Great North Road Solar and Biodiversity Park

Environmental Statement

Volume 4 – Technical Appendices

Technical Appendix A17.2 – Outline Soil Management Plan - Part 4 of 4

Document reference – EN010162/APP/6.4.17.2

Revision number 1

June 2025

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009, APFP Regulation 5(2)(a)

5. Annual report and annual meeting

All agricultural reclamation sites should have an annual aftercare report and annual meeting.

Operators should submit the annual aftercare report to you before an annual meeting of all interested parties. All interested parties should have time to read the report before the meeting. The report should include:

- work carried out that year (include soils analysis results and fertiliser and pesticide applications)
- details of work for the coming year
- any changes to original proposals set out in the outline aftercare strategy see section 4.2

The operator needs to agree with you:

- any further remedial work, such as improving drainage or removing soil compaction
- any changes to the aftercare plan, such as changing a crop

You can issue a 'certificate of compliance' if the aftercare plan meets the aftercare obligations. This can be in the form of a simple letter. This doesn't mean the restoration standard is met.

6. Government policies to protect agricultural land and soil

Read the Guide to reclaiming mineral extraction and landfill sites to agriculture (https://www.gov.uk/government/publications/reclaim-minerals-extraction-and-landfill-sites-to-agriculture) to make sure development proposals are appropriate and sustainable.

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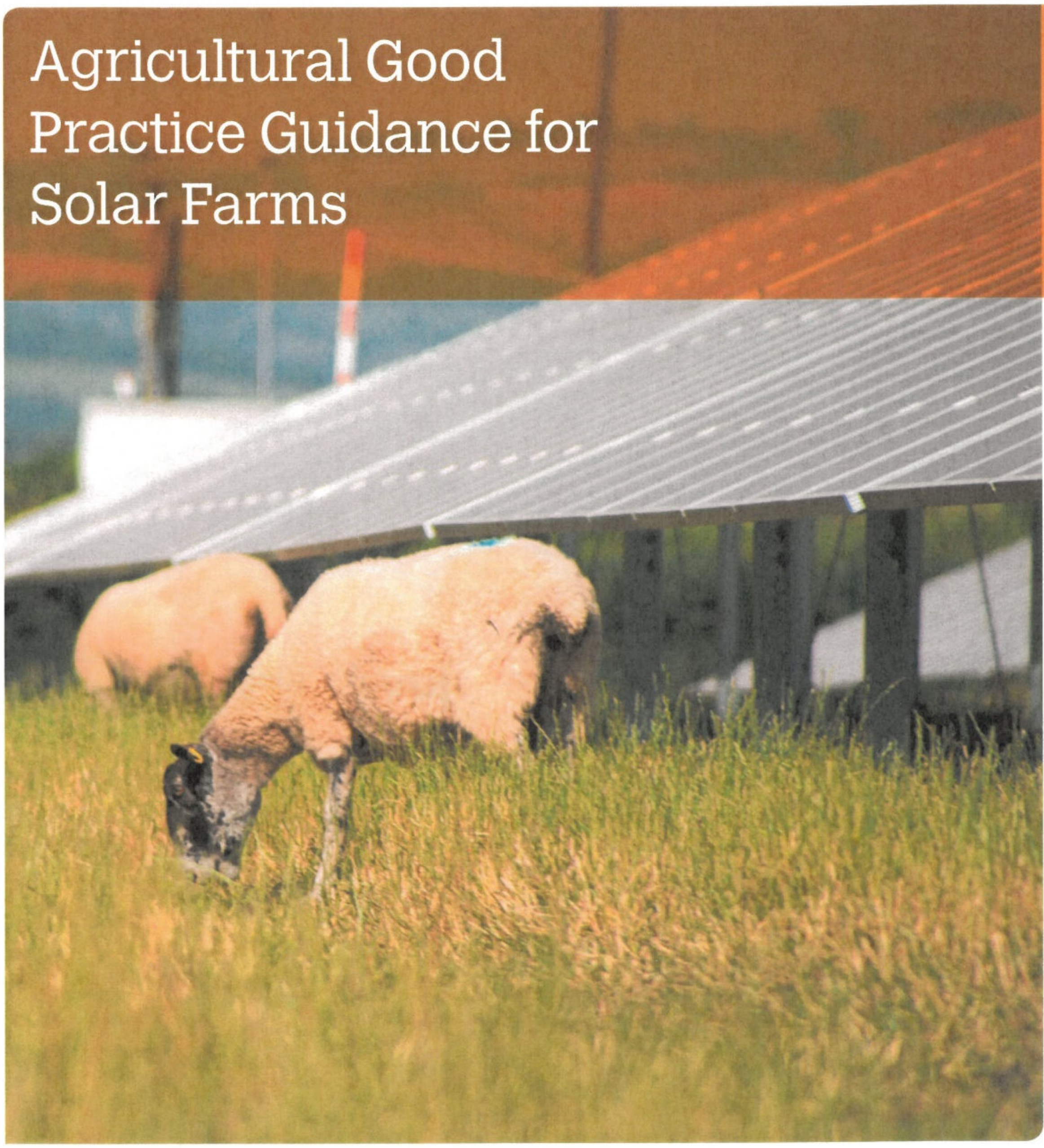
Appendix SMP8

BRE Agricultural Good Practice Guide Extract

bre

www.bre.co.uk/nsc

Agricultural Good Practice Guidance for Solar Farms



NFU

EUROPEAN UNION
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BRE NATIONAL SOLAR CENTRE

Principal Author and Editor Dr Jonathan Scurlock, National Farmers Union

This document should be cited as: BRE (2014) Agricultural Good Practice Guidance for Solar Farms. Ed J Scurlock

BRE National Solar Centre would like to sincerely thank colleagues from the following organisations who have made significant contributions to the development of this guidance:

With thanks to:

Marcus Dixon and Neil Macdonald of British Solar Renewables; Liza Gray of Lightsource; Julie Rankin and Amy Thorley of Lark Energy; Kate Covill of Orta Solar; Ben Cosh of TGC Renewables; Ben Thompson of Foresight Group; Simon Stonehouse of Natural England; Leonie Greene of the Solar Trade Association; and Tom Fullick, Gary Ford and Richard Wordsworth of the NFU.

With thanks to NSC Founding Partners:

Context

This document describes experience and principles of good practice to date for the management of small livestock in solar farms established on agricultural land, derelict/marginal land and previously-developed land.

Proposed for publication as an appendix to existing best practice guidelines by the BRE National Solar Centre[1], it should be read in conjunction with BRE (2014) Biodiversity Guidance for Solar Developments (eds. G.E. Parker and L. Greene).

The guidance presented here has been developed with, and endorsed by, a number of leading UK solar farm developers and organisations concerned with agriculture and land management.

Introduction

Field-scale arrays of ground-mounted PV modules, or "solar farms", are a relatively recent development, seen in Britain only since 2011, although they have been deployed in Germany and other European countries since around 2005. In accordance with the "10 Commitments" of good practice established by the Solar Trade Association[2], the majority of solar farm developers actively encourage multi-purpose land use, through continued agricultural activity or agri-environmental measures that support biodiversity, yielding both economic and ecological benefits.

It is commonly proposed in planning applications for solar farms that the land between and underneath the rows of PV modules should be available for grazing of small livestock. Larger farm animals such as horses and cattle are considered unsuitable since they have the weight and strength to dislodge standard mounting systems, while pigs or goats may cause damage to cabling, but sheep and free-ranging poultry have already been successfully employed to manage grassland in solar farms while demonstrating dual-purpose land use.

Opportunities for cutting hay or silage, or strip cropping of high-value vegetables or non-food crops such as lavender, are thought to be fairly limited and would need careful layout with regard to the proposed size of machinery and its required turning space. However, other productive options such as bee-keeping have already been demonstrated. In some cases, solar farms may actually enhance the agricultural value of land, where marginal or previously-developed land (e.g. an old airfield site) has been brought back into more productive grazing management. It is desirable that the terms of a solar farm agreement should include a grazing plan that ensures the continuation of access to the land by the farmer, ideally in a form that that enables the claiming of Basic Payment Scheme agricultural support (see page 2).

[1] BRE (2013) Planning guidance for the development of large scale ground mounted solar PV systems. www.bre.co.uk/nsc

[2] STA "Solar Farms: 10 Commitments" http://www.solar-trade.org.uk/solarFarms.cfm

Conservation grazing for biodiversity

As suggested in the Biodiversity Guidance described above, low intensity grazing can provide a cost-effective way of managing grassland in solar farms while increasing its conservation value, as long as some structural diversity is maintained. A qualified ecologist could assist with the development of a conservation grazing regime that is suited to the site's characteristics and management objectives, for incorporation into the biodiversity management plan.

Avoiding grazing in either the spring or summer will favour early or late flowering species, respectively, allowing the development of nectar and seeds while benefiting invertebrates, ground nesting birds and small mammals. Hardy livestock breeds are better suited to such autumn and winter grazing, when the forage is less nutritious and the principal aim is to prevent vegetation from overshadowing the leading (lower) edges of the PV modules (typically about 800-900mm high). Other habitat enhancements may be confined to non-grazed field margins (if provision is made for electric or temporary fencing) as well as hedgerows and selected field corners.

Agricultural grazing for maximum production

The developer, landowner and/or agricultural tenant/licensee may choose to graze livestock at higher stocking densities throughout the year over much of the solar farm, especially where the previous land use suggested higher yields or pasture quality. Between 4 and 8 sheep/hectare may be achievable (or 2-3 sheep/ha on newly-established pasture), similar to stocking rates on conventional grassland, i.e. between about March and November in the southwest and May to October in North-East England.

The most common practice is likely to be the use of solar farms as part of a grazing plan for fattening/finishing of young hill-bred 'store' lambs for sale to market. Store lambs are those newly-weaned animals that have not yet put on enough weight for slaughter, often sold by hill farmers in the Autumn for finishing in the lowlands. Some hardier breeds of sheep may be able to produce and rear lambs successfully under the shelter of solar farms, but there is little experience of this yet. Pasture management interventions such as 'topping' (mowing) may be required occasionally or in certain areas, in order to avoid grass getting into unsuitable condition for the sheep (e.g. too long, or starting to set seed).

Smaller solar parks can provide a light/shade environment for free-ranging poultry (this is now recognised by the RSPCA Freedom Foods certification scheme) – experience to date suggests there is little risk of roosting birds fouling the modules. Broiler (meat) chickens, laying hens and geese will all keep the grass down, and flocks may need to be rotated to allow recovery of vegetation. Stocking density of up to 2000 birds per hectare is allowed, so a 5 megawatt solar farm on 12 hectares would provide ranging for 24,000 birds.

Solar farm design and layout

In most solar farms, the PV modules are mounted on metal frames anchored by driven or screw piles, causing minimal ground disturbance and occupying less than 1% of the land area. The rest of the infrastructure typically disturbs less than 5% of the ground, and some 25-40% of the ground surface is over-sailed by the modules or panel. Therefore 95% of a field utilised for solar farm development is still accessible for vegetation growth, and can support agricultural activity as well as wildlife, for a lifespan of typically 25 years.

As described above, the layout of rows of modules and the width of field margins should anticipate future maintenance costs, taking into account the size, reach and turning circle of machinery and equipment that might be used for 'topping' (mowing), collecting forage grass, spot-weeding (e.g. of 'injurious' weeds like ragwort and dock) and re-seeding. Again, in anticipation of reverting the field to its original use after 25 years, many agri-environmental measures may be better located around field margins and/or where specifically recommended by local ecologists. All European farmers are obliged to maintain land in "good agricultural and environmental condition" under the Common Agricultural Policy rules of 'cross compliance', so it is important to demonstrate sound stewardship of the land for the lifetime of a solar farm project, from initial design to eventual remediation.

The depth of buried cables, armouring of rising cables, and securing of loose wires on the backs of modules all need to be taken into consideration where agricultural machinery and livestock will be present. Cables need to be buried according to national regulations and local DNO requirements, deep enough to avoid the risk of being disturbed by farming practice – for example, disc harrowing and re-seeding may till the soil to a depth of typically 100-150 mm, or a maximum of 200 mm. British Standard BS 7671 ("Wiring Regulations") describes the principles of appropriate depth for buried cables, cable conduits and cable trench marking. Note also that stony land may present a risk of stone-throw where inappropriate grass management machinery is used (e.g. unguarded cylinder mowers).

Eligibility for CAP support and greening measures

From 2015, under the Common Agricultural Policy, farmers will be applying for the new Basic Payment Scheme (BPS) of area-based farm support funding. It has been proposed that the presence of sheep grazing could be accepted as proof that the land is available for agriculture, and therefore eligible to receive BPS, but final details are still awaited from Defra at the time of writing. Farmers must have the land "at their disposal" in order to claim BPS, and solar farm agreements should be carefully drafted in order to demonstrate this (BPS cannot be claimed if the land is actually rented out). Ineligible land taken up by mountings and hard standing should be deducted from BPS claims, and in the year of construction larger areas may be temporarily ineligible if they are not available for agriculture.

Defra has not yet provided full details on BPS 'greening' measures, but some types of Ecological Focus Areas may be possibly located within solar farms, probably around the margins, including grazed buffer strips and ungrazed fallow land, both sown with wildflowers. Note that where the agreed biodiversity management plan excludes all forms of grazing, the land will become ineligible for BPS, and this may have further implications for the landowner, such as for inheritance tax.

Long-term management, permanent grassland and SSSI designation

Since solar farms are likely to be in place typically for 25 years, the land could pass on to a succeeding generation of farmers or new owners, and the vegetation and habitat within the fenced area is expected to gradually change with time. According to Natural England, there is little additional risk that the flora and fauna would assume such quality and interest that the solar farm might be designated a SSSI (Site of Special Scientific Interest) compared with a similarly-managed open field. However, there could be a possible conflict with planning conditions to return the land to its original use at the end of the project, e.g. if this is specified as 'cropland' rather than more generically as 'for agricultural purposes'. If the pasture within a solar farm were considered to have become a permanent grassland, it may be subject to regulations requiring an Environmental Impact Assessment to restore the original land use, although restoration clauses in the original planning consent may take precedence here. It is proposed that temporary (arable) grassland should be established on the majority of the land area that lies between the rows of modules. This would be managed in 'improved' condition by periodic harrowing and re-seeding (e.g. every 5 years), typically using a combination disc harrow and seed drill.

Other measures to maintain the productivity of grassland, without the need for mechanised cultivations or total reseeding, could include: maintaining optimum soil fertility and pH to encourage productive grass species; seasonally variable stocking rates to prevent over/under-grazing with the aim of preventing grass from seeding and becoming unpalatable. Non-tillage techniques to optimise grass sward content might include the use of a sward/grass harrow and air-seeder to revive tired pastures. When applying soil conditioners (e.g. lime), fertilisers or other products, consideration should be taken to prevent damage to or soiling of the solar modules.

Good practice in construction and neighbourliness

Consideration should also be given to best practice during construction and installation, and ensuring that the future agricultural management of the land (such as a change from arable cropping to lamb production) fits into the local rural economy. Site access should follow strictly the proposed traffic management plan, and careful attention to flood and mud management in accordance with the Flood Risk Assessment (e.g. controlling run-off by disrupting drainage along wheelings), will also ensure that the landowner remains on good terms with his/her neighbours.

Time of year should be taken into account for agricultural and biodiversity operations such as prior seeding of pasture grasses and wildflowers. Contractors should consider avoiding soil compaction and damage to land drains, e.g. by using low ground pressure tyres or tracked vehicles. Likewise, when excavating cable trenches, storing and replacing topsoil and subsoil separately and in the right order is important to avoid long-term unsightly impacts on soil and vegetation structure. Good practice at this stage will yield longer-term benefits in terms of productivity and optimal grazing conditions.

Evidence base and suggested research needs

A number of preliminary studies on the quantity and quality of forage available in solar farms have suggested that overall production is very little different from open grassland under similar conditions. A more comprehensive and independent evidence base could be established through a programme of directed research, e.g. by consultants (such as ADAS) or interested university groups (e.g. Exeter University departments of geography and biosciences), perhaps in association with seed suppliers and other stakeholders. Productivity of grasses could be compared between partial shade beneath the solar modules and unshaded areas between the rows. Alternatively daily live weight gain could be compared between two groups of fattening lambs (both under the same husbandry regime) on similar blocks of land, with and without solar modules present.

Case Steiger Quadtrac used to deliver inverters and other heavy equipment to site under soft ground conditions (photo courtesy of British Solar Renewables)

Cable trenching, showing topsoil stripped and set to one side, with subsoil placed on the other side ready for reinstatement (photo courtesy of British Solar Renewables)

Agricultural case studies

Benbole Farm, Wadebridge, Cornwall

One of the first solar farms developed in Britain in 2011, this 1.74 megawatt installation on a four-hectare site is well screened by high hedges and grazed by a flock of more than 20 geese. A community scheme implemented by the solar farm developers enabled local residents to benefit from free domestic solar panels and other green energy projects.

Eastacombe Farm, Holsworthy, Devon

This farm has been in the Petherick family for four generations, but they were struggling to survive with a small dairy herd. In 2011/12, a solar developer helped them convert eight hectares of the lower-grade part of their land into a 3.6 megawatt solar farm with sheep grazing, which has diversified the business, guaranteeing its future for the next generation of farmers.

Higher Hill, Butleigh, Somerset

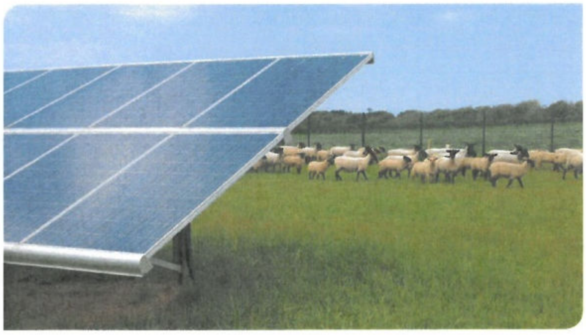
Angus Macdonald, a third-generation farmer, installed a five megawatt solar farm on his own land. Located near Glastonbury, the site has been grazed by sheep since its inception in 2011.

Newlands Farm, Axminster, Devon

Devon sheep farmer Gilbert Churchill chose to supplement his agricultural enterprise by leasing 13 hectares of grazing land for a 4.2 megawatt solar PV development, which was completed in early 2013. According to Mr Churchill, the additional income stream is "a lifeline" that "will safeguard the farm's survival for the future".

Trevemper Farm, Newquay, Cornwall

In 2011, the Trewithen Estate worked with a solar developer to build a 1.7 megawatt solar farm on 6 hectares of this south-facing block of land, which had good proximity to a grid connection. During the 25-year lease, the resident tenant farmer is still able to graze the land with sheep at his normal stocking density, and is also paid an annual fee to manage the pasture.

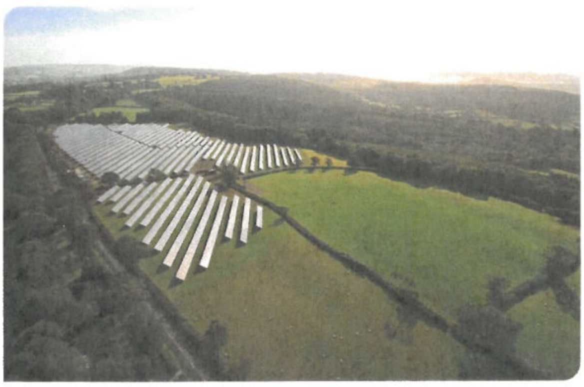


Yeowood Solar Farm, North Somerset

Completed in 2012, this 1.3 megawatt installation on 4 hectares of land surrounds a poultry farm of 24,000 laying hens, which are free to roam the land between and underneath the rows of solar modules, as well as other fields. The Ford family, farm owners, also grow the energy crop miscanthus to heat their eco-friendly public swimming pool and office units.

Wyld Meadow Farm, Bridport, Dorset

Farmers Clive and Jo Sage continue to graze their own-brand Poll Dorset sheep on this 4.8 megawatt solar farm, established on 11 hectares in 2012. The solar farm was designed to have very low visual impact locally, with an agreement to ensure livestock grazing throughout the project's lifetime.



Wymeswold Solar Farm, Leicestershire

The author pictured in July 2014 at Britain's largest connected solar farm. At 33 megawatts, this development provides enough energy to power 8,500 homes. Built on a disused airfield in 2013, this extensive installation over 61 hectares (150 acres) received no objections during planning and is grazed by the landowner's sheep – just visible in the background.

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BRE Trust
The BRE Trust uses profits made by BRE Group to fund new research and education programmes, that will help it meet its goal of 'building a better world together'.

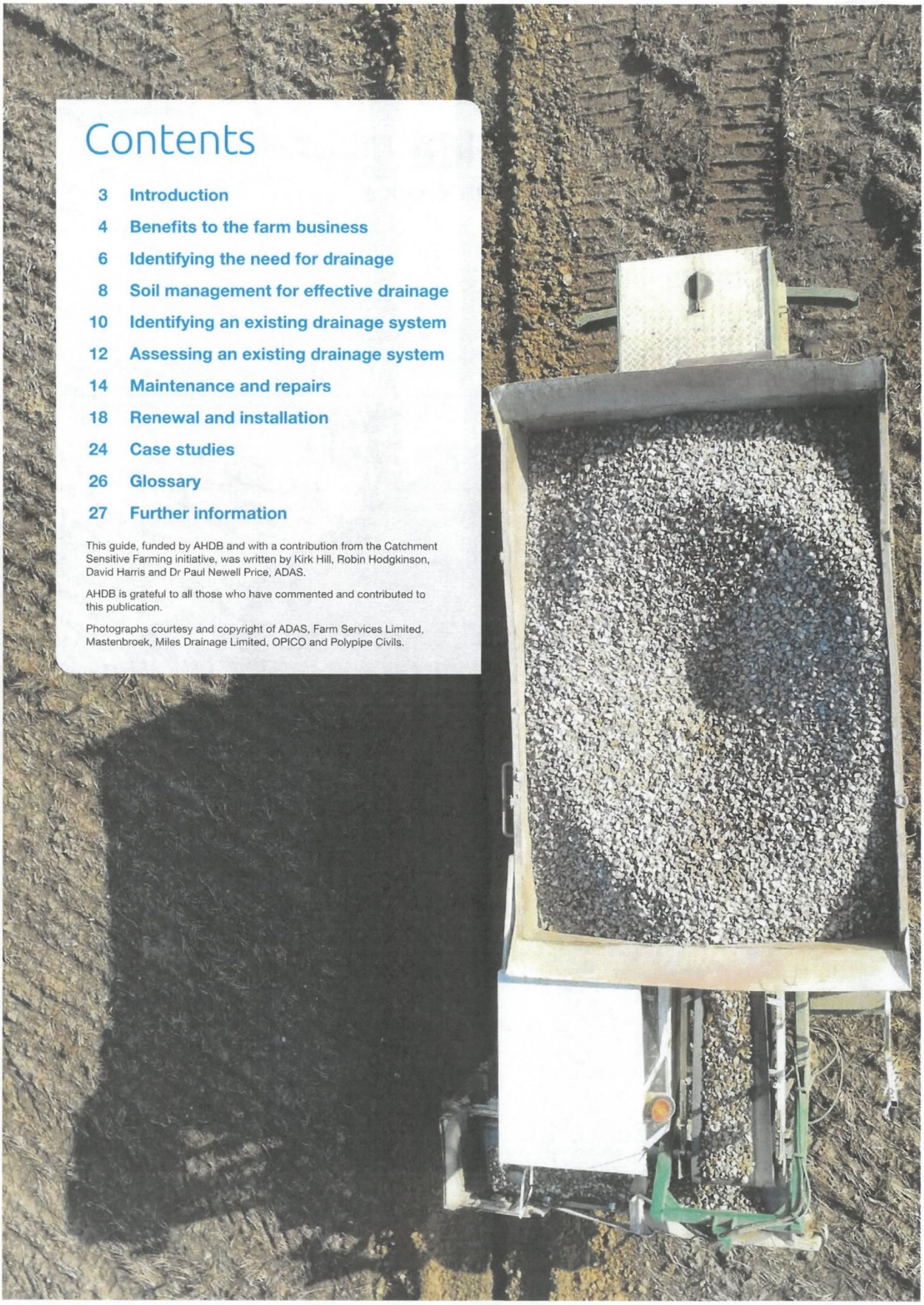
Appendix SMP9

AHDB Field Drainage Guide

AHDB

Field drainage guide

Principles, installations and maintenance



Contents

This guide, funded by AHDB and with a contribution from the Catchment Sensitive Farming initiative, was written by Kirk Hill, Robin Hodgkinson, David Harris and Dr Paul Newell Price, ADAS.

AHDB is grateful to all those who have commented and contributed to this publication.

Photographs courtesy and copyright of ADAS, Farm Services Limited, Mastenbroek, Miles Drainage Limited, OPICO and Polypipe Civils.

Introduction

What is field drainage?

Field drainage is installed to rapidly remove excess soil water to reduce or eliminate waterlogging and return soils to their natural field capacity. Drains can be used to control a water table or to facilitate the removal of excess water held in the upper horizons of the soil.

A good drainage system will reduce the risk of detrimental waterlogging to acceptable levels.

Where soils are coarsely textured and well structured, the soil may be freely draining enough to support field operations and crop growth without the need for artificial drainage systems. Field drains should be considered in the following situations:

- **Heavy clay soils:** These are slowly permeable and, without drainage, can be waterlogged for long periods, particularly in areas of high rainfall
- **Medium-textured soils in high-rainfall areas:** Drainage may be needed to reduce vulnerability to compression, slaking and compaction
- **Light-textured soils:** These soils are highly permeable, but drainage may be required to provide water table control in low-lying areas
- **Springs:** Drains are used to intercept springs before they reach the surface; this helps prevent erosion, localised waterlogging and poaching, and the intercepted water, if clean, may be used as drinking water for stock

There has been a general reduction in organic matter levels in arable soils over the past 70 years. This makes them more susceptible to waterlogging and more in need of drainage.

History of field drainage in the uk

Around 6.4 million hectares of agricultural land in England and Wales have been drained with piped systems.

The rate at which land was drained increased rapidly during World War II, as part of the drive to increase food production, and peaked during the 1960s to 1980s, when grant aid was available.

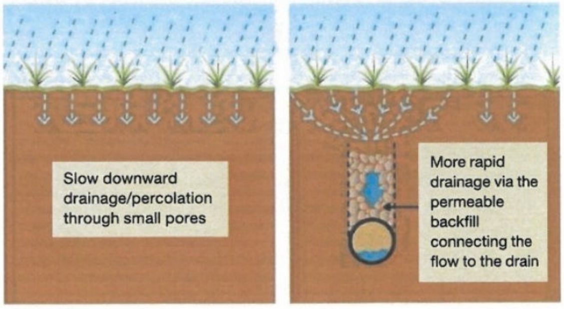


Figure 1. Drainage of heavy soil

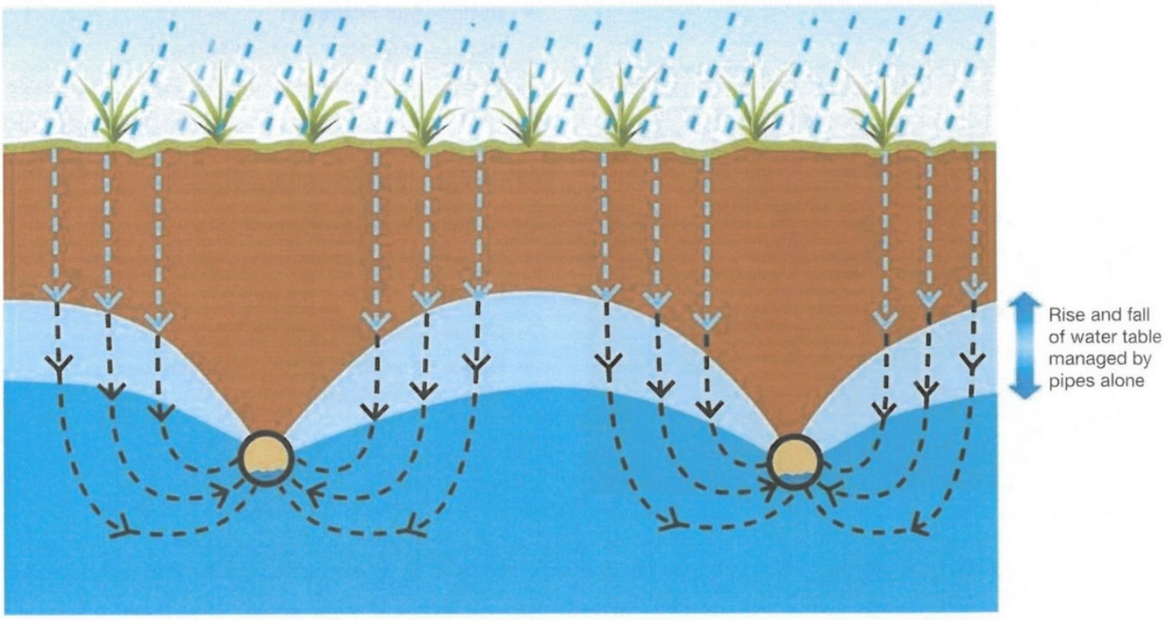


Figure 2. Water table control on permeable soils

Benefits to the farm business

In some years, drainage can make the difference between having a crop to harvest and complete crop loss; or whether or not the land can be accessed to harvest the crop.

The benefits of field drainage to the farm business are substantial, but installation can be expensive. The magnitude of the benefit varies considerably with climate, soil type and land use, so it is important to carry out both environmental and cost–benefit assessments before installing or managing field drainage systems.

Drainage is a long-term investment. Given good maintenance, a useful life of at least 20 years can be expected and some systems can last many decades longer.

Good field drainage reduces the peak surface water run-off rates by increasing the availability of storm-water storage within the soil. Rainfall then percolates down through the soil into the drains, producing a more balanced flow after storms. This reduces the risk of flooding and soil erosion, not only within the field but also further downstream in the catchment.

The cost of installation

The cost of installing a new comprehensive field drainage system varies greatly according to the scale and intensity of the system.

Based on 2024 prices, typical costs per hectare are around:

- £2,500–£3,500 with permeable backfill
- £1,400–£2,000 without permeable backfill

Improved plant performance

- Improved crop yield and quality
- More rapid warming of soils in spring, improving germination
- Improved environment for soil organisms
- Better access to water and oxygen for plant roots
- Better crop uptake of soil mineral nitrogen

Better access to land

- Reduced duration/risk of autumn waterlogging
- Quicker accessibility of fields following any period of wet weather
- Crop inputs more likely to be applied at optimum time
- An extended growing and grazing season

Improved speed of work and fuel use

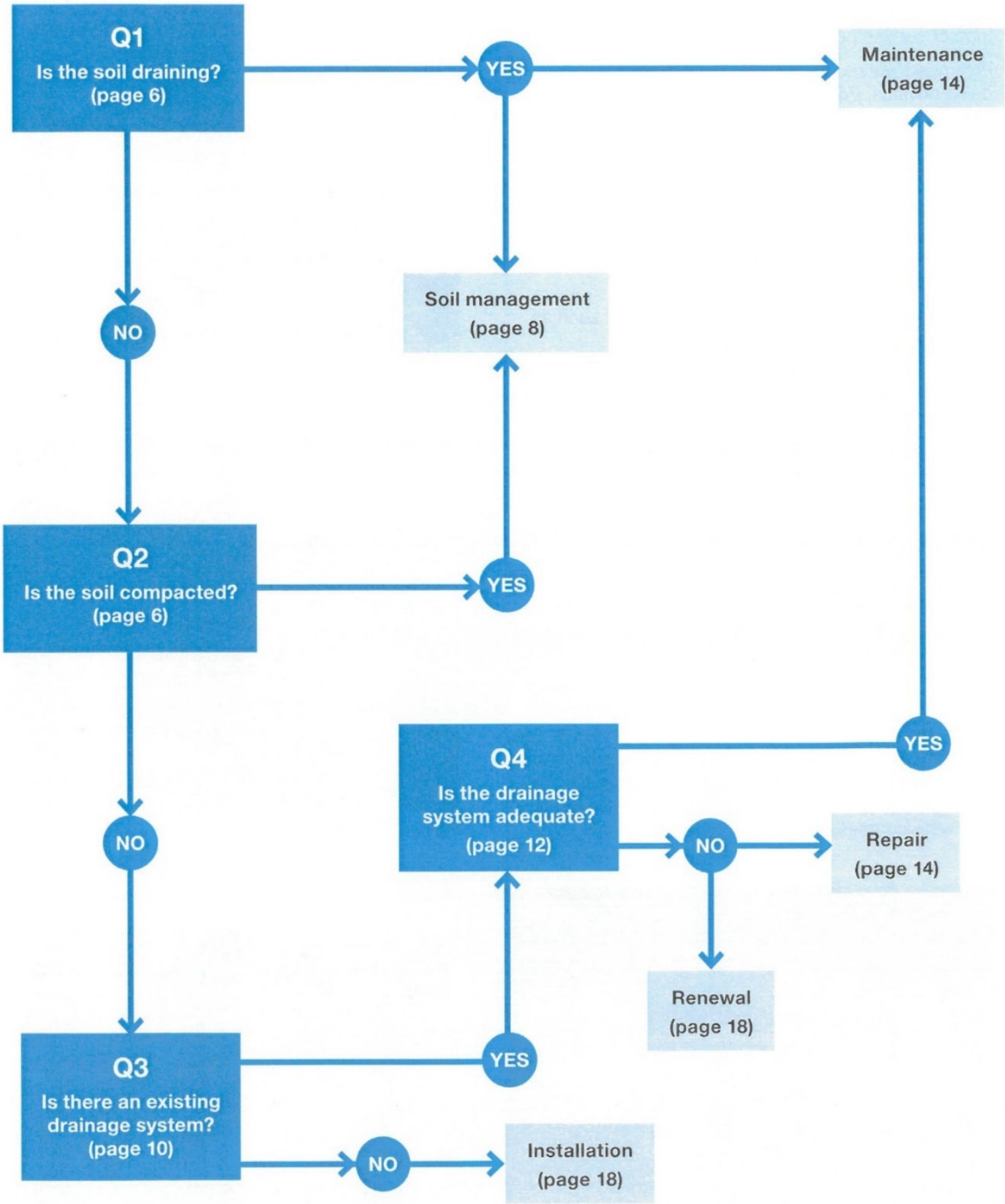
- Better traction
- Fewer cultivation passes
- Reduced draught forces
- Reduced wear and tear
- Fewer wet areas to avoid

Benefits to soil structure and the environment

- Less structural damage to soils
- Reduced frequency and extent of livestock poaching
- Better water infiltration
- Reduced surface run-off and erosion
- Reduced phosphorus and pesticide losses to water
- Decreased potential for slug activity and reproduction

Reduced risks to livestock health

- Reduced survival of parasitic larvae
- Snails carrying liver fluke do not thrive
- Footrot and foul of the foot are less common
- Udder hygiene for grazing stock is improved
- Reduced risk of soil contamination during silaging operations


Q1
Is the soil draining?
(page 6)
YES
Maintenance
(page 14)
Soil management
(page 8)
NO
Q2
Is the soil compacted?
(page 6)
YES
Q4
Is the drainage system adequate?
(page 12)
YES
NO
Repair
(page 14)
NO
Renewal
(page 18)
Q3
Is there an existing drainage system?
(page 10)
YES
NO
Installation
(page 18)

Identifying the need for drainage

Evidence of poor drainage

The evidence of poor drainage may be obvious in the form of surface ponding or saturated topsoils.

Prolonged waterlogging under the surface may not be so obvious. Poor drainage conditions may be identified by:

- Poor crop health or yields: overlaying a yield map onto a field drainage map can identify problem areas
- High surface run-off rates and soil erosion
- Limited field access without rutting or poaching (animal hoof damage) compared with other fields in the area
- The presence of wet-loving plant species, such as common rush and redshank
- Susceptibility to drought due to poor root development and limited rainfall percolation into the soil

If drainage problems are widespread across the field, it may be that:

- Soil management is not adequate
- No drains have been installed
- Mole drains need to be renewed
- In flatter fields, the outfall may simply be blocked
- The drainage system requires maintenance or has reached the end of its useful life

Environment

Surface run-off may occur, which can result in transport of faecal material, sediment, soilborne diseases (e.g. clubroot), nutrients or agrochemicals to watercourses.

Figure 3. Surface ponding

Figure 4. Areas of grassland may become heavily poached at times when soil conditions in other fields on similar soils do not lead to poaching

Figure 5. Saturated topsoils

Figure 6. Areas within arable fields may be waterlogged, resulting in crop loss or soil damage due to wheel ruts

Is the soil draining?

Examining the soils to determine if they are naturally freely or slowly draining or have damaged structure should be the first action when drainage problems are suspected.

Without good soil structure, soil drainage will be poor, whether it be by natural drainage or pipes.

Compacted layers can restrict surface water from reaching underlying drainage systems. If compacted layers are identified, remedial action should be undertaken to remove them before considering field drainage maintenance or reinstallation.

It is essential to routinely assess soil structure. This can easily be incorporated into the farm soil sampling programme and should be completed in spring or autumn. Examine the soil at several points in the field to a depth of:

- Arable land: at least 600 mm
- Grassland: at least 500 mm

Soil structure

✔ Well-developed structure is evident from the ease of digging and if the soil readily breaks down into small structural units with many vertical fissures

✗ Soils with poor structure are hard to dig and break down into larger dense blocks, with poor penetration by water, air and roots

Soil colour

Greyish-coloured soils and soils with rusty or grey-coloured mottles are signs of poorer drainage.

Soil texture

The higher the clay content, the more likely the soil is to be naturally poorly drained.

Root development

✔ Deep rooting indicates good structure

✗ Shallow rooting with many fine horizontal roots and tap roots that are diverted horizontally indicate the presence of compacted layers

Perched water table

Soil compaction occurs when soil particles are compressed, reducing the space (pores) between them. This restricts the movement of vital air and water through the soil.

When soil water is present, dig a pit (to a depth where the soil becomes drier) to aid diagnosis. Saturated soils overlying a layer of dry soil after a period of heavy rain may indicate the presence of a compacted layer preventing drainage.

It is not uncommon to find both naturally and artificially compacted layers (pans) in susceptible soils. Plough pans can develop if a field is repeatedly ploughed to the same depth.

If the pan, whether artificial or natural, is limiting water infiltration and/or root growth, it should be removed by subsoiling or topsoil loosening.

Figure 7. Natural pans – often very hard bands of soil particles cemented together by iron and manganese

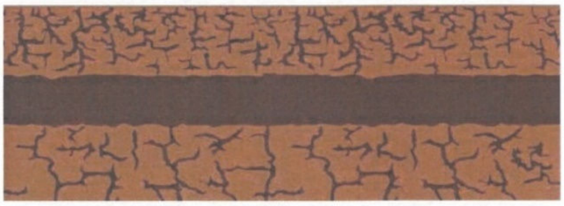


Figure 8. Compaction pans – dense layers caused by farm machinery operation; often 50–100 mm thick, they generally have a platy structure and frequently contain crop residues

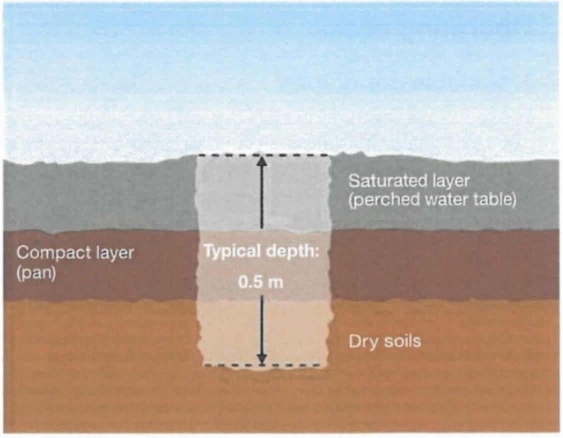


Figure 9. Soil inspection pit extending below the compacted layer

Soil management for effective drainage

Effective drainage relies on good soil management

If soil examination identifies compacted layers that act as a barrier to water movement, remedial action should be undertaken to remove them before considering new drainage.

Maintaining a good soil structure may avoid the need for capital investment.

Minimise soil damage by reducing:

- Field trafficking
- Weight of machinery
- Tyre pressures
- Poaching of livestock
- Overworking of the seedbed

Other potential solutions include the use of low-pressure tyres, minimum tillage, controlled traffic farming and fixed wheelings, avoiding turnout in poor soil conditions, and considering the placement of livestock feeders and drinkers and livestock tracks.

Subsoil and topsoil loosening

When soils are wet, they are easily damaged by cultivation, machinery traffic and livestock trampling. If the soil structure has been damaged, subsoil or topsoil loosening (normally referred to as 'subsoiling' and 'sward lifting', respectively) in suitable conditions can be used to help restore the structure of a damaged soil. It can also be used to improve subsoil permeability.

Slit aerators can also be used in grassland fields but should only target the top 10 cm. Research has shown that they can increase infiltration rates, but good conditions are needed below the target area or they can just move water more quickly towards a drainage problem.

Operating notes

1. Suitable conditions

Topsoil loosening and subsoiling should only be carried out when the soil at working and loosening depth is in a 'dry' and friable condition, so that it will shatter rather than smear. Examine soils early in the operation to ensure effective shattering is occurring.

For arable subsoiling, both the soil surface and the compacted layer should be 'dry' to avoid soil structural damage.

For topsoil loosening in grassland using a 'sward lifter'-type machine, the ideal conditions are when the soil surface is slightly moist, to allow disc and tine leg entry while avoiding excessive sward tear, and the lower topsoil is moist to dry, to enable 'lift' and loosening.

2. Choice of soil-loosening equipment

Winged subsoilers (as seen in Figure 10), developed in the 1980s, shatter the soil much more effectively than conventional subsoilers. They require higher draught force but can disturb a volume of soil two to three times greater than a conventional subsoiler, resulting in more effective disturbance.

The use of leading tines can result in an increased volume of soil disturbed without increasing the draught, but they are not suitable for grassland as they cause considerable surface disturbance.

Topsoil looseners (as seen in Figure 11) or 'sward lifters' for grassland incorporate a leading disc, a vertical or forward-inclined leg and a tine leg and a packer roller behind to minimise sward tear and surface disturbance.

Figure 10. Winged subsoiler

Figure 11. Topsoil loosener for grassland

3. Depth

It is best practice to use a depth wheel or rear packer roller to maintain a constant tine depth.

Aim for tines to be about 25–50 mm below the base of the compacted layer, up to a maximum depth of approximately 450 mm below ground level.

Maximum depth may be limited by shallow field drains, rock or the critical depth of the tine (related to tine width and soil conditions). Normal drain depth is around 700 mm below the soil surface.

For subsoiling to result in improved drainage, the depth to which the soil is loosened must be just greater than the depth down to the top of the permeable backfill.

This will connect the fissures and allow water to move to the permeable fill over the drains.

4. Spacing between tines

- Conventional subsoiler: up to 1.5 times the tine depth
- Winged subsoiler: up to 2 times the tine depth
- With leading shallow tines: up to 2.5 times the tine depth

After a trial run, dig down and examine the effect. Spacing can be adjusted, where possible, to achieve the desired degree of soil disturbance.

Avoiding re-compaction

Recently loosened soils are very sensitive to re-compaction.

Avoid running over land that has already been subsoiled. In grassland, avoid grazing after autumn loosening and cut rather than graze in the first spring after treatment.

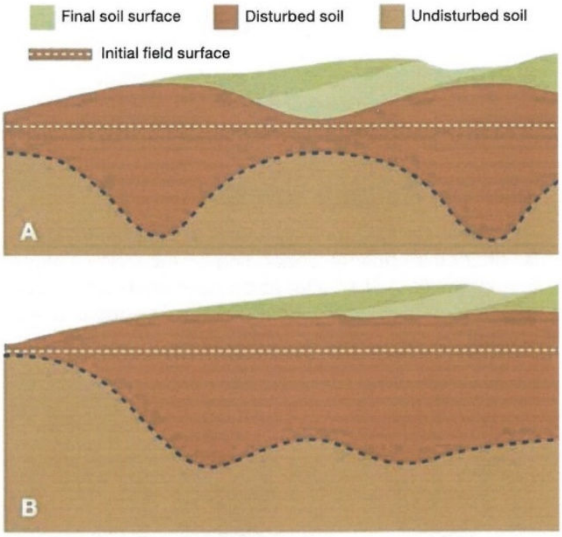


Figure 12. A is an example of tines set too wide and B shows tines correctly set

Further information

- A guide to better soil structure (Cranfield University) **landis.org.uk/downloads**
- Soil management **ahdb.org.uk/greatsoils**
- Think soils (Environment Agency) **gov.uk/managing-soil-types**
- Principles of subsoiling videos on the Practical Pig app (**practicalpig.ahdb.org.uk**)

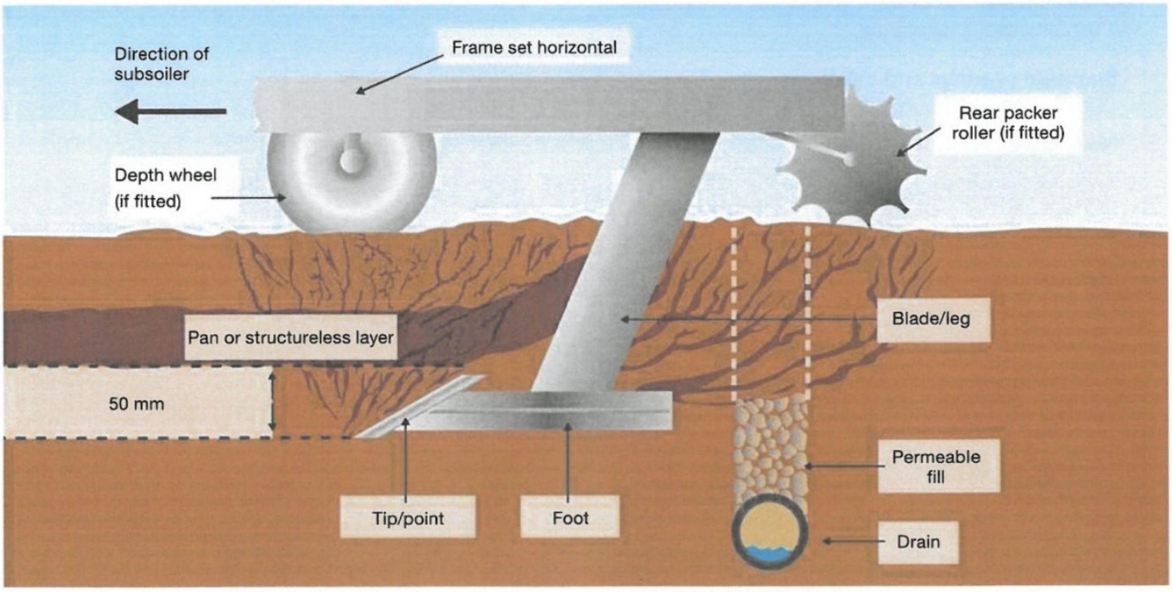


Figure 13. Subsoiler operation

Identifying an existing drainage system

Existing drainage

Fields are likely to already have some form of field drainage if they have heavy soils or medium soils in heavy rainfall areas or a naturally high water table. The system may, however, not be functioning properly or may be inadequate for the current farming needs.

Typical drainage layouts

A field can contain a combination of different layouts or be drained irregularly, depending on the surface slopes across the field. If smaller fields have been merged into one, the outfalls may be found at the low points of each original field and not the current field.

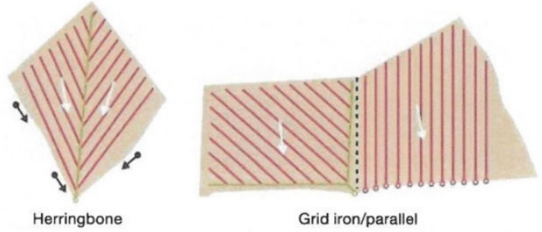


Figure 14. Typical drainage layouts

Understanding drainage plans

On many farms, final drainage plans are available that detail exactly what type of drainage was installed and where it is within each field. Final plans are normally accurate and, provided the key above-ground features shown are visible, should enable the drains to be found.

Ensure it is a final drainage plan, not a proposal. A final plan may include the words 'completion' or 'as built' and should always be signed.

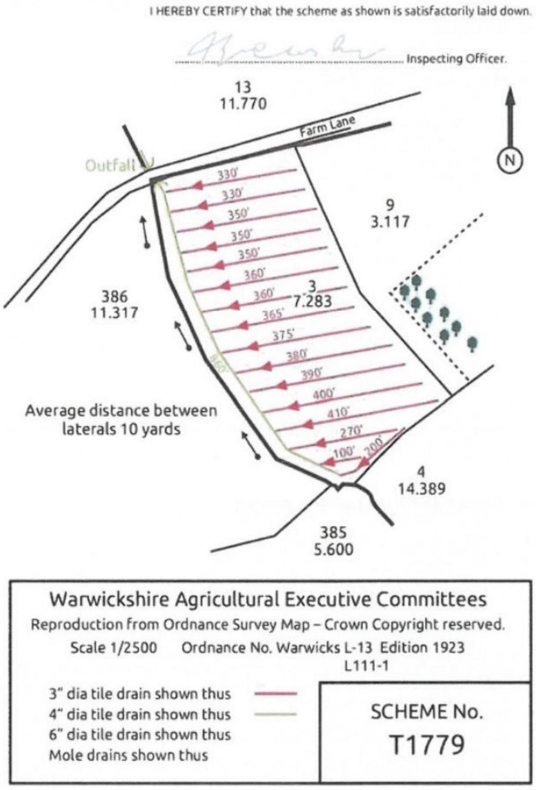


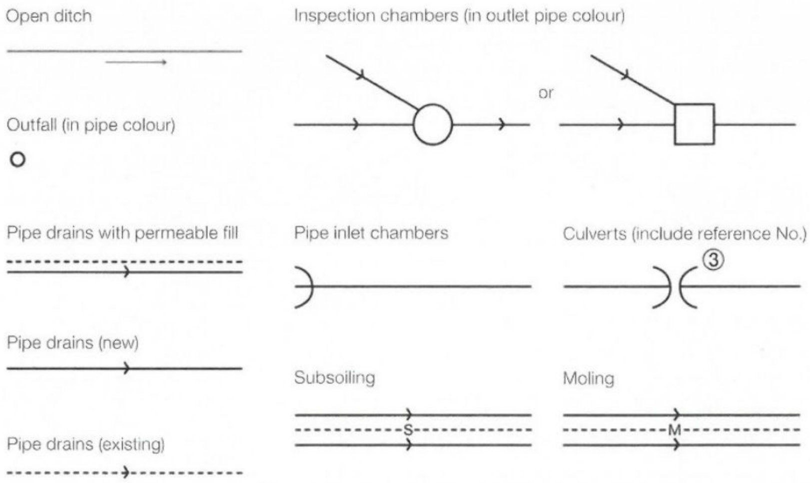
Figure 15. Example final drainage plan

Standard symbols and colours

Plastic pipes

Diameter mm	Colour
60 mmØ	Red
80 mmØ	Purple
100, 110, 125 mmØ	Green*
160 mm, 170 mmØ	Blue*
200, 225 mmØ	Yellow*
Over 225 mmØ	Black

*Indicate diameter



In the absence of a final drainage plan

Local drainage contractors may hold copies of any final record plans. If the land has been recently acquired, the previous owners may hold the plans.

Creating your own drainage plan

1. **Produce a sketch map** showing the ditches and the direction in which they flow, along with the dominant direction of slope in each field. It may also be helpful to mark any removed field boundaries or ditches, as one large field may contain several small drainage schemes.
2. **Locate any visible outfalls.** These are generally found at the lowest points within a field. There may be more than one outfall, depending on the layout of the drainage scheme.

- Walk the ditches after rainfall: you may hear an outfall running that you cannot see
- The best time to look for outfalls is in winter when drains are running and vegetation growth is reduced
- Even if an actual pipe is not visible, seepage from the bank or an area where the bank has receded can indicate the location of a drain outfall
- If the ditch is badly overgrown, it may be necessary to clear vegetation
- If the ditch has become silted up or the pipe blocked, the ditch may first need to be cleared – typically, to at least 1 m below the adjacent field level

Figure 16. Drainage ditch

3. **Look for field surface signs.** Some features may only be apparent in a certain light during the day or during particular ground moisture conditions.

- Aerial photographs available online may reveal the lines of the drains, although they may be confused with other features, such as underground pipelines
- Slight linear depressions may be visible on the field surface
- The crop may vary in quality or colour over the line of a drain
- The soil may be drier directly over the drain than between drains
- Localised wet areas or small depressions ('blow holes') may be found upslope of a blocked drain

Figure 17. A 'blow hole'

4. If the outfall cannot be found by visual inspection alone, or surface signs need to be confirmed, it may be necessary to **dig trenches across the most likely locations** for drains.

Health and safety

Before excavating any trenches, ensure that:

- There are no underground cables or pipelines present that may be hazardous or damaged
- Personnel do not enter a trench unless adequate precautions have been taken to prevent trench collapse

Some helpful information can be found at **hse.gov.uk**

Figure 18. Signs indicating potential underground hazards

Assessing an existing drainage system

Risk management

An effectively designed field drainage system should afford a level of protection against waterlogging that is appropriate to the value of the crop, land access and other benefits. It should be designed to drain the field effectively up to an appropriate return period, usually based on crop value.

Thinking of drainage as insurance, a higher-value crop may justify a more intensive field drainage system than, for example, grassland, which may be able to better tolerate a small amount of waterlogging. Equally, improved drainage may attract high-value horticulture crops into the rotation, increasing the rental value.

The degree to which drainage systems provide protection against waterlogging should be matched with the value of the crops to be grown. A typical high-value crop would need to be protected against all rainfall, except very infrequent rainfall events, whereas grassland warrants a lower level of protection.

The following waterlogging risk frequencies are typically used for design:

- Very high-value specialist crops: 1 in 25 years
- Horticultural crops: 1 in 10 years
- Root crops: 1 in 5 years
- Intensive grass and cereals: 1 in 2 years
- Grassland: 1 in 1 year

Is the existing system adequate?

There are a number of reasons why an existing field drainage system may be inadequate for current needs:

- The scheme may have been designed to work with mole drains that have since collapsed and need renewal
- The drainage system may have reached the end of its useful life (e.g. blocked or collapsed)
- The land use may have changed since the system was installed
- The drains may have been installed without permeable backfill

On soils where permeable backfill is required for optimum performance, the scheme may work well initially due to the soil disturbance during trenching. With the passage of time, however, the soil will return to a more consolidated, less permeable condition that may limit water movement.

It can be difficult to recognise the signs of crop stress on fields where old drains are gradually becoming less effective and where only some crops in the rotation may be affected by stress. When deciding whether the existing field drainage system is adequate, take into account the history of the field and whether it has been deteriorating. Consider:

- Year-on-year variation in yield
- Instances of delayed cultivation or harvest due to field conditions
- Past damage due to poor drainage
- Frequent blow holes may be a sign that pipes are too small or are blocked downstream
- Increases in the presence of moisture-loving plants

Figure 19. Crop loss due to drainage problems

Assessing the costs and benefits of field drainage

While field drainage can have economic, practical and environmental benefits, installation can be expensive.

Drainage can also exacerbate water pollution and impact negatively on some habitats. It is, therefore, important to carry out an environmental and cost-benefit assessment before installing or carrying out maintenance on field drainage systems.

Production benefits resulting from drainage are most likely to be obtained in areas of high rainfall or on:

- Heavy clay soils, especially where arable or intensive livestock production is practised
- Medium soils where potatoes, other root crops or high-value crops are grown
- Low-lying permeable soils where the groundwater level comes close to the land surface in winter or after rainfall

In many cases, it is better for both agricultural production and the environment to remove excess water by field drainage, but there are cases when the production benefits are outweighed by the costs and there are opportunities to mitigate climate change, flooding, protect water quality or create wildlife habitats by allowing field drainage to deteriorate.

Waterlogged land may be low value agriculturally but it may have biodiversity benefits or help to reduce flooding risk.

Sacrificing an area of waterlogged land may reduce costs by acting as a sediment trap and reducing the need for costly activities, such as watercourse dredging. Suitable areas where drainage might be allowed to deteriorate could include land adjacent to watercourses, natural wetlands and ribbon areas at the base of steep slopes, particularly on intensive grassland on heavy soils in the centre and west of the UK.

For more information for farmers in priority areas at risk of water pollution, contact Catchment Sensitive Farming: **gov.uk/catchment-sensitive-farming**

Environment

In the Mires on the Moors project (a partnership between South West Water, two National Park Authorities and other organisations, such as the Environment Agency), drainage ditches on Dartmoor and Exmoor were blocked to restore peatland. This increases the carbon and water storage on the moor and slows the flow of water off the moor so that storm and flood damage is reduced, sediment settles out and drinking water quality is improved. Read more on **www.exmoormires.org.uk**

The impact of field drainage on pollution risk

The relationship between field drains and pollution can be contradictory.

Positive points

Maintaining good field drainage and good soil structure reduces waterlogging

↓

This reduces the likelihood of causing soil compaction through untimely field operations

↓

This decreases surface run-off, soil erosion and the loss of sediment and associated pollutants, such as phosphorus, to water

Negative points

When soils are wet or dry with deep cracks and rain falls within a few days of agrochemical application…

↓

…field drains can provide a rapid route for water enriched with ammonium, phosphorus, pesticides, fine sediment or other associated pollutants

↓

Drains are most effective at providing a conduit for agricultural pollutants when newly installed or in fields with deep cracking clays

Remember

- Best practice should always be followed when applying manures, fertilisers and agrochemicals to avoid losses via surface run-off or field drains
- Organic manures should not be applied to land within 12 months of pipe or mole drainage installation
- Organic manures should not be applied to drained land when soils are wet and drains are running
- Organic manures should not be stored within 10 m of a field drain

Maintenance and repairs

Ditches and outfalls

If ditches become infilled and outfalls are not kept clear, the field drainage system will cease to function effectively, leading to the need for more expensive maintenance or premature renewal.

In flat areas, in particular, blocked culverts and ditches can lead to waterlogging over large areas of land, restricting drainage upstream. This can cause flooding and soil erosion as the water backs up and tries to find an overland route to escape.

Given the significant cost of installing a new field drainage system, cleaning ditches and clearing outfalls is a simple, cheap and effective method of improving the effectiveness of existing systems.

Ditches are best cleared in autumn to minimise soil and crop damage.

Ditch maintenance

Fencing off ditches and watercourses from livestock can reduce maintenance needs by preventing bank damage and erosion.

It can also protect water from sediment and microorganisms in livestock manures, which impact water quality and ecology.

Blocked outfalls

The most common cause of drainage system deterioration is the failure to keep outfalls clear. This can cause the whole drainage system to fail, resulting in poor drainage, pipe siltation and possibly even blow holes across the field over time.

Environment

Ditches can be an important habitat for aquatic plants, invertebrates, amphibians, birds and small mammals. Timing of clearance operations or ditch maintenance may have implications for wildlife. Avoid disturbing breeding or nesting animals.

Localised over-digging of ditch beds can form small shallow pools that benefit invertebrates. The ditch will function as long as it has stable banks, the overall gradient is consistent such that it does not reduce drainage efficiency and it is deep enough to allow drainage outfalls to discharge.

Figure 20. Cleaning ditches is a simple way of improving the effectiveness of drainage systems

Figure 21. A blocked outfall can often be cleared in a matter of minutes with a spade

Pipes

Blockage by tree or hedge roots

When designing the drainage system, trees and hedges should be avoided wherever possible. When this is not possible, a sealed pipe should be used for any pipes within a tree rooting zone or within 1.5 m of a hedge.

If a blockage occurs, it may be possible to dig up the pipe on one or both sides of the blockage and use rods to clear the roots, but the section of pipe will often need to be replaced with a sealed pipe.

Environment

Take care to avoid unnecessary damage to tree roots or disturbing archaeological remains.

Pipe siltation

If drain outfalls are left submerged or blocked for a long period of time, siltation of the pipes may occur. This can be difficult or impossible to remedy.

Other than as a result of damaged or blocked pipes, siltation most commonly occurs on fine sandy and fine silty soils.

If pipe siltation is not too severe, it may be possible to rod the drains clear or to employ a contractor with specialist drain jetting equipment.

Figure 22. Silted clay drain

Where pipe siltation is a naturally recurring problem, a drainage system with separate outfall pipes for each drain is best. This allows easier access for cleaning operations.

Figure 23. Drain jetting

Ochre

Ochre is a generic term used to describe deposits that form in drains when soluble iron leaching out of the soil in drainage water comes into contact with air and is oxidised, at which point it becomes insoluble. It can also be caused by bacterial growths that secrete iron.

In some cases, a drainage scheme may fail completely due to ochre accumulation. In these cases, redrainage is only worthwhile if future ochre development is unlikely.

Preventing ochre formation

- Soils rich in iron may be prone to ochre and there is little that can be done to prevent ochre formation
- There are methods that attempt to prevent the build-up of ochre, but these can be specialist, intensive and often not very successful

Removing ochre

- Regular rodding or jetting may remove the ochre
- If the pipe slots or permeable fill is blocked, the benefits may be limited or nil

Design

- Where ochre is a problem, systems with separate outfall pipes for each drain are best, as they allow easier access for clearance operations

Figure 24. Drainage outfall blocked by ochre

Replacing field drains

When replacing a field drain, the same diameter (or metric equivalent) drain should be used as the drain being replaced. If the drain is a carrier drain or culvert, increasing the pipe diameter would reduce the risk of blockage or excess flows collapsing the pipe in the future. However, care may be needed to avoid increasing flood risk downstream. Expert advice should be sought if in doubt.

Mole drains

Mole drains are unlined channels formed in a clay subsoil. They are used when natural drainage needs improving in particularly heavy or calcareous clay subsoils that would require uneconomically closely spaced pipes for effective drainage.

Mole drains act as closely spaced pipe drains and conduct water to the permanent pipe drains or direct to open ditches.

Mole drains are not suitable for controlling rising groundwater or areas prone to flooding.

Soils should have a minimum of 30% clay for best results. Clay gives the soil the ability to hold together and reduces the chances of the channel collapsing after the mole is pulled.

Sand content should be less than 30%. The soil should be free of stones at the mole drain depth.

Mole drains are formed by dragging a 'bullet' (effectively, a round-nosed cylindrical foot shaped like a bullet, with slight tapering towards the tail) followed by an expander (a cylindrical plug of slightly larger diameter than the bullet) through the soil to form a circular semi-permanent channel – i.e. a natural pipe with fissuring in the soil above the channel.

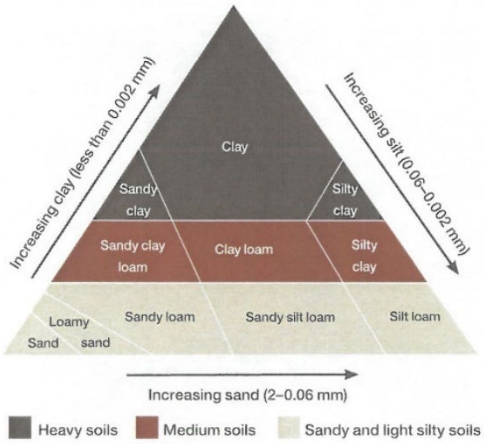


Figure 25. Soil texture classification
Source: Controlling soil erosion (Defra, 2005)

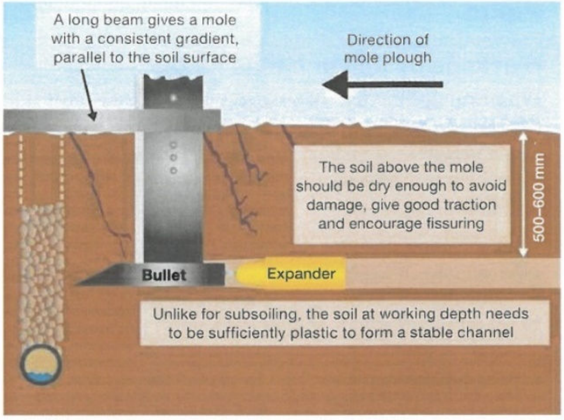


Figure 26. Appropriate conditions for forming mole drains

How long do mole drains last?

The longevity of mole drains depends on a number of factors, including:

- Soil texture (high clay content is better)
- Soil calcium content (high levels of calcium will increase longevity)
- Climate (wetter conditions will reduce longevity)
- Slope (too shallow or too steep will reduce longevity)
- The moisture conditions in which the moles were formed

Mole channels in very stable, clay soils (clay content ~45%) can last over 10 years, but the method can still be effective in soils with at least 30% clay, particularly calcareous soils.

Typical lifespan in suitable soils ranges from five to ten years, but it can be reduced where patches of sandier soil occur, leading to premature collapse. Bad soil management can seal off the routes by which water reaches the mole drains.

If the pipe drainage system was designed to be supplemented by mole drains, it is good practice to renew mole drains on a cycle of around once in every five years.

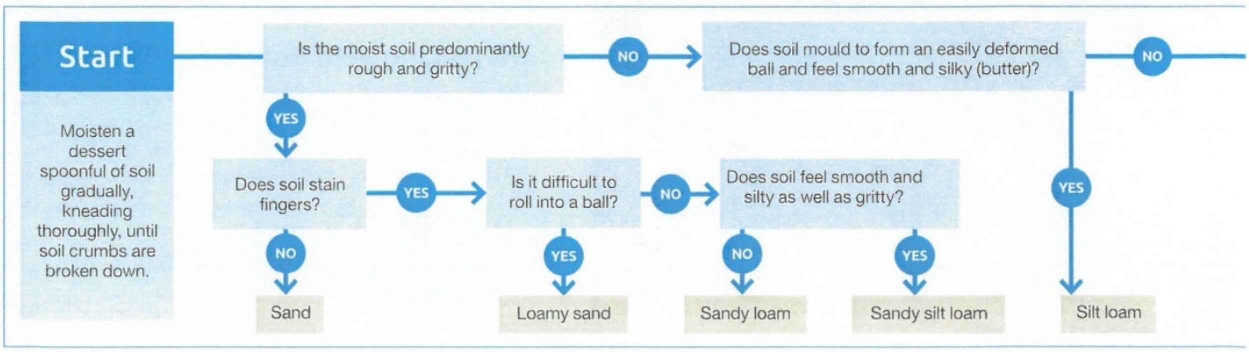


Figure 27. Appropriate conditions for forming mole drains
Source: Controlling soil erosion (Defra, 2005)

Installing mole drains

1. Suitable conditions

To achieve satisfactory results, the soil in the vicinity of the mole channel needs to be moist enough to form a channel but not dry enough to crack and break up and not soft enough to slough off and form a slurry.

Moling should be undertaken when:

- The soil at working depth is plastic, i.e. it forms a 'worm' without cracks when rolled on the hand
- The soil surface is dry enough to ensure good traction and avoid compaction

The drier the soil above moling depth, the greater the fissuring produced and the more efficient the water removal.

These conditions are most likely to arise during May to September/October, depending on the season and location.

2. Depth

Optimum mole depth depends on the soil type and the conditions when the moles are installed.

Generally, moles are pulled at 500–600 mm depth. Often, when first mole draining, the shallower depth is used, due to tractor limitations in tight, compacted soils. As the soil structure improves over time, they can often be pulled deeper, although care must be taken not to damage piped drains.

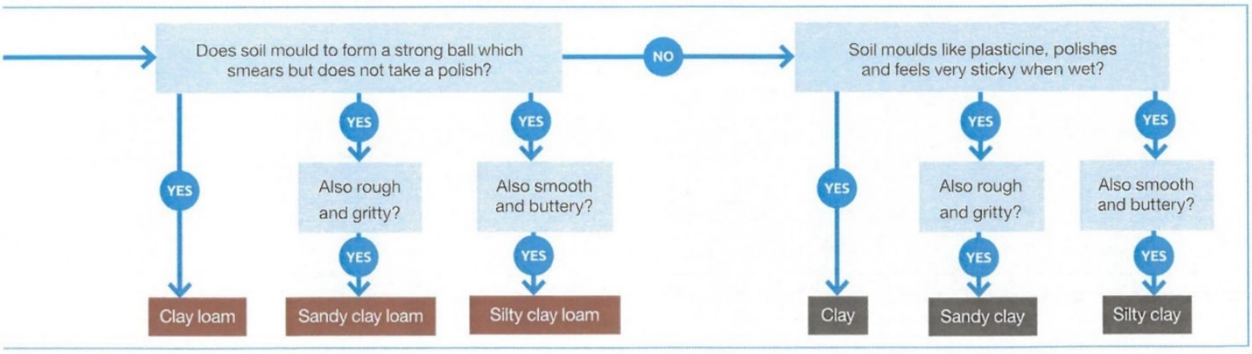
Moles less than 400 mm deep are liable to be damaged by tractors and animals during, or immediately after, rain and tend to be short-lived.

A rule of thumb is that the expander to mole-draining depth ratio is 1:7 (for example, a 70 mm diameter should have a mole depth of 490 mm).

3. Points to note

- It is essential that the 'bullet' is drawn through the permeable backfill over the pipe drains
- The mole plough should be in good condition, with minimal wear to the 'bullet' and tip
- Set up the mole plough so the 'bullet' is parallel to the ground surface when at working depth; a poorly set up mole plough will produce a poor channel and increase the draught requirement
- If the soil is liable to smearing, removal of the expander will reduce channel smearing, increasing the potential for water to enter the mole drain and reducing draught requirements
- When moling, dig a pit to expose the channel formed; it should be round and there should be fissuring above it
- Install moles at 2–3 m spacing, or closer on unstable soils
- Moles should be drawn up and down the slope across the lateral drains, making sure that they cross and connect with the permeable backfill over the drains
- Pull the plough out as soon as the mole plough has crossed the last drain: blind ends accumulate water
- If large stones are encountered, pull all the moles uphill and pull out after the channel has been disrupted

To aid decision-making, keep a record of where at least one of the most recent mole drains was pulled to allow examination of the mole drains by excavating a profile pit. This should be done just downslope of a lateral drain and, if still functioning, the mole drain should be reinstated afterwards with a short length of pipe.



Renewal and installation

Figure 28. Installing land drains and stone backfill

Factors to consider when designing a new drainage system

Drain depth

In slowly permeable soils, research has shown that (unless there is a specific crop need) lateral drain depths greater than 0.75 m give no additional benefit. Drains simply need to be deep enough to avoid damage from soil implements.

In permeable soils, where the drains control the depth of the water table, deeper drains allow the spacing between drains to be increased. Drain depths in such soil types are typically 1.2–1.5 m.

Maximum drain depth is often limited by the depth of the ditches or watercourses into which the drains discharge. These can be deepened, but only to the level of the downstream channel.

Figure 29. Recently installed drains

Drain spacing

Drain spacing has always varied according to local custom, but it has become more standardised in recent years. The correct spacing can be calculated using theoretical equations, but this is not often done in practice.

In heavy clay soils, the theoretical correct drain spacing will almost always be so small as not to be economically viable. Where soil conditions are appropriate, wide-spaced drains with permeable backfill supplemented with mole drains are the best choice. Pipe drain spacing for a mole drainage system can be as wide as 80 m, although 40 m is more typical. The main limiting factors are soil stability and landform.

On land with soils not suitable for moling, a modern system would have a spacing of 20–25 m with permeable backfill over the drains. The effectiveness of this type of system will rely greatly on maintaining good soil structure, sometimes aided by subsoiling.

Figure 30. Installing mole drains

If permeable backfill is not used, drain spacing in the region of 10 m will be needed, but this is unlikely to be as effective as a scheme using permeable backfill.

In permeable soils with a rising groundwater, the drain spacing will be determined by the depth of the drains and the level at which the groundwater is to be controlled. Permeable backfill is not usually needed.

Outfall availability and gradient

Outfall availability and gradient have an impact on the efficiency of the drainage system. As a comparison, a bath/shower is designed to slope and has a strategically positioned plughole (outfall) to drain the water. Lack of available outfall and/or gradient to enable water to drain away materially affects the efficiency of the field drainage system.

Drain diameter

In the UK, drain diameters are calculated using the procedures set out in MAFF/ADAS Reference Book 345 (The design of field drainage systems). This method takes account of:

- Soil type and slope: speed of water movement
- Land use: the degree of risk that is acceptable depending on the crop value
- Climate: rainfall intensity
- Type of drainage system: for example, mole drains must not be left submerged for more than 24 hours and, therefore, excess water must be evacuated rapidly

The rainfall figures used in the method set out in MAFF/ADAS Reference Book 345 are now outdated and in some areas may not match current rainfall patterns. They also take no account of potential future increases in storm intensities due to climate change. However, these remain the current guidelines.

Figure 31. Installing land drains with laser gradient control

Figure 32. Install drains at an appropriate depth and constant gradient (fall)

Renewal and installation

Use of permeable backfill

Permeable backfill refers to the gravel/stone chippings applied to the trench above the drain, typically to the base of the topsoil.

The use of permeable backfill has been a long-debated subject, primarily due to the significant associated cost. There are many examples of very old drainage systems without permeable backfill that still have some function; however, research indicates that on drained clay soils without permeable backfill, while the drains may initially function well, the permeability of the soil in the drain trench decreases with time.

Best practice is to install sufficient permeable backfill so that a connection exists between the drain trench and the cultivated layer. As a minimum, the permeable backfill layer should connect with the mole drains or any fissures caused by subsoiling.

If mole drains are to be installed over the pipes, the use of permeable backfill is essential to provide a hydraulic connection between the mole channels and the drain.

The performance of drains installed without permeable backfill cannot be rejuvenated by subsoiling.

The one circumstance where permeable backfill is never required is where the function of the drainage is to control a rising water table in a coarsely textured soil.

Figure 33. Mole plough

Figure 34. Permeable backfill in trench over drain

Site

Field drainage should be planned carefully to avoid negative impacts on water bodies used for drinking-water abstraction, fisheries or Sites of Special Scientific Interest (SSSIs) sensitive to raised nitrate levels. Field drains and outfalls could be designed to discharge into a wetland buffer area before flows enter a watercourse or be directed away from sensitive water bodies. Field drains should not be installed within at least 10 m of a slurry or silage store.

Sustainable drainage systems (SuDS) or novel approaches, such as bioreactors, can be used with field drainage systems to trap sediment and slow water/soil run-off and to filter pollutants in drainage water.

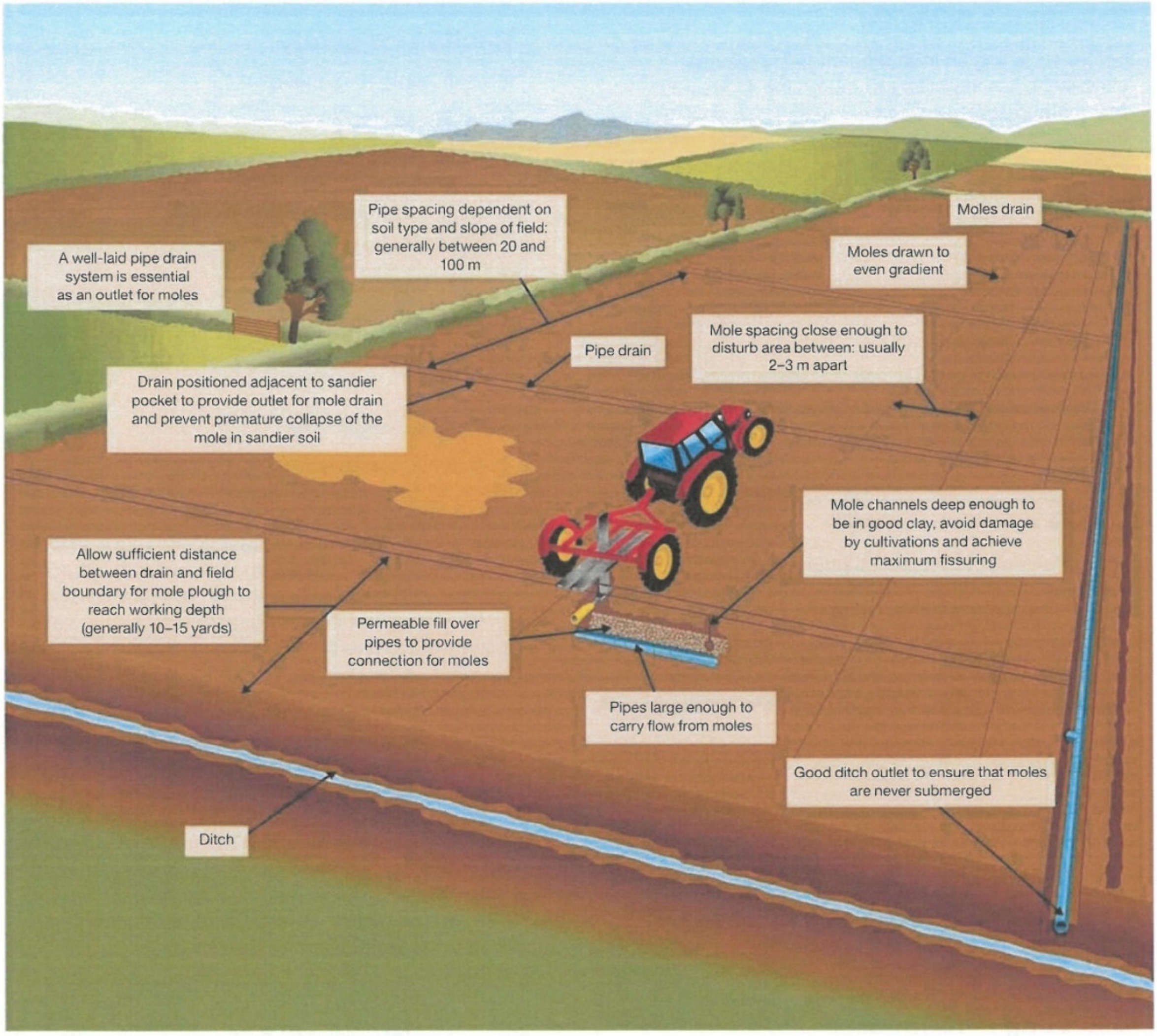


Figure 35. Layout of piped drainage and mole drains

Environment

Outfalls

New outfalls should be positioned sensitively at ditches and ponds to avoid damaging habitat. Land drains should not divert water away from areas that may depend on this water for drinking, washing or habitat. Diverting flows can also increase the risk of flooding and infrastructure failure.

Conservation

A new drainage scheme can provide an opportunity to create new conservation features. Old farm ponds that have silted up could be reopened to provide a habitat and catch pit for eroding soils, and ditches could be over-dug into localised ponds.

Government-funded schemes may be available for a range of land management options and capital items that can be used to reduce the negative impacts of field drainage on water quality or to create/improve wetlands and ditch habitats. These include the creation of wet grassland, ditch management and buffering of water bodies. For more information, see **gov.uk/guidance/countryside-stewardship-manual**

Selecting a designer

Before engaging an independent field drainage consultant, it is important to determine if they have adequate experience and qualifications. A specialist designer will have a thorough understanding of the needs and management of the soils, as well as of field drainage.

To enable them to determine if a new drainage system is required or whether maintenance of the existing system and/or improved soil management may be adequate to resolve the problem, a designer should always:

- Discuss any problems you have with the site and how you intend to manage the site in the future
- Survey the soil types, soil conditions, existing drainage systems, field topography, proximity to utility services and other features that may affect the final design
- Consider potential environmental impacts, drainage law and economic feasibility

Given the scale of the investment that a new drainage system represents, it is recommended that independent advice is sought with regard to the design.

Using an experienced consultant designer will ensure that the scheme is the best and most economically appropriate to meet the requirements.

Environment

Archaeological features can be damaged by field drain installation and drains may conflict with the conservation of a wetland or water habitat or species. Where relevant, contact Natural England, the drainage authority or a county archaeologist before commencing work.

Selecting a contractor

To install a new comprehensive field drainage system, it is essential to employ a specialist land drainage contractor with access to specialist machinery that can install and backfill drains rapidly. A drainage machine shapes the trench bed and can set a consistent gradient, even in the flattest of fields. A specialist contractor should fully understand field drainage requirements and employ the approved standards and materials.

The National Association of Agricultural Contractors (NAAC) is a trade association and has a list of members on its website (**naac.co.uk/findacontractor**) which can be a useful starting point for selecting a land drainage contractor. Not all drainage contractors are members of the NAAC, however.

Recommendations from others in the local farming community can be another helpful source of information.

Contractors may have different approaches to dealing with the scale, access and physical aspects of the location, so quotes may vary.

Health and safety

It is advisable to request:

From the contractor:

- A risk assessment and method statement (RAMS)
- Verification that they have sufficient public liability insurance cover

From the designer:

- Verification that they have sufficient professional indemnity insurance cover

Land drainage law

A landowner has an obligation to accept the natural flows of water from adjoining land and must not cause any impedance to these flows that would cause injury to adjoining land. 'Natural water flows' refers to water that has not been diverted from its natural path, artificially increased or had the run-off flow rate changed (e.g. by the construction of unauthorised paved areas within the catchment).

This means that if a landowner neglects or fills in their ditch, such that water may not freely discharge from higher neighbouring land, the landowner is guilty of causing a nuisance. In this situation, the landowner or occupier of the higher land may ask the Agricultural Land Tribunal to make an order requiring the landowner guilty of nuisance to carry out the necessary remedial works. It must be emphasised, however, that it is usually far better to attempt to resolve such situations by amicable discussions with the offending party first, as they may be unaware of the nuisance.

If the neglected ditch in question runs directly along the boundary between respective ownerships, the assumption that would be made is that the owner of the original hedge is also the owner of the ditch. On watercourses, the ownership boundary is assumed to be down the middle of the bed. Only clear evidence to the contrary, such as the deeds to the land, will rebut this assumption.

No ditch or watercourse should be piped, filled in, restricted or diverted without the approval of the regulatory authority, for example, the local authority or the EA, NRW, SEPA, NIEA or the local internal drainage board. Consent may be needed for works within 8–10 m of the bank top of a watercourse. Uncultivated or semi-natural land is protected under the Environmental Impact Assessment Regulations (Agriculture) and should not be drained without prior approval from the relevant national body.

Standards, materials and quality

There are two fundamental standards to which any designer will be working:

- Reference Book 345: The design of field drainage pipe systems (MAFF/ADAS, 1982)
- Technical Note on Workmanship and Materials for Land Drainage Schemes (ADAS, 1995)

Within these primary standards, there will be a number of decisions to be made about the design specification.

Pipe type

Currently, all new drainage schemes are installed using plastic pipes, although many older schemes were installed with clay pipes and may be replaced with the same.

It is essential that a material designed for use in field drainage is used.

Consideration should be given to the use of twin-wall or ductile iron pipes or gravel pipe surround where there is a risk of pipe crushing.

Figure 36. Modern perforated plastic drainage pipe

Permeable backfill type

- The material used must be hard and durable when wet and when dry
- The bulk of the material should be in the range 5–50 mm
- The material should not contain more than 10% fines

Figure 37. Washed gravel permeable fill over drain

Outfall type

Most modern outfalls are installed with glass-reinforced concrete headwalls; however, the actual outfall type may vary according to its location.

Figure 38. Precast concrete headwall (type K)

Filter wrap

Filter wrap is a geotextile barrier around the outside of the pipe to prevent soil particles entering the drain. It is not commonly used in the UK, as research has shown that pipe sedimentation is not usually a problem if the pipes have been laid and maintained properly. There are, however, some cases with fine, sandy soils when filter wrap can be beneficial.

Filter wrap should never be used where there is a risk of ochre.

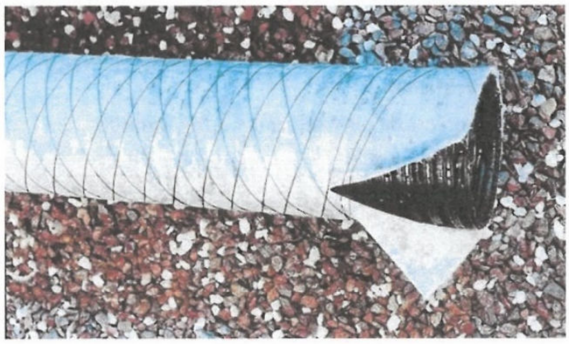


Figure 39. Single-wall pipe wrapped in geotextile

Case studies

Molescroft Farm, Beverley, East Yorkshire

The farm

- 485 ha farm with deep loam and alluvial clay soils
- Land is at or below 5 m above sea level and suffers from waterlogging
- Arable cropping: wheat, barley, oilseed rape, field beans and vining peas
- 10% of the farm is in Higher Level Stewardship and grazed by cattle and sheep appropriate to meet the requirements

The problem

The problem field had a full tile drainage system installed in the 1980s, but:

- Wet patches had started to appear
- Crops had to be drilled early to avoid soil damage and poor establishment
- The cost of weed control had increased due to the lack of opportunity for stale seedbeds
- Recent wet seasons had resulted in patchy crops with increased weed problems and soil damage

The main drain was found to be completely blocked by willow roots and some tiles were misaligned.

The solution

The solution was to drain a 6 ha area of the field, with new plastic pipes installed between the existing tiles and gravel backfill used to improve effectiveness.

The outcome

- New drainage has made the field far easier to work and manage
- It was the highest-yielding field in the following harvest year
- Lower inputs of herbicides were required

The cost

The total cost of the upgrade was £14,500 (£2,417/ha).

Maintenance costs estimated at approximately 1% of capital cost (£25/ha/year).

Benefits estimated at a total of £229/ha/year:

- Typical yield increased from 7 t/ha to 8.75 t/ha, a total of £175/ha/year
- Herbicide costs were reduced by £30/ha/year
- Better soil structure reduced subsoiling costs by 25%, saving £3/ha/year, and cultivation costs by £21/ha/year

Simple payback period

$$\frac{\text{Cost}}{\text{Benefits}} = \frac{\text{£2,417}}{\text{£229 - £25}} = \text{12 years}$$

Comment

Once the investment has been paid off, the benefits may continue to be received for many years (provided maintenance is sustained).

These calculations assume average changes to costs and returns; however, extreme weather will have a far greater effect. It is difficult to factor in random occurrences, such as the avoidance of significant crop loss due to waterlogging, and the decision to invest in drainage should be made on a field-by-field basis. The costings do not take into account the cost of finance or increased land value.

Evershot Farms Ltd, Melbury Osmond, Dorset

The farm

- 1,500 ha farm, largely on heavy, poorly drained soils
- Rainfall is over 1,000 mm/year
- Stocking: 900 cows and 2,500 mule ewes; heifers are contract reared off the farm
- Cropping: mainly grassland with about one-third cut for silage; maize is no longer grown
- The farm has a 750 kW biogas plant

The problem

The aim is for cows to be turned out in late March and housed from mid-September, but the grazing season can be very variable from year to year.

Maize was causing significant soil damage.

The solution

The solution was to replace maize with Italian rye-grass, introduce whole-crop wheat to balance the ration (and save on purchased straw) and drain a 10.2 ha field, including:

- A main drain with laterals and headwalls at outlets
- Digging out the ditches downstream to obtain sufficient fall
- Moling to increase connectivity every five years at reseeding

The outcome

- Soil problems are now avoided and increased rainfall infiltration minimises run-off
- The field is accessible two weeks earlier and for two weeks longer
- The Italian rye-grass has increased yield (from 37 t/ha to 45 t/ha) and forage value
- Reduced risk to operations and increased forage quality and dry matter yield

The cost

The total cost of the drainage was £5,245/ha (£48,500 for the drainage, plus £5,000 on ditching), plus maintenance at £52/ha and additional annual silage-making costs of £132/ha.

Benefits estimated at a total of £595/ha/year:

- The change from maize to grass silage has produced a higher dry matter yield and greater forage value from four cuts
- The change to Italian rye-grass resulted in an increase in forage value
- Cultivation savings:
  - Moving to grass, the cultivation savings were £105/ha/year
  - The average annual cost of moling was the same as subsoiling
- Forage savings (total of £490/ha) from:
  - Increased value of silage (at previous yield level): 37 t/ha at £4/t gives £148/ha
  - Increased yield of silage: 8 t/ha at £34/t gives £272/ha
  - Value of additional grazed forage: £70/ha

$$\frac{\text{Cost}}{\text{Benefits}} = \frac{£5,245}{£595 - £52 - £132} = 13 \text{ years}$$

Comment

Once the investment has been paid off, the benefits may continue to be received for many years (provided maintenance is sustained).

These calculations ignore the potential for extreme weather, without drainage, to result in significantly lower forage yields, soil damage and increased housing and forage requirements. Wet conditions during silage making can result in contamination from soil, leading to poor fermentation, poor milk yield and potential health problems. The costings do not take into account the cost of finance or increased land value.

Glossary

Compaction	The process by which the soil density increases due to trafficking or soil working when conditions are unsuitable, i.e. too wet
Culvert	A short length of pipe installed to allow access over the ditch or watercourse
Drain jetting	Removal of deposited sediment from a drain using a high-pressure water jet
Field capacity	The moisture content of the soil after excess water has drained away
Filter wrap	A geotextile barrier wrapped around the pipe to prevent particles entering the pipe
Friable	Soil where the aggregates crumble easily into smaller pieces
Infiltration	Water entering the soil e.g. through rainfall
Laterals	The drains installed, usually parallel to each other, to intercept soil water and transport flows to the main drain
Mains	Drains installed to collect the water from several laterals and transport it to a ditch
Mole drains	Unlined channels formed in a clay subsoil
Natural water flows	Water that has not been diverted from its natural path, artificially increased, or had the run-off flow rate changed, such as by the construction of unauthorised paved areas within the catchment
Ochre	Insoluble deposits that form in drains when soluble iron leaches out of the soil, into drainage water, and becomes oxidised. It can also be caused by bacterial growths that secrete iron
Outfall	Point at which the main drains or individual laterals discharge into a ditch
Percolation	The process of water moving down through the soil to depth
Perched water table	Saturated layer above compacted soils
Perforated drainage pipe	A slotted drainage pipe, which is used to collect water from the soil
Poaching	Damage to the soil surface caused by animal hooves
Slaking	The collapse of the soil aggregates as the soil wets up rapidly
Water table	The saturated zone of the soil

Further information

Other sources of information

Catchment Sensitive Farming:
gov.uk/catchment-sensitive-farming

Catchment Sensitive Farming officers provide free advice and support to farmers in priority catchments to reduce water pollution. This includes information on soil and water management and a review of field drainage.

National Association of Agricultural Contractors (NAAC):
naac.co.uk

Think soils (Environment Agency):
ahdb.org.uk/thinksoils

A guide to better soil structure (Cranfield University):
www.landis.org.uk/downloads

Geographic information for Great Britain:
magic.gov.uk

Countryside stewardship manual (Natural England):
gov.uk/guidance/countryside-stewardship-manual

Environmental permits for flood defence:
gov.uk/permission-work-on-river-flood-sea-defence

Guidance on owning a watercourse:
gov.uk/guidance/owning-a-watercourse

Flood and coastal erosion risk management R&D (Environment Agency):
gov.uk/government/publications/national-flood-and-coastal-erosion-risk-management-strategy-for-england--2

Pinpoint best practice information sheets (The Rivers Trust):
theriverstrust.org/our-work/farm-advice/best-practice-advice-sheets-for-farmers

Constructed farm wetlands: A guide for farmers and farm advisers in England (Wildfowl and Wetlands Trust):
wwt.org.uk/farmwetlands

Sustainable drainage systems: Maximising the potential for people and wildlife (RSPB and Wildfowl and Wetlands Trust):
www.wwt.org.uk/uploads/documents/2019-07-22/1563785657-wwt-rspb-sustainable-drainage-systems-guide.pdf

Godwin, R. J. and Spoor, G. (2015). Choosing and evaluating soil improvements by subsoiling and compaction control. In Ball, B. C. and Munkholm,L. J. (eds). *Visual Soil Evaluation: Realising Potential Crop Production with Minimum Environmental Impact.* CABI, Wallingford, UK.

Video demonstrating the principles of subsoiling

AHDB Pork has produced a series of videos demonstrating the general principles of subsoiling. The videos look at cultivation depth, choice of machine and the effects of tines and wings.

The videos are available to watch online at **youtube.com/AHDBPork** and on the Practical Pig app (**practicalpig.ahdb.org.uk**).

Further information

AHDB GREATsoils

AHDB provides a range of practical information on improving soil management for farmers, growers and advisers. Whether you need an introduction to soil biology or a detailed guide to soil structure, AHDB has the information and guidance to support you.

Information for grassland, pig producers, arable and horticultural crops is available at **ahdb.org.uk/greatsoils**

Visit ahdb.org.uk to:

- Find resources on our **knowledge library**
- Listen to our **podcasts**
- Visit **farm events and agricultural shows**
- Contact your local **knowledge exchange manager**

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APPENDIX SMP10

Extracts from MAFF's ALC Guidelines

Ministry of Agriculture, Fisheries and Food

Agricultural Land Classification

of

England and Wales

Revised guidelines and criteria for grading the quality of agricultural land

OCTOBER 1988

SECTION 1

INTRODUCTION

The Agricultural Land Classification provides a framework for classifying land according to the extent to which its physical or chemical characteristics impose long-term limitations on agricultural use. The limitations can operate in one or more of four principal ways: they may affect the range of crops which can be grown, the level of yield, the consistency of yield and the cost of obtaining it. The classification system gives considerable weight to flexibility of cropping, whether actual or potential, but the ability of some land to produce consistently high yields of a somewhat narrower range of crops is also taken into account.

The principal physical factors influencing agricultural production are climate, site and soil. These factors together with interactions between them form the basis for classifying land into one of five grades; Grade 1 land being of excellent quality and Grade 5 land of very poor quality. Grade 3, which constitutes about half of the agricultural land in England and Wales, is now divided into two subgrades designated 3a and 3b. General descriptions of the grades and subgrades are given in Section 2.

Guidelines for the assessment of the physical factors which determine the grade of land are given in Section 3. The main climatic factors are temperature and rainfall although account is taken of exposure, aspect and frost risk. The site factors used in the classification system are gradient, microrelief and flood risk. Soil characteristics of particular importance are texture, structure, depth and stoniness. In some situations, chemical properties can also influence the long-term potential of land and are taken into account. These climatic, site and soil factors result in varying degrees of constraint on agricultural production. They can act either separately or in combination, the most important interactive limitations being soil wetness and droughtiness.

The grade or subgrade of land is determined by the most limiting factor present. When classifying land the overall climate and site limitations should be considered first as these can have an overriding influence on the grade. Land is graded and mapped without regard to present field boundaries, except where they coincide with permanent physical features.

A degree of variability in physical characteristics within a discrete area is to be expected. If the area includes a small proportion of land of different quality, the variability can be considered as a function of the mapping scale. Thus, small, discrete areas of a different ALC grade may be identified on large scale maps, whereas on smaller scale maps it may only be feasible to show the predominant grade. However, where soil and site conditions vary significantly and repeatedly over short distances and impose a practical constraint on cropping and land management a 'pattern' limitation is said to exist. This variability becomes a significant limitation if, for example, soils of the same grade but of contrasting texture occur as an extensive patchwork thus complicating soil management and cropping decisions or resulting in uneven crop growth, maturation or quality. Similarly, a form of pattern limitation may arise where soil depth is highly variable or microrelief restricts the use of machinery. Because many different combinations of characteristics can occur no specific guidelines are given for pattern limitations. The effect on grading is judged according to the severity of the limitations imposed by the pattern on cropping and management, and is mapped where permitted by the scale of the survey.

The guidelines provide a consistent basis for land classification but, given the complex and variable nature of the factors assessed and the wide range of circumstances in which they can occur, it is not possible to prescribe for every possible situation. It may sometimes be necessary to take account of special or local circumstances when classifying land. For this reason, the physical criteria of eligibility in this report are regarded as guidelines rather than rules although departures from the guidance should be exceptional and based on expert knowledge. Physical conditions on restored land may take several years to stabilise; therefore, the land is not normally graded until the end of the statutory aftercare period, or otherwise not until 5 years after soil replacement.

To ensure a consistent approach when classifying land the following assumptions are made:

1. Land is graded according to the degree to which physical or chemical properties impose long-term limitations on agricultural use. It is assessed on its capability at a good[1] but not outstanding standard of management.

2. Where limitations can be reduced or removed by normal management operations or improvements, for example cultivations or the installation of an appropriate underdrainage system, the land is graded according to the severity of the remaining limitations. Where an adequate supply of irrigation water is available this may be taken into account when grading the land (Section 3.4). Chemical problems which cannot be rectified, such as high levels of toxic elements or extreme subsoil acidity, are also taken into account.

3. Where long-term limitations outside the control of the farmer or grower will be removed or reduced in the near future through the implementation of a major improvement scheme, such as new arterial drainage or sea defence improvements, the land is classified as if the improvements have already been carried out. Where no such scheme is proposed, or there is uncertainty about implementation, the limitations will be taken into account. Where limitations of uncertain but potentially long-term duration occur, such as subsoil compaction or gas-induced anaerobism, the grading will take account of the severity at the time of survey.

4. The grading does not necessarily reflect the current economic value of land, land use, range of crops, suitability for specific crops or level of yield. For reasons given in the preface, the grade cut-offs are not specified on the basis of crop yields as these can be misleading, although in some cases crop growth may give an indication of the relative severity of a limitation.

5. The size, structure and location of farms, the standard of fixed equipment and the accessibility of land do not affect grading, although they may influence land use decisions.

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[1] Previously described as 'satisfactory'; no change in the assumed standard of management is intended.

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