple water access points.

Ground conditions are often difficult on farms with heavy soils. It is inevitable some damage will be done; therefore it is essential that when animals come off a damaged area they do not go in there again until the next rotation. This cannot be done without an adequate farm roadway system and an easy-to-operate paddock system with multiple access/exit points and easy access to water for cows. Cow paths or spur roadways may need to be considered.

It is vital to consider the quality of your grazing infrastructure and acknowledge where deficits have arisen in recent years. An audit of grazing infrastructure can be carried out to assess paddock size, shape and access points; extent, quality and condition of the farm roadway network and any connections between roadway runoff and water bodies which would contravene regulations) and access to drinking water in paddocks. Ideally enlist the help of your advisor or another farmer to bring an outside perspective.

Increases in herd sizes have placed pressures on existing infrastructure which has knock-on effects on grass utilisation, cow performance and health and labour input. Maximum grazing efficiency will not be achieved unless all grazing infrastructure is sufficient for the needs of the farm.

Slurry Storage

Longer winters mean more slurry storage. Many farmers who farm on heavy soils have adequate slurry storage and housing for the existing herd. However expansion will require more slurry storage and animal housing. Slurry management is a significant challenge on farms with heavy soils. You must avoid being forced to spread slurry due to inadequate storage.

Key points

- Ensure roadways are designed to comply with nitrate regulations and prevent direct runoff of surface water from farm roadways to waters (includes open ditches and surface waters).
- Paddock size should allow for 2-3 grazings during the main grazing season.
- Be flexible in setting up paddock fences - allow for at least two entries off the roadway to each paddock, and ensure there is provision to drop the fence easily.
- Water troughs of adequate size should be located in the centre of paddock with potential access from both sides.
- Reseed the paddocks that have the most open swards. Use grass varieties rated highest for ground cover score. (Ground cover rating of 7 or higher for late perennial ryegrass varieties).
- Soil fertility (including lime) must be at optimum levels to ensure maximum growth response and survival of ryegrass in the sward.

Key goal

Set up your paddock system so that stock never have to walk over previously grazed areas. These areas are particularly vulnerable to damage.

3 What tactical management decisions should I make to minimise soil damage?

The growing season will be shorter on heavy farms but the peak growth rate may be higher than on other soils. This must be harnessed to maximise the amount of quality silage harvested. Making round bale silage from surplus, high quality grass, will keep grass supply under control and provide quality short-term feed in times of deficits and/or poor grazing conditions. There should be a great emphasis on quality silage as cows will end and begin their lactation on some silage.

- On-off grazing (where animals are allowed to graze for 2-3 hours and then removed from the field) is ideal during low- to moderate- poaching risk weather (see Figure 1). However, in a broken weather spell, when soil is close to saturation, full housing is the only option.

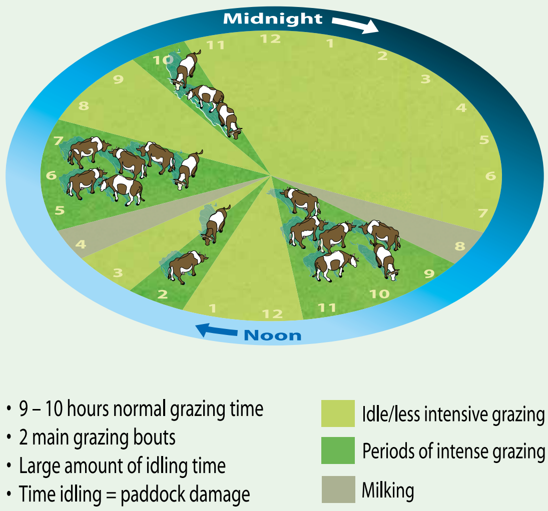


Figure 1. Natural grazing pattern of dairy cows. Cows tend to do most damage to swards when they are not grazing intensively. They can be restless and move around, particularly in poor weather. On-off grazing makes use of the cows' natural grazing pattern to ensure they have enough time to graze. Cows are removed from the paddock when idle.

Key risk

Heavy rain. Play it safe and always remove stock before heavy rainfall.

Managing Livestock **on Heavy Land Soils**

- Highly vulnerable paddocks should be identified and used for silage conservation rather than grazing. Timing the silage harvest can be difficult but avoiding a number of potential poaching events is essential.
- Paddocks rated by you as most susceptible to damage must be grazed during 'windows' of drier weather even where this involves diverging from a rotation based on pre-grazing grass covers. Paddocks with open swards on heavy soils are generally the most susceptible to damage.

In difficult weather conditions:

- Backfence after each grazing (so animals can't return to grazed ground). Soils are at their most vulnerable immediately after grazing, when the sward is open.
- Accept an increased grazing residual cover if necessary to avoid soil damage.

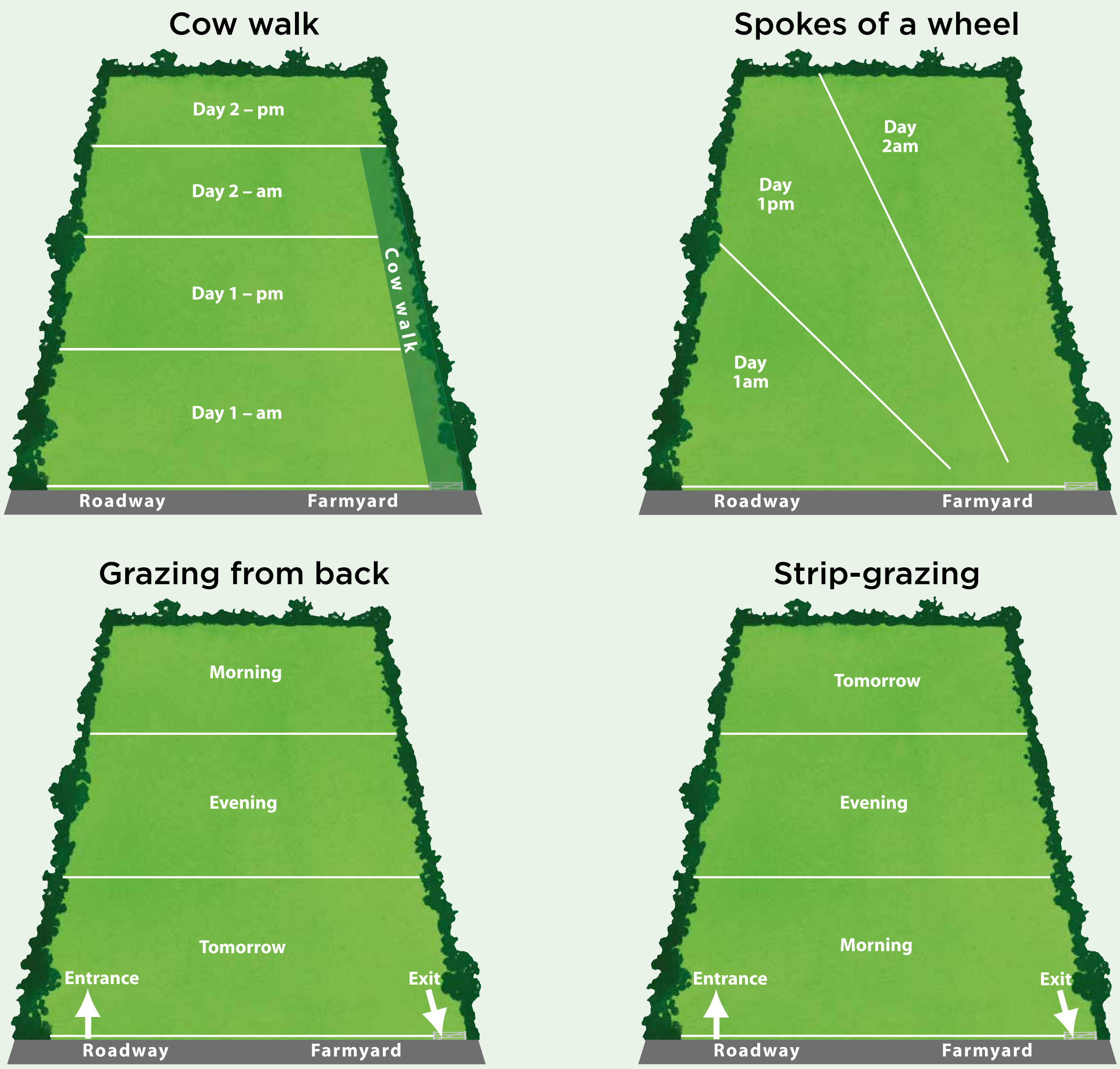


Figure 2. Grazing techniques. Four options to manage grazing to minimise animal damage to swards. Backfencing is vital to prevent animals walking back onto (vulnerable) grazed ground. Cows will always want to leave the field at the exit nearest the farmyard so in this case they enter on the bottom left and leave bottom right.

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4 How do I maintain animal performance during poor weather?

- Target 5-8 kg grass dry matter in the cow's daily diet. On-off grazing for about three hours when cows have full appetite will ensure this grass intake is achieved.
- Supplement with high quality bale silage and concentrates to maintain full intake.
- Dairy farms on heavy soils require a reserve of 0.5 tonnes dry matter of high quality silage (+ 70 DMD) per cow in addition to normal winter silage stocks.
- Forward purchase feed straights (e.g. soya hulls) if the price represents good relative value. Adequate storage and feed space is required. Allow 600mm per cow feed space when feeding concentrates.

Key goal

Plan for a reserve of 2.5 to 3 high quality silage bales/cow/annum.

5 What are the grass management targets for a 'Heavy Soil' dairy farm?

Key facts

- Grass swards on heavy waterlogged soils have slower growth rates in spring and give a lower response to applied nitrogen.
- The grazing season is shorter on heavy soils. Aim for dairy cows to be 250 days at grass each year.

Key management goals

- To maximise grass utilisation aim for a calving start date of Feb 10th in a spring-calving system with a 90% six week calving rate.
- Graze 1/3 of the grazing area by March 17th. This will allow a significant proportion of the farm to receive slurry applications (including additional paddocks with low grass covers). An additional 1/3 should be grazed by April 1st.
- Match N applied to grass growth rates as this varies over the spring. Apply up to 30 kg N/ha (24 units N/ha) maximum in the 1st split and avoid fields that have received an application of cattle slurry.
- Finish first round grazing by April 15th. If grass growth is good, close and fertilise 30% of area for high quality silage harvested in mid-late May.
- Maintain mid-season grass cover at 180 - 200 kg DM/cow.
- Avoid pre-grazing covers of greater than 1,700 kg/ha as they are difficult to manage on heavy farms.
- Have a strict policy of removing surplus grass for baled silage as weather and ground conditions allow. Often grass quality deteriorates during wet spells and the better grass quality which results after removing the surpluses (which may be of poor quality) makes autumn grass management easier.
- Build autumn grass covers from mid-August.
- Blanket spread the last N application by mid-late August.
- Extend rotation length by two days/week, e.g. 22 days on Aug 15th up to a maximum of 30 days by Sept 15th.
- Calculate the daily area allocation by dividing total area by target rotation length, e.g. 30 ha available on a 25 day round therefore allocate 1.2 ha/24 hours.
- In broken weather allocate a fresh break of grass after each milking to protect paddocks from poaching.

Managing Livestock on Heavy Land Soils

- Be flexible - graze the lower grass covers during wetter periods with the on-off grazing technique but monitor total intake.
- Where silage feeding is required to maintain intake bring cows in two hours before evening milking and feed silage at the barrier. In that case the daily grass allocation is smaller.
- Target peak cover of 850 kg DM/ha by mid-September on heavy farms and 1,000 kg DM/ha on mixed farms.
- Close first paddocks from October 1st.
- Target full closure by November 10th at farm cover of 550 kg/ha.
- Soil pH should be corrected before embarking on a soil P buildup programme. This will maximise response from all nutrient applied and prevent losses. The farm liming programme must comply with nitrates regulations.
- Apply P & K fertilisers on a little and often basis throughout the growing season in accordance with a fertiliser plan.
- Be mindful of the weather forecast when planning to spread slurry or fertiliser, make the most of dry spells when they come. You must not spread when land is waterlogged, flooded or where heavy rain is forecast.
- P applications should only start when growth kicks off (at appropriate soil temperature and moisture level). Build up P should be applied in settled weather in the April-June period.
- In a P buildup programme it is still possible to apply the P required as high P compounds and apply at least 50% of your Nitrogen in protected urea form.
- On organic soils apply P requirement of the growing crop on “a little and often basis” as these soils don’t have the capacity to hold phosphorus.

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Section 3

Drainage Legislation, Environmental Losses and Solutions

Section 3

chapter 6

Section 3

Statutory Obligations **When Draining Land**

by **Department of Agriculture, Food and the Marine**

Introduction

Drainage can be hugely beneficial for farmland but the environment must also be considered. All drainage projects must comply with relevant regulations and may require screening by the Department of Agriculture, Food and the Marine.

1. **Which regulations apply to drainage on land used for agriculture?**
2. **When is screening of a drainage project by DAFM required?**
3. **Which regulations apply to wetlands?**

Statutory Obligations **When Draining Land**

1 Which regulations apply to drainage on land used for agriculture?

The Environmental Impact Assessment (EIA) Agriculture Regulations (2011, as amended) Regulations came into force on 8 September 2011 and cover.

- Land drainage works on lands used for agriculture.

Such drainage works include the following:
- Installing open drains;
- Installing field drains (not open) such as field drains using plastic pipe with drainage stone or field drains with drainage stone only or mole drains (no pipe or drainage stone) or gravel filled mole drains (no pipe but filled with gravel);
- Opening of a short distance of watercourse.

Installing a field drain is covered by the Regulations; such work is not regarded as maintenance work for the purposes of the legislation (regardless of whether the field had field drains installed in the past or not).

- Subsoiling of improved lands is not covered by the Regulations. Cleaning of open drains and adjacent levelling of spoil from such cleaning operations is also exempt (not covered by the Regulations).

The Regulations do not apply to reclamation, infill or drainage of wetlands, which are subject to planning permission under the Planning and Development (Amendment) (No. 2) Regulations 2011 and the European Communities (Amendment to Planning and Development) Regulations 2011.

2 When is screening of a drainage project by DAFM required?

Key point

If you intend to undertake land drainage works that (a) exceed 15 hectares, (b) the works are to be carried out within (or may effect) an NHA, a proposed NHA, an SAC, an SPA or a nature reserve or (c) the proposed works may have a significant effect on the environment, screening by DAFM is required.

For the purposes of the Regulations the area will be considered to be the area of works (drains plus immediate vicinity) rather than the area of the field. The 15 hectares threshold can be made up of all new drainage works or new works in combination with upgrading of previous works (since 8th Sept 2011).

Where you intend to drain more than 15 ha in a rolling five-year period you must make an application to the Department of Agriculture, Food and the Marine (DAFM) Johnstown Castle, Wexford (053-9163444) for screening, giving details of the works.

DAFM will, following receipt of your application, conduct screening of the project and will let you know whether you can proceed with the intended work without the need for a full Environmental Impact Assessment or whether you need to apply for consent (Which requires an Environmental Impact Statement and/or Natura Impact Statement be completed before permission to proceed can be granted).

Activities and environmentally sensitive areas

If you propose to undertake drainage within (or the activity may effect) an NHA, a proposed NHA, an SAC, an SPA or a nature reserve you must apply to DAFM for screening, regardless of the size of the area involved.

In other environmentally sensitive areas (NHAs, SACs and SPAs), certain activities or operations that might be damaging can only be carried out with the permission of the Minister for Housing, Local Government and Heritage. These are called **notifiable actions** or activities requiring consent and vary depending on the type of habitat that is present on the site. Landowners are sent copies of the notifiable actions that are relevant to their lands. The activities listed in the notifiable actions are not prohibited but require the landowner/occupier to consult in advance. In the case of NHAs, 3 months written prior notice is required to be given to the Minister before undertaking any notifiable activities.

Many of the activities covered by the EIA Regulations are notifiable actions if they are going to be carried out in an SAC, SPA or NHA and may only be carried out with the permission of the Minister for Housing, Local Government and Heritage. It is therefore necessary that you consult with the local National Parks and Wildlife Service Conservation Ranger or Regional NPWS Staff before undertaking works identified as notifiable actions.

Significant effect on the environment

Screening may also be required where the proposed works may have a significant effect on the environment. Where the proposed development work is below the threshold for screening, it is a matter for the person who proposes to carry out the works to make an assessment to establish as to whether the works may have a significant effect on the environment (professional advice may be required).

In assessing whether the development is likely to have a significant effect on the environment, the person concerned must consider matters such as the relative abundance of the habitat in the area (which may be lost as a result of the proposed works) and the environmental sensitivity of the areas likely to be affected by the project.

Figure 1. Orchid-rich semi-natural grassland (picture - courtesy of J. Cross, NPWS).

Regardless of the foregoing, you should always apply to DAFM for screening (Local Authority in the case of wetlands) where you suspect that the proposed works may impact adversely, either directly or indirectly, on rare semi-natural grasslands such as orchid-rich grasslands (Figure 1), dune systems, raised and blanket bogs, oligotrophic lakes, fens and mires or on species such as the Atlantic salmon and freshwater pearl mussel.

Figure 2. Pond used by Natterjack Toad.

You should apply for screening for any activities that result in the exposure and/or works are likely to give rise to losses of soil to drains, streams and rivers thereby impacting on SAC protected features/species and or general water quality.

Thresholds

The thresholds will, for the purposes of monitoring, generally be the areas (or lengths) of works undertaken in any one year or the sum of such areas (or lengths) over a five-year period, up to the time of the application for screening or consent. However, DAFM reserves the right to monitor cumulation over periods greater than five years and farmers are advised to keep an ongoing cumulative record of their activities and to seek advice from DAFM as appropriate.

Accordingly, sub-threshold works carried out over a number of years, or in different areas of your farm, will, if taken together, where they exceed the threshold, require an application to DAFM for screening before such works are carried out.

Screening by DAFM is required where the proposed works exceed the prescribed thresholds. Where a person proposes to undertake a number of activities it is the threshold that first applies that determines when screening is necessary.

Statutory Obligations **When Draining Land**

The thresholds are applicable to the person who is undertaking an activity covered by the Regulations and for the purposes of controls, will, in the absence of information to the contrary, be taken to be the person that makes an application under the Single Payment Scheme.

3 Which regulations apply to wetlands?

Drainage (open drain, pipe drainage or other method) or reclamation (by infilling or other method) of wetlands can have a major impact on habitats and wildlife. Such drainage works are not subject to the EIA (Agriculture) Regulations but are subject to alternative controls (Planning and Development (Amendment) (No. 2) Regulations 2011) and the European Communities (Amendment to Planning and Development) Regulations 2011.

What are wetlands?
For the purposes of the legislation the following are regarded as wetlands;

- Lakes, reservoirs and ponds
- Turloughs
- Rivers and canals
- Swamps and marshes
- Floodplains that are permanently inundated with water or inundated for a period each year (including callows). Floodplains will be taken to mean the area of land along a river which would be expected to flood for a period at some time in the course of a normal year
- Peatlands (bogs, wet heath and fens)
- Wet woodlands
- Caves
- Cliffs
- Salt marshes
- Dune slacks and machairs
- Transitional waters (e.g. estuaries and lagoons)
- Intertidal habitats (to 6 m below the lowest spring tide level)

For further information on issues and considerations relating to wetlands see www.wetlands.ie and the Ramsar Convention on Wetlands website; www.ramsar.org

Section 3

Reducing the **Environmental Impact**

by Karl Richards, Owen Fenton, Gary Lanigan, Pat Tuohy,
Daire Ó hUallacháin, John Finn, Karen Daly, David Wall, Stan Lalor

Introduction

Drainage systems alter the soil physical characteristics and can lead to environmental degradation. In recent years there has been much research to characterise and minimise their environmental impact.

1. What are the negative impacts of land drainage?
2. What are the options for reducing these impacts?

Reducing the **Environmental Impact**

1 What are the negative impacts of land drainage?

Soil nutrients

Drainage increases the aeration in soil and this can result in increased rates of nutrient release from soil organic matter. This increases the plant availability of the soil nutrients to the grass or crop, and can therefore increase yields through higher nutrient uptake, particularly of nitrogen (N), sulphur (S) and phosphorus (P). This can also result in fertiliser savings on the farm due to higher nutrient release from soils. On the other hand, nutrients, dissolved carbon and sediment can be lost in drainage water. The loss of nutrients to watercourses can negatively impact water quality. In rivers, nitrogen and phosphorus loss can result in excessive plant and algal growth. This reduces the amount of oxygen in the river and suffocates sensitive fauna. Excessive fine sediment in a river can smother the stream bed habitat and clog the gills of many sensitive mayfly species.

Key risks

Nutrients lost through drainage systems are lost to the crop and impose a financial cost. Drain only enough water to ensure good crop growth and soil trafficability.

Cultivations following drainage can also impact on soil nutrients. Where soils are ploughed for reseeding following drainage, some of the nutrients such as P can become buried deeper in the profile resulting in lower P levels in the soil at the surface. Phosphorus buried in the soil profile can be in direct contact with subsurface flow pathways that can carry P directly to rivers/lakes.

Key point

It is important to soil test after ploughing to prepare an appropriate fertiliser plan. Lime application may also be needed during reseeding to increase soil pH. Raising the pH will also improve nutrient release from soil.

Flooding

Drainage will reduce flooding on the drained lands. But drainage will also lead to more rapid movement of water from the land surface to the receiving river or lake. This greatly alters the hydrology of the catchment.

Water movement is speeded up as drainage bypasses the soil and is discharged directly into a surface water body. Increasing the speed of water movement from soil to rivers increases the potential for down stream flooding of agricultural land or urban settlements in floodplains.

Water pollution

Land drainage may change the forms of N and P that leave agricultural lands in overland flow and subsurface flow. For example more ammonium can leave in overland flow, with more nitrate being lost in subsurface pathways.

Increasing the speed of soil infiltration changes the soil hydrology from one dominated by overland flow to one dominated by subsurface lateral flow through the soil. This will result in reduced overland flow to rivers and lakes. The channelling of water in drainage networks increases the speed of water delivery to rivers and by passes the soil's ability to remove nutrients such as nitrate, Phosphorus, and also pathogens, sediment and pesticides from the drainage water. Drainage also by-passes potential methods to mitigate diffuse pollution such as riparian buffers beside rivers.

In terms of nutrient and sediment losses from land drainage systems; fertiliser inputs, crop type, rainfall, drainage system type, soil type and soil chemistry are important factors that distinguish what load of pollutants is to be lost from pipes and ditches to the environment. Shallow drainage systems are more likely to promote high intensity flows which have little interaction with the soil body relative to groundwater systems which promote water movement through the soil. Land drainage system design needs to account for such variability and specify works that identify and negate against impacts on water quality.

Carbon footprint

Land drainage is likely to effect emission of greenhouse gases, particularly in the first couple of years after drainage. The drainage of mineral soils affects a reduction in greenhouse gas emissions both directly through lower nitrous oxide emissions, which tend to be higher in poorly drained soils, and indirectly through the benefits of extended grazing. However the drainage of high organic content and peat dominated soils will result in substantial CO_2 emissions to the atmosphere, that would dwarf any non CO_2 benefit. Therefore current climate change mitigation policy dictates that further drainage of high organic content and peat soils cannot be justified.

Biodiversity

Wetlands (such as fens, marshes, ponds) and species-rich wet grassland habitats (Figure 7) make a very important contribution to farmland wildlife, and contribute to the environmental sustainability of farmland. Such habitats and their species are dependent on water systems, and surface and subsurface drainage causes a loss of habitat diversity and quality, resulting in loss of farmland biodiversity. Land drainage can impact negatively on ecologically-important habitats such as species-rich wet grassland, which has many rare farmland species, but has undergone significant reductions in area and quality in recent decades. Drainage can also impact negatively on a variety of our most threatened wetland habitats including ponds, fens and bogs. Numerous specialist plant species, including for example Meadowsweet, Devil's Bit Scabious and a number of orchid species are directly associated with species-rich wet grassland habitats, and management that results in the drainage of these habitats will impact negatively on these and other threatened plant species. A variety of invertebrate (e.g. dragonflies, butterflies) and vertebrate species (e.g. frogs, lizards, newts, wading birds) are dependent on wet grassland and wetland habitats, therefore drainage would have serious impacts on ecological conservation. Species-rich wet grassland habitats are vital as nesting and feeding sites for some of our most threatened bird species (e.g. Lapwing and Curlew, both of which are listed on the Red-List of Ireland's most threatened bird species). Land drainage on sites where breeding waders occur will reduce the habitat quality of that land, in turn further impacting on already threatened species.

Agricultural drainage is typically associated with negative impacts on biodiversity; However, appropriate management of existing surface drainage systems can play an important role in providing a variety of small-scale wet habitats on farmland. Open drains associated with surface drainage can provide valuable wet vegetated non-cropped habitats to both aquatic and terrestrial plants and animals. They can also supply an important source of food to a variety of species, which is particularly important in intensively-managed systems. Furthermore, open drains can play a role in habitat connectivity, acting as wildlife corridors connecting habitats to one another in the wider landscape, facilitating the movement and interaction of a variety of species.

Key risk

Land drainage on farmland habitats causes a loss of habitat diversity and quality, resulting in losses of farmland wildlife.

Key point

Drainage generates pros and cons for the environment. The most sensitive sites will be covered by DAFM 'screening' but even on mineral soils it may be prudent from both a financial and environmental point of view to leave areas undrained. The value of these small areas in terms of protecting the environment and water courses in particular may outweigh the additional production achieved. Teagasc recommends that any drainage scheme, even where screening by DAFM is not obligatory, should be viewed by a professional to assess any possible environmental impact.

2 What are the options for reducing these impacts?

Land drainage can impact on the environment as outlined previously. Increasingly worldwide there is a movement to design drainage systems with environmental sustainability at the core. For such developments to be successful, local experience, experimental field results and theoretical approaches need to be combined at any site. This section outlines some infield and discharge techniques for reducing the environmental impacts of land drainage.

Checklist

1. **To drain or not to drain**. In some circumstances, as outlined previously, the installation of land drains can have an excessive environmental impact and as such cannot be justified. If dealing with high organic content or peat soils, vulnerable habitats or wetlands then any benefits yielded will come at too high a cost to the wider environment and cannot be justified. Such works must be avoided. Consider all impacts and seek appropriate advice. Ensure compliance with statutory obligations (Chapter 6) and always seek to minimise adverse impacts when proceeding with drainage works.

Reducing the **Environmental Impact**

2. **Weather.** Aim to carry out drainage operations in good weather conditions where soil erosion and sediment loss during and following excavation works is minimised. Drainage installation under the wrong conditions can also lead to compaction and decreased effectiveness e.g. - in the case of mole drains.

3. **New crop.** Establish a new crop as soon as possible after drainage works are completed to initiate nutrient uptake and encourage ground cover and rooting to minimise soil erosion.

4. **Nutrient management.** Drainage will change and/or increase the pathways for nutrients between the land and the watercourse. Therefore, optimised nutrient management of fields following drainage is essential. Match fertiliser N and P rates to crop requirements, and time applications of fertilisers and manures to maximise nutrient uptake and minimise losses. Soil test again after ploughing. Optimise pH to improve nutrient-use efficiency, for example, an increase in soil pH from 5.5 to 6.3 can reduce the N fertiliser required by up to 70kg N ha^{-1} yr^{-1} for the same level of production and increase P uptake by the grass sward.

5. **Sediment traps in drainage outflows.** When positioned strategically in existing surface drains, these minimise the risk of sediment and nutrients reaching larger watercourses during drainage installation. After installation, drainage detention ponds should be installed to trap sediment leaving the landscape (Figure 1). Added baffles increase their efficiency.

Figure 1. A bespoke silt trap installed in a fast flowing eroding land drain to prevent silt run-off to the River Allow (source Michael Morrissey IRD Duhallow Farming for Blue Dot Catchments EIP Project March 2021).

6. **Backfilling closed drains.** Ensure that a soil blinding layer of >15 cm is used above the gravel in closed drains to prevent the direct entry of fertiliser nutrients to drainage waters.

7. **Engineering solutions:**

   - **Water table management**. The amount of water leaving the system needs to be balanced with the amount of drainage required and the crop's needs (Figure 2). Getting this balance correct will lead to less nutrient loads leaving the system. Water table management is now being used as an effective means of controlling nutrient and greenhouse gas losses in many countries.

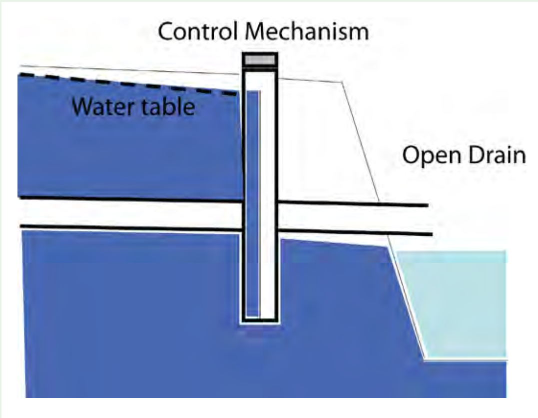

Figure 2. Water table management.

A significant programme of water table management is required on those organic soils that were previously drained. It is proposed that a significant area of drained peat grassland soils will be rewetted in the coming years to reduce the large emissions from those soils. This will involve proposing suitable locations and liaising with landowners to establish a workable programme of rewetting, and thereafter undermining existing drainage features (open and field drains) on selected sites to manipulate the depth of the water table and reduce CO_2 emissions to the atmosphere.

Key risk

High organic content and peat soils should not be drained in order to prevent substantial CO_2 emissions.

Figure 3. Two-stage ditch example from Sweden. Before, during and after installation. (Courtesy of Kaisa Västilä)

- **Trap phosphorus and nitrogen**. Use of reactive materials in the gravel fill to trap phosphorus. Worldwide, the use of reactive materials e.g. zeolite can be effective along ditches to trap ammonium and phosphorus lost through drainage implementation. These can be recycled as fertiliser.

- **Gravel backfill.** Gravel should be washed to removed sediment. Gravel should be 10-40 mm to maintain drainage capacity and also trap sediment transported to the drainage network.

- **Surface drains.** Cleaning in-field pipe drains and their outlets to remove blockages should be the priority. If cleaning other sections of an open drain/ditch, it is imperative vegetation should be removed from the drain bed and one bank only. The other bank should be left undisturbed throughout that season. Where drains are providing a habitat for fish, removal of channel bed vegetation and sediment should be kept to a minimum. When cleaning drains be aware of potential damage to fish and their habitats, including impacts downstream. Where sediment removal is necessary, this work should be undertaken between July and September, to protect fish eggs and small salmonids. One should note that The Fisheries Acts states that it is an offence to disturb channel beds where fish may spawn during the autumn or winter. If in doubt, consult Inland Fisheries Ireland (www.fisheriesireland.ie).

- **The riparian margin** adjacent to the drain can also play an important role in the protection of biodiversity, water quality and flood control. Vegetation in this margin should be allowed to regenerate naturally and the use of herbicides, pesticides and fertiliser should be excluded from this area. Periodic grazing or cutting of this riparian vegetation will prevent scrub dominance and will provide benefits for a variety of species associated with agricultural ecosystems.

- **End of pipe solutions or ecologically engineered options** such as zeolite (for ammonium and phosphorus) or wood chip (for nitrate) trenches to treat drainage discharges are now commonplace on farms around the world and to a limited extent in Ireland. Another option currently being researched worldwide is implementation of a two stage ditch system (Figure 3) which allows flow but also uses vegetation along grass benches to remove nutrients and trap sediments. Rural Sustainable Drainage Systems slow the flow and reduce nutrient loads reaching connected waters. Other end of pipe options include having subsurface drains delivering to a mitigating feature such as riparian zone or a wetland, as opposed to delivering directly to the watercourse.

Reducing the **Environmental Impact**

Figure 4. Farm roadway cambered with a mound installed to prevent nutrient and sediment run-off to the River Allow (source Michael Morrissey IRD Duhallow Farming for Blue Dot Catchments EIP Project March 2021).

Figure 5. A two chamber settlement pond installed down drain in a fast flowing eroding farm connection drain to prevent sediment run-off to the river Allow (source Michael Morrissey IRD Duhallow Farming for Blue Dot Catchments EIP Project March 2021).

- **Diverting and intercepting** runoff away from open drains to buffer areas e.g. fields that are adjacent to farm roadways or farmyards is appropriate where open drains are adjacent to farm roadways or farmyards where there is potential for excessive nutrient loss. Runoff can be diverted by ensuring surface water does not flow to outlets by correcting fall direction or installing obstructions (Figure 4). Diverted water can be directed towards settlement ponds or other retention features (Figure 5).

- **Integrated constructed wetlands.** These are the subject of on-going research and there are examples of such systems already in operation in Ireland. These are another option to retain nutrients and sediment from surface water and prevent pollution downstream.

Figure 6. A settlement pond installed at a confluence of land drains to prevent sediment run-off to the River Allow (source Michael Morrissey IRD Duhallow Farming for Blue Dot Catchments EIP Project March 2021).

Figure 7. Species Rich Wet Grassland (County Wexford).

Figure 8. Buffer strip example (County Wexford).

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Section 4

Diagnosing a Drainage Problem and Finding a Solution

Section 4

Section 4

Diagnosing **the Problem**

by **Pat Tuohy, Owen Fenton**

An update of a previous version written by Pat Tuohy, Owen Fenton, Tristan Ibrahim, Rachel Creamer

Introduction

Every field and drainage situation is different and a field may suffer a number of different drainage problems. There is no substitute for systematically investigating the problem by gathering as much relevant information as possible.

1. What information should I gather at home about my farm?
2. What information should I gather outside on my farm?
3. What information do I need to know about digging soil test pits?
4. What information should I note from a soil test pit?
5. How can I judge if a drainage system would be feasible?
6. What is the final diagnosis?

Diagnosing the Problem

1 What information should I gather at home about my farm?

Checklist

- **Information from maps:** With the help of online soil (topsoil and subsoil) and bedrock geology maps, write down the general soil type, drainage characteristics (well drained, moderately drained or poorly drained) and rock type on and under your farm. Remember that not all fields were surveyed to draw these maps, which means that the actual soil and geology types at your particular farm might differ from what you find on the map. Such general information is nevertheless useful.

- **Information based on local knowledge:** What type of stone is used for walls in the locality? This stone is likely to be the same as the underlying rock on your site. Also, local quarries will almost certainly be able to give you information about types of bedrock in the area. Often, field names give you information on poor drainage conditions e.g. flaggers, poaching or rush field.

- **Information using the Met Éireann website:** Note down the annual rainfall nearest to your location. Typically, the amount of rainfall increases from the east (600 - 1,000 mm) to the west of Ireland (- up to 3,600 mm rainfall). Total rainfall - evapotranspiration is the amount of water which needs to be drained at the surface or through the soil, the respective amount of both components is linked to soil type, soil saturation, slope etc. See Section 1, Chapter 1.

- **Information using satellite imagery:** These are available on the internet for any part of Ireland. Such images will help to place your farm in its wider context. For example how far away from problem areas is the nearest river or the sea?

- **Altitude:** What is the altitude of your site? This will have a significant impact on grass growth. Altitude is measured in meters above sea level (ASL) or above a set reference level, referred to as an ordnance datum (AOD) as in Figure 1.

2 What information should I gather outside on my farm?

- Information on the slope direction and steepness on your site.

- The location of visual indicators of poor drainage such as:
  - Water lying on the land surface for long periods;
  - Water loving plants (e.g. rushes, horsetail, silver weed, sedge or flaggers);
  - Patchy crop growth;
  - Shallow root systems on plants;
  - Grey-white-rust colouring in the top soil;
  - Wheel rutting, areas of poor grass or crop growth.

Checklist

Information on the present position and characteristics of drains already installed:

- What depth are these open drains and is there any flow and in what direction?
- Is there seepage of water coming into these drains when it is not raining?
- Is water flowing in the subsurface drains, in what direction is the water flowing?
- Is there evidence of drain blockages?
- Can you find an outfall?

How to

Manage the information gathered.

- It is always helpful to draw a sketch of your overall farm marking in field boundaries and the existing features mentioned earlier (Figure 1 is an example). Some farmers/landowners may have an electronic version available, which can be printed out and used.

- With the help of your sketch, make notes at different locations where appropriate.

- It is best to create a topography map of the field showing the elevations of the potential or existing outlet(s). A number of methods may be used to create the map, including standard topography surveys, a GPS or a laser system. The topography map will help you assess the overall slope and identify the high or low spots in a field which might pose challenges.

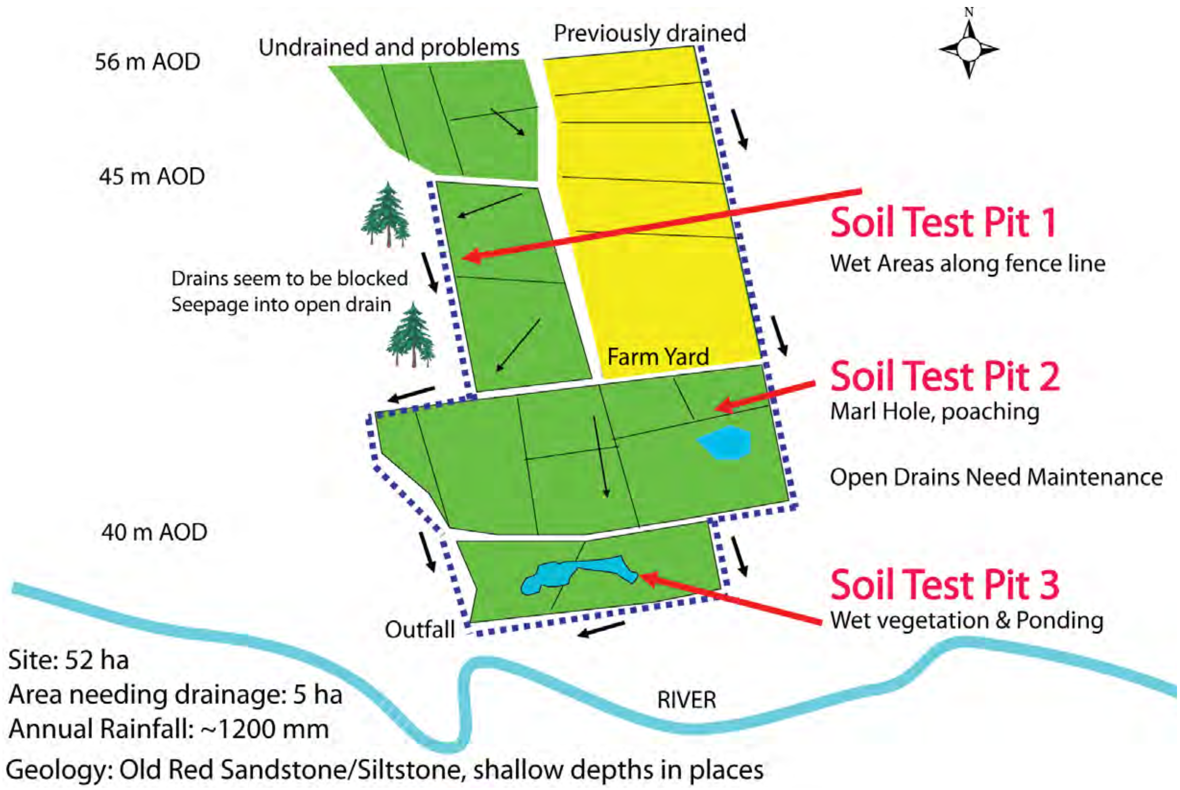


Figure 1. Example farm sketch indicating problem areas, previously drained areas and soil test pit locations.

Diagnosing the Problem

3 What information do I need to know about digging soil test pits?

- **Where to dig** - Look for representative areas where a soil test pit will best identify your drainage problem. Dig soil pits even in areas with no perceived drainage problem.
- **How many?** - On sloping ground dig soil test pits on the top, middle and bottom of the slope. Always dig more than one soil test pit within these contrasting areas. In addition, use a soil auger to investigate areas around the soil test pits to 0.9 m.
- **Other soil profiles may be useful** - Look at the soil profile along open drains to see if it looks very different to your in-field soil test pit profiles. You may need to scrape away the outer surface for a fresher look.
- **When digging (phase 1)** - To make the most of your visual assessment and photographs, orientate your digging so that the sun is shining on the face of the test pit. Typically, the soil test pit should be dug in two phases. Initially, dig the soil test pit (Figure 2) to a shallow depth (approx. 1 m) and leave to settle. This phase allows you to safely stand into the soil test pit, clear off the face with a knife and examine the topsoil and subsoil.
- **When digging (phase 2)** - Continue digging to a final depth of approximately 2.5 m (Figure 3) or until solid rock will not let you go further. If you dig the entire profile in one go, shallow layers may become sealed by the digger's bucket.
- **Be careful** - Soil test pits are very dangerous and prone to collapse. You should not enter deep soil test pits but instead observe from a safe distance. Inspect different soil layers as it comes up with the digger bucket.

4 What information should I gather from a soil test pit?

- After digging, look at the boundaries between distinct layers - a flat boundary between topsoil and subsoil typically identifies the ploughing depth.
- Note the depth and thickness of each visually distinct layer. It is better that the vertical walls are rough and not smeared by the bucket. Where possible, scrape away the outer layers making the surface rough.
- Soil texture (sand, silt and clay per cent) of soil samples from the soil profile. There are explanations on how to determine soil texture at the end of this chapter.

Key point

Drained high organic content and peat soils are significant emission sources. Such soils should not be drained to prevent excessive GHG emissions.

Figure 2. Shallow excavation to approximately 1m.

Figure 3. Permeable layers will be indicated by seepage of water into the soil test pit.

- Depth of rooting. Well developed roots typically indicate better drainage. Poor drainage will only allow roots in shallow layers.

- Permeable layers will be indicated by seepage of water into the soil test pit and collapsing layers (see Figure 3).

- The presence of stones in shallow layers is important as it may hinder the use of shallow techniques such as moling or subsoiling. The depth to bedrock may also have the same effect. In some cases the bedrock may be the permeable layer.

- Colour of different depths:

  - rich dark brown indicates loam, brown or brownish shades typically throughout the profile indicate that there is no drainage problem,

  - pale grey indicates gley or water logged soil, black indicates a high organic matter,

  - depending on the time of the year, the water table may be deeper than your shallow pit. This will become more obvious as you dig further, but evidence for the position of the water table throughout the year can be gained by colours in the profile. Orange and grey indicate water movement (washing out and rise and fall of water table and is often called mottling),

  - Gley soils occur in all counties and are identifiable by their pale grey colours. A problem here is that colours might relate to other soil features such as minerals inherited from the bedrock. Again colours are only indicative and not definite i.e. if you are on shale bedrock the soil may naturally be grey in colour,

  - In permanent grassland, rusty mottles can be seen close to the surface and is not an indication of water logging,

  - Is there a chemical pan present which impedes drainage? Look for black manganese or red iron pans in the soil profile.

Diagnosing the Problem

⑤ How can I judge if a drainage system would be feasible?

- A key question is whether there is sufficient slope on the site. Is there adequate 'fall' to install drains?

- What is the condition and position of outflow channels (open drains, streams etc.)? Is there an accessible outflow channel at all?

- Drainage outlets are typically located 1-1.5 m below the soil surface. Sometimes, pumping is required to create an adequate outlet. The bottom of an outlet pipe should be located above the normal water level in a receiving ditch or waterway. It is to be expected that floods or high water levels may submerge the outlet occasionally for brief periods. Drainage outlets must be kept clean at all times and this may require co-operation with neighbours. Outlets must also be protected from erosion, damage from machinery and cattle. An opportunity to trap nutrients before they reach a water body exists at this location (see Chapter 7).

- What is the frequency and extent of local flooding? If your poor drainage is due to flooding, there is very little that can be done to move water to the river.

- Is there any indication that a particular drainage system could be installed? If the test pit fills with water seeping from one of the soil profile layers there is almost certainly a permeable layer of soil in the profile. A permeable layer is essential for a groundwater drainage system (see Chapter 10). Alternatively the upper soil layers may be suited to a shallow drainage system (Chapter 11). Both of these options require an outfall nearby.

- High organic content and peat soils (a soil having >20% organic carbon content and a thickness of at least 40 cm) should not be drained due to potential for substantial CO_2 emissions following drainage.

Key point

Sometimes a site will not be suitable for, or benefit from, drainage works e.g. sites with shallow water tables beside rivers as at certain times of the year drainage will introduce water from the river to the land.

How to

Determine soil texture.

Soil texture describes the sand, silt and clay per cent content of mineral soil samples. See Table 1 for a detailed explanation of key textural classes.

The texture indirectly tells you about how fast the water will travel through a soil. This is important for drainage, as it identifies the permeable or impermeable layers.

Typically, a sample is sent away for analysis and the exact sand, silt, clay per cent is determined. This is expensive and time consuming but is the most accurate assessment of soil texture.

In the field there are a few simple ways of estimating textural classes.

- Simply take some soil out of the digger bucket which represents a particular layer that you have noticed.
- Remove any plant (organic) or stone material.
- Pour a little bit of water on your sample and in the palm of your hand work the water into the sample. Now start to roll the sample into a ball. While you are rolling the sample into a ball or ribbon you should note any feeling of grittiness as this denotes sand content. Also do this near to your ear and listen for this grittiness. Ask yourself the following questions, make yourself familiar with the notes in Table 1 and then follow the pictures provided. Your sample will have a textural class indicated on the table or in the textural triangle. Practice makes perfect.

Is the soil sample more gritty than anything else?

- If so it is a sandy soil of some kind and no drainage problems should prevail. Sand does not stain your fingers.

Is the soil sample more sticky than anything else?

- If so it is a soil with a lot of clay. Clay binds together easily. It takes a high polished look and you can easily make long ribbons when pushed between your thumb and fingers. It will have a feathery look. Can be difficult to work.

Is the soil sample more smooth and silky than anything else?

- If so it is a silty soil. This has a smooth silky feel when pressed between thumb and fingers. Finger prints will remain on a silt but not on a clay. Hands are often left with a white coating from silt.

Is the soil sample more or less equally gritty, sticky and smooth and it is difficult to come up with a clear answer?

- If so it is a loam soil. This is typically the hardest soil texture to define. Typically a way around this is by a process of elimination. If it is not the other categories the default texture is loam.

Texture Name	Behaviour of Moist Soil	Approx Clay %
Clay Loam	Ribbon of 40 - 50 mm.	30 - 35
Clay Loam, Sandy	Medium size sand grains visible in finer matrix; will form ribbon of 40 - 50 mm.	30 - 35
Silty Clay Loam	Fine sand can be felt and gritty sound when held up to ear during ribboning; will form ribbon of 40 - 50 mm.	30 - 35 & silt >25
Sandy Clay	Fine to medium sand can be seen, felt or heard in clayey matrix; will form ribbon of 50 - 75 mm.	35 - 40
Silty Clay	Smooth and silky to manipulate; ribbon 50 - 75 mm.	35 - 40 & silt >25
Light Clay	Smooth to touch; slight resistance to ribbon shearing between thumb and forefinger; will form ribbon of 50 - 75 mm.	35 - 40
Light Medium Clay	Smooth to touch; slight to moderate resistance to ribboning (greater than for light clay); will form ribbon of about 75 mm.	40 - 45
Medium Clay	Like plasticine; will form ribbon of 75 mm or more.	45 - 55
Medium Heavy Clay	Handles like plasticine; will form ribbon of 75 mm or more.	>50
Heavy Clay	Handles like stiff plasticine; will form ribbon of 75 mm or more.	>50

Table 1. Typical behaviour of soil sample during hand texturing and clay content of various textural classes when using the ribbon method.

Diagnosing the Problem

1 Sand

Sands are highly permeable soils and rarely suffer from drainage problems.

It is not possible to form a ball with the moist soil sample.

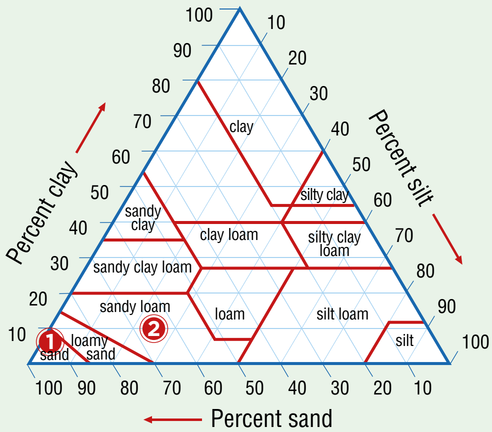
The soil sample cannot be shaped into a ribbon.

2 Sandy Loam

Sandy loam soils suffer few drainage problems.

The moist soil sample can be formed into a ball.

It is possible to form a ribbon short but the ribbon breaks at less than 25 mm.



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3 Loam

Loam soils are usually well drained and productive.

The moist soil sample can be formed into a ball relatively easily.

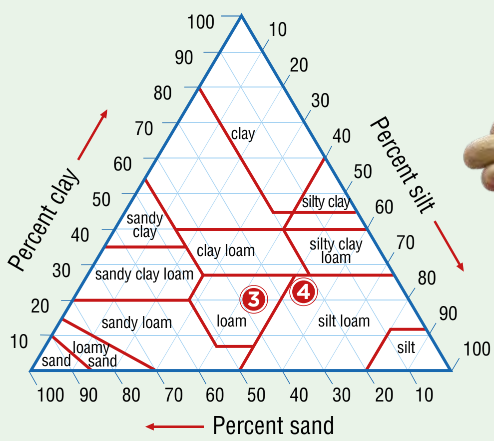
The soil can be pressed into a ribbon and the ribbon breaks at about 25-30 mm.

4 Silt Loam

Drainage problems rare when clay content low.

A moist sample of silt loam soil can be readily formed into a ball.

A ribbon of 30 mm or more can be formed.



A feature of silt loam soils is that when a very wet sample is allowed to dry on your hand a ‘floury’ residue will remain.

Diagnosing the Problem

5 Clay Loam

Poorly drained when clay content high.

It is very easy to create a ball with a moist soil sample.

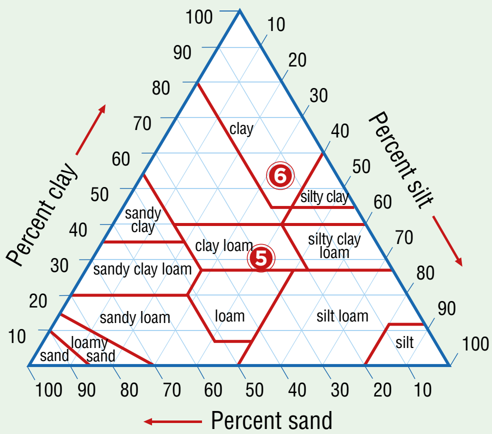
It is also easy to form a stable ribbon which can be extended to 40-50 mm before breaking.

6 Clay

A moist soil sample is like plasticine.

It is very easy to create a ball with a moist soil sample.

It is exceptionally easy to form a ribbon which can be extended to 50 mm or more.



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6 What is the final diagnosis?

At this stage you should have:

Separate your soils and open drain profiles into permeable (groundwater options) and impermeable (shallow options) layers. This establishes what layers transmit water and what layers hold water.

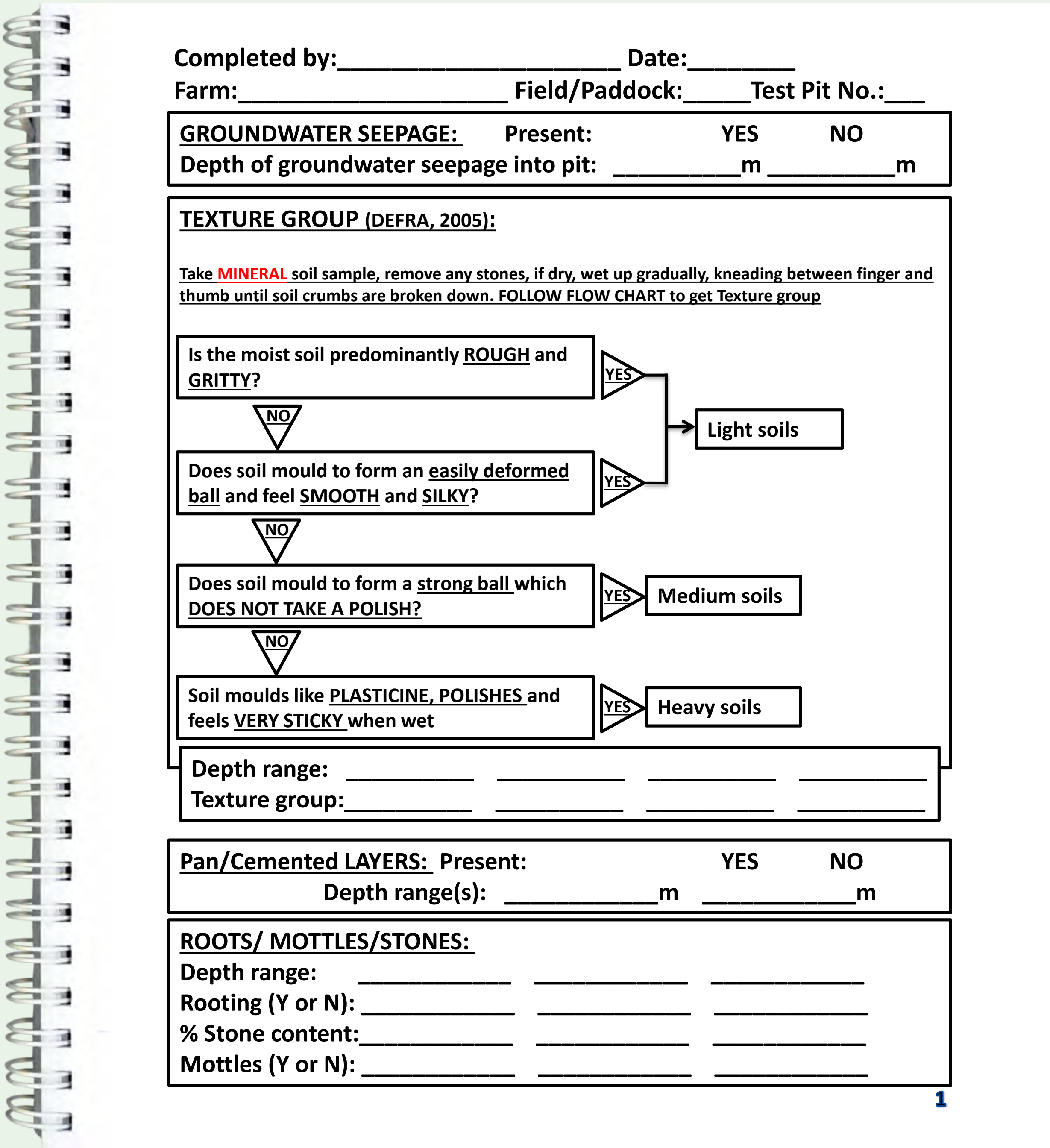
For impermeable layers (shallow drainage options) that hold water you should have sent samples from the soil test pit and open drains away for textural analysis or at least hand textured the different layers to find out the approximate sand, silt, and clay percentages.

Mineral soil profiles with high permeability horizons (at drainable depth, up to approximately 2 metres) are suited to groundwater drainage systems. The depth of the drainage system depends entirely on the depth of the high permeability layer in the soil. The drainage system must sit in this layer. Soil profiles with low permeability horizons are suited to shallow drainage systems. Every effort must be made to maximise water movement through the profile as rapidly as possible. The type of shallow drainage system employed depends on what specific issue needs to be addressed.

You now need options to solve your groundwater or shallow drainage problems (see Chapters 9, 10 and 11).

The following pages summarise the key soil permeability indicators and can be used as an aid to determine the drainage characteristics of a given soil and help prescribe an appropriate drainage solution.

Diagnosing the Problem



Completed by:______________________ Date:_________
Farm:_____________________ Field/Paddock:_____Test Pit No.:___

GROUNDWATER SEEPAGE: Present: YES NO
Depth of groundwater seepage into pit: __________m __________m

TEXTURE GROUP (DEFRA, 2005):

Take MINERAL soil sample, remove any stones, if dry, wet up gradually, kneading between finger and thumb until soil crumbs are broken down. FOLLOW FLOW CHART to get Texture group

Is the moist soil predominantly ROUGH and GRITTY? — YES → Light soils
NO ↓
Does soil mould to form an easily deformed ball and feel SMOOTH and SILKY? — YES → Light soils
NO ↓
Does soil mould to form a strong ball which DOES NOT TAKE A POLISH? — YES → Medium soils
NO ↓
Soil moulds like PLASTICINE, POLISHES and feels VERY STICKY when wet — YES → Heavy soils

Depth range: __________ __________ __________ __________
Texture group:__________ __________ __________ __________

Pan/Cemented LAYERS: Present: YES NO
Depth range(s): ____________m ____________m

ROOTS/ MOTTLES/STONES:
Depth range: ____________ ____________ ____________
Rooting (Y or N): ____________ ____________ ____________
% Stone content:____________ ____________ ____________
Mottles (Y or N): ____________ ____________ ____________

1

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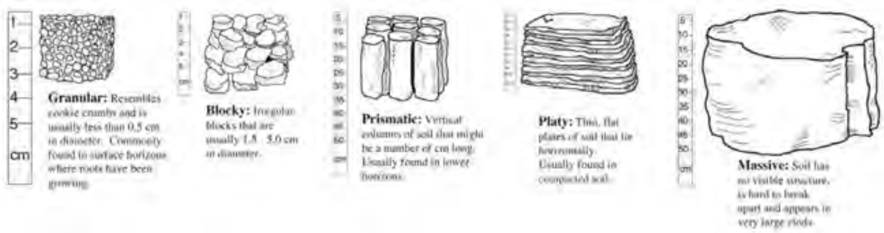
STRUCTURE (FAO, 2006) & POROSITY (Shepherd, 2009):

GRADE: **Aggregates are "clumps" of soil particles that are bound together**

Weak	Aggregates are barely observable
Moderate	Aggregates are observable
Strong	Aggregates are clearly observable

TYPE:



Depth range: ___________ ___________ ___________ ___________

Grade: ___________ ___________ ___________ ___________

Type: ___________ ___________ ___________ ___________

Good: Soils have many macropores between and within aggregates

Moderate: Macropores are fewer but are present on close examination

Poor: No visible macropores, massive structureless smooth surfaced, sharp edges

Porosity: ___________ ___________ ___________ ___________

PLASTICITY (FAO, 2006):

Roll the soil in the hands to form a wire about 3 mm in diameter

Non-plastic	No wire is formable
Slightly-plastic	Wire formable but breaks immediately if bent
Plastic	Wire formable but breaks if bent into a ring
Very plastic	Wire formable and can be bent into a ring

Plasticity: ___________ ___________ ___________ ___________ 2

Diagnosing the Problem

SOME TYPICAL CHARACTERISTICS

*****A soil layer may not comply with all of these characteristics the aim is to <u>PICK THE MOST APPROPRIATE CATEGORY</u> for a particular depth range*****

****RED TEXT ITEMS ARE TELLTALE SIGNS IN EITHER CASE, but do not necessarily have to be present for a soil layer to fit that category****

Highly permeable (HP)

- **Ground water seepage**
- Medium/light texture
- Strong granular, blocky or prismatic structure
- Good porosity
- Non-plastic

Poorly permeable (PP)

- **Pan layer**
- Heavy texture
- Massive or platy structure
- Poor porosity
- Poor root development
- Plastic
- Mottled

Moderately permeable (MP)

Intermediate between HP and PP

- Medium/light texture
- Moderate grade structure
- Moderate porosity
- Non-plastic
- May be mottled

	Permeability Class (TICK to specify)		
Depth Range (m)	Poor	Moderate	High

3

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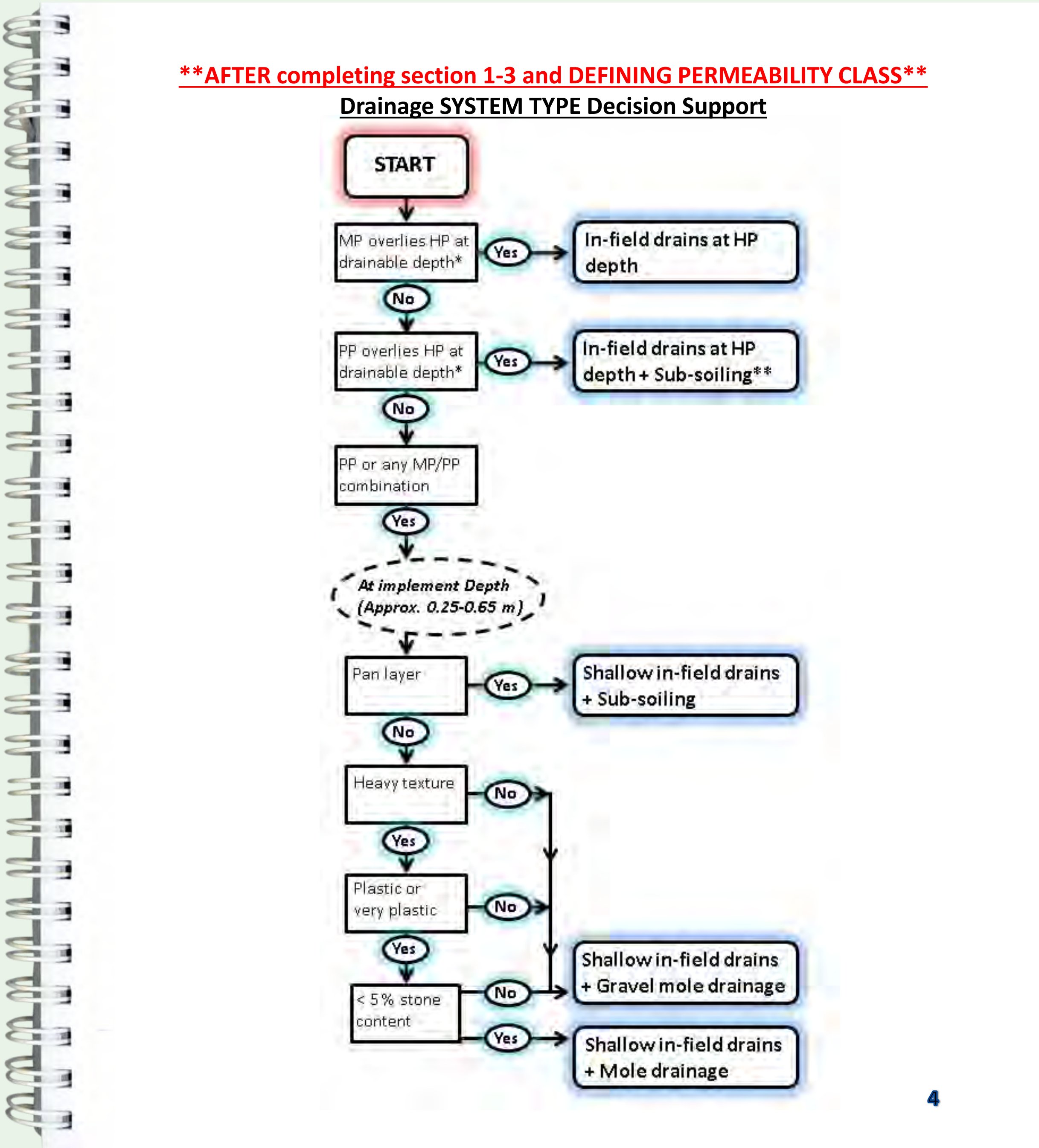

Section 4

Main Drainage **Systems**

by **Pat Tuohy, Owen Fenton**

Introduction

A main drainage system is typically made up of open drains of varying sizes usually placed along field boundaries connecting field drains to the local stream or river.

1. **What is a main drainage system?**
2. **Where and how should main drains be installed?**
3. **Can main drains be closed?**

chapter 9

Main Drainage **Systems**

1 What is a main drainage system?

- The main drainage system receives water from the field drainage system (Figure 1).
- Main drains will receive water from the field drainage systems in place as well as surface runoff and groundwater in their immediate vicinity. Large volumes of water will be collected.
- The water level where the main drainage system discharges into the local stream or river dictates how far the water table can be lowered below the land surface.
- If the water level is to be lowered below this point the groundwater may have to be pumped out.

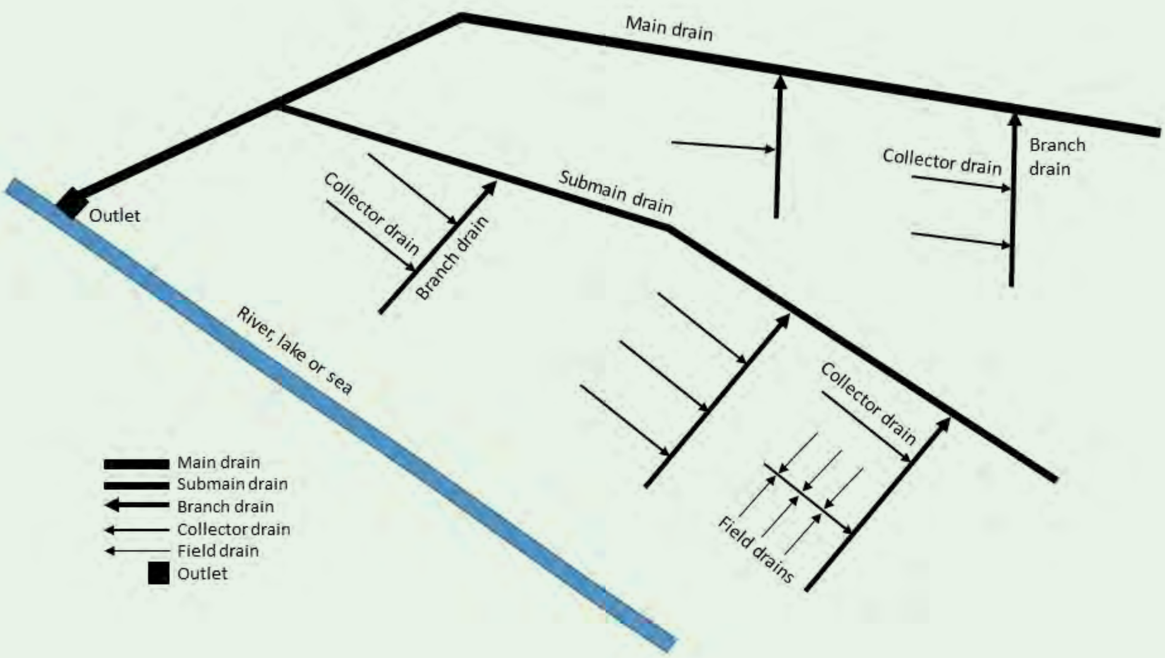

Figure 1. Layout of entire drainage system. After Schultz et al. (2007)

2 Where and how should main drains be installed?

Large fields are good for efficient farming but they may result in long drains which reduce the drainage potential of the land. This is because every field drain needs an outlet i.e. an open main drain - the fewer of these the lower the potential for land drainage. The goal is to have a regular pattern of open drains rather than huge fields with nowhere to outlet field drains.

Farms on poorly drained soils generally already have extensive networks of main drains already in place although many are in poor condition.

- New open drains or those being upgraded must be installed with appropriate batter (side slope) so as to minimise slippage and collapse. Generally heavy clay soils are the most stable and can support a steeper batter than the sandy soils. Always drain under suitable weather conditions to avoid negative soil quality impacts e.g. soil compaction.

Key point

Spoil removed from drains must be spread carefully. Spoil left adjacent to open drains can hinder overland flow into them, and trap surface water. If not evenly spread it can also decrease the permeability of the soil around that area, causing poor drainage.

Soil	Channel less than 1.3 m deep	Channel greater than 1.3 m deep	Max. allowable water velocity (m/sec)
	Horizontal : Vertical		
Heavy clay	0.5 : 1	1 : 1	1.5
Clay or silt loam	1 : 1	1.5 : 1	1.0
Sandy loam	1.5 : 1	2 : 1	0.75
Sand	2 : 1	3 : 1	0.75

Table 1. Channel side slopes. Horizontal : Vertical.

3 Can main drains be closed?

- Under Cross Compliance open drains have been designated as landscape features. Since 2009, they cannot be removed / piped and closed in unless a replacement drain of similar length is dug at a suitable location on the holding in advance of the removal of the drain.
- Where an appropriate replacement drain has been installed there are scenarios where existing drains will be closed, with two possible options:

Option 1
Close the drain completely (fill it in): this may cause problems as flow of water is now inhibited, and this would require large quantities of soil.

Option 2
Pipe the open drain: this will facilitate water flow from the drain, but surface water collection will be limited and the ability to maintain existing field drains and the potential to install new field drains will be severely reduced.

Key fact

Existing open drains, no matter how small or dilapidated, were installed at some time with good reason. Closing them completely is often regretted. They cannot be closed unless a replacement drain of similar length is dug at a suitable location on the holding in advance of the removal of the original drain.

Key risks

Piping an open main drain.

- Incorrect pipe size - the pipe must be big enough for the highest water volumes expected - even if these peaks occur rarely.
- Blocking off existing outlets - all existing field drain outlets must be catered for. Surround existing outlets with suitable stone fill to ensure existing field drain outlets are well connected to the new pipe.
- Silt and Iron deposits commonly found in drains may build up, so the pipe will require on-going maintenance. Roots from bushes or trees in hedges can enter and grow along the pipe causing blockages.
- Unstable, poorly graded drain bed - if the drain bed is soft and unstable, some hardcore fill will be required to ensure a stable, evenly graded bed for the pipe.

Section 4

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Groundwater **Drainage Systems**

by **Pat Tuohy, Owen Fenton**

Introduction

A groundwater drainage system exploits the free-draining permeable layers in the soil to remove water from the soil profile and lower the water table.

1. What is a groundwater drainage system?
2. How deep should the drains be installed?
3. How far apart should the drains be placed?
4. How do I layout the drains?
5. What is used for identifying and tapping springs?

Groundwater Drainage Systems

1 What is a groundwater drainage system?

A groundwater drainage system consists of a network of pipe drains collecting water which is moving through free-draining soil layers in the soil profile.

- By tapping into a permeable layer, the drain will discharge water throughout the year, even under dry summer conditions (see Figure 1). Lowering the water table means removing water from the soil from below and therefore allowing for more water to infiltrate from above. This can also change the permeability of the soil, either naturally (water will move more easily into new formed cracks in a dryer soil or along more deeply penetrating roots) or artificially (techniques which increase permeability such as subsoiling or ripping can be implemented in a dryer soil).

Key point

A groundwater discharge system will work if:

- The soil contains a layer of reasonable permeability and thickness (at any depth) to allow water movement;

- The layers above the permeable layer will shrink and crack when drained, allowing water to percolate to the water table at a reasonable rate.

Key fact

Piped field drains, on their own, are only worthwhile where they tap a permeable layer.

How to

Detect a permeable layer.

If you have dug a soil test pit and water begins to seep from the soil profile and accumulate in the bottom of the soil pit you have a permeable layer. If water can flow into the soil test pit at this level then water will flow to a drain placed at this level.

High potential for water discharge

- A piped drain in the permeable layer will remove the groundwater. This is the ideal scenario for land drainage. A permeable layer at a workable depth is an opportunity not to be wasted.

- This scenario as illustrated is relatively common throughout the country. As many of our soils were formed by deposits from melting glacial ice, the

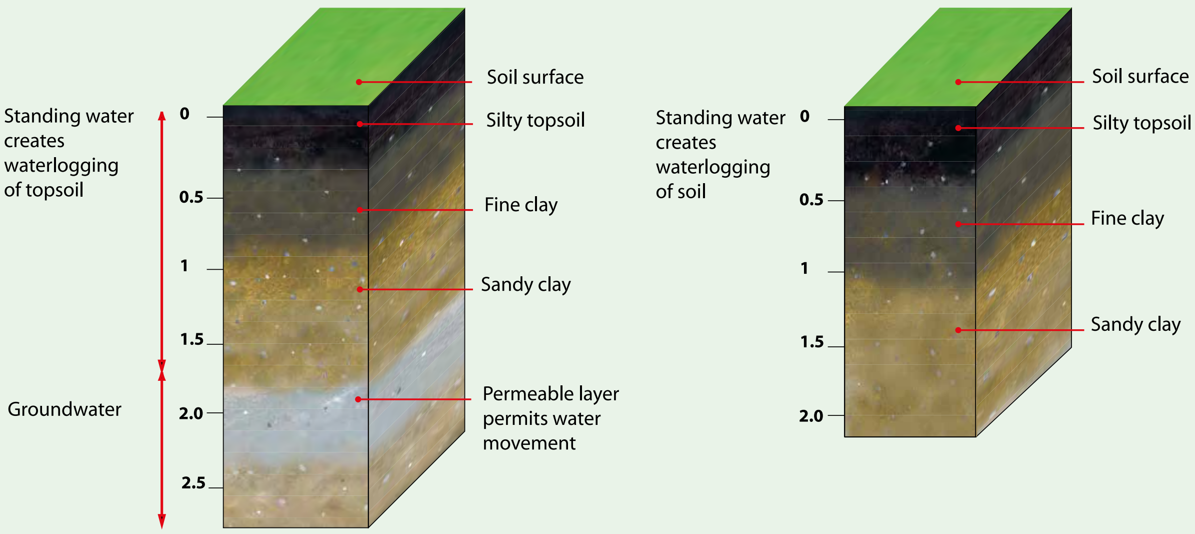


Figure 1. A typical heavy soil profile (on the left). If a free draining layer is present (called "permeable layer" here) at any depth then groundwater drainage is the most appropriate solution, if not (as in the profile on the right) then shallow drainage is required (see Chapter 11). In some situations a combination of groundwater and shallow drainage systems will be appropriate.

heavier coarser particles (sands and gravels) tended to be dropped first followed by the light fine particles (silts and clays). As a result, the poorest subsoil can be close to the surface while more permeable layers can be found further down the profile.

- Areas of the farm with a permeable layer at a workable depth offer the best potential for successful drainage and should be prioritised over other areas. Some areas are not suitable for land drainage especially those areas which act as a natural buffer holding onto P and N that could be potentially lost if drained.

2 How deep should the drains be installed?

- The drain depth will depend entirely on the depth of the permeable layer: installing a pipe in impermeable soil is useless and costly.

- The drain must be placed in, or at least on the upper part, of this permeable layer ensuring a direct connection.

Key risks

- The soil test pit investigation will have given you the depth and thickness of the permeable layer at only a few points (where the test pits are located). The depth of the permeable layer may vary. Ensure the variation is not too large and that the drain will be discharging water from this layer over its full length.

- Conventional piped drains at just 0.8 to 1.5 m below ground level have been successful where they encounter layers of high permeability. However, where layers with high permeability are deeper than this, deeper drains are required. Deep piped drains are usually installed at 1.5 to 2.5 m below the surface.

- For water to move into the drain it must have a 'fall' even if very slight.

Figure 2. The drain depth will depend entirely on the depth of the impermeable layer.

Groundwater
Drainage Systems

Key risk

An excessive fall in the pipe can result in the 'upstream' end of the drain being very shallow, usually too shallow to discharge water from the permeable layer being targeted. This may lead to waterlogging at the surface at the furthest point away from the outfall and a false conclusion that the drain is not working.

Key question

What if I cannot achieve the required outfall depth?

- If you are restricted by outfall depth, the permeable layer should still be targeted with field drains as its potential to discharge water is too great to be ignored.

- The diagram below shows the arrangement of a pumped outfall. The open drain is dug to the depth of the permeable layer. This acts as a sump for water flowing from the field drains at this level. A small submersible pump is then used to discharge water from this open drain to the local outfall level.

- Such pumps are currently retailing at approximately €150 and can be run very cheaply from mains electricity. However, because they are likely to be located away from a mains connection their widespread use will depend on the availability of cheap solar power. This technology is advancing rapidly. In Figure 3 the level of the base of the trench is lower than the base of the river.

Outfall Trench Lower Than River

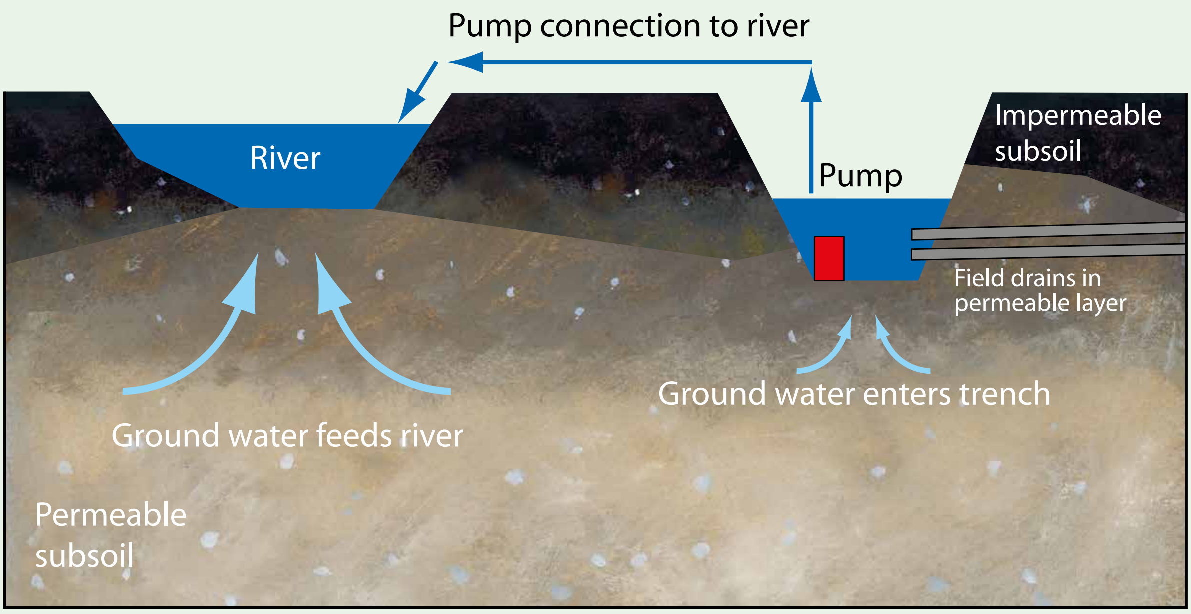


Figure 3. An example of a pumped outfall.

How to

Achieve the required depth while avoiding drain collapse.

- Deep drains can be difficult to install due to the risk that the field drain will collapse. Excavating in two stages will help avoid this.

  1. Use a moulding bucket (the shape promotes a stable bank) to open the drain to approximately 1m depth. This will allow excess water to soak away.

  2. When weather conditions allow, the drain should be further deepened by the contractor to the final depth using a narrow drainage bucket.

  With the top 1 metre removed, the operator can move through the unstable layers quickly reducing the risk of collapse.

- In particularly unstable soils, immediately install the pipe and stone backfill as the drain is being excavated.
- Exercise caution with regard to deep trenches. Do not enter trenches under any circumstances
- Deep drains are more difficult to install, but thanks to the large drain spacing allowed, less are needed. Hence, they are quite cost effective.

Where suitable in non stoney subsoil trenchers can be very effective and can install pipe and gravel or pipe complete with envelope to 1.6 m depth. The trench is later backfilled with soil. A trencher may be connected directly to a tractor.

3 How far apart should the drains be placed?

Key fact

The permeability and thickness of the drainage layer determines how wide an area an individual drain can discharge water from and therefore how close the neighbouring drains need to be.

- Drain spacing and depth can be estimated directly if the hydraulic conductivity or measure of permeability and thickness of each layer, the desired depth of the water table, and the amount of water to be drained are known.
- Given the huge variations found in soil permeability, very accurate spacings cannot be estimated without detailed, expensive measurements. From an economic and environmental perspective groundwater drains should be at least 15 m apart.
- Generally groundwater drains can be spaced at 15 to 50 m apart, but are typically installed at 15 to 25 m apart.

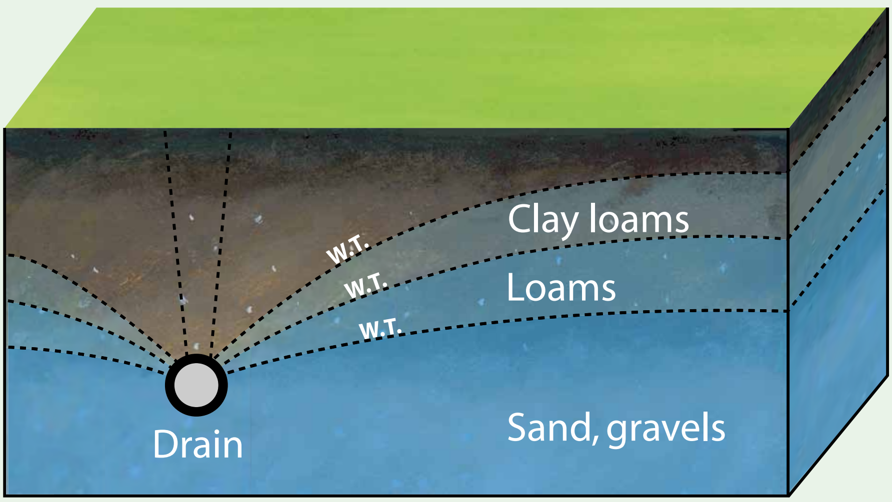


Figure 4. Effect of soil type on steepness of water table (W.T.).

Groundwater
Drainage Systems

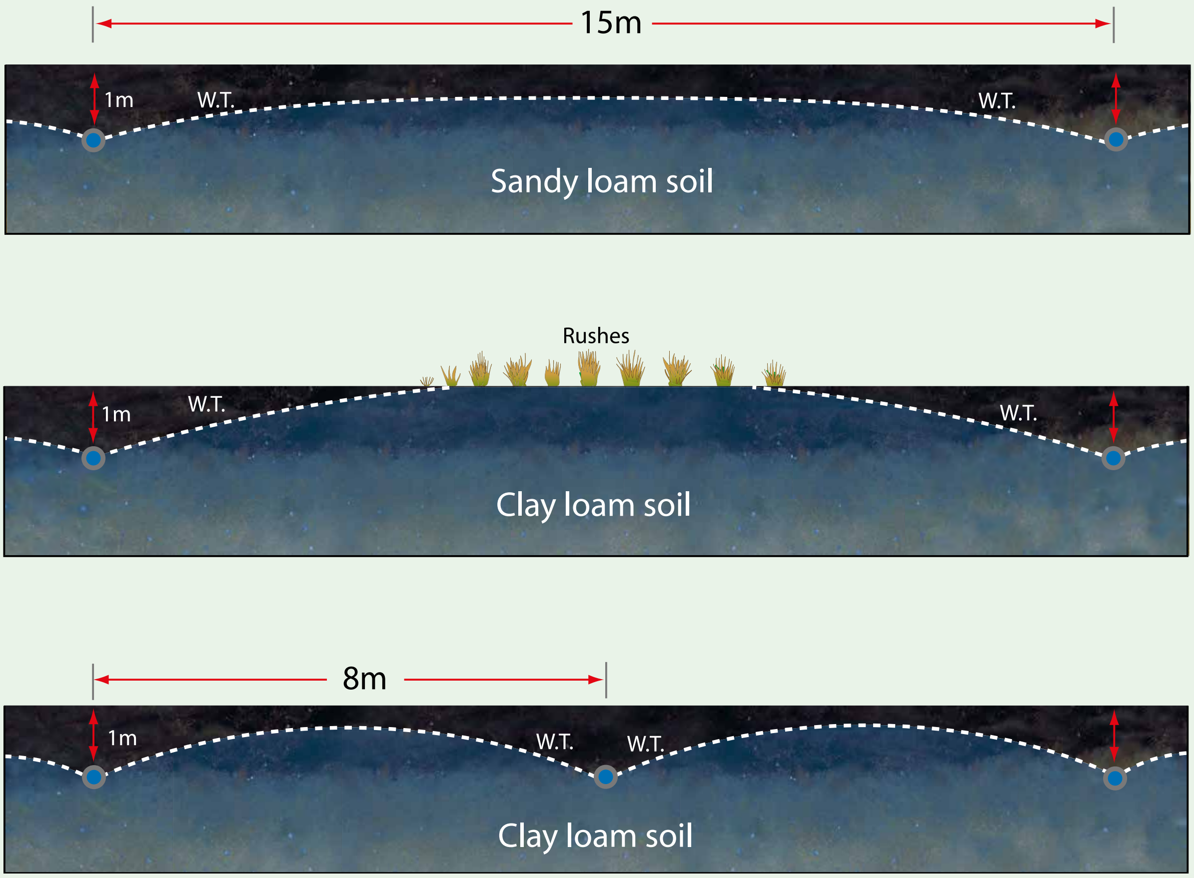
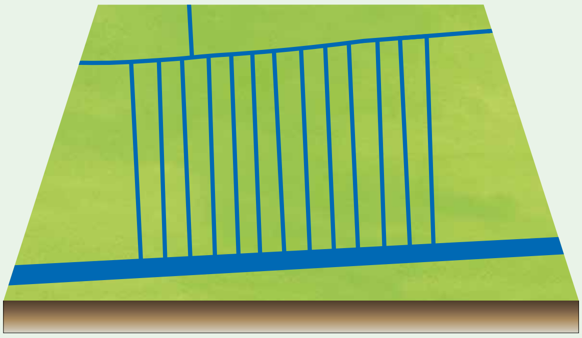


Figure 5. Shows how the water table position with the same spacing for different soil textures. Decreasing the spacing or increasing the depth can change this form.

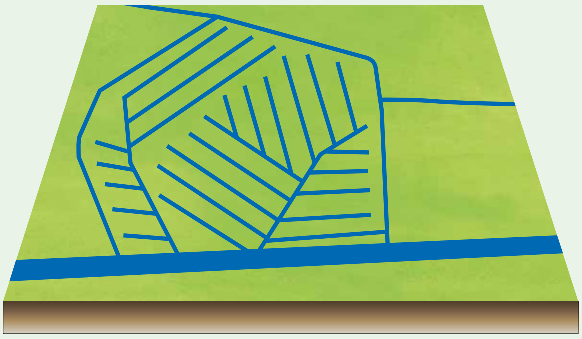
④ How do I layout the drains?

- Piped drains should always be installed across the slope to intercept as much groundwater as possible, with main drains (open or piped) running in the direction of maximum slope.

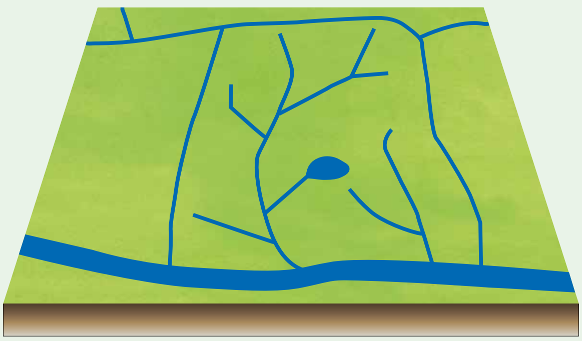
- Groundwater drainage systems are usually based on one of four layout patterns
  - **A:** Parallel
  - **B:** Herringbone
  - **C:** Natural
  - **D:** Interceptor



(a) Parallel



(b) Herringbone

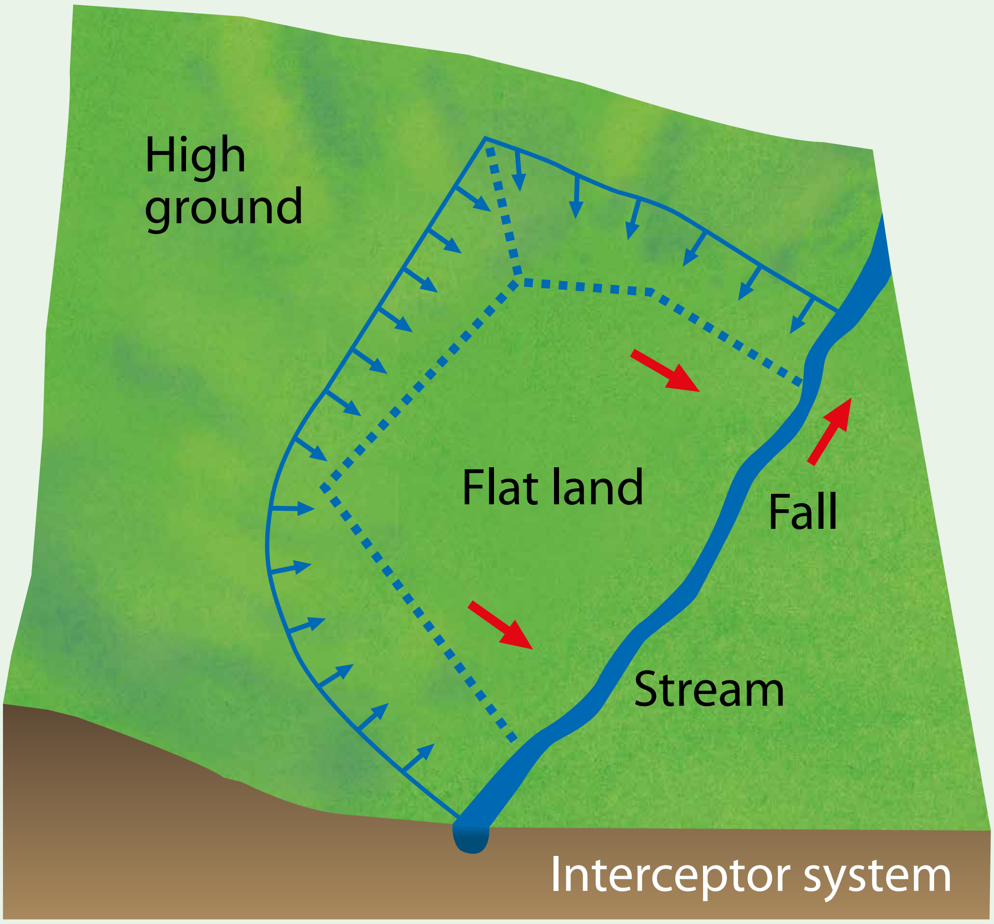


(c) Natural

Figure 6. Drainage system layout patterns.

- In uneven terrain, drains are most effective when they pass through depressions in the land. By doing so they exploit falls and low lying areas where water gathers naturally.
- Where land is relatively flat, a parallel network of drains is suitable.
- In a parallel system, field drains should be aligned across the slope with main drains running down the slope.
- In a herringbone system field drains are aligned across the slope but at a slight angle, to aid falls in the drains.
- In both the parallel and herringbone systems the main drain should be open for ease of maintenance. Blockages in a similar fully piped system would be difficult to find and remove.
- Interceptor drains are strategically placed to intercept springs and are generally at the lower side of sloping ground.

Groundwater **Drainage Systems**



(d) Interceptor

Figure 7. Groundwater drainage design.

5 What is used for identifying and tapping springs?

- Where groundwater flows through a permeable layer, with an impermeable layer lying on top of it, the water will try to find a discharge point on the landscape. Springs are found where the ground surface and groundwater intersect, usually on the side of a hill or where flat land is adjacent to higher ground.

Key point

You must go deep enough to intercept the flow where it is moving through permeable layers upslope from the point where it is boiling out to the surface and saturating a large area.

- The drainage of seepage and springs requires an 'interceptor' type of groundwater drainage (Figure 8).
- Pipe drains are always most effective in, or on, the layer transmitting groundwater flow (as shown by high water breakthrough in the soil test pit). This issue is very site specific as the depth and length of spring lines varies hugely.

Figure 8. Cutaway of how an impermeable layer can result in springs emerging on a hillside (see also Chapter 1).

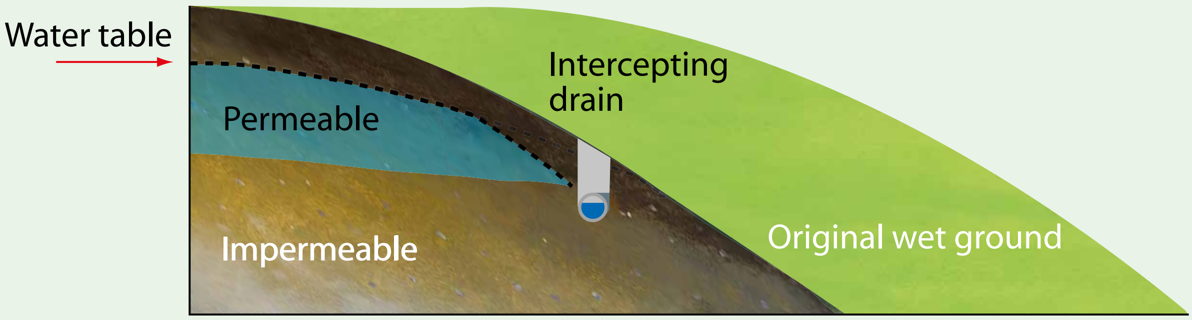


Figure 9. A well placed interceptor drain will greatly alleviate the problem.

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Shallow Drainage Systems

by **Pat Tuohy, Owen Fenton**

Introduction

If there is no permeable layer in the soil profile and permeability generally is low at all depths a shallow drainage system is required.

1. What is a shallow drainage system?
2. What is land forming?
3. What is mole drainage?
4. What is gravel mole drainage?
5. What are collector drains?
6. What is meant by subsoiling?

Shallow
Drainage Systems

① What is a shallow drainage system?

A shallow drainage system is used where the permeability (the ability of the soil to allow water to move through it) is low at all depths. Excess water cannot flow through the impeding layers and a number of measures are used to promote infiltration and drainage. These include land forming, mole drainage and subsoiling in tandem with piped collector drains.

Key point

Piped field drains alone will not collect any water from the soil in this situation and the water table will not be lowered. Only some surface water will be collected. This is clear when looking at many conventional field drains, which only flow on wet days despite the fact that the land directly adjacent to the drain remains saturated.

Key goal

The aim is to introduce new pathways for water movement in the soil and provide piped field drains as collectors for this water.

② What is land forming?

- Land forming aims to restrict surface ponding as much as possible by eliminating unevenness of the land surface - hollows etc.

- In all soil types, be careful to avoid anything that might prevent the natural removal of surface water. This is particularly important in those soils that are heavy throughout as water will be more inclined to move over the surface in wet conditions as it cannot easily move down through the soil profile.

Key fact

Surface ponds are self-perpetuating as the soil structure (cracking) in the depressions deteriorates due to the frequent ponding and soil pores become clogged by the sediments carried into them by the water.

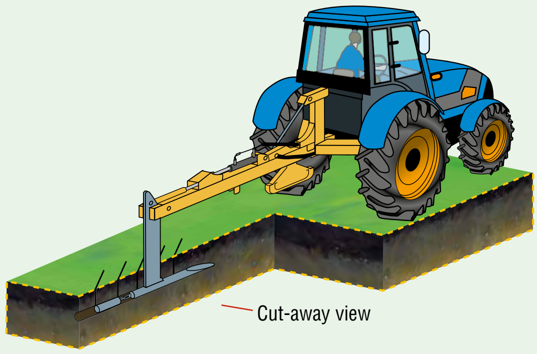

Figure 1. Installation of a mole drain.

- Land forming will not solve the full drainage problem on a deep heavy soil but it is an important starting point.

Land forming techniques

- Any small differences in height should be eliminated to ensure a continual slope from all points of the field to an open drain.

- Where large quantities of soil must be moved, it is best to strip topsoil from the affected area and grade the subsoil, before reinstating the topsoil. Failure to do this may cause localised drainage problems. Avoid causing compaction to soils during the process.

- Remember to carefully spread spoil from upgraded open drains. Soil left adjacent to open drains can cause the greatest ponding. Poorly planned passageways are also a common culprit.

③ What is mole drainage?

- The aim of mole drainage is to improve soil permeability by fracturing and cracking the soil. Mole ploughs are used to create mole channels 1.5-2.0 m apart in the soil.

- A mole plough consists of a torpedo-like cylindrical foot attached to a narrow leg, followed by a slightly larger diameter cylindrical expander (Figure 1).

- Mole drainage transfers surface water to pipe collector drains or open drains, which are running at right angles to the mole channels.

- A mole plough typically has a 7 to 8 cm diameter foot with an 8 to 10 cm expander and a leg adjustable to extend to depths up to 60 cm.

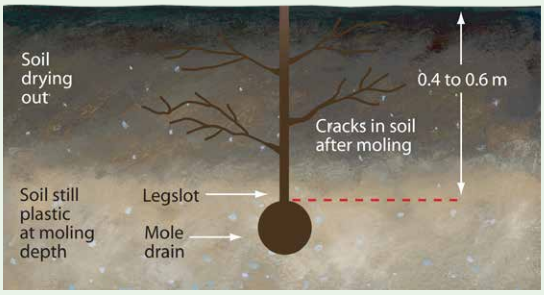

Figure 2. Mole drain showing cracking.

How does it work?

- As the mole plough is pulled through the soil, the foot of the plough creates a channel; the trailing expander helps to finish and solidify this channel.

- As the soil is lifted and disturbed, cracks are formed which radiate from the tip of the mole plough to the soil surface. Surface water can move to the channel through these cracks (Figure 2).

- The mole plough creates both a zone of increased permeability adjacent to the mole plough leg (shallower depths) and a channel for water outflow at moling depth.

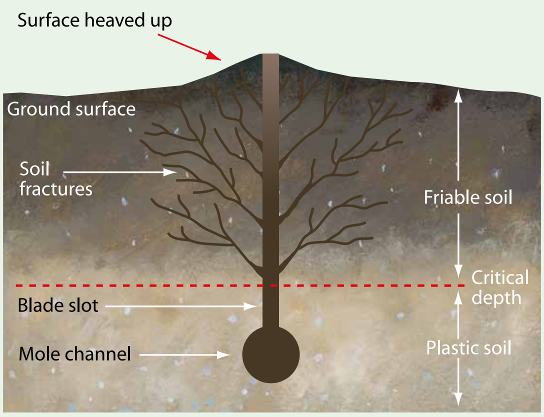

Figure 3. Mole drain showing surface heave.

Suitability of soils for mole drainage

- Mole drainage requires soils with high clay (greater than 40%) and low sand content which will form stable channels. Local experience and examination of the soil in the test pits will give a good indication of a soil's suitability.

- The presence of large stones, gravel or sand pockets in the soil will make it unsuitable for mole drainage.

- The suitability of soil types for mole drainage is identified on the soil texture chart, see Figure 4 below.

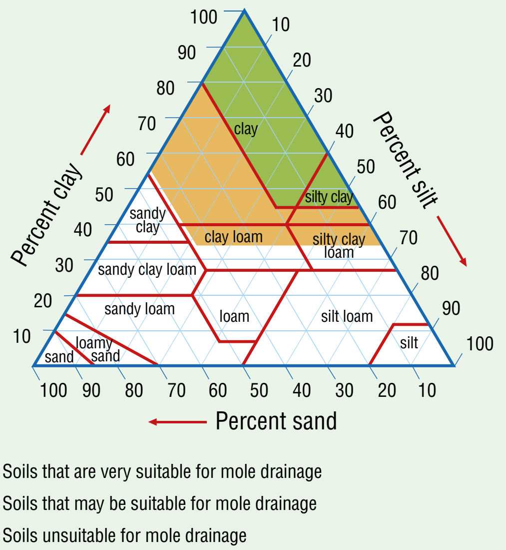

Figure 4. Soil texture triangle.

The green section identifies the soil types that have a suitable texture (see Chapter 7 for explanation of textural classes) for producing stable mole drains (this includes some of the clayey soils).

The orange section identifies soil types that may be suitable for mole drainage (this includes the remainder of the clayey soils as well as parts of the fine loamy and fine silty groups).

chapter 11

Shallow
Drainage Systems

The uncoloured section identifies soil types which are unsuitable for mole drainage, due to poor stability.

Mole drain installation

- The mole drains should be spaced 1 to 2 m apart. This close spacing is required to ensure maximum cracking of the high-clay-content soils.

Key point

The depth at which moles are drawn should be related to the soil profile; ideally the leg should be located in the brittle soil with the mole foot in a heavy clay layer free from stones, where it will form a stable channel.

- Typically, mole drains are pulled at 50 to 60 cm depth. In wet heavy clay soils, the soil at this depth is unlikely to crack and shatter as desired. It may be necessary to shallow mole or subsoil after collector drains are installed, to aid the drying process before aiming for the full mole depth.

Key point

It may not be possible to reach full moling depth at first attempt so something must be done to help remove water to get you to the point where full depth can be achieved.

- The mole plough should be drawn up-hill in the direction of maximum fall across an even gradient to ensure rapid removal of excess water. Also, any loose material will be carried up the channel.

Key risks

Moling downhill carries the risk of depositing loose material in the lower part of the channel, blocking the channel close to the exit.

The mole plough will follow the contours of the soil surface. Moling should be conducted along as even a gradient as possible. Dips in the ground will cause water to sit in the mole channel possibly causing the mole channel to collapse soon after installation.

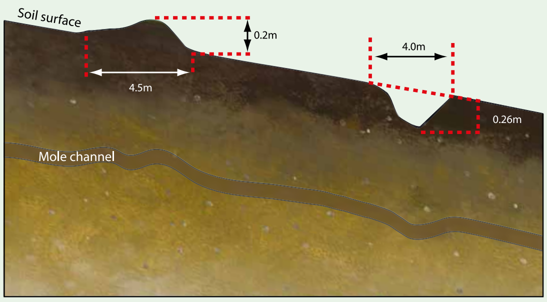

Figure 5.

Figure 6. Figures 5 and 6 mole channel following the contours of the surface.

- The depth of the mole foot must be maintained during mole ploughing. Any breaks or discontinuities in the channel will lead to the failure of that channel, due to increased load on adjacent channels. As a result, large parts of the system could fail.

- If the mole drain is to lead into an open drain, 1 m pipe lengths with a similar diameter to the expander must be inserted into the channel ends to stabilise them.

- Even in ideal soils and installation conditions, the lifespan of mole drainage is limited to 2-5 years in most circumstances. The process can be repeated at low cost to ensure that the positive effects are sustained overtime.

Key risks

- If the mole plough is not strong enough, distortions can result due to the stresses imposed on it by the soil during the moling operation.

- The mole foot may have insufficient "bite" causing the mole plough to ride out of the ground especially in higher strength soils. This may affect mole channel continuity.

- If the mole foot does not run parallel to the ground surface, and in line with the direction of travel, the channel formed will be oval rather than round in cross section and poorly formed, lacking stability and prone to collapse.

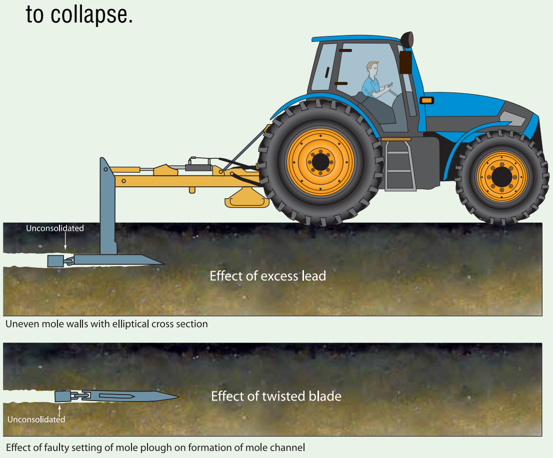

Figure 7. Problems which can arise if the mole plough is incorrectly adjusted.

4 What is gravel mole drainage?

There are many soils which require the close drain spacing and soil loosening - which good mole drainage delivers - but in which the mole drains themselves are unstable, due to low clay content or the presence of sands, gravels or stones. The alternative in this case is gravel mole drainage, where the mole is filled wih stone to provide stability.

Key fact

Gravel mole ploughing is the most generally applicable of the drainage methods, but it is also the most expensive.

- The mole channel is formed as normal but is then immediately filled with gravel from a hopper mounted on the tractor. The gravel supports the walls of the mole drain.

- A typical gravel mole plough has an 8 cm diameter leading foot and can install channels to depths of up to 50 cm (18 inches).

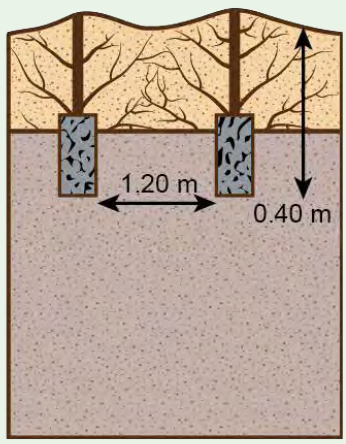

Figure 8. Gravel mole drain.

How does it work?

- The gravel mole plough carries a hopper which has a hydraulically operated shutter to control the flow of gravel; the gravel chute also has an adjustable door which regulates the height of gravel in the mole channel.

Shallow Drainage Systems

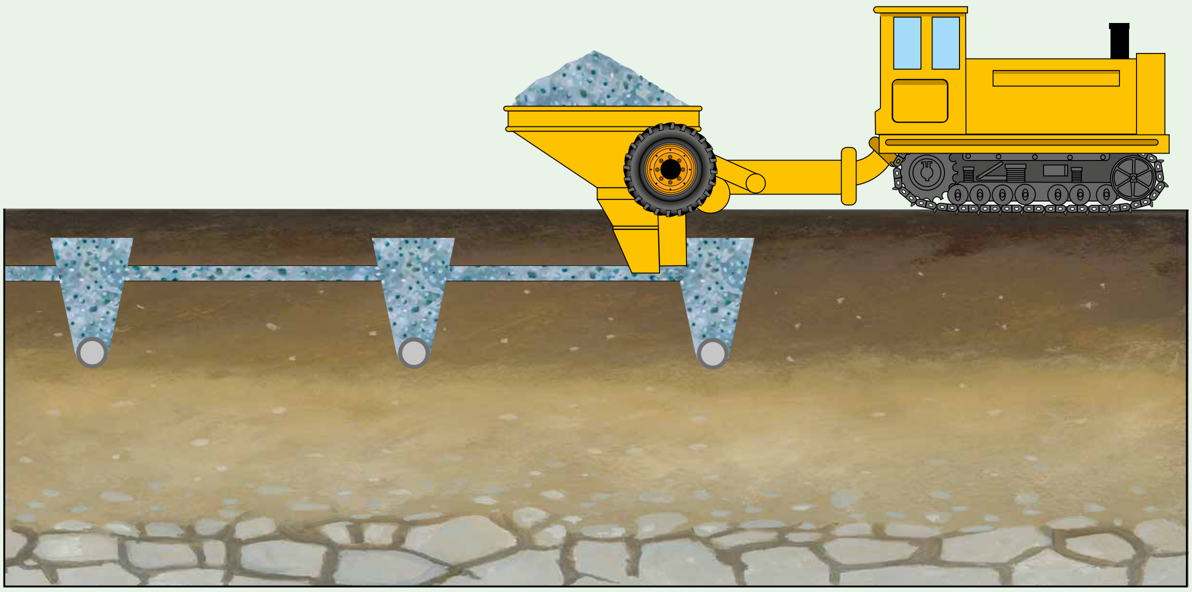

Figure 9. Tracked vehicle installing gravel moles at right angles to collector drains.

- During operation the hopper is filled using a loading shovel or a belt conveyor from an adjacent gravel cart.
- Gravel mole drainage channels are spaced slightly wider apart than conventional moles - 1.5 to 2.5 m.
- All points made in relation to mole drainage installation also apply to gravel mole drainage.

5 What are collector drains?

- A well laid piped collector system is an essential outlet for mole and gravel mole channels.
- This is simply a shallow piped drain (up to 1 m deep) which acts as an outlet for the mole or gravel mole drains.
- The collectors are laid across the slope of the field (at right angles to planned mole channel direction) before mole/gravel mole drainage is carried out at spacings of approximately 15 to 40 m for mole drains and 20 to 60 m for gravel mole drains.
- Collectors must be placed in any low-lying areas to ensure every mole channel has an outlet.
- The spacing of collectors determines the length of the channels. Longer channels require large collector spacings but become more prone to inundation and collapse as they lengthen. Shorter channels require smaller collector spacings and are more expensive as a result, but they generally have a longer life span. A balance must be struck between a reasonable lifespan and reasonable cost.

Key fact

Mole and gravel mole channels will break down over time (5 to 20 years). If a robust collector drain network is in place new moles can be created.

- If an existing drainage system of closely spaced piped drains is already in place at the appropriate depth, it may be possible to pull mole or gravel mole drains through this existing network or from existing open drains.

6 What is meant by subsoiling?

- Subsoiling and pan-busting are closely related. Pan-busting can refer to the breaking of a distinct iron (red in colour) or manganese (black in colour) pan (or other cemented layer) while subsoiling usually refers to a more general loosening of the soil.
- These techniques are another method aimed at improving soil permeability.
- The implement used is less refined than a mole plough and execution can be less precise. No attempt is made to form a stable channel and shattering the soil is the main aim.
- Subsoiling is not effective unless a shallow impermeable layer is being broken or field drains have been installed prior to the operation. Otherwise it will not have any long-term effect in relieving excess water and may be counterproductive.
- Subsoiling can be carried out at a range of depths, depending on the depth of the soil needing structural improvement.

Main Uses

- These methods come into their own where impermeable soil layers are within reach of the surface.
- A general loosening or breaking of an iron/manganese or plough pan may be sufficient to relieve excess water.
- As with mole drainage, effectiveness is likely to decrease over time. Soil compaction can return to previous levels and pans can reform. This is a relatively low cost technique which will need to be repeated over time.

In combination with other techniques

- Subsoiling can be used in tandem with mole or gravel mole drainage in very hard and compacted soils. If carried out pre-mole drainage, it can help bring about the desired cracking, which may not be possible using the mole plough alone.
- In the case of gravel moling in particular, subsoiling at 1 m spacings can facilitate gravel moles at 2 m, reducing overall cost.
- Subsoiling can also be used in combination with groundwater drainage where the less permeable surface layers are particularly heavy. Subsoiling will help bring about the desired cracking of these layers to allow surface water flow to the water table which is being discharged by the groundwater drainage system.

Figure 10. Effect of depth on the impact of subsoiling.

Shallow Drainage Systems

How to

Maximise the chances of success.

Soil Type

- The technique used must be suited to the soil type being drained. If mole draining, ask yourself; will the channels be stable? If subsoiling; will there be a worthwhile effect?

- Would another technique be better suited?

Timing

- The effectiveness of the shallow drainage technique depends on the extent of fissures and cracks formed in the soil during installation.

- The development of sufficient cracking is heavily dependent on soil moisture content. The ideal time to carry out shallow drainage is during dry summer conditions, this will cause maximum cracking in the upper soil layers as well as improving traction and minimising wheel-spin on the soil surface.

- Dry weather after mole drainage also helps prolong the life of the mole channel as it allows time for the newly arranged soil particles to bond, strengthening the channel.

Key risk

Never work soils under wet conditions. The desired soil shattering will be replaced by smearing, which will reduce drainage capacity.

- Cleaning and deepening of existing open drains, maintenance of existing field drains and the installation of collector drains will aid the drying process and facilitate shallow drainage installation when the opportunity arises.

Equipment

- The implement used must be in good order and fit for purpose.

- It should be able to reach the desired depth to:
  - Reach a suitable soil layer to form a stable channel,
  - Connect with collector drains, or
  - Shatter the impeding layers or pan.

- Sufficient power and traction should be available to provide an even pull.

Key points

- In areas of particularly high rainfall, the shallow drainage systems will have to cater for large water volumes.

- Capacity is improved by increasing the density of disturbance (reducing the spacing or incorporating a supplementary measure such as subsoiling), reducing the spacing of collector drains, isolating the site with open drains to reduce runoff from adjacent areas. Maintaining collectors and outfalls in good working order is also key.

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Implementing the Solution

Section 5

Section 5

Managing a **Drainage Project**

by **Pat Tuohy, Owen Fenton**

An update of a previous version written by Pat Tuohy, Owen Fenton, James O' Loughlin

Introduction

Once you have decided to drain an appropriate piece of land, complied with environmental regulations, carefully diagnosed the problem and identified the optimum system, it is vital that the plan is carried out to the highest standard. Commit to a clear plan and communicate it effectively to the drainage contractor. Soil test pits and examination of open drains are a vital starting point, but a drainage plan may need to be adapted as the drainage work proceeds.

1. **What are the key steps in managing a drainage project?**
2. **How do I get best value when buying materials?**
3. **What drawings and records are useful on a drainage project?**

chapter 12

Managing a **Drainage Project**

① What are the key steps in managing a drainage project?

Checklist

What must be done before, during and after installation?

Before Installation

- Before you begin any drainage project consider the potential for environmental risks and compliance with statutory obligations (see Chapters 6 and 7).
- It is always good to have a clear template ready before you meet the contractor.
- Discuss with the contractor when the best period of the year to do the job might be, emphasising that installation should occur in dry weather.
- On the template provided (see examples later) fill in all relevant details of your drainage plan. Include proposed spacings, depth, pipe and stone size required as well as shallow drainage type, spacings and depths as required.
- Well in advance of field work sit down with your contractor and go over the drainage plan. Use maps and sketches to explain the drainage design. These can be kept as a record of field drain locations for future ease of maintenance.
- Check the drainage plan and ensure it is properly marked out in the field. Stakes indicating the start and end of a field drain should be colour co-ordinated.
- Walk the site with the contractor and explain the marking system of field drains which you have put in place.
- Check all materials and equipment (e.g. grade of pipe, gravel diameter, digger buckets, shallow drainage implements etc.)

During Installation

- Start with main drains which are to be installed/ up-graded, then move on to the field drains and finally cross-cutting field drains e.g. mole drains.
- Begin at the downstream end of the site and work upwards to the upslope part. This will discharge water away from the drainage works.
- Check that no damage to pipes has occurred.
- Constantly check levels. In some cases gravel infill may help correct final levels. In a deep drainage installation, ensure drain depth to the permeable layer has not been compromised by achieving an excessive fall. This may be counter intuitive in places, but laying drainage in an impermeable layer will lead to problems later.
- For mole drains, gravel mole drains or sub-soiling, ensure the necessary depth is being achieved and the spacing is as planned.

After Installation

- Ensure that the soil backfill is not compacted causing local drainage problems. Instead, let the backfill settle naturally. Do not compact with the digger bucket to make things look neat!
- Over time, regularly inspect the drain discharge points to ensure water is exiting the system.
- Maintain the system and where possible install an in-ditch mitigation measure to minimise nutrient, carbon and sediment losses to waters. Refer to Chapters 6 and 7.

How to

Choose a contractor.

Land drainage requires specialist skills and equipment and great care must be taken in selecting a contractor.

- Get references from other farmers about previous work carried out.
- The contractor must have access to the necessary equipment and be skilled in its use, particularly in the case of mole and gravel mole ploughs.
- The contractor must be able to follow a clear plan.

- The contractor must be competent to assess site levels and falls and to install the full system as specified. This is especially important where the drain needs to be kept deep for long distances from the outfall.

- While price is the not the most important criterion, get several quotes, and negotiate.

2 How do I get best value when buying materials?

The quality of the drainage system will largely depend on the quality of the materials used. There is a range of options for drain pipes and the accompanying stone.

1. **Do I need to use a pipe?**
2. **What type and size of pipe is suitable?**
3. **What are the functions of drainage stone?**
4. **What type and size of stone is suitable?**
5. **How do I backfill the drain?**
6. **What do I do with excess soil?**

Key points

Pipes.

- In long drain lengths (greater than 30 m), a drain pipe is vital to allow as high a flow-rate as possible from the drain. Stone backfill alone is unlikely to have sufficient flow capacity to cater for the water volume collected.

- Only short drain lengths (less than 30 m) or the upstream end (less than 30 m) of any drain are capable of operating at full efficiency without a pipe.

- Avoiding pipe blockages is often the main motivation for not using one. Unfortunately what caused the pipe to become blocked in the first place will also block the stone-only drain but in a much shorter period.

- Pipe blockages are to be expected in land drainage. They can be minimised by choosing a smaller stone size which will act as a better filter, or removed by consistent maintenance. Choosing to go without a pipe is not a solution.

How to

Choose pipe.

- The type of pipe used has progressed over the years from clay tiles to the plastic piping that dominates today. Both can be found on most farms.

- The driving factors in the evolution of drainage pipe have been cost, labour efficiency and fitness for purpose. Under these headings the low cost, lightweight and durability provided by the standard corrugated perforated PVC pipe will always win.

- This pipe comes in a range of diameters suitable for most field drainage projects and performs well when installed correctly.

Pipe size (mm)	Pipe size (inch)	Discharge capacity (litres/second)	Area drained (acre)	Area drained (hectare)
50	2	0.37	0.6	0.24
65	2.6	0.78	1.2	0.49
70	2.8	1.02	1.6	0.65
80	3.1	1.44	2.3	0.93
100	3.9	2.75	3.3	1.34
110	4.3	3.62	5.6	2.27
155	6.1	6.40	12.1	4.90

Table 1.

- The pipe size required depends on the maximum amount of flow to the pipe which is determined by the expected rainfall, the soil permeability, the land area serviced by the drain, the fall in the pipe, and the pipe material.

- Table 1 gives an indication of the area drained by a range of pipe sizes. The area you drain with a pipe is calculated as the pipe length multiplied by the drain spacing.

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Managing a Drainage Project

The following assumptions are made:
- Corrugated plastic pipe;
- Pipe slope of 1 in 200;
- The aim is to drain 10mm per day;
- A 25 percent loss in capacity due to sedimentation is allowed for.

- Some pipes are supplied with a pre-installed filter wrap material and are designed to be used without stone.

- A drainage pipe without stone is limited, however, because the water must follow a more arduous path to the pipe and the effective size of the drain is reduced. The filter material is also prone to clogging in inappropriate soil types.

- The filter wrap is a poor replacement for good drainage stone in most Irish mineral soils. These filters are common in other parts of the world, where creating an outlet and discharging water are enough to create gradients and remove water. In some Irish groundwater drainage systems, these filters would be an appropriate alternative to stone aggregate.

How to

Choose drainage stone.

Good quality drainage stone is a vital part of any drainage system. The drainage stone:
- Acts as a connector: connecting the drain pipe to permeable layers in the soil, mole channels, subsoiling cracks, spring lines or existing drains;
- Permits easier inflow of water to the pipe;
- Acts as a filter: preventing fine particles getting into the pipe;
- Supports the pipe, preventing damage or collapse.

- The material used needs to be robust and must not deteriorate after installation.

- The size of stone generally specified is in the 10 to 40 mm (0.4 to 1.5 inch approx) range, with further benefits evident for smaller (10-20 mm) material. It should be clean and free from waste material. It should also be of consistent grading (i.e. small variations from the given diameter).

- This is generally a smaller size than is commonly in use in many areas. Excessively large stone presents handling problems and allows for easy ingress of sediment to the pipe, increasing the risk of blockages over time.

- Gravel mole channels require clean 'pea' gravel in the 10 to 20 mm (0.4 to 0.8 inch approx.) grading band.

- Get to know the grade and quality of gravel/stone which is available from local quarries. Some may not be suitable for land drainage. Shop around to confirm available material types and sizes and remember you generally get what you pay for. Local stone / gravel which may cost less is not always the most appropriate option.

Key fact

Remember that drainage stone accounts for the bulk of the cost in most drainage schemes. It is important to use the stone as efficiently as possible, don't be wasteful. The width of the drainage bucket used will also be a major factor in the total amount of stone required.

How to

Backfill a drain.

- Remember that the main function of the drainage stone is to connect the drain with the permeable layer (in groundwater drainage) or mole drains/subsoiling cracks (in shallow drainage) or spring lines (when tapping springs). Any drainage stone filled above the point where this connection has been made is a waste of stone (Figure 1).

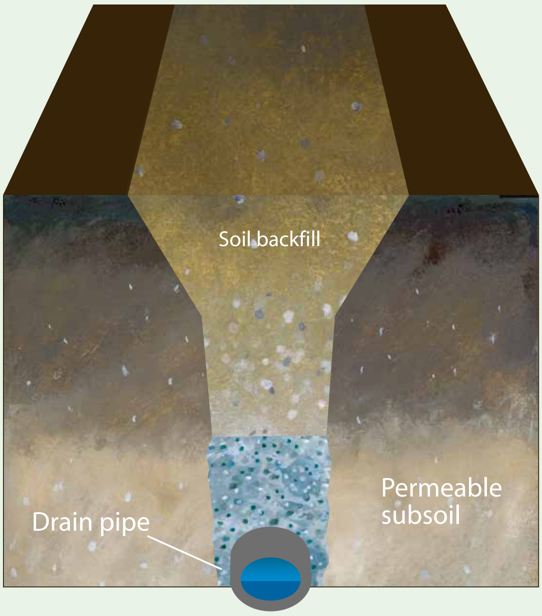

Figure 1. Connection with permeable layer.

Key point

- Drainage stone should be filled to a point where these connections have been made and no more (see diagrams).

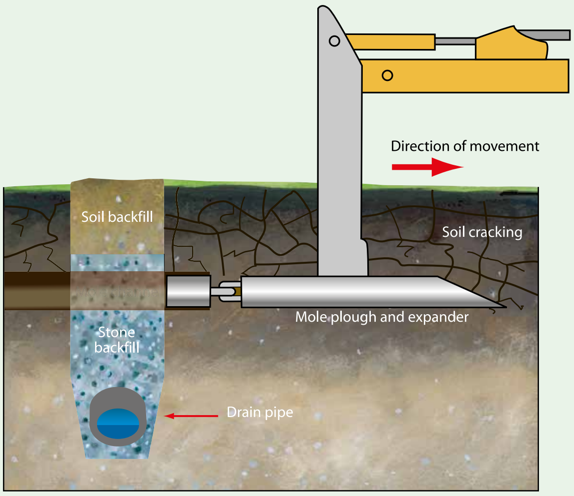

Figure 2. Connection with mole channel.

- In groundwater systems, the gravel/stone should be filled to a minimum depth of 300 mm from the bottom of the drain, to cover the pipe. Stone backfill for mole channel collectors should be filled to within 250 mm of the surface to ensure interconnection with the mole channels (Figure 2).

- Where practical, a bed of stone should support the pipe. This will be a thin layer of 25 - 50 mm depth.

How to

Reuse of excess soil.

- Remember soil is a finite resource with value. The soil removed from field drains can be spread over adjoining land, filling depressions if of suitable quality. Remember soil is a finite resource and should be recycled on the farm. Consider environmental risks and always aim to complete this work in dry weather.

- Alternatively it may be buried by stripping back topsoil and filling before reinstating the topsoil; or the soil can be bunded to prevent surface runoff where required (adjacent to roadways, yards, etc.).

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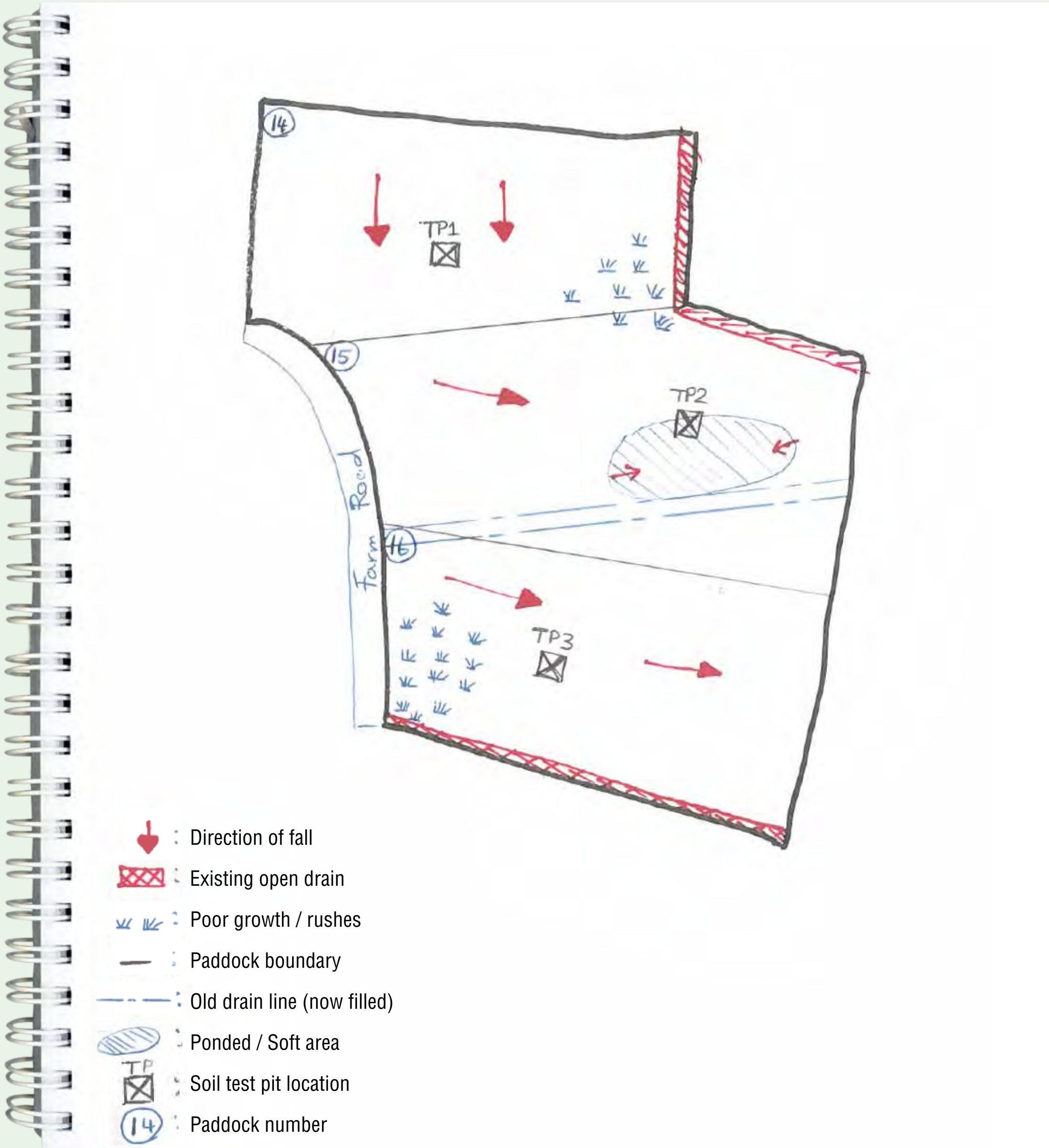
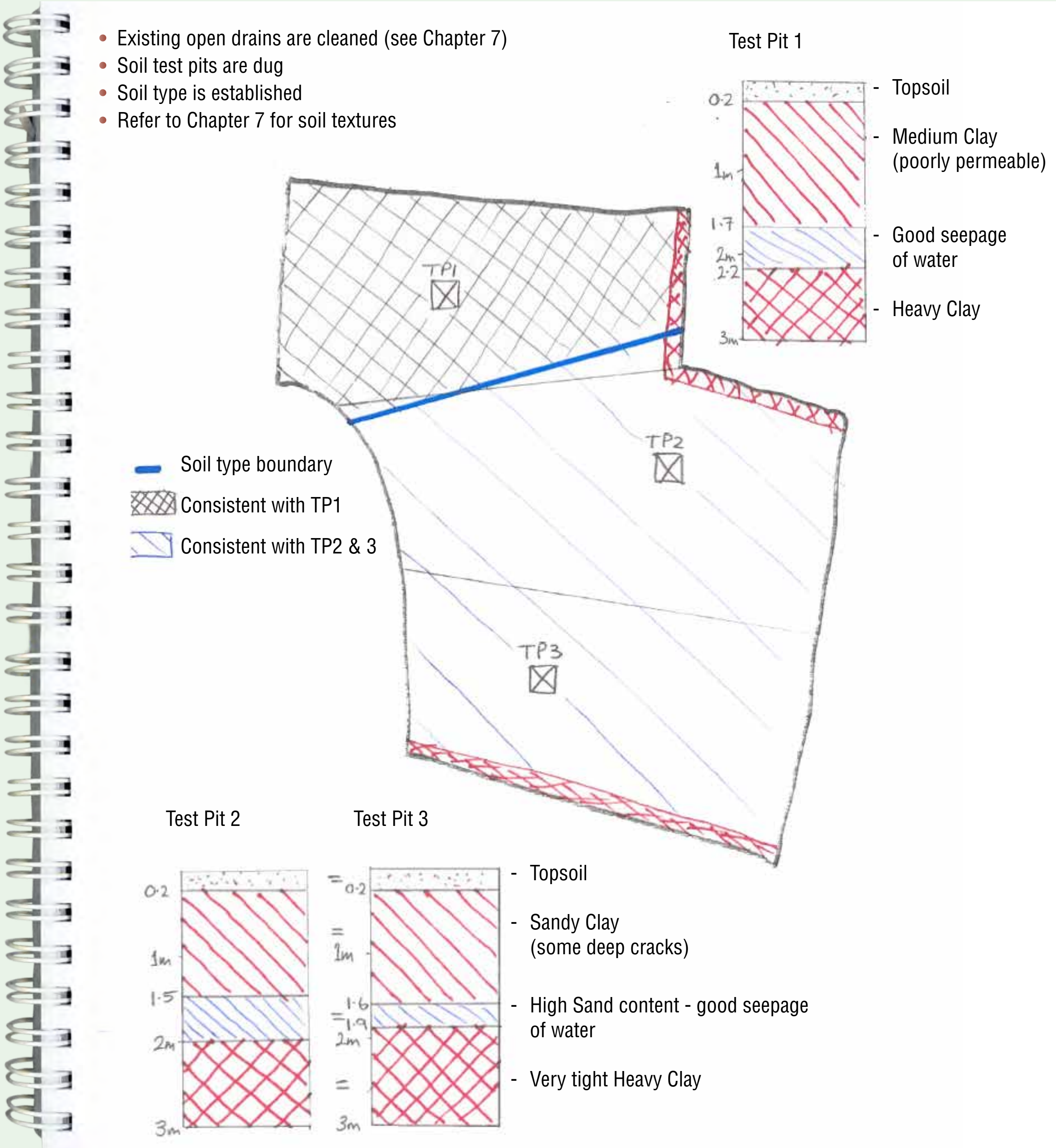
③ **What drawings and records are useful on a drainage project?**

Example 1: A groundwater drainage system with costings.

Rough sketch



Establishing soil type



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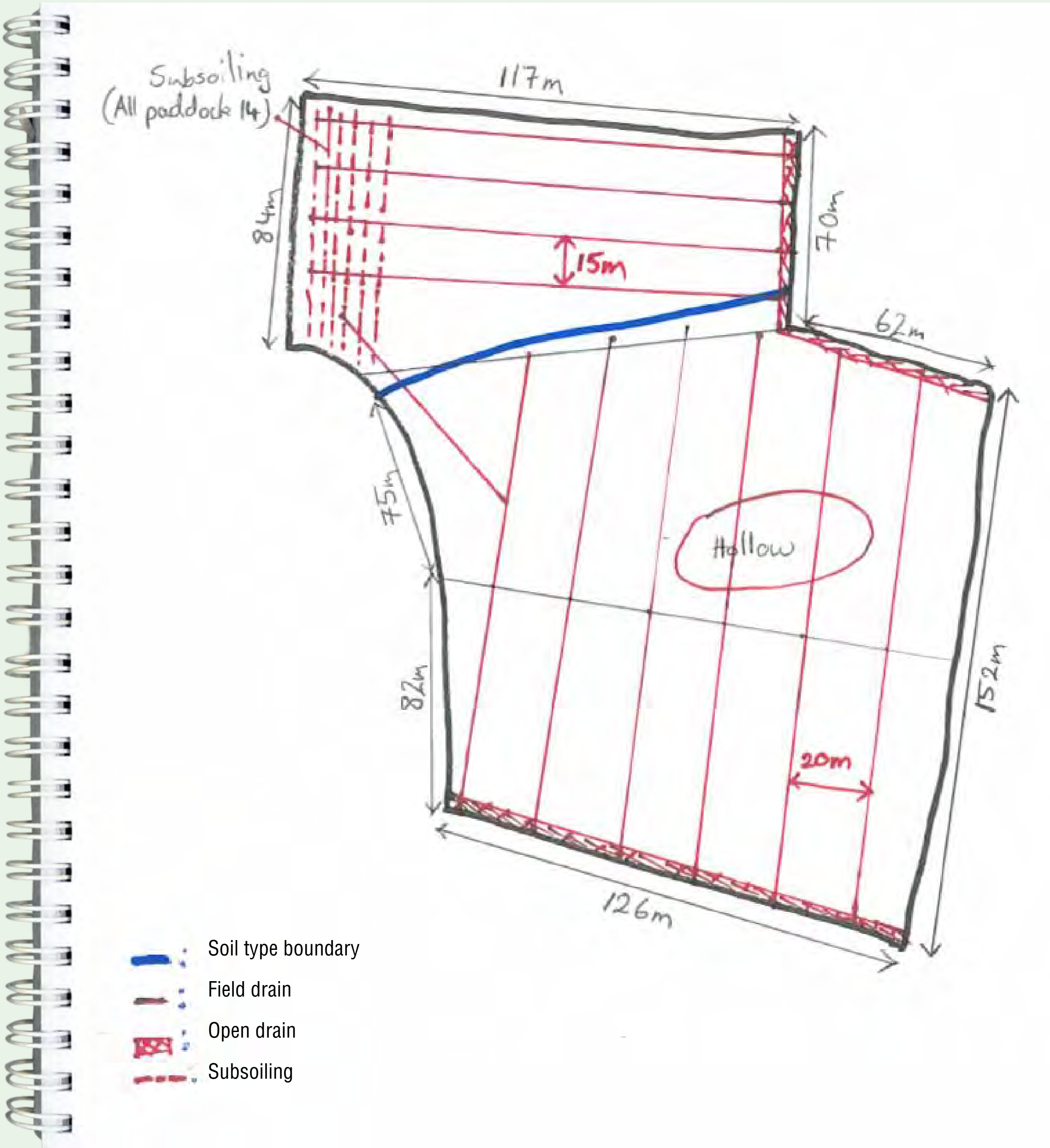
Drain layout sketch



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Drainage specifications (to be kept as a record, with layout sketch)

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Detailed Drainage Specifications

Land Owner J. Smith

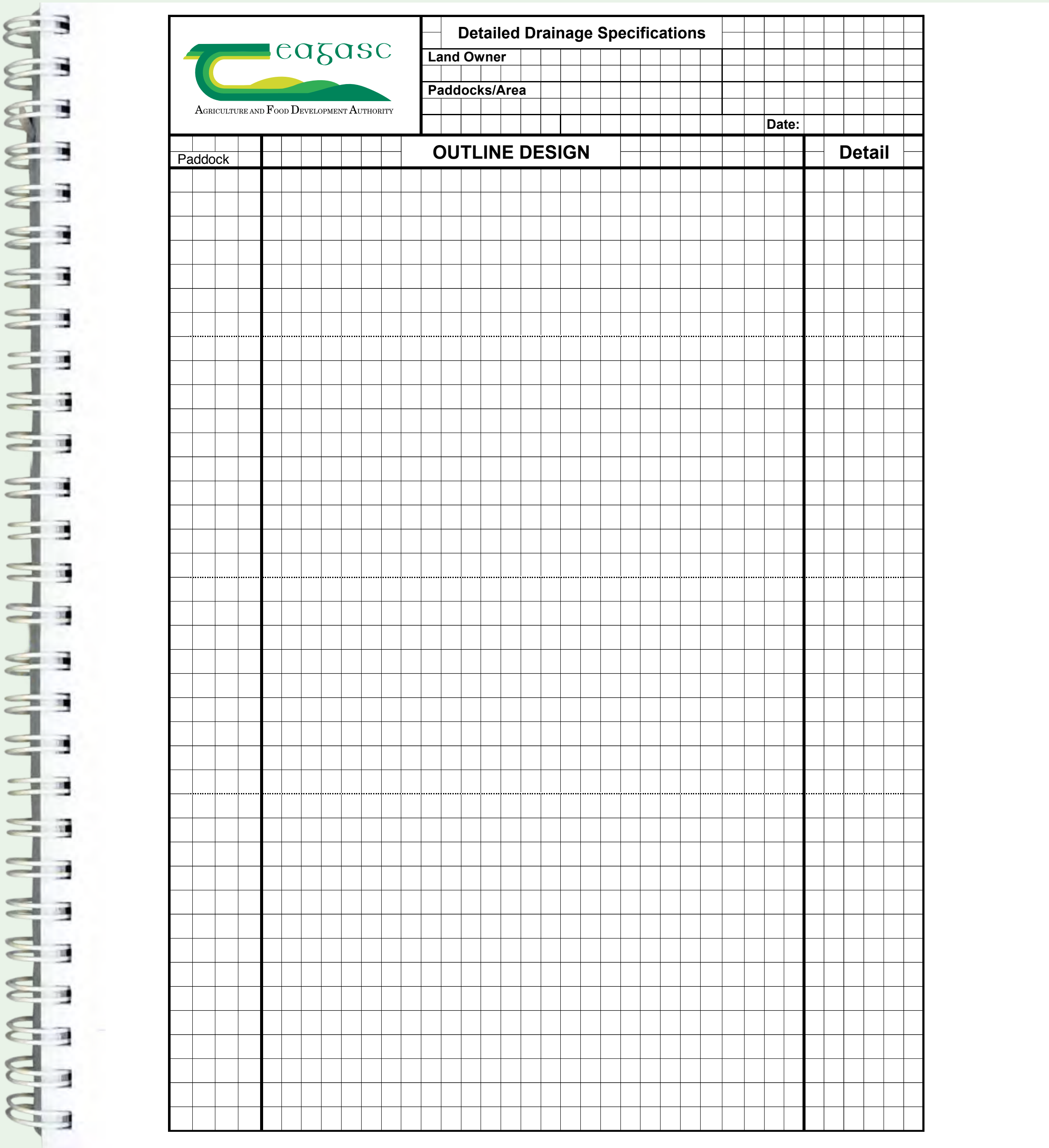
Paddocks/Area 14, 15, 16

Date: 01/05/20xx

Paddock	OUTLINE DESIGN	Detail
All	Open Drains	Total Length:
	- All existing open drains to be deepened to 1.9 m	
	- Bank slope must not be greater than 2:1 (vertical:horizontal)	258 m
	- Spoil to be used in Paddock 15 (Detail Below)	
14	- 4 x 115 m field drains across slope at 15 m spacing	460 m
	- To a minimum graded depth of 1.8 m	
	- Use 80mm corrugated pipe, 1m concrete shore at all outlets	
	- Add 300 mm depth porous fill being 20-30 mm round washed stone (Bradys Quarry)	
	- Backfilled with soil, spoil to be removed	
	- All paddock 14 to be subsoiled to 80 cm depth using single leg winged subsoiler at 1.5 m spacings	
15, 16	- 6 x 150 m field drains across slope at 20 m spacing + 62 m branch to southwest corner of paddock 14	962 m
	- To a minimum graded depth of 1.8 m	
	- Use 80 mm corrugated pipe, 1 m concrete shore at all outlets	
	- Pipe jointed with appropriate fitting as supplied by manufacturer	
	- Add 300 mm depth porous fill being same as detailed above	
	- Backfilled with soil, spoil to be removed	
	Low ground in paddock 15 (Prior to field drains)	
	-Top soil to be stripped	
	- Spoil removed from open drains to be used as fill	
	- Ensure continual fall formed in line with the rest of the paddock	
	- Topsoil to be reinstated	

Managing a **Drainage Project**

Blank template



Notes on drainage design example 1:

These sketches and specification document are presented as a guide to the simple steps taken to establish and document the most suitable drainage design for a particular site. This stage is only relevant where the farmer is satisfied that environmental and statutory obligations have been met and that land drainage is an appropriate option for this site. Initial observations are noted on the site sketch. Land slope, historic features, areas of poor growth, water loving vegetation or poor underfoot conditions are noted as well as any surface water features.

This information is used to pick the most suitable areas for a more detailed investigation and a soil test pit. Remember the test pits should be dug in areas that represent the range of soils to be found on the site. In this case the soil test pits are spread throughout the site; soil test pit (TP1) and soil TP3 look at conditions in central areas on two of the paddocks, while soil TP2 looks at conditions in a waterlogged low lying area. This will determine if any soil problem is evident in this area or if the waterlogging is just a result of a depression in the field.

After digging the test pits and inspecting the cleaned open drains it was clear that the whole site is underlain by a consistent layer of free-draining permeable material, first encountered at depths of 1.5 to 1.7 m below the surface. Most of the area of paddock 14 had more of an impermeable subsoil (consistent with TP1) than that of paddock 15 and 16 (consistent with TP2 and 3).

The first step in improving the site is to remove the depression from paddock 15. Here the topsoil would be stripped and the spoil material from the deepening of the open drains used as fill. This would then be levelled in line with the rest of the field, and the topsoil reinstated. This would be carried out prior to the drainage work.

The proposed approach to drain the site is a series of groundwater drains at 1.8 to 1.9 m depth, backfilled with 300 mm of clean, 20 to 30 mm round stone, thereafter backfilled with soil. All drains would be pulled across the field slope, that is east-west in paddock 14 and north-south in paddock 15 and 16.

One drain would be branched to account for the irregular field shape. In paddocks 15 and 16 drains would be spaced at 20 m apart. There was evidence in the subsoil (higher sand content and cracking) that lowering the water table in this area would facilitate the natural improvement of this layer over time.

In paddock 14 drain spacings will be 15 m, reflecting the heavier nature of the subsoil there. The soil was also slightly thicker and water would not move as quickly from the surface layers to the drains, so more drains per unit area need to be provided. In dry summer conditions all of paddock 14 should be sub-soiled to a depth of 80 cm. This will improve the level of cracking in the heavy subsoil, allowing surface water to move through the profile more easily. As described above, the nature of the subsoil in paddock 15 and 16 will allow this process to happen naturally. Subsoiling to this depth requires a lot of pulling power and surface traction. A single-leg subsoiler is advised, to be pulled at 1.5 m spacings. Several legs on the subsoiler would greatly increase the power required.

Costings example 1:

Estimated cost of draining paddocks 14,15 &16.

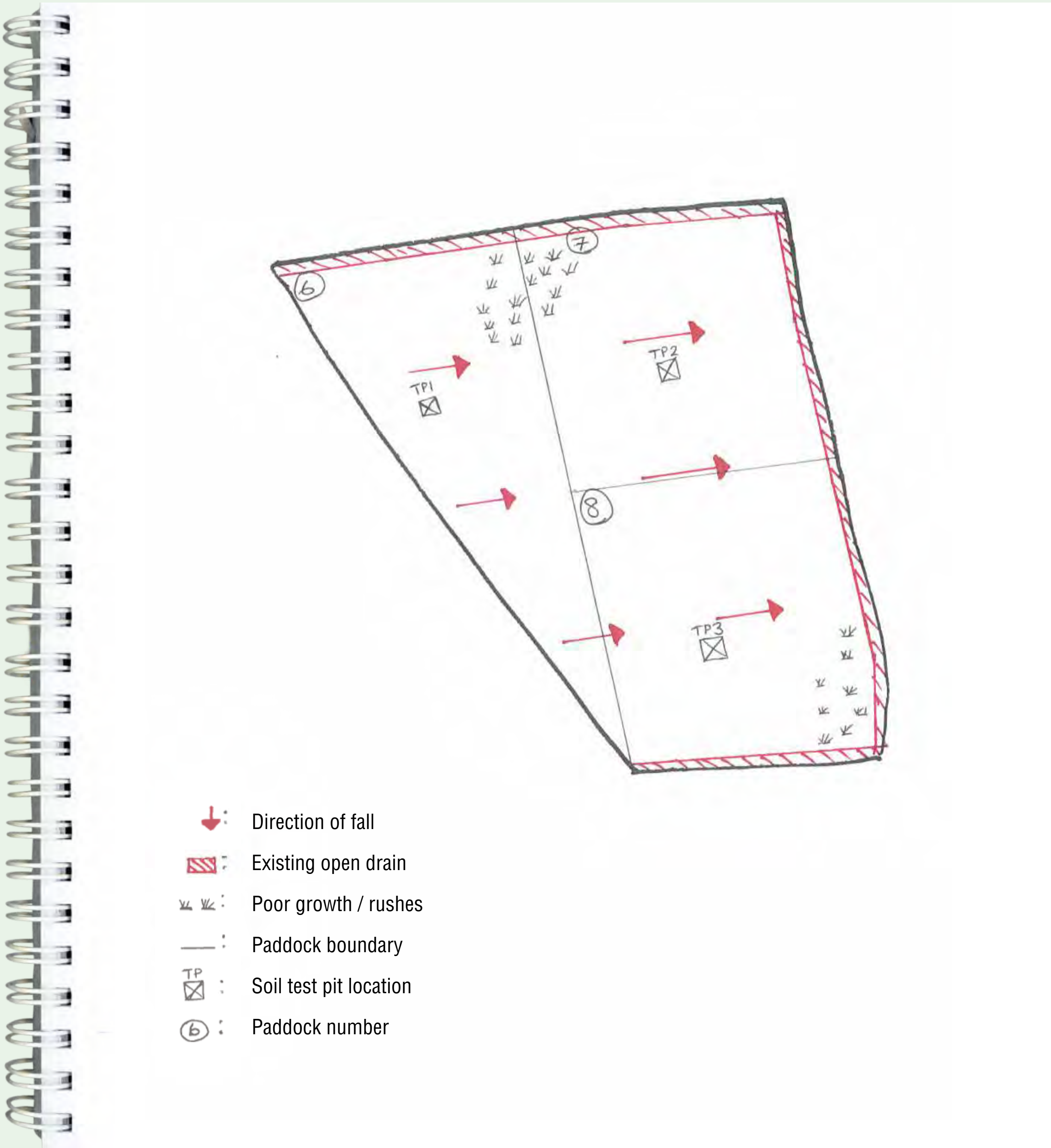
Cleaning existing open drains and move spoil	258 m @ 50 m cleaned per hour @ €45 per hour	€232
Cut and fill in paddock 15	5 hours @ €45 per hour	€225
Installation of 1.8 m deep drains, supply pipe and stone	1,422 m @ €8 per metre	€11,376
Full grass reseed	2.8 Ha @ €600 per Ha	€1,680
Total		**€13,513** €4,826 / Ha €1,953 / acre

Table 2.

Managing a Drainage Project

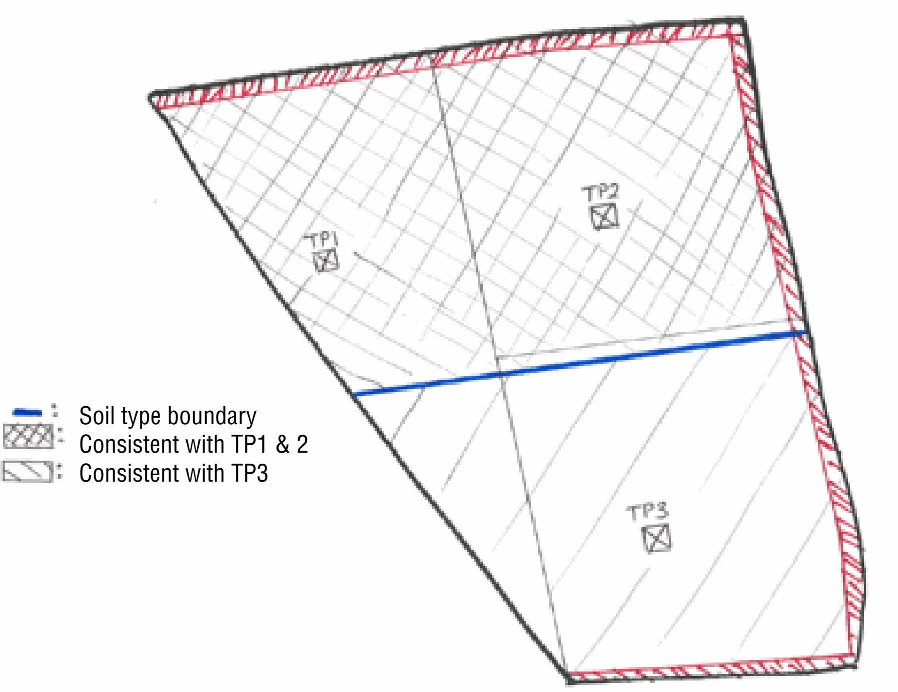
Example 2: A shallow drainage system with costings.

Rough sketch

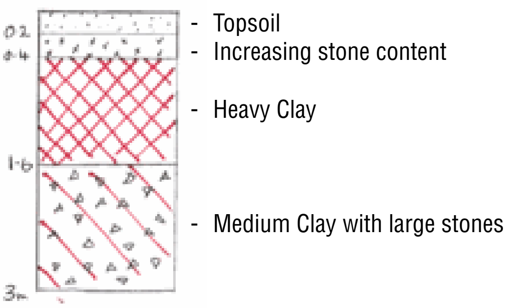


Establishing soil type

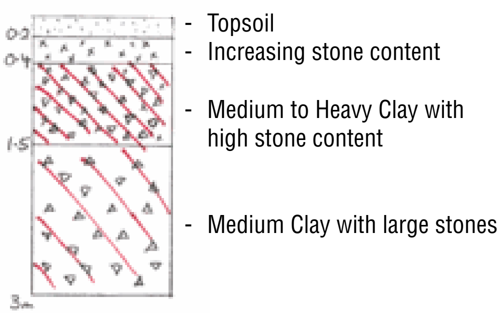
- Existing open drains are cleaned (see Chapter 7)
- Soil test pits are dug
- Soil type is established
- Refer to Chapter 7 for soil textures



Test Pit 1 & 2



Test Pit 3



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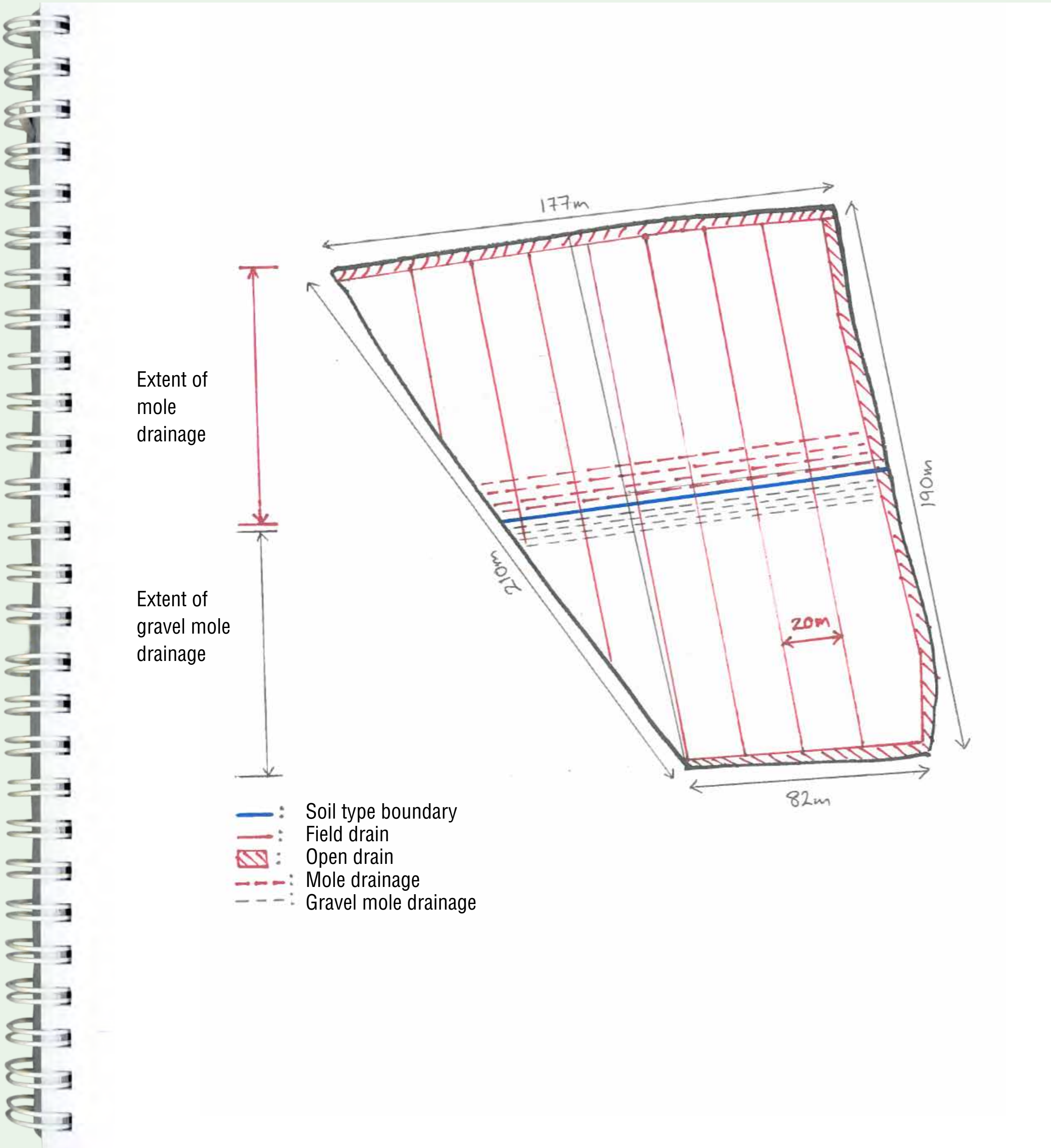
Managing a **Drainage Project**

Drain layout sketch



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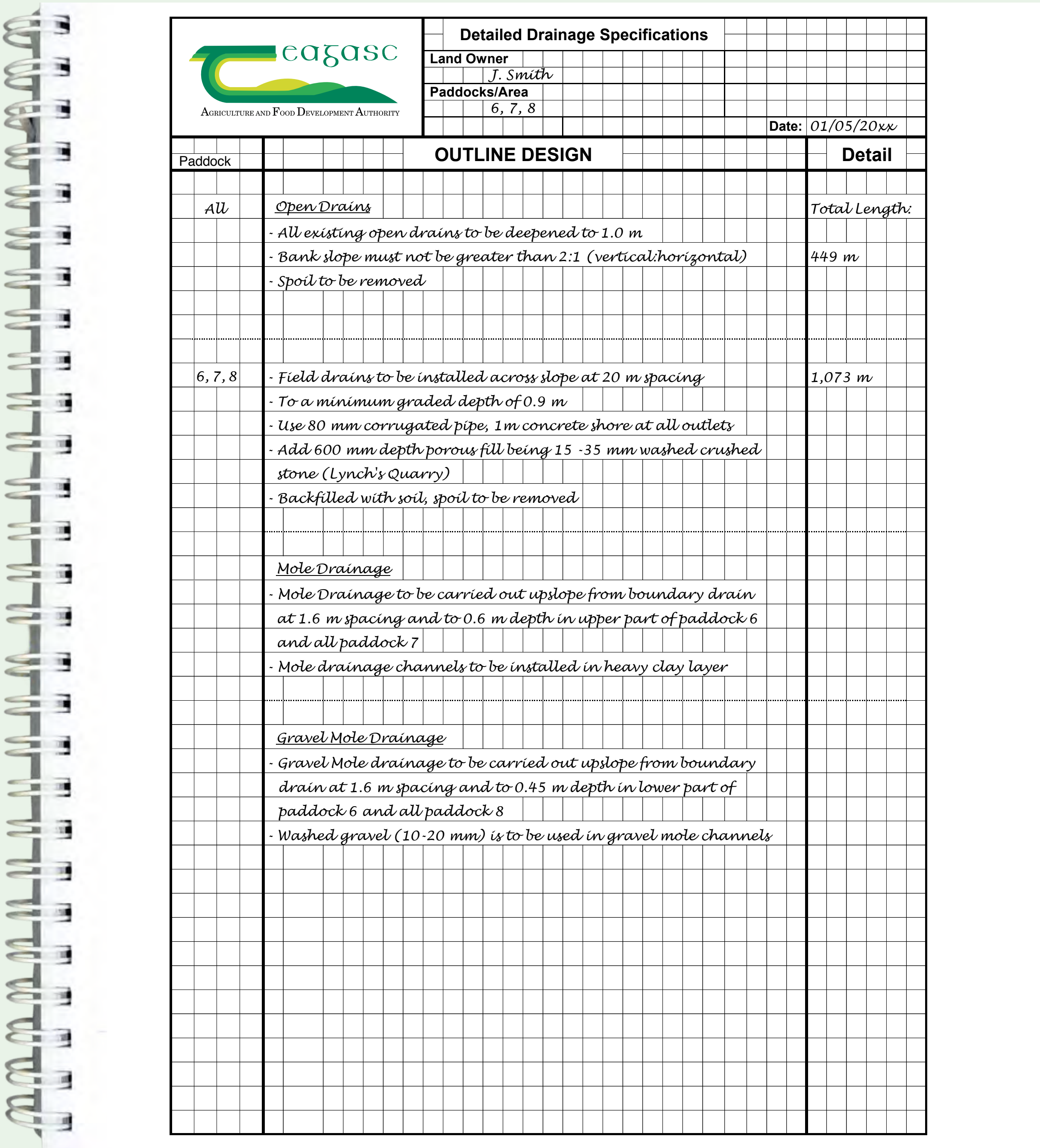
Outline design



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Detailed Drainage Specifications

Land Owner J. Smith

Paddocks/Area 6, 7, 8

Date: 01/05/20xx

Paddock	OUTLINE DESIGN	Detail
All	Open Drains	Total Length:
	- All existing open drains to be deepened to 1.0 m	
	- Bank slope must not be greater than 2:1 (vertical:horizontal)	449 m
	- Spoil to be removed	
6, 7, 8	- Field drains to be installed across slope at 20 m spacing	1,073 m
	- To a minimum graded depth of 0.9 m	
	- Use 80 mm corrugated pipe, 1m concrete shore at all outlets	
	- Add 600 mm depth porous fill being 15 -35 mm washed crushed stone (Lynch's Quarry)	
	- Backfilled with soil, spoil to be removed	
	Mole Drainage	
	- Mole Drainage to be carried out upslope from boundary drain at 1.6 m spacing and to 0.6 m depth in upper part of paddock 6 and all paddock 7	
	- Mole drainage channels to be installed in heavy clay layer	
	Gravel Mole Drainage	
	- Gravel Mole drainage to be carried out upslope from boundary drain at 1.6 m spacing and to 0.45 m depth in lower part of paddock 6 and all paddock 8	
	- Washed gravel (10-20 mm) is to be used in gravel mole channels	

Managing a **Drainage Project**

Notes on drainage design example 2:

This stage is only relevant where the farmer is satisfied that environmental and statutory obligations have been met and that land drainage is an appropriate option for this site. Initial observations are noted on the site sketch. Land slope, historic features, areas of poor growth, water-loving vegetation or poor underfoot conditions are noted, as well as any surface water features. This information is used to pick the most suitable areas for a more detailed investigation and soil test pit (TP). Remember the test pits should be dug in areas that represents the range of soils to be found on the site. In this case the soil test pits are spread throughout the site.

After digging the test pits and inspecting the cleaned open drains it was clear that the soil profile across the site is consistently heavy to 3m with slight variations in clay and stone content with depth. While heavy clays, highly suitable for the formation of mole drainage channels, are found in a large part of paddock 6 and all of paddock 7, the soil in a portion of paddock 6 and paddock 8 contains a lot of stones which would greatly reduce the lifespan of a mole channel. For this reason this area will need to be drained using gravel moles.

The plan is to install collector drains at 0.9 m depth and 20 m spacings, running across the dominant field slope. This regular pattern of field drains will act as an outlet for the mole and gravel mole channels to be installed at a later date. These drains will be filled with 0.6 m of stone and then topsoil. This level of stone fill is required to ensure the mole channels are adequately connected to the drains.

Mole and gravel mole drains will then be installed as per the drain layout map and specification document during optimum soil conditions.

Costings example 2:

Estimated cost of draining paddocks 6, 7 & 8.

Cleaning existing open drains and move spoil	449 m @ 50 m cleaned per hour @ €45 per hour	€404
Installation of 0.9 m deep drains, supply pipe and stone	1,073 m @ €5.40 per metre	€5,794
Mole drain	1.43 Ha @ €250 / Ha	€358
Gravel mole	1.03 Ha @ €1,850 / Ha	€1,906
Full grass reseed	2.46 Ha @ €600/Ha	€1,476
Total		**€9,938**
Mole drain	€3,369 / Ha €1,364 / acre	€4,040 / Ha €1,635 / acre
Gravel Mole	€4,992 / Ha €2,020 / acre	

Table 3.

Section 5

Maintenance

by **Pat Tuohy, Owen Fenton**

An update of a previous version written by Pat Tuohy, Owen Fenton, James O' Loughlin

Introduction

Maintenance of the outlet and in-field drains promotes an efficient drainage system. A little and often approach is best suited to on-going maintenance of open drains where and when necessary. The open drainage system should only be maintained at a blockage point. The open drainage system must offer long term opportunities for biodiversity, habitats and mitigation of nutrients, carbon and sediment losses. These open drains if maintained correctly provide an existing infrastructure or opportunity to safeguard connected waters.

1. **What factors do I need to consider?**
2. **Why do drains stop performing?**
3. **How can I ensure future ease of maintenance?**
4. **How should the system be maintained?**

chapter 13

Maintenance

① What factors do I need to consider?

- Maintenance works must comply with statutory and environmental obligations as outlined in Chapter 6 and 7.
- When cleaning drains be aware of potential damage to fish and their habitats, including impacts downstream.
- Fish and their spawning grounds are protected under Fisheries Acts.
- In-stream work from July to September is least disruptive to fish.
- If in doubt, consult Inland Fisheries Ireland www.fisheriesireland.ie

② Why do drains stop performing?

- Drainage systems generally deteriorate at a fairly steady rate over time. It is usually during a prolonged wet period that their shortcomings become visible.
- In most cases, in-field drains stop working due to neglect. If regular cleaning and maintenance is not carried out, drains will inevitably deteriorate.
- Minor blockages and impediments to flow start to build up as the rate of water flow in the drain is slowed. These eventually clog the system to such an extent that it is rendered ineffective. Blockages (Figure 1) are formed by:
  - Fine soil particles,
  - Iron deposits,
  - Plant roots.
- Blockages are more likely to occur at the pipe outlet and junction points but can occur anywhere in the system.
- In wet years, excessive damage caused by machinery and livestock can reduce the natural drainage capacity of the soil surface, handicapping the drainage system.

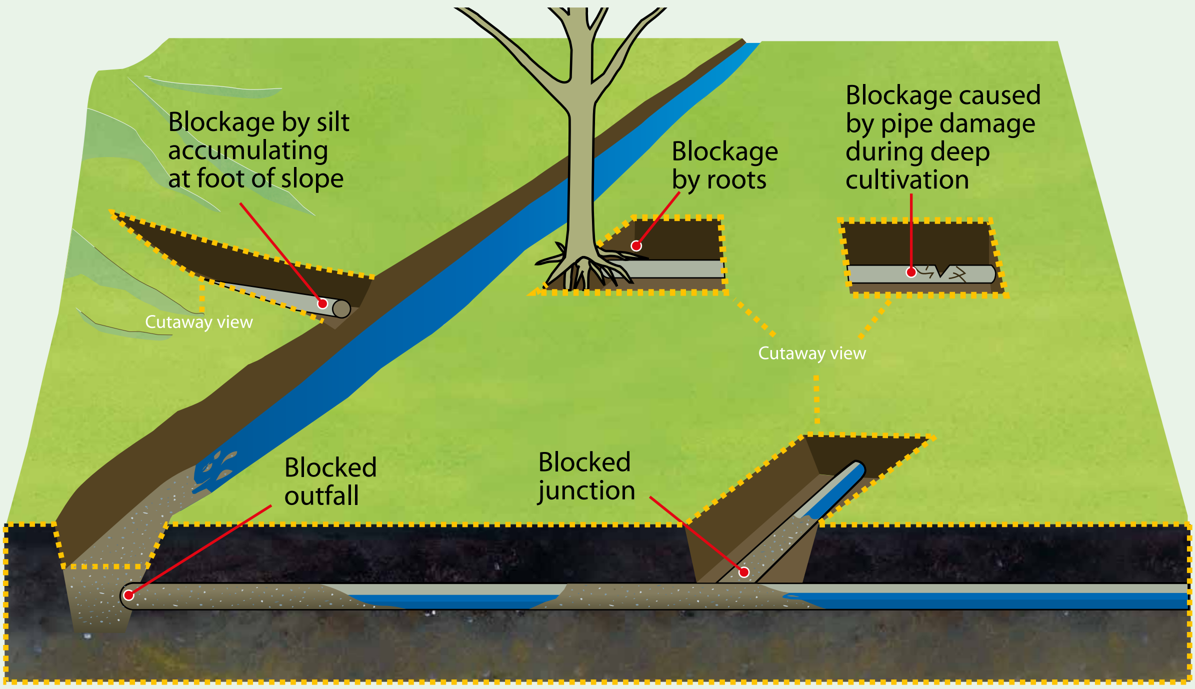

Figure 1. Examples of where problems and blockages may arise in an artificial open drain and field drains.

3 How can I ensure future ease of maintenance?

- When installing drainage systems, consider future maintenance. Avoid piping existing open drains; avoid overly elaborate networks; and avoid the use of junctions where possible. Consider installing points within the network that you can access through surface or buried manholes (see Figure 2).
- Mark every field drain with a permanent marker in the field and on a farm map and field sketch. This will make locating them easier in the future.
- Field drains should never be installed without pipes due to resulting restrictions on water flow. By not using pipes you will reduce the lifespan of the drainage and severely restrict field drain maintenance.
- Place concrete or un-perforated plastic pipe over the end of the drain pipe, at least 1m in length, to protect the outlet from damage. This will also make the drain easier to locate and maintain.
- If junctions are used, an inspection/maintenance point should be provided. This should include a sediment trap.
- Leaving vegetation grow and sediment traps in open drains are advisable to prevent sediment losses which decreases the efficiency of the drain and increases losses to a watercourse.

4 How should the system be maintained?

- Open drains should be periodically cleaned to remove any obstructions in the channel. They should be established to as great a depth as possible to maximise the potential for future works.
- Where a blockage occurs clean only one side of the open drain at a time, leave the other bank for the following year. Leaving vegetation on one side of the drain is preferable for the environment (Figure 3). A little and often approach is best suited to on-going maintenance where and when necessary. Regular removal of small amounts of debris facilitates adequate discharge of water and maintenance of other functions such as nutrient and sediment retention, biodiversity and habitat provision.

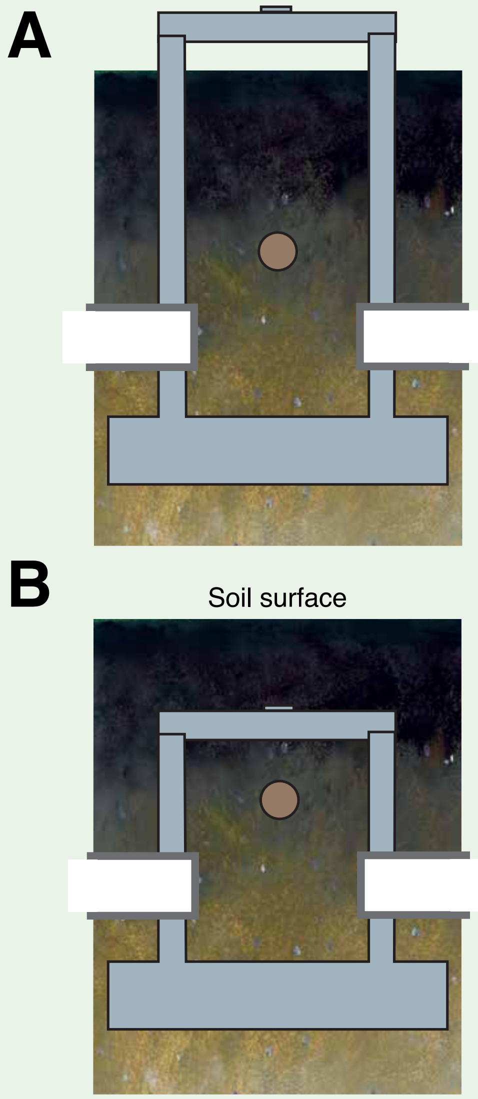

Figure 2. Manhole.
A: Cover above soil surface;
B: Buried cover.

- Spoil from such works, where suitable, can be spread over the adjoining land filling depressions while not impeding overland flow directly to the drain. Unsuitable spoil should be buried and covered with topsoil or removed to waste ground.
- Take care when removing blockages from open drains to protect field drain outlets from damage.

Maintenance

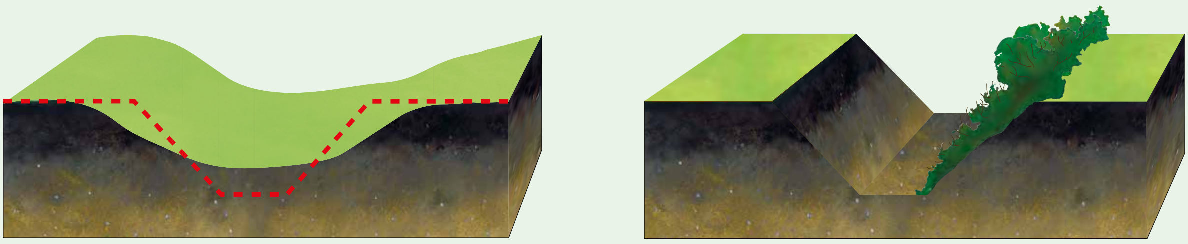

Figure 3. Maintenance of open drains to remove blockages changes the shape of the drain at that position. Over time these open drains should be left to promote habitat provision and biodiversity, mitigate nutrient and carbon losses and trap sediment.

- Field drains need to be cleaned regularly to prevent deposits of fine soil particles or iron from clogging the pipe.
- Pipes are easily cleaned using drain jetters, where available. These are specially designed high-pressure hoses which are fed up the drain pipe from the outlet. The water pressure removes any dirt, sediment or iron deposits from the pipe and its perforations.
- The technique is very simple and very effective in rejuvenating underperforming drainage systems. The equipment is becoming more popular and is available from contractors in most parts of the country.
- The movement of soil particles and iron into the drain will peak in the period immediately after installation and before the soil resettles. So it is best to clean the field drains 1 to 2 years after installation and every 3 to 5 years thereafter.
- If such equipment is not available, simple rodding may relieve minor blockages, which are often most common close to the pipe outlet.

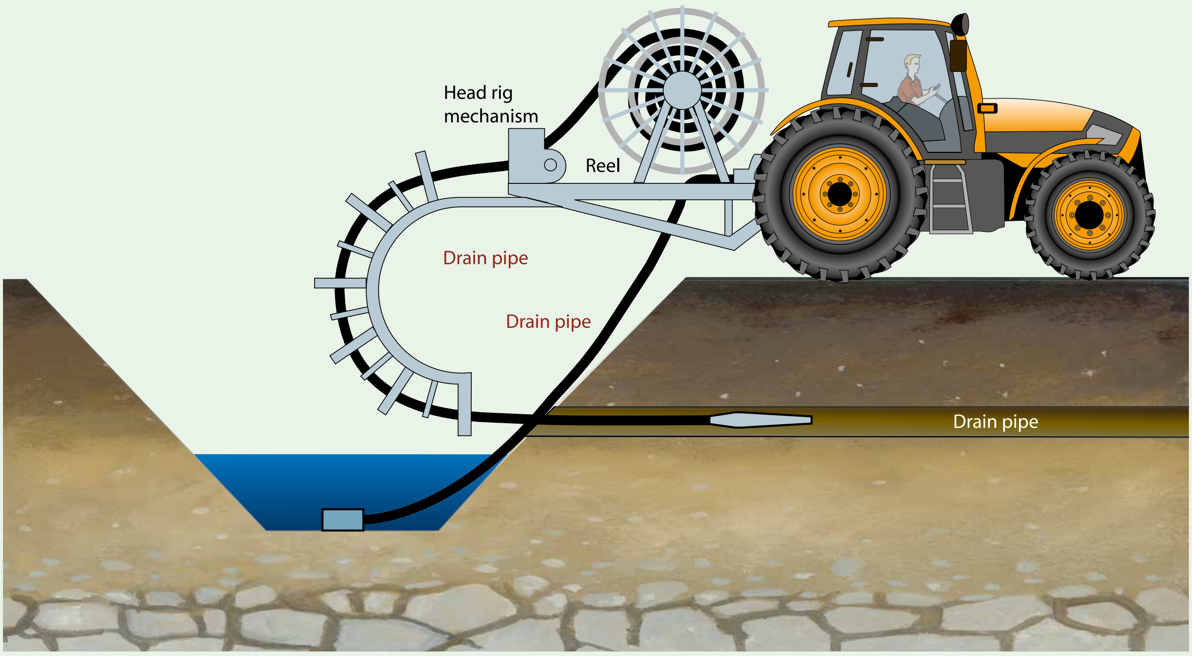

Figure 4. An example of drain jetting.

Section 6

Drainage as an Investment

Section 6

Section 6

The Economics of Land Drainage

by Paul Crosson, Laurence Shalloo, Fiona Thorne

Introduction

Land drainage is an investment and any drainage project must be judged in the light of the costs and the likely benefits.

1. What are the key costs and benefits associated with a drainage project?
2. What are the specific costs associated with a drainage project?
3. What are the specific benefits associated with a drainage project?
4. What would a cost/benefit analysis look like for beef, dairying, tillage?

The Economics of Land Drainage

① What are the key costs and benefits associated with a drainage project?

Checklist

Cost factors.

(i) Field conditions at the commencement of the project - soil type, existing drainage system, etc. will have a major influence on the overall cost.

(ii) The materials needed and the cost of those materials including transport should be established in advance.

(iii) The expected cost of the contractor hired to carry out the project is key.

(iv) What is the expected lifespan of the drainage works - i.e. what depreciation time span will be applied to cost the project?

Key risk

As discussed previously (Section 3) based on their high potential for carbon loss, high organic content and peat soils should not be drained. Apart from international best practice pertaining to climate and environmental risks there is a direct risk for the landowner that future policy may look at penalising any new drainage works on high organic content and peat soils with fines imposed based on Carbon emissions from this land on a per area basis. This could impose significant additional costs to such drainage works.

Checklist

Benefits.

(i) What is the expected increase in grass growth/ utilisation or crop yield?

(ii) What is the expected benefit in terms of a longer grazing season?

(iii) To what extent will the drainage project facilitate higher stocking rates and output?

(iv) To what extent will improved drainage systems enable other fodder conservation practices or cropping choices?

② What are the specific costs associated with a drainage project?

The cost of drainage works will vary depending on:

- soil type;
- site access;
- extent of open drains available;
- availability/cost of backfill stone;
- experience of the operator;
- the need for mitigation measures to protect against nutrient and sediment losses.

Clearly, these are very site specific and therefore Table 1 provides only a guideline of typical costs. The requirement for collector drains has a considerable effect on total costs - where an existing drainage system of closely-spaced piped drains is already in place it may be possible to pull mole drains through this network, reducing the cost.

Key point

The calculations presented here refer to whole-field drainage. Drainage of very small areas of land may involve considerations other than cost/benefit alone. Also, costings are done for collector drain spacings of 20 metres. If, for example, 60 metre spacings were appropriate (each drainage project is unique, see chapters on designing a drainage system) then the cost would be significantly lower.

③ What are the specific benefits associated with a drainage project?

The main goal of land drainage is to increase the utilisation of grass or crop output from a parcel of land. In a grass-based system increased grass utilisation arises due to: (i) more grass grown; (ii) better utilisation rate (kg consumed by the animal per kg grown) and (iii) longer grazing seasons.
In a crop based system increased crop yield arises due to: ensuring timely planting and field operations and minimising soil compaction. These factors promote conditions for good seedbed establishment and germination. Ultimately, well-drained soils out-yield poorly-drained soils and have less year-to-year yield variability.

Drainage System	Drain Spacing (m)	Depth (m)	Cost/m (€)	Cost/ha (€)
Main Drainage Systems				
Open Drains	-	-	3 - 6	500 - 2,000
Groundwater Drainage Systems				
Deep Drainage	15 - 50	1.5 - 2.5	9 - 11	3,700 - 6,200
Shallow Drainage Systems				
Mole	1.5 - 2.0	0.45 - 0.6	-	125 - 250
Gravel Mole	1.5 - 2.5	0.35 - 0.5	-	1,500 - 3,500
Collector Drains	20	0.75 - 1.0	5 - 8	2,500 - 4,000
Collector Drains	40	0.75 - 1.0	5 - 8	1,200 - 1,920
Collector Drains	60	0.75 - 1.0	5 - 8	800 - 1,400

Table 1. Approximate costs of different land drainage systems.

Key point

The degree of benefit from land drainage will depend on the level of productivity at the commencement of the project. Where productivity is low (for example, 2 t grass DM utilised per ha, or 6 tonnes of spring barley per ha) then it is likely that there will be a significant increase in productivity and output from the land area. However, where productivity is moderate to high (for example, 9 t DM utilised per ha or 8 tonnes of spring barley per ha) then the benefit is likely to be much less.

4 What would a cost/benefit analysis look like for beef, dairying, tillage?

Cost/benefit analysis - Beef

A cost/benefit analysis was carried out to provide some indication of the likely impact on net farm margin of land drainage when different levels of output price (€ / kg beef carcass), improved productivity and land drainage costs were assumed.

Three drainage systems were evaluated based on draining 30% of the base farm (12 hectares). The systems evaluated were:

- Mole draining with collector drains 20 metres apart (total cost €3,125 / ha),
- Gravel mole with collector drains at 20 metres apart (€4,480 / ha) and
- Deep drains (1.5 to 2.5 metres depth) at 30 metres apart (€4,950 / ha).
- The cost benefit of a 10%, 20% and 30% increase in grass production (kg DM grown per hectare) were evaluated.

Suckler beef systems

The economics of land drainage for suckler calf to beef systems were quantified. Key assumptions are presented in Table 2. The analysis involved comparing a baseline system where no land drainage is carried out with scenarios where land drainage is carried out incurring long-term land improvement costs but also resulting in higher stocking rates and output.

The Economics of Land Drainage

In the baseline system stocking rate was 1.7 LU / ha with 41 suckler cows taking progeny to beef at 24 months of age for steers and 20 months of age for heifers. Replacements were bred from within the herd. It is also assumed that where land drainage has occurred reseeding (at €700 / ha) is also carried out.

Land area (ha)	40
Mean calving date	12th March
Replacement rate (%)	20
Weaning weight (kg)*	295
Steer carcass weight (kg)	400
Heifer carcass weight (kg)	315
Fertiliser (CAN) price (€ / t)	340
Concentrate price (€ / t)	295

*Average of bulls and heifers.

Table 2. Assumptions used for cost/benefit analysis of land drainage for suckler calf to beef production systems.

From Table 3 it can be seen that where land drainage costs €3,125 / ha there is no economic benefit unless the increase in grass production across the farm is greater than 20% and beef price exceeds €4.75 / kg carcass.

Where grass growth increases by 30%, an economic benefit can be expected unless beef price is less than ~€4.15 / kg carcass.

Increase in grass growth	Beef price per kg carcass			
	€4.00	€4.25	€4.50	€4.75
10%	-631%	-119%	-59%	-35%
20%	-332%	-46%	-13%	0%
30%	-45%	22%	30%	33%

Table 3. Profitability (-/+) of a land drainage project where total costs are €3,125 / ha for a range of beef prices and productivity increases.

From Table 4 it can be seen that there is unlikely to be an economic benefit where land drainage costs €4,480 / ha unless beef price is greater than €4.50 / kg carcass and grass productivity increases by 30%.

Increase in grass growth	Beef price per kg carcass			
	€4.00	€4.25	€4.50	€4.75
10%	-808%	-156%	-79%	-50%
20%	-508%	-84%	-34%	-15%
30%	-222%	-15%	9%	19%

Table 4. Profitability (-/+) of a land drainage project where total costs are €4,480 / ha for a range of beef prices and productivity increases.

Similarly, from Table 5 it can be seen that there is unlikely to be an economic benefit where land drainage costs €4,950 / ha unless the beef price is greater than €4.50 / kg carcass and grass productivity increases by 30%.

Increase in grass growth	Beef price per kg carcass			
	€4.00	€4.25	€4.50	€4.75
10%	-871%	-169%	-87%	-55%
20%	-571%	-97%	-41%	-20%
30%	-285%	-28%	2%	14%

Table 5. Profitability (-/+) of a land drainage project where total costs are €4,950 / ha for a range of beef prices and productivity increases.

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Cost/benefit analysis - Dairying

Four drainage systems are evaluated based on draining 30% of the base farm (12 hectares). The systems evaluated were:

- Mole draining with collector drains 20 metres apart (total cost €3,125 / ha),
- Gravel mole with collector drains at 20 metres apart (€4,480 / ha) and
- Deep drains (1.5 to 2.5 metres depth) at 30 metres apart (€4,950 / ha),

The cost benefit of a 10%, 20% and 30% increase in grass production were evaluated.

Dairy systems

The economics of land drainage for dairy systems are quantified. Key assumptions are presented in Table 6. The analysis involves comparing a baseline system where no land drainage is carried out with scenarios where land drainage is carried out incurring long-term land improvement costs but also resulting in higher stocking rates and output.

It is also assumed that where land drainage has occurred reseeding (at €700 / ha) is carried out.

Land area (ha)	40
Mean calving date	1st March
Replacement rate (%)	18
Milk yield (kg)	5,437
Protein %	3.60
Fat %	4.30
Fertiliser (CAN) price (€ / t)	340
Concentrate price (€ / t)	270

Table 6. Assumptions used for cost/benefit analysis of land drainage for dairy production systems. In this instance the assumed prices for beef and dairy concentrates are different.

From Table 7 it is clear that where land drainage costs €3,125 the increase in output of 20% or greater will increase profitability irrespective of milk price.

Increase in grass growth	Milk price		
	22 cpl	28 cpl	34 cpl
10%	-€675	€2,705	€6,087
20%	€1,970	€7,324	€12,739
30%	€4,567	€10,860	€19,154
Base Farm	**-€2,376**	**€21,587**	**€45,549**

Table 7. Profitability (-/+) of a land drainage project where total costs are €3,125 / ha for a range of milk prices and productivity increases.

For spring barley and beef percentages provide a good evaluation of the investment. For dairying, percentages can prove misleading due to base line referencing so actual Euro figures are used.

From Table 8 it is clear that a 30% increase in herbage output results in a positive return from drainage irrespective of the milk price when the drainage costs are €4,950 / ha. A 20% increase in production is profitable at a milk price above 23.5 cpl.

Increase in grass growth	Milk price		
	22 cpl	28 cpl	34 cpl
10%	-€3,798	-€418	€2,963
20%	-€1,153	€4,201	€9,556
30%	€1,444	€8,737	€16,031
Base Farm	**-€2,376**	**€21,587**	**€45,549**

Table 8. Profitability (-/+) of a land drainage project where total costs are €4,950 / ha for a range of milk prices and productivity increases.

The Economics of Land Drainage

Cost/benefit analysis - Tillage

A cost/benefit analysis has been carried out to provide an indication of the likely impact on net farm margin of land drainage when different levels of output price (€ / tonne of cereal crop), improved productivity and land drainage costs are assumed.

Figure 1. Poor drainage at the edge of this field of oilseed rape led to crop failure and the area was replanted with spring barley.

Four drainage systems were evaluated based on draining 30% of the base cereal crop area (18 hectares).

Again, the systems evaluated were:

- Mole draining with collector drains 20 metres apart (total cost €3,125 / ha),
- Gravel mole with collector drains at 20 metres apart (€4,480 / ha),
- Deep drains (1.5 to 2.5 metres depth) at 30 metres apart (€4,950 / ha),

The cost/benefit of a 10%, 20% and 30% increase in cereal production (on the drained land only) were evaluated.

Example: Spring barley

The economics of land drainage for a crop of spring barley was quantified. Key assumptions are presented in Table 10. The analysis involves comparing a baseline system where no land drainage is carried out with scenarios where land drainage is carried out incurring long-term land improvement costs but also resulting in higher crop yields.

In the baseline system cereal yield was 6 t/ha and the output price of barley was €180 per tonne (based on Teagasc National Farm Survey results from 2010, 2011, 2012). The drainage was assumed to take place on an average sized specialist tillage farm with a third of the land devoted to growing spring barley.

Total land area (ha)	63
Spring barley area (ha)	18
Land drained area	18
Variable costs per ha	€612
Fixed costs per ha	€584
Spring barley yield t / ha	6

Table 10. Assumptions used for cost/benefit analysis of land drainage for a spring barley production system.

From Table 11 it is clear that where land drainage costs €3,125 / ha, this provides an economic benefit only where the spring barley yield increases by between 20 - 30% (depending on output price) on the drained land. Otherwise the investment costs are not covered by the benefit in terms of increased farm output.

Increase in Spring barley yield	Barley price per tonne			
	€140	€160	€180	€200
10%	-31%	-20%	-13%	-9%
20%	-5%	2%	6%	8%
30%	20%	23%	25%	26%

Table 11. Profitability (-/+) of a land drainage project where total costs are €3,125 / ha for a range of cereal prices and productivity increases.

Table 12 shows that there is unlikely to be an economic benefit where land drainage costs €4,480. Only where cereal price is €160 or greater and cereal yield increases by 30% does the investment return a greater net farm margin.

Increase in Spring barley yield	Barley price per tonne			
	€140	€160	€180	€200
10%	-55%	-37%	-27%	-21%
20%	-30%	-16%	-8%	-3%
30%	-4%	5%	11%	14%

Table 12. Profitability (-/+) of a land drainage project where total costs are €4,480 / ha for a range of cereal prices and productivity increases.

Table 13 shows that where land drainage costs €4,950 the increase in output is only sufficient to offset the extra cost incurred when cereal price is greater than €180 per tonne and cereal yield increases by 30%.

Increase in Spring barley yield	Barley price per tonne			
	€140	€160	€180	€200
10%	-64%	-43%	-31%	-24%
20%	-38%	-22%	-13%	-7%
30%	-13%	-1%	6%	10%

Table 13. Profitability (-/+) of a land drainage project where total costs are €4,950 / ha for a range of cereal prices and productivity increases.

Key point

While the first two drainage scenarios for the tillage system examined did show a net benefit attributable to the investment, the necessary increase in yield gains to attain this benefit are about 20-30% over the baseline. Yield gains of this magnitude are significant and may be difficult to attain in practise.

Section 6

Performance of Land Drainage Systems

by **Pat Tuohy, Owen Fenton**

Introduction

While drainage systems costs and their effect on production and utilisation are measurable in the short term, a long term analysis of performance and lifespan is required before we can draw full conclusions with regard to their economic benefit. Performance analysis of drainage systems highlights how drainage system type, soil type and seasonal variations in soil moisture affect drainage system performance.

1. **How is performance measured?**
2. **How well do drainage systems respond to rainfall?**
3. **What effect do drainage systems have on grassland productivity?**

Performance of Land Drainage Systems

1 How is performance measured?

- The drainage systems installed across land drainage demonstration sites established as part of the Teagasc Heavy Soils Programme (HSP) represent a range of drainage system types (in terms of depth, spacing and supplementary measures) across a range of soil types and climatic conditions.

- After drainage systems were installed, a monitoring programme was established. Flow-meters record water flow rates, a number of in-field wells with water level sensors record water-table fluctuations, moisture sensors close to the surface monitor soil moisture content, while weather conditions are recorded by on-site weather stations.

2 How well do drainage systems respond to rainfall?

- Analysis of these data allows an assessment of the effectiveness of the various drainage systems in terms of drainage discharge rates, response times and overall system performance over a range of seasons and weather conditions. All systems (where correctly designed, implemented and maintained) reduce the overall period of waterlogging and improve the conditions for both the production and utilisation of the grasslands they drain.

- Those deeper systems with direct connectivity to groundwater are seen to discharge greater volumes of water and maintain a deeper water table relative to shallow drainage designs. The comparison of such systems highlights contrasting behaviours of individual drainage systems and drainage design types, which is dictated largely by the drainage capacity of the soil within their catchment and their connectivity to different water bodies. This work is allowing a more complete understanding of the capacity and limitations of individual drainage systems, and further informing on appropriate drainage design practices for poorly drained soils.

Key facts

The functional capacity of each specific land drainage system is inherently different. Groundwater drainage designs exploit natural conditions to discharge large volumes of water and can control water table directly by means of their interaction with layers and zones of high permeability.

Shallow drainage designs are combatting the natural state of their host soils by relying on shallow disruption techniques which are ultimately destined to revert to their original state, particularly in the case of mole drainage and sub-soiling techniques. They have a smaller zone of influence, no direct connectivity to the water table and displace lower volumes of water which is collected directly from the surface.

The response of each system to rainfall is quite clear. Examples are presented in Figure 1. In each drainage system, rainfall events show corresponding increases in drain discharge.

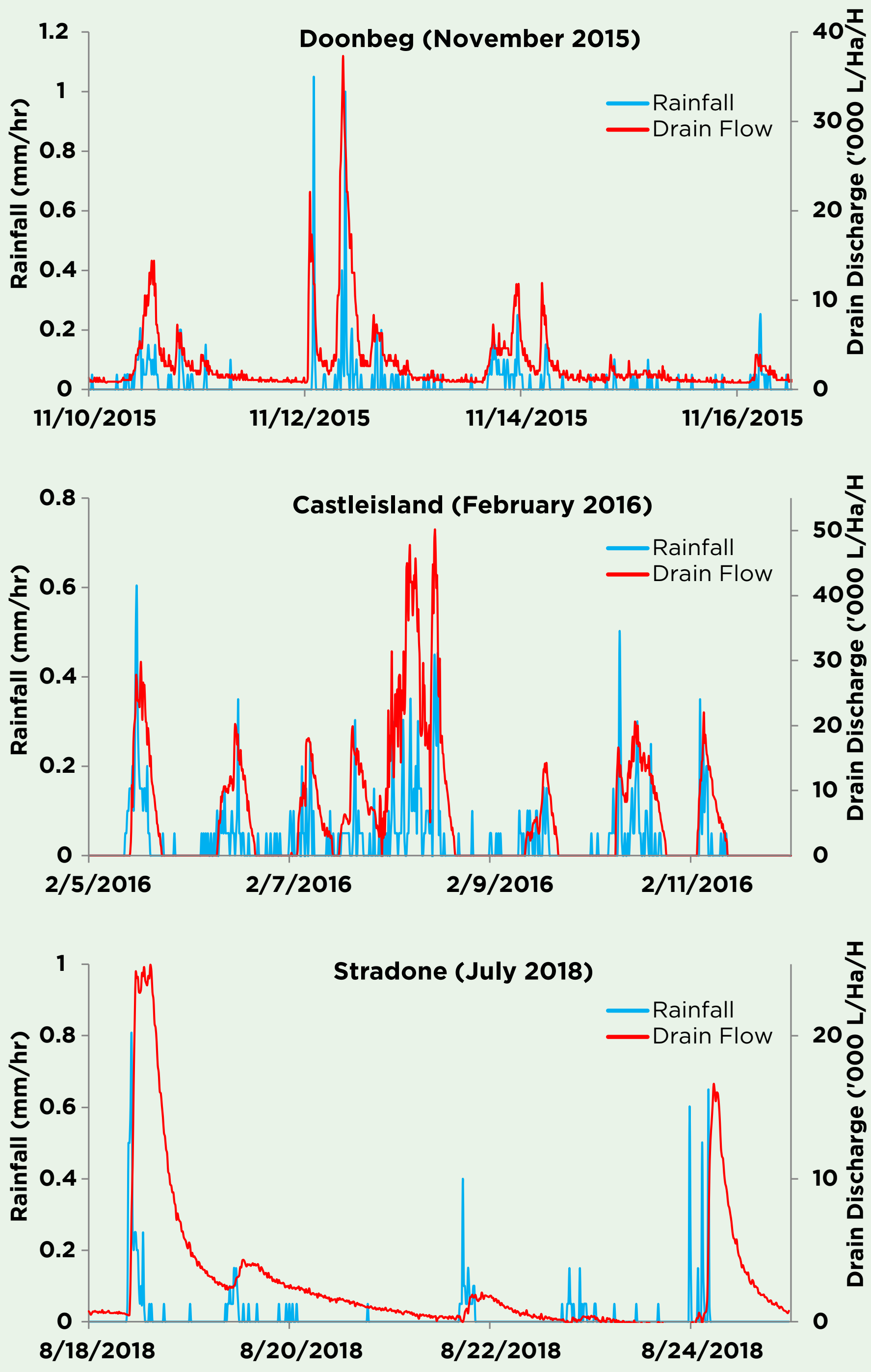

Figure 1. Drain discharge vs. rainfall at 3 drained sites.

Performance of
Land Drainage Systems

③ What effect do drainage systems have on grassland productivity?

- All systems were shown to reduce the overall period of waterlogging and thereby improve the conditions for both the production and utilisation of the grasslands they drain.
- These benefits allowed for other complimentary benefits including the opportunity to improve overall soil fertility, extend the grazing season and maintain a high proportion of productive grasses in the sward, which all contribute towards increased production.
- Drained sites increased grass production by between 4 and 7 T DM/Ha/year.

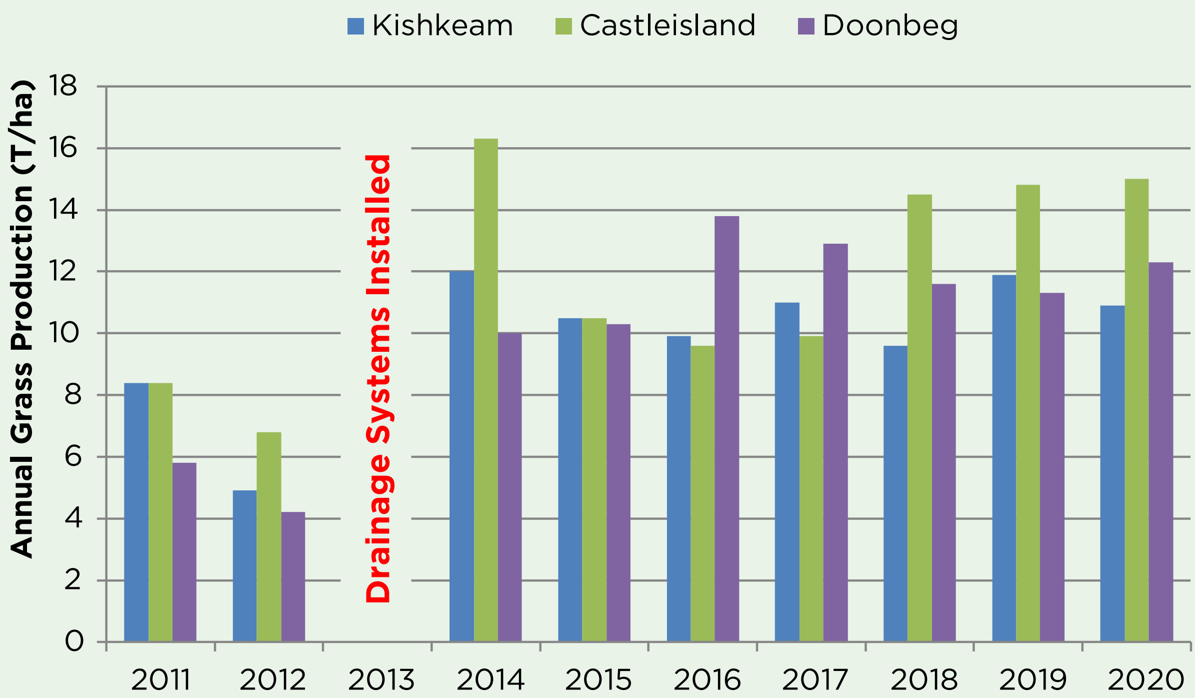

Figure 2. Grass production at 3 Heavy Soils Programme drainage sites before and after drainage works.

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