

Using quality compost to reclaim land for forestry and woody biomass



A practical guide for forestry and allied professions to planning, specifying and managing operations for cultivation and compost incorporation

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Summary

This guide provides practical advice to professionals involved in the planning and managing of schemes that reclaim land for forestry using compost and cultivation techniques. The advice is based upon experience gained by the Forestry Commission in the challenging former industrial areas of Central Scotland, but the principles are relevant across the British Isles.

The wide range of site and soil types, climatic conditions, methods and desired objectives is such that detailed planning for individual schemes will need informed judgment.

There is no single correct template: individual site specifications should arise from an assessment of the relevant factors explained in this guide.

This guide includes information on the benefits of using compost in land reclamation together with regulatory information and practical advice on application rates, methods and costs. Best practice and legislation will inevitably develop but the principles should remain relevant. Guidance is tailored to sites where the primary aim is to establish sustainable woodland.

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Introduction

This is a guide for forest managers, planners, civil engineers and other professionals concerned with restoring land for tree planting using compost as a soil improver.

There is already a range of published Forestry Commission guidance on land reclamation and restoration for forestry, which also applies to growing woody biomass¹. This advice includes compost as one of the potential ameliorants. There is also a range of guidance produced by other organizations such as SNIFFER² and CL:AIRE³. However, the available guidance is both broad, in that it covers a range of issues and ameliorants, and of a general nature suited to the master-planning end of the process.

The purpose of this guide is to give practical advice on the use of quality compost in land reclamation to establish woodland from initial scoping survey, through to planning and implementing reclamation operations. Early woodland performance may be heavily influenced by reclamation operations, so the early years of forest tree establishment is also covered, including a section on crops for woody biomass.

Quality compost is a proprietary product made from organic input materials according to the British Standards Institution Publicly Available Specification 100 (BSI PAS 100) and then sold. Compost which does not meet this (or an equivalent) standard may still be acceptable for some uses but will be subject to waste management regulations, so these are summarised.

The guide is founded on practical experience, drawing on best practice and scientific advice that has evolved over recent years. Best practice will continue to change, as will the regulatory arena and operational practice, but the general principles should remain broadly applicable. The aim is for a simple, widely applicable guide that could, if required, form part of a more complex regeneration process. It is not feasible to cover all work that may be involved in restoring a site for woodland establishment in detail, so further specialist input will be required for site investigation, remediation of chemical contamination, earthworks and civil engineering. The primary focus is on the aspects of reclamation most important for

¹ Atkinson, G. & Doick, K. (2014). Planning for brownfield land regeneration to woodland and green infrastructure. Practice Note 22. Forestry Commission

Bending, N.A.D., McRae S.G. & Moffat, A.J. (1999). Soil-forming Materials: Their use in Land Reclamation. The Stationary Office

Kilbride, C. (2006). Application of sewage sludges and composts. Best Practice Guide for Land Regeneration BPG Note 6. Forestry Commission

Moffat, A. (2005). Use of sewage sludges and compost in forestry. Information Note. Forestry Commission

Moffat, A.J. & McNeill, J. (1994). Reclaiming Disturbed Land for Forestry. Forestry Commission Bulletin 110. HMSO

Sellers, G. (2006). Fertiliser application in land regeneration. Best Practice Guide for Land Regeneration BPG Note 7. Forestry Commission

² SNIFFER (2010). Code of Practice for the use of sludge, compost and other organic materials for land reclamation.

³ Van Herwignen, R *et al.* (2008). Sub 10. The Use of Compost in the Regeneration of Brownfield Land. Claire

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woodland establishment i.e. using an organic amendment - compost - to improve soil and SFMs to support healthy and sustainable growth of trees.

Natural soil resources may be limited on reclamation sites and frequently a satisfactory soil medium needs to be generated by using SFMs.

Soil forming material (SFM) is a parent material used as a substitute for top-soils and sub-soils in reclamation of sites devoid of soil cover or to augment inadequate soil resources⁴.

In this guide key statements are given in highlighted boxes:



Grey: Information



Blue: Practice

Suggested action



Warning



Consider

⁴Adapted from: Bending, N.A.D., McRae, S.G. & Moffat, A.J. (1999). SFMs: Their Use in Land Reclamation. DETR. The Stationary Office, London

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The role of compost in land reclamation

Restoration, reclamation and remediation

Work to regenerate and re-use disturbed, damaged and previously used land is a highly technical and complex subject encompassing a range of specialist professions. This guide covers one aspect of reclamation of soils, which is a distinct part of the whole subject. Definitions of the common terms⁵ are:

Land restoration is an activity to restore a **former state**, for example 'the process of making a site fit for purpose through, among activities carried out, amelioration of the site's soil or SFMs'. This can include both remediation and reclamation.

Land remediation is 'the process of making a site fit-for-purpose through the destruction, removal or containment of **contaminants**. Environmental damage is reversed or treated through the management, removal, sealing or treatment of dangerous substances or stabilisation in order to render the site safe for use, but not necessarily for all possible uses'.



Land reclamation is 'the return of damaged, degraded or derelict land to a **beneficial use**'⁶. This is the term used in the Guide.

The quality of soil available on a site to be restored for a 'green' end use is often poor. Such 'disturbed' soils are found on former industrial, derelict or 'brown-field' sites. Frequently the term 'soil forming material' is more appropriate because it indicates that a functioning soil, capable of sustaining healthy plant growth, needs to be created. In an extreme case an SFM, such as very sandy or stony ground, may have very little of the desired end properties in its unimproved state.

Species choice, which is of crucial importance, is one of the important roles of professional foresters. However, there are certain characteristics of soils that are known to be particularly important for trees in general, as explained in the **Basic forestry requirements of reclaimed soils** section of this guide. Trees can be remarkably forgiving in their demands on soils and can often tolerate some forms of chemical contamination. Nevertheless, they are naturally adapted to a narrower or wider range of conditions, some of which are more important than others for a particular species.

The main problems of disturbed soils that affect sustainable, healthy tree growth are compaction, low organic matter content, high stone content, and deficiency in major

⁵ WRAP & EA 2013. Quality Protocol, Compost. End of waste criteria for the production and use of quality compost from source-segregated biodegradable waste.

⁶ BSI (2013). Draft BS EN ISO 11074 Soil quality - Vocabulary

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plant nutrients. Satisfactory landform, drainage and soil chemistry will also be required.

The benefits of compost

Incorporation of compost combined with deep cultivation helps to reduce compaction and prevent re-compaction. Compost improves soil aggregate stability, increasing resilience to physical stress, thus increasing trafficability and workability. It can potentially alleviate the effects of high stone content and ameliorate soil chemistry⁷.

Compost improves aggregation of soil mineral particles, increasing porosity and aeration, promoting drainage of excess water and increasing rooting depth. It also helps to retain moisture, making dissolved nutrients more available for plant uptake.

Quality compost is also a good source of plant available nutrients, which are often limiting factors for healthy tree growth on reclamation sites. A comparison of typical nutrient content of compost with other bulky organic fertilisers is given in **Table 1**, although exact figures will vary.

Table 1. Example of nutrient value of compost compared to other bulky organic fertilisers⁸

Fertiliser type	Dry Matter	kg/fresh tonne					
		Total N	Avail. N	Total P ₂ O ₅	Total K ₂ O	Total S ₂ O ₅	Total MgO
Cattle FYM (manure)	25%	6.0	1.2*	3.2	8.0	2.4	1.8
Biosolids, digested cake (sewage sludge)	25%	11	1.6	18	0.6	6.0	1.6
Biosolids, thermally dried (sewage pellets)	95%	40	2.0	70	2.0	23	6.0
Green compost (green garden waste only)	60%	7.5	0.1	3.0	5.5	2.6	3.4
Green / food compost (as above with food waste added)	60%	11	0.6	3.8	8.0	3.4	3.4

Note: * Fresh, half this value if old

The reclamation process itself can also improve landform to further help with drainage



When mixed into soil or SFMs compost can help to alleviate, to a greater or lesser extent, the main problems of disturbed soils for tree growth.

⁷ Kilbride, C. (2006). Application of sewage sludges and composts. Best Practice Guide for Land Regeneration BPG Note 6. Forestry Commission

WRAP (2007). Using quality compost to benefit crops

⁸ From: Sinclair, A., Litterick, A., Crooks, B. & Chambers, B. (2013). Optimising the application of bulky organic fertilisers. SRUC

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Creating soils is a long term process that is initiated at reclamation, so although fast early plant growth can be helpful, the sustainability of growth is more important. Healthy soils are living ecosystems rather than just a mix of inert materials. Soil micro-organisms are an essential component of a soil that is functioning correctly, so it is important to create conditions where the ecosystem can develop. Application of compost to SFMs with very low organic matter content promotes the growth of micro-organisms and a sustainable and healthy soil ecosystem.



Impoverished soils, and those that are being created from SFMs, need to develop a soil ecosystem to function correctly.

The reclamation of soil needs **organic matter**, which contributes in complex ways involving capture and release of nutrients, soil moisture, soil chemistry and the physical structure within the soil profile allowing movement of air, water, soil fauna, roots and so on.

Nitrogen and phosphorus are especially important **nutrients** in soils for trees and are particularly important for above-ground growth and roots respectively . Compost also supplies other important nutrients.

Slow release iron and magnesium improve the general health and resilience of most plant species and sulphur and the trace elements zinc, copper, manganese and boron are all important for healthy plant growth.



Compost is a good source of organic matter, phosphorus, potassium and, to a lesser extent, nitrogen and other essential plant nutrients^{9 10}.

The nitrogen mineralization rate of compost i.e. the rate at which it becomes 'plant available', is much lower than for other organic amendments such as sewage sludge and animal manures at c. 5% to 25% total nitrogen over the first three years. This gradual release of nitrogen means that it can be taken up by trees in nitrate and ammonium nitrogen form as growth progresses, rather than be lost by **leaching**¹¹.

⁹ 0% - 5% total nitrogen, 50% phosphorus and 80% potassium will be available from compost. Optimising the application of bulky organic fertilisers. Technical Note TN650. Sinclair, A., Litterick, A., Crooks, B. & Chambers B. (2013). SRUC

¹⁰ Organic fertilisers also supply useful quantities of magnesium and sulphur. Optimising the application of bulky organic fertilisers. Technical Note TN650. Sinclair, A., Litterick, A., Crooks, B. & Chambers B. (2013). SRUC

¹¹ Ammonium nitrogen under 'normal conditions' is rapidly converted to nitrate and can also be strongly fixed to clay particles in soils (Source: RB209)

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Nutrient leaching from compost is usually low owing to the slow release characteristics of nitrogen and phosphorus. Therefore, the timing of compost application is less critical than for inorganic fertilisers and manures.

Phosphate is highly bonded in soil, and does not leach much unless levels are already high, so if soils are low in phosphorus then phosphate will be bound in the soil rather than taken up by plants. Although much of the phosphorus present in soils is in forms unavailable to plants, compost does provide useful quantities of phosphate.

Compost is usually neutral or slightly alkaline and has a small **liming effect**, equivalent to 10% calcium carbonate (limestone) on a dry weight basis. This is a small benefit in acid soils and is not likely to be a significant problem in alkaline SFMs.



Soil processes and plant nutrient demand are greatly influenced by complex and variable site factors that develop and fluctuate over time, so compost application rate will always be a compromise.

Factors affecting compost application rate

The quantity of compost used in soil reclamation is important, and is a balance between variable and complex opposing factors. For agricultural crops, a shortage of any of the major or minor-nutrients¹² can limit growth and/or crop quality so that supply of the other nutrients may not be fully used¹³. Although utilisation of nutrients by agricultural crops in various soil types is well documented, there is no equivalent for trees in reclamation soils. Therefore, it is difficult to calculate a precise figure for a site's needs even for a single component such as total nitrogen. The exact composition of compost will also vary between sources.



Compost application rates for forestry planting on reclamation sites can be established by reference to the type of soil or SFM present, although this will not be the only factor to consider.

The nutrient, organic matter and other benefits of compost are tempered by associated problems in certain conditions if the application rate is too high. These include a tendency to elevate pH, albeit a benefit in acidic conditions, and oversupply of nitrogen, phosphorus and other chemicals including some potentially toxic elements. The cost of compost supply is also a consideration in the cost-effectiveness of an operation.

¹² i.e. *macro* and *micro* nutrients

¹³ In addition to C, H & O, major nutrients are N, P, K, Ca, Mg & S. Minor nutrients are Fe, Cu, Mn, Zn, B, Mo & Cl. Defra (2010). Fertiliser Manual RB209. 8th Edition

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Both nitrate and phosphate are important potential pollutants of surface and ground waters. For example both cause eutrophication of water bodies, and phosphorus is often the limiting factor in unwanted algal growth.



The broad nutritional needs of trees need to be assessed in terms of nutrient availability in the specific soil conditions versus the potential pollution risk. These factors are variable.

Green compost, i.e. compost derived from plant material, commonly contains around 20% to 30% of organic matter (air dry basis) and other composts may contain more. Soil organic matter is an indicator of soil health, and a high proportion of organic matter in compost is in a lignified (stabilised) form, so it has a long-lasting beneficial effect¹⁴. Typical organic matter contents of Scottish soils are 5% to 35% or more¹⁵ with organic and peaty soils containing over 10% and 20% respectively¹⁶. In agriculture, repeat applications over several years are necessary to raise organic matter levels. In land reclamation, compost needs to be applied during ground cultivation, which is essentially a single application.



Even a high single application of compost will not in itself markedly raise the organic matter content of a soil owing to the sheer volume of soil concerned (one hectare of soil 50 cm deep is 5,000 m³).

However, the important benefit of adding organic matter is that it helps to start the development of the key beneficial soil characteristics including nutrient and moisture retention capacities and soil processes. These processes include the development of a soil structure and communities of micro-organisms and soil fauna. High biological activity in cultivated soils will promote mineralisation and oxidation but will also increase demand for nutrients.



In healthy soil conditions chemical and biological processes release essential plant nutrients over time, e.g. available nitrogen is released from organic matter by microbial activity.

Appropriate compost application rates are a compromise between the benefits that may be significant over time, even at lower levels, and the potential oversupply of nutrients and leaching. Cost is also relevant.



Considering the 'precautionary principle', application rates should be set high enough to improve soil characteristics and provide some growth benefits but be low enough to avoid oversupply of nitrogen and phosphate.

¹⁴ From: WRAP (2007). Using quality compost to benefit crops

¹⁵ <http://www.soils-scotland.gov.uk/> (2013)

¹⁶ Defra (2010). Fertiliser Manual RB209. 8th Edition

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Quality compost

Compost can be defined as "solid particulate material that is the result of composting, which has been sanitised and stabilised, and which confers beneficial effects when it is added to soil, used as a component of growing media, or used in another way in conjunction with plants"¹⁷.

Compost is used as a soil improver or soil conditioner, which is a "material added to soil *in situ* primarily to maintain or improve its physical properties, and which may improve its chemical and/or biological properties or activity"¹⁸.

This is a guide to the use of **Quality Compost**, which is composted, source-segregated organic waste material meeting a standard accepted by the relevant regulators. These are the Scottish Environment Protection Agency, the Environment Agency in England, Natural Resources Wales and the Northern Ireland Environment Agency. Source-segregation means that the waste is not mixed with other types of waste prior to collection.



The term '**green compost**' is used to signify compost that is formed mainly from plant material from parks and gardens. It may contain animal manures but not food wastes. Green compost is commonly available for reclamation.

The BSI PAS 100 standard for compost

The Publicly Available Specification 100 (BSI PAS 100) improves confidence in composted materials among end-users, specifiers and blenders, and helps producers differentiate products that are safe, reliable and of high performance¹⁹. It only covers biodegradable materials that have been kept separate from non-biodegradables. Permitted input materials include plant derived green-waste and also some animal by-products and some food wastes. Sewage materials are excluded. Specifications are at **Appendix 1**.

Compost produced in accordance with PAS 100 will not be subject to waste regulatory controls if used correctly.



Compost will be supplied with a 'supply document' providing certification of PAS 100 compliance.

¹⁷ WRAP & EA (2013). Quality Protocol, Compost. End of waste criteria for the production and use of quality compost from source-segregated biodegradable waste

¹⁸ Quality Protocol, Compost, after PD CR 13456: 1999 Soil improvers and growing media. Labelling, specification and products schedules

¹⁹ WRAP website <http://www.wrap.org.uk>

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Regulatory requirements may alter over time, so the relevant regulatory authority's web site should be consulted when planning the use of compost.

Compost that does not meet the PAS 100 standard is likely to be regarded by regulators as a waste, albeit one with a potentially beneficial end use. It will then be subject to the countries' waste management regulations. Furthermore, any compost that is subsequently mixed with waste materials will itself be classified as a waste. Such 'waste' materials are subject to additional controls.



It is important to be clear whether or not the compost to be used is certified as PAS 100 accredited, because waste management regulations will apply if not.

The Quality Protocol

England, Wales and Northern Ireland have adopted a Quality Protocol for compost²⁰. The Protocol defines criteria governing how quality compost may be produced and used. The Protocol states that it 'is considered sufficient to ensure that the fully recovered product may be used without risk to the environment or harm to human health and therefore without the need for waste management controls'. Permitted feed-stocks, which include food and animal wastes, are listed and compost must be independently accredited. The Quality Protocol currently applies only to British Standards Institution's Publicly Available Specification for composted materials (BSI PAS 100: 2005).

In Scotland, which has not adopted the Quality Protocol, Quality Compost must comply with BSI PAS 100 and be used in accordance with SEPA's Composting Position Statement, 2004 or as updated²¹.



Quality Compost throughout Great Britain must be produced according to BSI PAS 100 and used in accordance with the Quality Protocol (or current regulatory conditions in Scotland). Waste management regulations will apply if not.

The Quality Protocol is adopted as a technical regulation under Technical Standards and Regulations Directive 98/34/EC as amended. Under the Protocol, which has the force of law, good practice must be followed in the use of the compost.

²⁰ This section contains extracts from: Quality Protocol, Compost

²¹ http://www.sepa.org.uk/waste/waste_regulation/composting.aspx Compost must be from source segregated biodegradable waste, produced for a market, have certainty of market, meets standards before any blending etc, can be used without any further recovery and will not be discarded

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Anyone who uses the compost must take account of all potential environmental issues such as application rates, impacts on soil function, potential for water pollution etc.

The Quality Protocol requires producers to demonstrate that its criteria have been met, and this includes certification by an independent body. The certification body must be accredited by the United Kingdom Accreditation Service to BS EN 45011: 1998 General requirements for bodies operating certification systems (or any subsequent amendments). Producers must also keep records of delivery, showing to whom the quality compost is supplied.



If Quality Compost is not used in the manner and market²² to which the Quality Compost applies then it will be subject to regulatory waste controls.

Quality Compost will be supplied with a certificate such as a 'Supply Document' for compost in the end use sector concerned, in this case land reclamation.

Compliance with the Quality Protocol requires good practice for the storage, handling and use of compost. Whilst some of this relates more specifically to agriculture and horticulture²³, the principles are relevant to land reclamation, further details of which are provided in the operational guidance section of this report.



Compliance with the [Compost Quality Protocol](#), and any resulting exemption from Environmental permitting, requires adherence to specified good practice. Therefore, the latest version of the Protocol should be checked prior to use.

The Quality Protocol specifies types of bio-wastes that are acceptable for the production of quality compost, which include some categories of animal by products amongst other wastes.

The 'fines' component of compost (0 - 10 mm) contains a relatively high proportion of the nutrient value. The maximum particle size influences characteristics such as rate of breakdown in the soil: larger particles will break down more slowly and can have a positive effect on soil structure and aeration.



Compost specification is likely to include the grade (e.g. 0 - 20 mm). If the fine fraction has been removed (e.g. 10 - 30 mm) it will have a reduced fertiliser value.

²² 'Land reclamation and soft landscaping operations; horticulture (this includes domestic use); or agriculture and soil-grown horticulture'

²³ e.g. DEFRA (2009). Protecting our Water, Soil and Air: A Code of Good Agricultural Practice for farmers, growers and land managers. The relevant requirements are based on legislation summarised in this report

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Regulatory regime

UK wide

The regulatory regime is taken to include legislation and relevant codes of good practice and guidelines that describe responsible practices.

There are several Acts and supporting Codes of Practice and Guidelines affecting the use of Quality Compost amendments in land reclamation. Specific directions based on legislation are often repeated in Codes and Guidelines so there tends to be overlap. The focus here is on the primary sources of control, which is usually in the legislation. In general the regulatory authorities are SEPA (Scotland), the Environment Agency (England), Natural Resources Wales and the Environment Agency Northern Ireland, whose websites should be checked for latest guidance.

The Forestry Commission in England and Scotland, Natural Resources Wales and the Forest Service in Northern Ireland have responsibility for forestry regulation and grants under the Forestry Acts and the Forestry Environmental Impact Assessment Regulations.

The legislation, relevant codes of practice and site circumstances are potentially complex, and there are variations between countries.



This Guide is an introduction and those planning or executing operations must satisfy themselves by reference to the latest information published by the regulators.

The main legislation relevant to the use of compost on land is:

- [Forests and Water: UK Forestry Standard Guidelines 2011](#): These apply throughout the [United Kingdom](#) and are effectively a code of good practice but are mandatory in respect of any forestry grant aided or regulated scheme. The Guidelines also include requirements of the CAR regulation scheme that applies in Scotland.
- [Forestry Environmental Impact Regulations](#): These apply throughout the [United Kingdom](#) and require approval of forestry schemes over certain thresholds, which would include land reclamation to forestry.
- [Controlled Activities Regulations \(CAR\) 2011](#): Applicable in [Scotland](#), governing land operations that may have an impact on the water environment, including application of compost to land. Although CAR does not apply in [Northern Ireland](#) related provision is made under the Water Environment (Water Framework Directive) Regulations (Northern Ireland) 2003 and the Water (Northern Ireland) Order 1999 and amendments.

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- **The Waste Management Licensing Regulations 2011:** Separate regulations apply in [Scotland](#) and [Northern Ireland](#) which cover, amongst others, application of wastes to land including 'off-specification' compost. *Compost that is PAS compliant and is used correctly is not considered a waste so is not included.*
- **Nitrate Vulnerable Zone regulations:** Separate regulations apply to Nitrate Vulnerable Zones in [Scotland, England, Wales and Northern Ireland](#), each of which has its own regulator. The regulations apply to agriculture but in practice relevant parts must be followed for land reclamation to minimise the risk of pollution, which is a statutory offence. This includes careful assessment, and where necessary limits, on the amount of total nitrogen (and by association of phosphate) applied, together with other operational restrictions.
- **Environmental Permitting Regulations:** These particularly comprehensive regulations govern land operations in [England and Wales](#) that may pollute the water environment. Waste management licensing is also included so the regulations apply to use of compost that is not Quality Protocol compliant.

A summary of supplementary information expanded in **Appendix 2** is:

- **The Code of Practice for the Agricultural Use of Sewage Sludge:** covers operational practice for the application of sewage sludge to agricultural land²⁴ and by extension through the 'Safe Sludge Matrix' to other land growing industrial crops. The Code includes limit values for potentially toxic elements (PTEs) in the mixed soil that should not be exceeded in the resulting soil profile after cultivation with compost.



Compliance with PTE levels for lead, cadmium, chromium, mercury, copper, zinc and nickel in the compost is a requirement of the Compost Quality Protocol in [England, Wales and Northern Ireland](#) and of the PAS 100 standard including [Scotland](#), and compliance within the finished soil profile is a requirement of the Quality Protocol.

- **The Code of Practice for the use of sludge, compost and other organic materials for land reclamation 2010**²⁵: produced by the Scotland and Northern Ireland Forum for Environmental Research to describe best practice in application of organic materials but does not replace codes of practice for specific materials or agricultural land. Compliance with the code is a requirement of the Compost Quality Protocol in [England, Wales and Northern Ireland](#) and is good practice in [Scotland](#). The Code provides Guideline Values for application of organic material

²⁴<http://archive.defra.gov.uk/environment/quality/water/waterquality/sewage/documents/sludge-cop.pdf>

²⁵<http://www.sniffer.org.uk/Webcontrol/Secure/ClientSpecific/ResourceManagement/UploadedFiles/ER11%20Code%20of%20Practice.pdf>

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and restrictions on ground conditions including slope and the water environment.



Compliance with the Code is a requirement of the Compost Quality Protocol.

The legislation and guidance is examined in more detail below:

Forests and Water: UK Forestry Standard Guidelines 2011

Compliance with the Forests and Water: UK Forestry Standard Guidelines²⁶ is a mandatory requirement for all forestry operations and grant schemes throughout the UK, regulated by Forestry Commission in Scotland and England, Natural Resources Wales and the Forest Service in Northern Ireland. The guidelines cover all aspects of forestry operations including drainage, cultivation, planting, maintenance, chemicals and roading. In the event of any pollution incident involving forestry or forest land, non-compliance with the guidelines would be a material factor in respect of prosecution under any relevant legislation.

The Forests and Water guidelines are considered to be a relevant code of good practice that must be complied with in application of the Quality Protocol for Compost in [England, Wales and Northern Ireland](#). The guidelines include statutory requirements including those that are also General Binding Rules under the Controlled Activities Regulations in [Scotland](#).





Plans for land reclamation involving forestry should be discussed in advance with the relevant forestry regulator.



The Forests and Water: UK Forestry Standards Guidelines contains mandatory minimum specifications for forest work that may affect the water environment (see box below).

The main provisions relevant to land reclamation involving cultivation with compost of the Forests and Water: UK Forestry Standards Guidelines include, but are not limited to the following (as specifically applicable to *compost* as an organic fertiliser amendment):

Cultivation and application of compost

-  **Do not cultivate land within 2 m** of any **surface water** or wetland, or 5 m of any spring, well or borehole or is waterlogged
-  Minimise soil disturbance and consider the impacts of soil disturbance when planning operations involving cultivation and drainage

²⁶ Forestry Commission (2011). Forests and Water: UK Forestry Standard Guidelines, Fifth Edition

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- ⚠ Minimise compaction, rutting and erosion during operations
- ⚠ **Do not apply compost** to land **in excess of the nutrient needs of the crop**
- ⚠ Plan *compost* applications with attention to weather and ground conditions
- ⚠ Consider phasing extensive *compost* applications to reduce nutrient losses
- ⚠ In NVZs, apply compost according to the Regulations
- ⚠ **Do not apply compost on land that is:**
 - **within 2 m** of any drainage **ditch** or
 - **within 5 m** of any **surface water** or wetland;
 - **within 50 m** of any **spring**, well or borehole;
 - **sloping** with an overall gradient **in excess of 15°**
 - is **frozen, waterlogged** or covered with snow; or
 - has an average **soil depth of less than 30 cm** and overlies gravel or fissured rock, except where the application is for forestry operations
- ⚠ Do not **store compost** on land that is:
 - **within 10 m of any surface water** or wetland;
 - within 50 m of any spring, well or borehole;
 - waterlogged; or
 - has an average soil depth of less than 30 cm and overlies gravel or fissured rock.

Drains

- ⚠ Drains should be aligned so that water is discharged slowly into vegetation buffer areas and not directly into watercourses and ensure that runoff is discharged in such a way as to minimise the risk of pollution
- ⚠ Minimum **buffer areas** are stated for the width of the bed of the natural watercourse they protect: Buffer **>10 m** for bed < 2 m and buffer **> 20 m** for bed > 2 m²⁷
- ⚠ Smaller buffers may be allowable for watercourse beds < 1 m, especially on steeper ground
- ⚠ Do not connect or divert natural water courses into drains, including roadside drains, or *vice versa* and do not divert water outside the natural catchment
- ⚠ Align drains up-valley with slope <3.5% (2°), or less on more erodible soils

Fuel and oils

- ⚠ Plan the storage, transportation and handling of fuels, oils etc to prevent spillage and pollution of watercourses; ensure a contingency plan is in place to mitigate any accidental spillage
- ⚠ A minimum of oil and fuel should be stored on site and where it is necessary temporarily use double-skinned or banded, securely lockable tanks
- ⚠ Others relating to operational practices including machinery.

The provisions of the Guidelines above must be considered in relation to local constraints.

²⁷ Forestry Commission (2011). Forests and Water: UK Forestry Standard Guidelines, Fifth Edition. See Table 5.1

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The Forests and Water guidelines provide for **buffer areas** where the aim 'is to establish and maintain a partial cover of riparian woodland comprising species native to the location and soils'. In the context of this guidance, buffer areas refer to planned use following reclamation. The stand-off distances for water courses or water bodies are greater than those stipulated for storage of, or cultivation with, compost. Reclamation operations should comply with an after-use forest design that establishes the correct buffer areas, and as such cultivation with compost within the buffers should be justified as necessary.



Minimum **buffer areas** alongside permanent water courses are:

- 50m for water supply abstraction point for (springs, wells and boreholes)
- 20m for >2 m wide watercourse, lakes, reservoirs, large ponds and wetlands
- 10m for 1-2 m wide watercourse
- a narrower buffer may be appropriate for <1m wide watercourse.

The Forestry Environmental Impact Assessment Regulations

Forestry Commission Scotland, Forestry Commission England and Natural Resources Wales are responsible for administering the Regulations introduced in 1999²⁸. The Department of Agriculture and Rural Development is responsible in Northern Ireland²⁹. Assessment and approval is required where operations involving afforestation, roading or quarrying (borrow pits) and deforestation exceed relevant thresholds. The threshold area for afforestation (including short rotation coppice) outside sensitive areas is 5 ha, and includes any adjacent areas from the previous 5 years. The deforestation threshold is set at 1 ha.



Land reclamation to forestry is likely to require determination under The Forestry Environmental Impact Assessment Regulations, except small areas.

Further details, contacts and application procedures are available on the relevant authority websites³⁰.

²⁸ HMG. Environmental Impact Assessment (Forestry) (Scotland) Regulations 1999 and Environmental Impact Assessment (Forestry) (England and Wales) Regulations 1999

²⁹ HMG. Environmental Impact Assessment (Forestry) Regulations (Northern Ireland) 2006 (replacing the 2000 Regulations)

³⁰ FC Scotland and England: www.forestry.gov.uk; Natural Resources Wales: www.naturalresourceswales.gov.uk
Northern Ireland: www.dardni.gov.uk

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Regulatory regime in Scotland

The Controlled Activities Regulations (CAR) 2011

The Controlled Activities Regulations (CAR) is legislation³¹ governing, amongst others, activities involving discharges of polluting matter to all wetlands and into surface and ground waters.



The CAR Regulations include a statutory offence of 'causing or knowingly permitting any poisonous, noxious or polluting matter to enter controlled waters'.

The system of regulation is proportionate to risk. This progresses from lower risk activities where General Binding Rules apply, through Registrations, to Licences for higher risk activities.



Land reclamation using Quality Compost will normally fall within the General Binding Rules, so will not require authorisation by SEPA, but the work must comply with the Rules.

Compost that is below the standard accepted by the regulators (such as BSI PAS 100) will also be subject to Waste Management Licensing Regulations in Scotland.

Land reclamation for forestry using Quality Compost is covered by the General Binding Rules³²:

- GBR 18 - the storage and application of fertiliser, where not already covered by certain regulations and
- GBR 20 - cultivation of land.

General Binding Rule 18 creates stand-offs for application of organic fertilisers from any river, burn, ditch or loch etc (10m) and drinking water sources (50m) together with slope limits (15 degrees or 25 degrees for uncultivated land intended for forestry). Additionally, General Binding Rule 20 provides for a lesser cultivation stand-off (5m) from most surface water or wetland and 2m from drinking water sources such as springs.



Cultivation of waterlogged land and of more than the minimum extent and depth necessary for satisfactory tree establishment is prohibited by GBR 20.

³¹HMG The Water Environment (Controlled Activities) (Scotland) Regulations 2011 as amended in 2013, made under the Water Environment and Water Services (Scotland) Act 2003

³² Under the Water Environment (Diffuse Pollution) (Scotland) Regulations 2008

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Importantly, the Rules state that:



'Fertilizers must not be applied to land in excess of the nutrient needs of the crop', must not be applied to frozen, waterlogged or snow covered land or slopes without run-off precautions (GBR 18) and 'land shall be cultivated in a way that minimises the risk of pollution to the water environment' (GBR 20).

The Waste Management Licensing (Scotland) Regulations 2011

There are regulations covering the use of compost that does not meet the BSI PAS 100 standard and the terms of the SEPA compost position statement (2004).

The Waste Management Licensing (Scotland) Regulations 2011 were made under the Environmental Protection Act 1990 to regulate, amongst other things, application of wastes to land.



Although an activity may be exempt from waste management licensing, it is still subject to statutory controls to prevent environmental pollution and harm to human health³³.

For land reclamation, the use of compost that is not PAS 100-compliant (or that for any other reason is classified as a waste) requires a '[Paragraph 9 Exemption](#) for 'The Reclamation or Improvement of land'.

Off-specification compost consisting only of bio-degradable waste is listed as eligible for Paragraph 9 Exemption in Schedule I, Table 3, Part 1.

The exemption only applies to land that has been subject to 'industrial or other man made development', and requires an assessment by, or based on advice from, a person who has appropriate technical or professional expertise.

Additional information including analysis of the waste and receiving soils, a statement of agricultural or ecological benefit and a statement explaining how pollution risks will be managed must be supplied. A fee must be paid at the time of application at SEPA's current rates. The exemption will be subject to conditions.



The latest SEPA guidance should be consulted when considering the application of off-specification compost.

³³ www.SEPA.gov.uk

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Nitrate Vulnerable Zones

The EC Nitrates Directive (91/676/EEC) was transposed into Scottish law by the Nitrates (Scotland) Regulations 1996. Together with subsequent implementing regulations³⁴, this legislation has established a regime of four Nitrate Vulnerable Zones across Scotland (**Figure 1**)³⁵ within which agricultural activities are controlled to reduce the risk of nitrates causing eutrophication³⁶ of surface and ground waters. The NVZ rules may also help reduce the risk of phosphate pollution.



The legislation applies to agricultural land, but it is recommended that any nitrogen fertilisation or application of organic amendments to forests within NVZs adhere to the limits on organic materials applications and other relevant good practice contained within the Regulations³⁷.

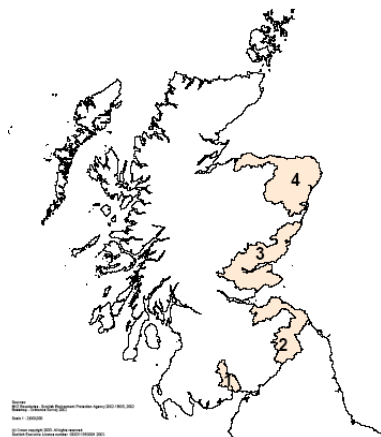


Figure 1. Nitrate Vulnerable Zones in Scotland³⁸

The regulations apply to "any farm which is in a nitrate vulnerable zone" and a *farm* is defined as "an area or areas of land and related buildings that are used for the growing of crops or the rearing of livestock by an individual farm business³⁹." The Scottish Government (SGRPID) is responsible for enforcement.



Reclamation of non-agricultural land that is not part of a farm should comply as far as possible with relevant parts of the NVZ regulations so as to comply with the Controlled Activities Regulations.

³⁴ HMG. The Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 2008 and The Action Programme for Nitrate Vulnerable Zones (Scotland) Amendment Regulations 2013

³⁵ Aberdeenshire, Moray, Banff and Buchan; Strathmore and Fife; Lothians and the Borders; and Lower Nithsdale (14% of the Scottish land area)

³⁶ 'Eutrophication is the enrichment of ecosystems by nitrogen or phosphorus. In water it causes algae and higher forms of plant life to grow too fast. This disturbs the balance of organisms present in the water and the quality of the water concerned.' Protecting our Water, Soil and Air: A Code of Good Agricultural Practice for farmers, growers and land managers. DEFRA. 2009

³⁷ From: Forestry Commission (2011). Forests and Water: UK Forestry Standard Guidelines

³⁸ <http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/Environment/NVZintro/NVZmap1> Scottish Government

³⁹ Scottish Government (2008). Guidance for Farmers in Nitrate Vulnerable Zones

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The Scottish NVZ rules set an upper limit of 500 kg total N / ha applied as green or food/green compost that does not contain any livestock manure in any 24 month period.



The amount of compost used in land reclamation may not *necessarily* be limited to a rate which provides 500 kg total N / ha in any 24 month period, owing to the nature of reclamation. The application rate should be considered with care in relation to the benefits and disadvantages.

Records should be kept of all applications of nitrogen fertiliser, including compost, such as date, application rate and total nitrogen. Maps should be kept showing relevant details including application rates and prohibition zones.

Environmental factors such as soil type and slope, climatic conditions and rainfall must be considered before making any compost applications. For example shallow and sandy soils are especially prone to nutrient loss following heavy applications of fertiliser or organic materials.



The Nitrates (Scotland) Regulations 1996 **prohibit application** on agricultural land where there is a significant risk of runoff getting into surface water, and specifically:

- with a **slope** >12° (1:5 or 20%), if there is a significant risk of nitrogen entering a surface water
- when **waterlogged**;
- when **flooded**;
- that has been **frozen** for 12 hours or longer in the preceding 24 hours
- when **snow covered** and
- within **10 m of surface water** or 50 m of a spring, well or borehole

Temporary storage areas or 'Field heaps' on agricultural land must not be sited on land prone to flooding, water-logging or that is within the water feature buffers (or 30 m of surface water, if the land is steeply sloping). There is a closed period for agricultural use of organic manure with a high readily available nitrogen content, but compost is not in this category.

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Regulatory regime in England, Wales and Northern Ireland

Environmental Permitting Regulations (England and Wales), 2010

These are a single site of regulations introduced in 2007, and amended in 2010 and subsequently, which combined the former Pollution Prevention and Control (PPC) and Waste Management Licensing (WML) regulations and include water discharge and groundwater activities, amongst others.



The Environmental Permitting Regulations will apply to the **use of off-specification or 'waste' compost** in England and Wales, but will not apply to the correct use of Compost under the Quality Protocol.

The regulations provide for **Exemptions**, which may need to be registered with the EA but are free and for **Standard permits**, having rules for common activities and fixed charges. There is a third category of **Bespoke permit**, which tend to be more expensive.

Although there is an **Exemption** for 'Spreading waste on non-agricultural land to confer benefit' that may cover compost⁴⁰ it is limited to 50 tonnes per hectare in any 12 month period. Use of larger quantities of off specification 'waste' compost, that is compost that is not certified as Quality Compost, will require a **Bespoke permit** for which the charge is likely to be significant. The Bespoke permit will require an approved waste recovery plan and management system.



The regulation of waste is a very complex subject, so early contact should be made with the relevant Environment Agency or Natural Resources Wales office if use of non-Quality Protocol compost is anticipated.

In **Northern Ireland**, a waste management licence or exemption under the Waste Management Licensing Regulations (Northern Ireland) 2003 (as amended) is required for the application of wastes to land⁴¹. These are similar to those described for Scotland. The water environment is also protected by application of the Forests and Water: UK Forestry Standard Guidelines 2011 and under legislation by the Water Environment (Water Framework Directive) Regulations (Northern Ireland) 2003 and the Water (Northern Ireland) Order 1999 and amendments.

⁴⁰ Schedule 3, Part 1, Chapter 2

⁴¹ <http://www.doeni.gov.uk/niea/waste-home/authorisation/license.htm>

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Nitrate Vulnerable Zones

The EC Nitrates Directive (91/676/EEC) was transposed into law in England and Wales by the Protection of Water against Agricultural Nitrate Pollution (England and Wales) Regulations 1996. Together with subsequent implementing regulations⁴², this legislation has established a regime Nitrate Vulnerable Zones across much of England and Wales within which agricultural activities are controlled to reduce the risk of eutrophication by nitrogen⁴³ of surface and ground waters. Safeguards are also relevant to Phosphorus, which can also cause eutrophication. The 2013 Regulations, amongst other amendments, made separate provision for England and Wales.



The legislation applies to agricultural land, but it is recommended that any nitrogen fertilisation or application of organic amendments to forests within NVZs adhere to the limits on organic materials applications and other relevant good practice contained within the Regulations⁴⁴.

The area of NVZ in Wales is relatively small but much of England is designated (**Figure 2**) although there are areas, particularly in the North West around Cumbria, which are not. About 70% of England drains to waters identified as nitrate-polluted under the EC Nitrates Directive⁴⁵. The latest NVZ map is available on the regulator's website⁴⁶.



Figure 2. Nitrate Vulnerable Zones in England and Wales⁴⁷

⁴² Nitrate Pollution Prevention Regulations 2008; the Nitrate Pollution Prevention (Wales) Regulations 2008 and The Protection of Water against Agricultural Nitrate Pollution (England and Wales) Amendment Regulations 2013

⁴³ 'Eutrophication is the enrichment of ecosystems by nitrogen or phosphorus. In water it causes algae and higher forms of plant life to grow too fast. This disturbs the balance of organisms present in the water and the quality of the water concerned.' Protecting our Water, Soil and Air: A Code of Good Agricultural Practice for farmers, growers and land managers (2009). DEFRA

⁴⁴ From: Forestry Commission (2011). Forests and Water: UK Forestry Standard Guidelines

⁴⁵ DEFRA (2009). Protecting our Water, Soil and Air: A Code of Good Agricultural Practice for farmers, growers and land managers

⁴⁶ E.g. Environment Agency: <http://maps.environment-agency.gov.uk/wiyby/wiybyController?topic=nvz&layerGroups=default&lang=e&ep=map&scale=4&x=357683&y=355134#x=542858&y=172108&lq=1,&scale=3>

⁴⁷ From: DEFRA (2013). Guidance on complying with the rules for Nitrate Vulnerable Zones in England for 2013 to 2016 and Welsh Government (2013). Review of Nitrate Vulnerable Zones in Wales

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The Compost Quality Protocol states: "In areas of England and Wales designated as Nitrate Vulnerable Zones (NVZs) (i.e. areas designated under legislation to implement the Nitrates Directive), applications of quality compost must comply with the relevant mandatory Action Programme measures. These include various requirements for maximum rates of application and permitted application windows for different types of manures and quality compost. In all other areas these requirements should be followed wherever practical".

The regulations apply to any holding which is in a nitrate vulnerable zone and a **holding** is "land and its associated buildings that are at the disposal of the occupier and which are used for the growing of crops in soil or rearing of livestock for agricultural purposes."⁴⁸ The Environment Agency is responsible for enforcement in England and, since 2013, Natural Resources Wales in the Principality.



Reclamation of non-agricultural land that is not part of an agricultural holding should comply, as far as possible, with relevant parts of the NVZ regulations so as to comply with the Controlled Activities Regulations.

The Regulations in England and Wales increased the organic manure application upper limit to 500 kg total N / ha applied as compost that does not contain any livestock manure in any two year period.

It is considered that,



The amount of compost used in land reclamation may not *necessarily* be limited to a rate which provides 500 kg total N / ha in any 24 month period, owing to the nature of reclamation. The application rate should be considered with care in relation to the benefits and disadvantages.



Records must be kept of all applications of nitrogen fertiliser, including compost, such as date, application rate and total nitrogen. Maps should be kept showing relevant details including application rates and prohibition zones.

Environmental factors must be considered before making any applications such as soil type (shallow and sandy soils are especially sensitive), slope, climatic conditions and rainfall.

⁴⁸ HMG. Nitrate Pollution Prevention (Wales) Regulations 2013

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The 1996 Regulations **prohibit application** on land where there is a significant risk of runoff getting into surface water, and specifically:

- with a **slope** >12° (1:5 or 20%), if there is a significant risk of nitrogen entering a surface water
- when **waterlogged**;
- when **flooded**;
- that has been **frozen** for 12 hours or longer in the preceding 24 hours
- when **snow covered** and
- within **10 m of surface water** or 50 m of a spring, well or borehole

Temporary storage areas or 'Field heaps' must not be sited on land prone to flooding, water-logging or that is within the water feature buffers (or 30m of surface water, if the land is steeply sloping). There is a closed period for use of organic manure with a high readily available nitrogen content, but compost is not in this category.

In [Northern Ireland](#), any application of compost to agricultural land must comply with the crop nitrogen limits and land application restrictions set out in The Nitrates Action Programme Regulations (Northern Ireland) 2010 (NAP)⁴⁹.

⁴⁹ http://www.ni-environment.gov.uk/water/agri_regs/nitrate.htm

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Basic requirements for reclaimed soils for forestry

Minimum standards

In many respects forestry is less demanding of reclamation than alternative land uses, particularly agriculture. However, there are certain fundamental requirements for sustainable healthy tree growth that should be met in any reclamation scheme. There are other reclamation requirements that are less critical and could be relaxed in order to focus on the key factors.

The Forestry Commission publishes best practice reclamation guidance that is backed by detailed research and expert consensus over many years. The resulting specifications establish both the minimum standards and preferred operational practice for sites (**Table 2**).

The main characteristics of pre-reclamation sites that will require remediation for tree planting are:

- Compaction (indicated by high bulk density)
- Low Organic Matter content
- High stone content
- Deficiency in major plant nutrients

Restored sites will also require acceptable:

- Landform and drainage
- Soil chemistry (pH, electrical conductivity/salinity, minor nutrient content, contaminant content).

Whilst this is not an exhaustive list, it covers the key soil physical and chemical parameters that are important to success on most sites. The value of organic soil amendments such as PAS100 compost in land reclamation is a consequence of these characteristics.

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Table 2. Minimum standards for SFMs (SFM) acceptable for woodland establishment⁵⁰

Parameter	Standard	Comments on method
Texture	No limitations; however, the placement location of materials of different texture on site should be related to site factors e.g. topography	Texture (% sand, silt and clay) should be determined by pipette method. Preferred textures include materials with > 25% clay
Bulk density (after placement)	<1.5 g / cm ³ to at least 50 cm depth <1.7 g / cm ³ to below 1 m depth	
Stoniness: Clay or loam	<40% by volume of material greater than 2 mm in diameter and <10% by volume of material greater than 100 mm in diameter	Measure mass of stone >2 mm and >100 mm in a known mass / volume of soil; divide each value by 1.65 to calculate the volume
Stoniness: Sand	<25% by volume of material greater than 2 mm in diameter and <10% by volume of material greater than 100 mm in diameter	
pH	Within the range 4.0 to 8.0	Based on a 1:2.5 soil: CaCl ₂ (0.01 M) suspension
Electrical conductivity	<0.2 S m ⁻¹ (2,000 uS/cm)	Based on a 1:1 soil:water suspension
Iron pyrite content	<0.05 %	British Standard 1016 method
Topsoil nutrient and organic content	N >1500 kg N/ha ⁵¹ P >16 mg/l (ADAS Index 2)* K >121 mg/l (ADAS Index 2) Mg >51 mg/l (ADAS Index 1) Organic matter content >10%	Standard ADAS methods
Specific metal and organic contaminants	These should fall between the Soil Guideline Values (DEFRA and EA, 2002) for residential without plant uptake and industrial / commercial. Where no SGVs are available acceptable limits should be derived using a risk based approach for human health. Levels of copper and zinc should not exceed 130 or 300 mg/kg respectively.	Determination according to substance using a method comparable with the Soil Guideline Values being used. Approval should be sought from Forest Research on the guideline concentrations being used before soil placement begins.

Note: * > 16 mg/l and < 25 mg/l to reduce risk of phosphate pollution. Litterick, A. Pers. Comm. (2014)

⁵⁰ Foot, K. & Sinnett, D. (2006). Best Practice Guidance for Land Regeneration. BPG Note 5. Imported Soil or SFMs Placement. Forestry Commission

⁵¹ Doick, K. Pers. Comm. (2013)

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The basic reclamation requirements and methods for achieving healthy forest growth, on which effort should be concentrated in cases where resources are limited, are summarised in **Table 3**.

Table 3. Basic key issues for healthy tree growth on restored forestry soils

Requirement	Do	Do Not
Compaction		
Loose soil / SFM to at least 1 m depth <1.5 g/cm ³ to at least 50 cm depth <1.7 g/cm ³ to below 1 m depth	<p><u>If soils are moved:</u></p> <ul style="list-style-type: none"> ◦ loose tip final soil / SFM layer and spread by excavator (first resort, cheaper) ◦ Rip the overburden surface before placing soils <p><u>If soils are in situ & compacted:</u></p> <ul style="list-style-type: none"> ◦ complete cultivate by excavator (last resort, expensive) 	<ul style="list-style-type: none"> ◦ bulldoze soil into place or traffic over with machinery unless essential e.g. for installing drains
Organic Matter (OM)		
>10% ^{52*} in the upper 30 cm	<ul style="list-style-type: none"> ◦ recover all peat and other OM rich soils for mixing within surface mineral soil / SFM layer across the site <p><u>If short:</u></p> <ul style="list-style-type: none"> ◦ concentrate available OM for tree planting blocks, leaving open land aside ◦ design woodland to cope using suitable pioneer species 	<ul style="list-style-type: none"> ◦ bury or otherwise waste peat - it is a valuable resource ◦ use best soils in the subsoil layer unless in surplus
Stone volume		
<40%* over 2 mm and <10%* over 100 mm (less in sand)	<p>In high stone content soils:</p> <ul style="list-style-type: none"> ◦ reduce stone volume by mixing in less stony soil or SFM ◦ remove larger rocks and boulders if excavator cultivating ◦ increase OM by mixing in peat or imported amendment (e.g. compost) ◦ design woodland to cope using suitable pioneer species 	<ul style="list-style-type: none"> ◦ expect acceptable tree survival and sustained growth without mitigation of very stony soils

⁵² * Figures relate to <2mm dry weight laboratory analysis fraction

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Major plant nutrients (N, P, K & Mg)		
N >1500 kg/ha ⁵³	<ul style="list-style-type: none"> ◦ use best available soils and OM in surface layer ◦ use amendment (e.g. compost) especially if levels of NPK are very low ◦ design woodland to cope using suitable pioneer species 	<ul style="list-style-type: none"> ◦ expect acceptable tree survival and sustained growth without mitigation where levels are very low ◦ use best soils for open ground ◦ over-supply N and P
P >16 mg/l* (ADAS Index 2)		
K >121 mg/l* (ADAS Index 2)		
Mg >51mg/l* (ADAS Index 1)		
Other Soil chemistry		
pH 4.0 - 8.0	<ul style="list-style-type: none"> ◦ avoid using excessively acidic or alkaline SFMs ◦ mix SFM, OM or amendments to achieve spec if necessary ◦ if necessary, design woodland to cope using suitable species 	<ul style="list-style-type: none"> ◦ plant areas that are below spec
Conductivity / salinity <0.2 S/m		
Phytotoxic Contaminants <Soil Guideline Values		
Landform and drainage		
Gentle slopes, avoid ponding except for planned water-bodies	<ul style="list-style-type: none"> ◦ restore contours to achieve specification ◦ minimise expensive re-contouring if funds are short ◦ plan main drains to be < 2 degrees slope (3.5%) ◦ provide contour 'berms' on slopes >1:10 (10%) ◦ reduce cultivation areas on steep slopes ~include silt traps 	<ul style="list-style-type: none"> ◦ allow erosion or soil slippage risks
Max slope 1:6 (17%)		

The basic reclamation requirements are discussed in more detail in the following sections.

Compaction

Trees will not grow effectively in compacted ground due to impeded root penetration and the reduction of air, water and nutrients in the soil to suboptimal or critically low levels. Compaction may be inherent, resulting from natural ground conditions or may be man-made, e.g. due to passage of machinery over the site. Soils vary in their susceptibility to compaction, which generally increases with increasing silt / clay

⁵³ Foot, K. & Sinnett, D. (2006, revised 2014). Imported Soil or SFMs Placement. Best Practice Guidance for Land Regeneration, BPG Note 5. Forestry Commission, Forest Research

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content and is considerably exacerbated by wet conditions. Even machinery regarded as having relatively low ground pressure such as tracked dozers is likely to cause significant ground compaction if used in wet conditions. Compaction is the result of damage to the soil by forces of compression and shearing. It is observed in the field as poor soil structure, very firm consistence, very few air spaces and fissures. Compacted soil or SFM is difficult to dig with a spade and difficult to deform in the hand, whereas a "normal" soil would be easy to dig and easy to crumble in the hand.

It is essential to relieve compaction during land reclamation for green after-use, and to ensure sufficient rootable depth. Forestry Commission guidelines are for a minimum of 1 m of rootable depth to satisfy the needs of a range of tree species and provide good soil drainage to the lower part of the soil profile.



It is important for tree growth that the surface 1 m of soil / SFM is not compacted.

Where compacted soils are already *in situ*, complete cultivation is the most effective means of relieving the compaction and can be achieved effectively by 360 degree excavator in combination with admixture of compost to reclamation soils.



If soils are being placed into desired final profiles then compaction should be avoided e.g. by 'loose tipping' of the final soil layer.

The loose tipped soils are block tipped by dumper onto the overburden surface and then spread by excavator. If better soils are available for the surface layer then this can be achieved by block tipping the layers close together but separately for excavator spreading one on top of the other, working across the site.



Do not bull-doze surface soils into position, even using 'low ground pressure' wide tracked dozers, or allow any other trafficking of heavy machinery across the final surface.

Ideally, the overburden surface should be ripped prior to surface soil placement, especially if heavily compacted.

Organic matter content

Organic matter is an important component of healthy soils, acting as a reservoir of soil moisture and nutrients and hosting micro-organisms and other soil flora and fauna that play key roles in soil processes including generation and release of nutrients. Organic matter is made up of dead plant material and soil organisms in various states of decay and is present mainly in the topsoil. It includes surface needle litter and leaf mould. Although soils with high organic matter content are generally less susceptible

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damage (compaction, shearing etc) they can still be damaged by heavy machinery and poor handling techniques, especially when wet. Organic matter is gradually broken down by bacteria, fungi and soil fauna and the nutrients made available to plants. In undisturbed soils this recycling of nutrients is sufficient to support all the living organisms, e.g. in mature woodland. In agricultural soils fertilisers are required to replace the nutrients taken away in crops. On land restoration sites it is thus important to retain and re-instate as much topsoil as possible. However, on some sites, such as old coal mines and various waste heaps, there is no topsoil so compost can then play a vital role in restoring a healthy soil ecosystem with a significant amount of organic matter supplying plant nutrients.



Compost is a valuable source of new soil organic matter, especially when mixed with SFM during cultivation to create a new topsoil layer.

Stone content

High stone content reduces the volume of soil available to plant roots and can have a significant impact on survival, stability, growth and drought tolerance. High stone content can be mitigated by importing soil, SFM and organic matter on the one hand and by removing the larger rocks and boulders during cultivation.



Addition of compost increases the soil volume by bulking-up the existing SFM. The process of mixing by excavator can also be used to remove larger rocks and boulders.

Plant Nutrients

Healthy and sustained tree growth requires availability of 'major' plant nutrients that are usually deficient in SFMs available on former industrial sites and mineral workings. Nitrogen is especially likely to be deficient, and potassium and phosphorus are likely to be 'low' or deficient. Other 'minor' plant nutrients (calcium, magnesium and sulphur) and trace elements (including boron, copper, zinc and manganese) may also be sub-optimal.

The availability of nutrients is influenced by the form in which they are held within the soil and by soil pH, so the total amount present may be significantly greater than the quantity that is available for uptake by plants. Some forms are also more likely to be lost through gaseous exchange or leaching which can lead to pollution, plant damage and perhaps subsequent deficiency following an initial surge. It is therefore important to match the quantity of organic amendment to soil type, climate and intended end use/vegetation in order to avoid pollution and unwanted effects on plants and the soil itself. The nitrogen and phosphorus in compost are in organic forms not readily available for uptake by plants and trees. However, they are released slowly by microbial breakdown of the organic compounds. For example, organic

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nitrogen is converted to soluble nitrate that can be absorbed by plant roots. This process occurs slowly so there is a low risk of leaching and water pollution compared to some other organic amendments.

Excessive amounts of soil organic matter (e.g. C:N ratio > 15:1)⁵⁴ can disturb soil chemical and microbial processes by immobilising nutrients, especially if the ratio of carbon to nitrogen is over 25:1⁵⁵. Organic amendments can contribute to nutrient leaching if the C:N ratio is below 10:1.

Organic soil amendments such as compost are significant sources of nitrogen, phosphorus and potassium.



In appropriate conditions, compost can be an effective source of plant available nitrogen, phosphorus and potassium.

The nutrient contents of one fresh tonne of green compost have been compared with other organic amendments in Table 1.

Landform and drainage

Land reclamation often involves creating a new landform that needs to be suited to the proposed end use and also blends in with the surrounds. In the case of reclamation to forestry or woodland with open space a landform of natural appearance without excessively steep ground is preferred. The new landform should be designed to promote drainage both off site and into wetlands or water courses as required, without erosion and subsequent uncontrolled siltation⁵⁶. The underlying standard for forestry reclamation sites adopted by FC Scotland is that slopes should not exceed 1:6 (c.17%) or less if the ground comprises more readily erodible material with low clay content such as sand.

Drainage may be required on reclamation sites to lead water away from the top of artificial slopes, avoid undesired 'ponding' or uncontrolled runoff, and to service designed water features such as ponds and wetlands, which may also have a silt control function. Healthy tree growth depends on adequate rootable depth, root anchorage and nutrient supply with good soil drainage and aeration, although some species or genera such as alders have greater tolerance of wet soil conditions and occasional or seasonal water-logging. Good drainage can be achieved with by a combination of artificial drains and landform. Well designed landform will reduce

⁵⁴ Litterick, A. Pers. Comm. (2014)

⁵⁵ Kilbride, C. (2006). Application of Sewage Sludges and Composts. Best Practice Guide for Land Regeneration, BPG Note 6. Forestry Commission, Forest Research

⁵⁶ Doick, K & Hutchings, T (2007). Greenspace Establishment on Brownfield Land: the Site Selection and Investigation Process. FC Information Note 91. Forestry Commission

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artificial drainage requirements whereas poor landform requires more artificial drainage.

Drainage on forestry reclamation sites should follow the Forests and Water: UK Forestry Standard Guidelines, in order to comply with best practice as demanded by legislation. In some cases the principles of the Guidelines will justify more stringent controls, including presumption for a 5 - 10m uncultivated buffer alongside loose tipped soil⁵⁷. However, there are additional factors to take into account when adding organic soil amendments such as compost to soils during reclamation operations.

Poor drainage will undermine the benefits of soil amendments by creating anaerobic (very low oxygen) soil conditions and possible pollution. Problems include:

- Reduction of 'plant available' nitrogen in nitrates to less available forms
- Impeding the (desirable) oxidation of nitrogen in ammonium to nitrate, resulting in greater tendency for nitrogen leaching into the water environment and release of ammonia, which is toxic to plant roots
- Impeding the (desirable) growth of aerobic bacteria and other soil micro-organisms, flora and fauna so blocking or lowering the rate of conversion and release of nutrients and promoting the (undesirable) development of anaerobic soil communities.
- Leaching of potassium, which is a major plant nutrient that is highly water soluble and is often already in short supply in reclamation soils⁵⁸.
- Leaching of phosphate and nitrate which are major plant nutrients and are implicated in eutrophication of water bodies
- Generation of hydrogen sulphide (unpleasant odour) and ethylene, which is toxic to plant roots.



Soils with a higher proportion of Organic Matter will have a higher absorption and water retention capacity. Addition of organic soil amendments such as compost to poorly draining soils could therefore exacerbate poor drainage and anaerobic conditions.

Soil chemistry

Acidity / alkalinity (pH value)

The availability of plant nutrients in the soil is very dependent on pH:

- The recommended pH range is 4 to 8 (Table 2)
- Excessive alkalinity (pH >8) and high electrical conductivity / salinity can result in soil conditions that are toxic to plants

⁵⁷ Foot K. & Sinnett D., (2006). Imported Soil or SFMs Placement. Best Practice Guidance for Land Regeneration, BPG Note 5. Forestry Commission, Forest Research.

⁵⁸ Potash levels (K₂O) tend to be higher in soils derived from igneous rock (source: RB209)

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- Excessive acidity (pH <4) can increase the availability of 'Potentially Toxic Elements' (PTEs) from unavailable forms e.g. the availability of zinc, copper and nickel, which can be phytotoxic (damaging to plants), increases in more acidic conditions.

Parent soil or SFM often has a pH near or outside the ideal pH range and even up to pH 9⁵⁹. For example, SFM at the Dalquhandy restored opencast site at Coalburn had a pH of 4.8 as compared to the oil shale site at West Calder which had a pH of 7.2 to 8.1.



Compost usually has neutral to slightly alkaline pH values, near the threshold of pH 8 for forestry soils, and this may be advantageous when mixing with an acidic SFM.

Toxic elements

Reclamation soils may contain toxic substances such as PTEs (heavy metals) and hydrocarbons from both natural and industrial sources. Acceptable limits for PTEs in compost used for soil amendment are enforced by environmental legislation and supported by standards such as the Compost Quality Protocol and BSI PAS 100. Contaminants concentrations in compost vary depending on the sources of raw materials, but they are generally very low and are limited by the standards. In the context of soil chemical properties, the important good practice requirement⁶⁰ is that the created topsoil (SFM / compost mix) should comply with the guideline contaminant limits. The compost application rate should therefore be based on the chemical characteristics of both the compost and the SFM.

The amendments may also contain elevated concentrations of contaminants such as PTEs. However, compost produced to BSI PAS 100 will have PTE levels below accepted threshold limits defined in the standard (see Appendix 1). Although the PTE limits in amended soils are defined for sewage sludge used in agriculture, they are should be used as the basis for similar limits on the application of compost to reclamation sites (See Appendix 2)⁶¹.



Soil or SFM with which the compost is mixed should be analysed to determine PTE concentrations, so that relevant overall limits are not exceeded when compost is applied.

In practice, it is more likely that the nitrogen or phosphate content of the organic amendment will be the factor limiting quantity applied to land.

⁵⁹ Doick, K. Pers. Comm. (2014)

⁶⁰ Code of Practice for the use of sludge, compost and other materials for land reclamation. SNIFFER. (2010)

⁶¹ Department of Environment. (Undated). Code of Practice for Agricultural use of Sewage Sludge

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Operational Guidance

Each section provides explanation and highlights:



Suggested action



Warning



Consider

Site assessment

Site investigations are an essential part of the site selection and reclamation process. Depending on site characteristics, this can be a major exercise the details of which are outside the scope of this Guide.



For a full description of the site selection and reclamation process refer to *FCIN091, Greenspace Establishment on Brownfield Land: the Site Selection and Investigation Process*⁶². This describes a Phase I survey, leading if required, to a comprehensive [site investigation](#) (Phase II) that includes intrusive surveying and sampling.

A comprehensive [site investigation](#) is a detailed (and potentially costly) professional investigation of the opportunities, constraints and risks presented by a site in its current state and factors that will affect regeneration. Intrusive site investigation is likely to be required if contamination is suspected, and this could also bring the site into the scope of the contaminated land legislation⁶³. The investigation will include regulatory and historical researches, especially of maps, to determine former use, coupled with ground surveying. Information is assessed through a source-pathway-receptor model to highlight issues that need to be considered in reclamation and after-use planning. Physical site investigation including boreholes and soil sampling may be required to clarify the composition of made ground and potential chemical contamination. Site investigations are usually undertaken by mineral or land use consultants with civil engineering, geological and chemistry specialists.



Reclamation using compost will require appropriate site information, for which specialist advice should be sought. It is very important that risks are correctly identified and considered, especially those related to contamination.

⁶² Doick, K & Hutchings, T (2007). *Greenspace Establishment on Brownfield Land: the Site Selection and Investigation Process*. FC Information Note 91. Forestry Commission

⁶³ Environmental Protection Act 1990, Part IIA

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Site investigation is outside the remit of this Guide but relevant elements can be adopted to help assess conditions specifically for planning and managing soil reclamation. Such assessment can be tailored to suit requirements, although two broad levels can be useful that incorporate elements of the Phase I and Phase II site investigation protocol:

- **Scoping site assessment:** a brief walk-over survey to gain a general understanding of the layout and physical condition of the main parts of the site that will inform subsequent more detailed site assessments for reclamation planning. It is useful to know something of the site's history, as revealed by old maps for example, so as to be able to visit locations of specific potential interest. The scoping site assessment involves *visually* gauging the general condition of the soils and/or potential SFMs around the site, the performance of the existing vegetation and trees and targeted soil sampling. The main zones having clearly different characteristics are broadly mapped. A protocol for a scoping assessment of the factors most relevant to tree growth is given in **Appendix 3**.
- **Site assessment:** a relatively thorough walk-over and soil sampling survey adding detail to the scoping assessment including factors that may affect reclamation work or end use such as landform, drainage, access, local housing and constraints including built or landform hazards, utilities, priority habitats and water courses etc. An example is in **Appendix 4**. Site assessment should be preceded by an investigation of *historical sources* such as old OS maps, which can be extremely useful in understanding the former uses of the land in terms of layout and timescale and will enable deduction of potential issues to be checked.

Soil and soil forming materials

The characteristics of the soil or SFMs on the site to be restored are of prime importance to specifying, planning and implementing reclamation to forestry using Quality Compost.



If earth movement is necessary or likely to be necessary for site reclamation, consider spreading better soils on the reclamation area using relevant best practice and avoid damage to site and soils.

This guide describes a simple method of classifying soils and SFMs in relation to tree growth.

Chemical parameters

The key chemical parameters important in soils and SFMs to be used for growing trees are:

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- Nutrient concentrations⁶⁴
- Other soil chemical parameters (pH, electrical conductivity/salinity, trace element content⁶⁵ and PTE content).

These factors will influence the compost application rate and are described in the section '[Compost requirements](#)'.

Physical parameters

The key physical parameters of the site soils and SFMs to consider as a medium for growing trees are:

- Bulk density or consistence (firmness / looseness) likely after cultivation, related to main particle size
- Soil drainage (wetness/dryness)⁶⁶
- Organic matter content before compost application
- Stone content.

Bulk density and **soil drainage** are the main factors determining tree stability and are influenced by site history and treatment of soils. On disturbed sites *compaction* by machinery may have increased the firmness of soil / SFMs, reducing porosity and increasing density, thus reducing drainage, aeration and root penetration. *Wet* soils will restrict rooting and anchorage, and therefore tree stability.

Soil and SFMs have inherent characteristics that make them more, or less, susceptible to compaction and water-logging, although compacted and wet soils can be ameliorated by cultivation and provision of drains.

Bulk density and soil drainage can be described on the basis of the inherent character of soil / SFM on the basis of firmness / looseness and wetness / dryness, likely after cultivation and provision of drains:



Soil firmness / looseness: porosity and anchorage resulting from the main particle size (heavy = clay, silt; loose = sand, gravel).



Soil wetness / dryness: combined effect of climate (rainfall, temperature, exposure) and site drainage (percolation, water table, slope, drains).

Tree stability is crucial because, once the site is cultivated with compost and planted with trees growing well as a result, the trees must be able to remain upright. The

⁶⁴ Especially NPK, also other macronutrients essential for plant growth Mg, Ca, S. Processes are described in e.g. Soil nutrient management for Maui County. 2004. University of Hawai'i at Manoa

⁶⁵ Minor nutrients essential for plant growth Fe, Zn, Mn, Mo, Cu & B. Source as above

⁶⁶ 'Wetness' is an empirical description of the general condition as in 'wet', 'seasonally waterlogged', 'poorly drained' as distinct from a measurement such as 'soil moisture', which varies by season

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newly amended soil must provide the necessary tree root anchorage for long term tree stability.

Bulk density and soil drainage can be used together to give four simple soil categories⁶⁷:

Simple soil category after cultivation / drainage

Firmer/drier
Looser/drier
Firmer/wetter
Looser/wetter

The simple soil categories will strongly influence site planning (erosion & drainage, nutrient leaching, sedimentation, machine bearing capacity, rutting) and compost application rate considered in the '[Compost requirements](#)' section. Therefore, it is important to know the distribution of soil categories across the site.



Map reclamation soils e.g. by simple soil category

Choosing areas for using compost

The justification for applying compost is to improve soil conditions to enable sustainable tree growth so these will be the primary locations to consider for incorporating compost into the SFM. This will be confirmed by [site assessment](#) and interpretation of associated soil analysis results. Tree planting locations will be determined through forest design, which is an interactive process resulting in a design that complies with the UK Forestry Standard⁶⁸ expressed as a map or maps and any supporting text. Design will balance environmental, social and potentially also economic objectives for the woodland as a whole and will include open space and, if applicable, wetland, riparian habitat, access and facilities. The forest design will be approved by the relevant forestry regulator⁶⁹ prior to implementation.

Areas chosen for cultivation and incorporation of compost will be specified in the approved forest design, but this should take into account the practicalities of implementing the plan and should avoid or mitigate potential problems. For example, areas that are likely to remain naturally wet are best avoided for compost addition and tree planting but can be useful as wetland that also mitigates siltation and erosion. If necessary to achieve desired objectives, it may be appropriate to specify

⁶⁷ Wall, M. (2014). Soil status and amendment needs on forest restoration sites: case studies. Technical Development Report TDJR105. Forestry Commission, Forest Research

⁶⁸ Forestry Commission (2011). UK Forestry Standard. <http://www.forestry.gov.uk/theukforestrystandard>

⁶⁹ Forestry Commission England, Forestry Commission Scotland and Natural Resources Wales

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compost application for areas designated for open space, such as amenity grassland or to support a specific open habitat type.

The results of the [site assessment](#) and a site map showing [simple soil categories](#), as described in the previous sections, are a useful forest design start point.



It is better to plant trees where they will grow with the minimum of ground preparation and amendment.

Forest design should cater for practicalities both of initial implementation and ongoing woodland development and maintenance. Examples include:



Avoid using compost⁷⁰ in areas that are:

- subject to flooding or where the permanent ground water table is less than 1 m depth
- within 20 m of surface water or 50 m of a drinking water supply
- greater than 25° slope (1:4), and in practice preferably less than 1:6



Choose areas for applying compost through the forest design process, which includes balancing environmental, social and practical implementation considerations

Soil sampling

Soil sampling and analysis are very important in planning and implementing new woodland for reclamation sites. The sampling process involves two stages to determine the [main soil characteristics](#) relevant for tree growth (see Table 1):

- o **Collecting** samples for laboratory analysis and, in the process, checking the additional key parameters of compaction, depth, consistency and stoniness of visibly different horizons and overall drainage of the soil profile.
- o **Analysis** of the soil and/or SFM samples for pH, plant nutrients (nitrogen, phosphorus and potassium), organic matter content, other soil chemical parameters and stoniness.

The same sampling procedure applies to [scoping](#) and full [site assessments](#). A scoping assessment would require a small number of sample points whereas a full site assessment justifies a greater number of sample points. The number of sample points should reflect the apparent site variability i.e. more sampling points are required as variability increases.

Soil sampling for [site investigation](#) i.e. where contamination is suspected is outside the scope of this guide. Detailed guidance on soil sampling strategies is given in 'Best

⁷⁰ See Code of Practice for the use of sludge, compost and other materials for land reclamation 2010 (Appendix 2)

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practice guidance for land regeneration, Note 1⁷¹, which highlights the difference between sampling for contamination and sampling to determine the remediation necessary for successful plant growth.

Sampling can be aimed at the 'normal' or most frequent apparent conditions of the site (for scoping site assessment) or **targeted** at specific locations of apparent problems, such as patches of noticeably poor plant growth. Targeted sampling may be used to check apparent 'hotspots' of markedly poor conditions.

The **number of samples** appropriate for a **scoping site assessment** or **site assessment** (for tree growth potential) will depend on the degree of variability of site conditions. Where distinct areas with relatively uniform soils and/or vegetation are identified, they should be delineated on the site map and sampled separately. For areas which are *not* suspected of having contamination hotspots:



As a rule, from **one to three sample points per hectare** should be appropriate for a **site assessment**⁷². A **scoping site assessment** may comprise just one or two for each distinct area. Sample points should be recorded to enable mapping of the areas to which they relate.

Where a full site investigation takes place after or instead of a site assessment, for example when contamination is anticipated, then the sampling strategy must be in accordance with British Standard for the Investigation of Potentially Contaminated Sites (BS 10175: BSI, 2001).

Sample points should be located within the main **simple soil categories** or other distinct areas, which are themselves identified by visually assessing the main variations in vegetation and obvious ground conditions during the site walk over:

- Compaction (high bulk density)
- Stoniness (high stone volume)
- Wetness (seasonal or permanent water-logging) and
- Texture (sand, silt and clay composition) in different parts of the site.

These characteristics are assessed in general terms by digging inspection pits, when differences across the site become readily apparent. There are techniques for measuring compaction, such as by coring or using a penetrometer device. However, they are difficult and time consuming in stony and very compact soils, which are usually those needing improvement and it is normally sufficient to use visual and hand assessments of soil samples from soil pits. Similarly, measurement of stone content

⁷¹ Hutchings, T., Sinnett, D. & Doick, K. (2006). Soil sampling derelict underused and neglected land prior to green-space establishment. Best Practice Guide for Land Regeneration, BPG Note 1. Forestry Commission, Forest Research

⁷² Hutchings, T., Sinnett, D. & Doick, K. (2006). Soil sampling derelict underused and neglected land prior to green-space establishment, BPG Note 1. Forestry Commission, Forest Research

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is not practicable at a scale above the relatively small sample that is bagged for analysis because the site will include more or less frequent larger rocks and boulders that cannot be sampled.

Assessment of soil parameters at sample points in the field that are not covered by laboratory analysis of the sample involves informed judgement.



On-site soil assessment should be carried out by people with relevant experience.

At each sample point it is important to take several samples and mix them together for laboratory analysis. Such **bulked samples** represent 'average' conditions at a location, reducing the possibility of extreme but rare conditions affecting the overall results. Bulk samples comprise three to five subsamples from each distinct soil horizon such as 'topsoil' or 'subsoil'.

Soil samples will be collected from pits, usually dug by spade excluding the surface 5 cm (2") where surface deposits such as humus and leaf litter could distort results. Soil samples should represent the soil profile to the likely depth of cultivation, usually to 1 m. However, samples are not needed to full depth if the subsoil appears to be reasonably uniform.



Take two samples per pit each of 250 to 500 g: from **5 - 15 cm** depth and **40 - 50 cm** depth, excluding stones e.g. > 10 mm if possible.



Note that assessment of **stone volume** from the sample will be an underestimate given that larger stones have been excluded during sampling.

Soil analysis

The **purpose** of laboratory analysis⁷³ of the soil samples collected during scoping assessment or full site assessment is to help understand the main characteristics relevant to tree growth and thus to determine the appropriate application rate of compost. Laboratory analyses for full site investigation that determine concentrations of key contaminants which may pose a risk to the environment or human health will be in addition to those described here for tree growth.

⁷³ The [Compost Quality Protocol](http://www.environment-agency.gov.uk/business/regulation/31835.aspx) requires that "chemical analyses are carried out by laboratories using appropriate methods that are accredited by UKAS to ISO/IEC 17025 for the Environment Agency's *MCERTS* performance standard for the chemical testing of soil".
<http://www.environment-agency.gov.uk/business/regulation/31835.aspx>

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The main soil characteristics relevant for tree growth assessed by **analysis** are:

- Organic matter content
- Primary major nutrient content (nitrogen, phosphorus and potassium)
- Secondary nutrient content (magnesium, sulphur and calcium)
- Acidity / alkalinity (pH) and electrical conductivity or 'salinity'
- Presence of PTEs or 'heavy metals', some of which can be toxic to plants (including copper, nickel, zinc, lead, arsenic and mercury) and
- Stone volume.

Stone volume is measured because the laboratory results refer to the sample < 2 mm particle size and therefore need reducing by the proportion of stone content in the sample. The laboratory stone volume will also be an underestimate of the actual stone volume in the field because it will need to exclude larger rocks and boulders.

Other parameters need to be measured or estimated to allow calculations of volumes and concentrations of materials to be made.

Bulk density can be measured using core samples of known volume, or it can be estimated in the field. Bulk density is used to calculate volumes of material needed to supply a given weight of nitrogen etc per hectare.

Moisture content is measured to allow conversion of dry weights to fresh weights (soil and other samples are oven dried and sieved before analysis). It is also required should the laboratory analysis results need to be converted to quantities within a volume or area of soil, because moisture content affects bulk density.



Compare the soil analysis results with the minimum standards for soil characteristics for acceptable tree growth (**Tables 4 and 5**).

Iron pyrite occurs in some mine spoils and other brownfield sites and oxidises to iron oxide (ochre) and sulphuric acid in the presence of air and water. A visual check for iron ('red ochre') staining and determination of acidity in surface water and soil are good indicators. The extreme acidity (often < pH 2) also severely limits plant growth, another visual indicator. Specific amelioration techniques would be required to isolate and/or neutralise the acidity.



Check the site for signs of **iron pyrite** such as red ochre staining in water courses, especially in areas of disturbed SFM. Seek expert opinion if iron pyrite risk is suspected.

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Table 4. Site assessment analysis parameters

Analysis	Method & unit	Reason	Comment
Organic matter	Loss on Ignition (LoI) % w/w air dry	In min. standard >10% in 'topsoil'	Loss on Ignition (LoI) increased by coal fragments***
Nitrogen (N) Total	% w/w air dry	In min. standard* 1500 kg/ha	Includes some plant unavailable nitrogen but good reference point
Phosphorus (P) available	Olsen mg/kg air dry (+ mg/litre & index) Phosphate (P_2O_5) = $P \times 2.291$	In min. standard P >16 mg/l (Index 2) in 'topsoil'	Phosphate is linked to eutrophication is sensitive in NVZs. Olsen method can overestimate in soils < pH 5.5
Potassium (K) extractable	Ammonium Nitrate mg/kg air dry (+ mg/litre & index) Potash (K_2O) = $K \times 1.205$	In min. standard K >121 mg/l (Index 2) in 'topsoil'	Result can cover potassium & magnesium, plus calcium and sodium if required
Magnesium (Mg) extractable	Ammonium Nitrate mg/kg air dry (+ mg/litre & index) Oxide (MgO) = $Mg \times 1.658$	In min. standard Mg >51 mg/l (Index 1) in 'topsoil'	
Stone volume	Water displacement % by volume < 2 mm	In min. standard* <40%** > 2 mm Inc. <10% 100 mm	Sample result will be an underestimate of field actual
pH	1:2.5 soil: $CaCl_2$ (0.01 M) suspension Unit = pH	In min. standard pH 4.0 - 8.0	
Electrical conductivity	1:1 fresh soil : water suspension uS/cm	In min. standard <2,000 uS/cm ($CaSO_4$ method add 1,700)	Initial higher values following application of organic amendment may reduce over time
PTEs extractable	Aqua Regia mg/kg air dry	In min. standard = below Soil Guideline Values etc	Potentially phytotoxic: Cu, Ni, Zn, Pb, As, Hg Others provided include: Al, Cd, Co, Cr, Mn
Iron pyrite (FeS_2)	Non usually analysed ⁷⁴	<0.05%	Exposed to air and water FeS_2 becomes iron oxide and sulphate (thence sulphuric acid) Indicated by 'red ochre' staining in water

Note: * Laboratory result requires calculation or conversion to minimum standard ** < 25% / 10% in sand *** The Walkley-Black alternative method has a low oxidation of charcoal, which therefore reduces any overestimate of organic carbon due to presence of coal fragments, but Walkley-Black also has a low recovery of organic matter.

Concentrations of **potentially toxic elements (PTEs)** specified in the Compost PAS 100 standard and the Sludge Code are shown in **Table 5**:

The Compost Quality Protocol requires that the receiving soil should be "analysed for PTEs (lead, cadmium, chromium, mercury, copper, zinc, nickel) to ensure that the soil limit values set in the Sludge Code⁷⁵ are not exceeded in the receiving soil." It is also stated that soil analysis should be repeated if and when levels are predicted to reach

⁷⁴ Bochereau, F. Pers. Comm. (2013)

⁷⁵ Department of Environment (undated). Code of Practice for Agricultural use of Sewage Sludge
<http://archive.defra.gov.uk/environment/quality/water/waterquality/sewage/documents/sludge-cop.pdf>

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75% of the Sludge Code soil limit. Although there is no equivalent requirement in Scotland, similar precautions are recommended here.

Table 5. PTE limits in PAS 100 compost and in soils according to the Sludge Code⁷⁶

Element	PAS 100 limit (mg/kg d.m.)	Soil limit* (mg/kg d.m.)			
		pH 5-5 ¹ / ₂	5 ¹ / ₂ -6	6-7	>7
Phytotoxic*					
Copper (Cu)	200	80	100	135	200
Nickel (Ni)	50	50	60	75	110
Zinc (Zn)	400	200	200	200	300
Lead (Pb)	200	300			
Arsenic (As)	-	50			
Mercury (Hg)	1.0	1			
Not phytotoxic*					
Cadmium (Cd)	1.5	3			
Chromium (Cr)	100	400			

Note: * Phytotoxic elements are toxic to plants



Use the soil analysis in calculations to ensure that **compost application** will not raise the levels of PTEs in the amended soil above the soil limits in Table 5.

Phosphorus applied in compost may be both useful for improved tree growth and also a risk to the environment as explained in the 'Compost requirements' section.



For soils with **phosphorus** Index 2 (Moderate in Scotland) or above, use calculations to ensure that, as far as possible, the compost application will not raise it above Index 3. A lower maximum may be desirable in NVZs.

Calculations are necessary where the laboratory analysis results need to be converted to quantities or volumes used on site (**Appendix 5**). However, analysis results for presence of nitrogen, organic matter, nutrients and other parameters, although accurate for the sample tested, cannot simply readily be equated with what is available to trees in the field because there are so many variable influencing factors.

Conversion of laboratory analysis results to quantities within an area and therefore a volume of soil which tree roots can exploit in the field can be achieved using a combination of laboratory results and assessment of additional parameters. An **example** of a methodology is shown illustratively in **Table 6**. The accuracy of the process is limited by the variability of soil in the field and the estimated values used

⁷⁶ Code of Practice for Agricultural use of Sewage Sludge [as at 2013, DEFRA]

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for bulk density and stone content. However, the degree of accuracy is adequate for land reclamation purposes as compared to, for example, precision agriculture.

Table 6. Converting laboratory analysis results to quantities in the field

a. Sample Air dry	b. Sample Fresh Moisture content (m.c.)	c. Convert weight/weight to weight/volume ⁷⁷	d. Exclude volume of stones in soil	e. Factor	f. Volume of soil & stones / ha	g. Quantity on site
< 2mm fraction			> 2mm fraction	Relates to units used	Depth of soil assessed	g =
Lab result (e.g. % Where 1% = 0.001)	x (100%- m.c.%) (wet basis)	x Bulk density (g/cm ³)	x (100%- Stones %) (vol/vol%)	(e.g.) x 10 ⁷	e.g. 0.50m: x 0.50 (e.g. m ³)	a * b * c * c * d * e * f (e.g. Kg/ha)
Accurate	Approximate	Approximate	Estimate	Fixed	Fixed	Result



If laboratory results need to be converted to quantities within soil in the field remember that, if some of the parameters are estimates, the result will be too.



Realistically, soil total nitrogen content in the field, as compared to laboratory sample soil total nitrogen content, cannot readily be measured, although the laboratory figure is a useful site indicator of soil properties on the site.

Compost requirements

The compost **application rate** will be a balance between the 'environmental benefit' and 'environmental impact'. The primary environmental benefit is likely to be **improved tree growth** and health, but improved development of a healthy functioning soil is also likely.

The optimum application rate of compost incorporated at cultivation will be a result of the interaction of key factors:

- SFM group
- Good practice (especially regarding potential for nutrient loss and pollution)
- Deficiency in major nutrients in the soil / SFM
- Potentially Toxic Elements in the soil / SFM
- Initial tree performance factors

These are discussed below **followed by indicative application rates.**

⁷⁷ *Weight* of analysis result in a *weight* of soil converted to *weight* of analysis result in a *volume* of sample

Using quality compost to reclaim land for forestry and woody biomass

Soil forming material group

Compost application can improve tree growth through supply of essential plant nutrients, soil cultivation and an increase in organic matter. The common SFMs can be summarised in broad groups based on soil particle size and pH (acidity/alkalinity). Soil particle size influences chemical status and thereby to some extent the availability of nutrients. On this basis SFMs can be divided into six main groups⁷⁸ (**Table 7**):


Table 7. The characteristics of the main SFM groups for tree growth

Main SFM type	Sand	Chalk	Clay	Colliery Spoil	Hard rock ⁴	Civil.Eng. Wastes
Nitrogen ¹						
Phosphorus ¹	Ⓔ		ⒺⒺ			ⒺⒺ
Potassium ¹	Ⓔ		Ⓔ			
Magnesium ¹	Ⓔ	ⒺⒺⒺ Dolomite	Ⓔ	ⒺⒺ		
CEC-fertility ²						Ⓔ
pH ³	Ⓔ		Ⓔ-ⒺⒺ	ⒺⒺ-Ⓔ		ⒺⒺ
Associated SFM type	Gravel	Limestone	Opencast	Opencast	Slate, shale Oil shale	Aggregate

Notes: (Ⓔ) May be categories higher or (Ⓔ) lower. ¹ Plant available ² Cation Exchange Capacity; in general, the higher the CEC, the higher the potential soil fertility (Wikipedia), although there are exceptions (Litterick, A. Pers Comm) ³ Where low is 'deficient' ⁴ If fines are present they will affect nutrient availability and there will be differences owing to pH status (Litterick, A. Pers Comm)


Key	0 Severe deficiency	1b Moderate deficiency	1a Slight deficiency	2 Adequate	3-7 Slight excess	8-9 Moderate excess
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Additional SFM groups have more specific chemical status or physical make-up. An example is 'silt', which can be a good SFM⁷⁹ if present in sufficient quantities.

 Consider higher application rates where SFM is particularly low in nutrients. Lower application rates may be appropriate in some situations e.g. where soil phosphorus status is already Index 3 (High).

Good practice

The Compost Quality Protocol covers 'Good practice for the storage, handling, application and use of compost as an agricultural fertiliser and in soil grown horticulture'. This includes provision to seek advice from a **Fertiliser Advisor** qualified under the Fertiliser Advisers Certification and Training Scheme (FACTS), which is an agriculture-based qualification. Application should also be made according to the guidance given in the Defra *Fertiliser Manual* (RB209) 8th edition (and subsequent issues)⁸⁰. Use of compost in land reclamation should follow similar rules i.e.:

 'Match compost applications to the nutrient status of the receiving soil, crop nutrient requirement, growth stage and prevailing weather conditions'.

⁷⁸ Adapted from Table 3.4: Bending, N.A.D., McRae, S.G. & Moffat, A.J. (1999). Soil forming materials: Their Use in Land Reclamation. DETR. The Stationary Office, London

⁷⁹ Litterick, A. Pers Comm (2013)

⁸⁰ <http://www.defra.gov.uk/publications/files/rb209-fertiliser-manual-110412.pdf>

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Further relevant guidance is given in the Code of Practice for the Use of Sludge, Compost and Other Organic Materials (see Appendix 2)⁸¹.

Deficiency in major nutrients

Green compost helps to address a lack of plant nutrients in the soil because it is a good source of potassium, phosphorus and organic matter. It also contains slow release nitrogen and useful amounts of other essential 'secondary' plant major nutrients such as sulphur and magnesium, and trace elements (**Table 8**).

Table 8. SFM target parameters and examples of green compost

Parameter	Unit	SFM target (Table 2)	Target in Compost ⁸²	FC Field trial actuals				Typical values ⁸³
				2011 ⁸⁴ ADL	2011 ⁸⁵ DQY	2013 ⁸⁶ DQY	2013 ⁵⁸ PIP	
pH (1:5 water extract)	pH	4.0 - 8.0	6.5 - 8.7	7.6-8.4	7.6-8.4	7.3	7.0	7.6
Moisture content	% wb	-	35 - 55%	46%	45%	53%	35% ^h	44%
Bulk density (laboratory, dry matter)	g/cm ³	-	-	0.63	0.63	0.71	0.67	0.51
Bulk density (delivered, wet basis)	g/cm ³	< 1.5	-	-	-	0.68 ^h	0.47 ^h	-
Elec. Conductivity ^c	uS/cm	< 2,000	< 3,000 ^b	786	809	-	9814	693
Total N	dm	> 1500 kg/ha	-	0.99%	1.17%	1.12%	1.67%	1.47%
N, Ammonium	mg/kg	-	-	956	998	-	-	-
N, Nitrate	mg/kg	-	-	4.1	12.2	-	-	-
Phosphorus (ext) ^d	mg/l	> 16 (<25) ^k	-	71	112	130	84	17
Potassium (ext) ^e	mg/l	>121 (<240) ^k	-	1616	2446	3323	4049	1,127
Magnesium (ext) ^e	mg/l	> 51 (<100) ^k	-	296	397	459	501	-
Organic matter (LOI)	% dm	> 10%	>25%	30%	23%	24%	30%	33%
C:N ratio	ratio	15:1 - (<25:1) ⁱ	< 20:1	17.6	11.6	13:1	10:1	-
Boron	mg/l	-	-	1.71 ^f	2.25 ^f	-	12.75 ^g	-
Sulphur ^e	% dm	-	-	0.17%	0.20%	0.02%	0.14%	-
PTEs:		Appendix 1						

Note: ^a FC Information Note 079. Moffat, A. (2006). Forestry Commission ^b if > 2,000 uS/cm, apply at pro rata reduced rate ^c 1:1 soil: water ^d Olsen ^e 1M NH₄NO₃ (1 soil :5) ^f Hot water soluble ^g Aqua Regia ^h Site measurement ⁱ Soil Forming Materials, Their Use in Land Reclamation. Bending, N.A.D. et al (1999). DETR. London. Natural soils have ratios of c 15:1. Above 25:1 micro-organisms may remove plant available inorganic nitrogen ^k Upper recommendation from Litterick, A. Pers. Comm. (2014)

⁸¹ Code of Practice for the Use of Sludge, Compost and Other Organic Materials. SNIFFER. (2010)

⁸² Use of sewage sludges and composts in forestry. Moffat, A. FC Information Note 079 (2006). Forestry Commission

⁸³ Pod Soil Booster. Scottish Water (2008)

⁸⁴ Source: Hipkin, A., (2011). WRAP Interim Report, Addiewell Project, Site Reclamation using Anaerobic Digestion 'Fibre'. WRAP. [this field trial also used PAS 100 20 mm compost]

⁸⁵ Source: Hipkin, A., (2011). WRAP Interim Report, Dalquhandy Project, Site Reclamation using Anaerobic Digestion 'Fibre'. WRAP. [this field trial also used PAS 100 20 mm compost]

⁸⁶ Wall, M. (2013). Soil status and amendment needs on forest reclamation sites: case studies. TDJR105. Forest Research. Dalquhandy field trial (left column), Pipe test (right column)

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Choose an application rate to achieve the minimum standards for major nutrient levels in SFM (Table 2) so far as is practicable given constraints

- Nitrogen 1,500 kg / ha (for calculation method see Table 6)
- Phosphorus Index 2
- Potassium Index 2
- Magnesium Index 1.

Phosphorus lost from agricultural and other land is an important contributory cause of poor quality in surface waters and is often the key limiting factor for compost application⁸⁷. Phosphorus contributes to eutrophication of freshwater but may also be highly bonded within soil. Phosphorus is strongly adsorbed by clay particles and organic molecules in the soil and, where soil levels are very low or low (Index 0 or 1), uptake by plants and trees will be limited. Addition of compost should provide more phosphorus, in a slow release form.



Phosphorus applied in compost is most likely to be lost from the site if SFM levels are already high (Index 3 or above).

Phosphorus can drain or 'leach' from reclaimed land dissolved in water, as organic matter or attached to soil particles, particularly silt which can be particularly important where phosphorus levels are high.

Good practice for **agricultural** phosphate use is⁸⁸:

- Aim towards Index 2 (Moderate) for most crops, (beyond which apply only as much as will be removed by the crop)
- Aim towards Index 3 (High) for phosphate-responsive crops (beyond which apply only as much as will be removed by the crop)
- Where Index is above target reduce applications (especially for non-responsive crops).



For soils with **phosphorus** Index 2 (Moderate) or above, aim if possible for a compost application rate that will not raise levels in the amended soil above Index 3 during initial tree establishment (e.g. after the first two seasons). A lower rate may be desirable in NVZs.

However, given that land reclamation for **forestry** is targeted to very small areas compared to agriculture, and involves a single not annual application of fertiliser (as compost), a higher initial Index may be targeted to achieve acceptable long term benefits.

⁸⁷ This section uses information from the Fertiliser Manual RB209. (2010). DEFRA & Litterick, A. Pers Comm. (2013)

⁸⁸ Litterick, A. Pers Comm. (2014)

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Potentially Toxic Elements

The BSI PAS 100 sets upper limits for concentrations of PTEs in compost. The limits for PTEs in soils are set out in the Code of Practice for the Agricultural Use of Sewage Sludge, which must be followed for approved use of Quality Compost (except in Scotland). Details are given in Appendix 1. The addition of compost must not raise the level of PTEs above the limits for the soil.



Check the PTE levels in SFM samples and ensure that the application envisaged will not breach the limits in Table 5, by calculating PTEs in the compost if necessary.

Initial tree performance factors

The tree health, survival and growth together describe the overall performance of newly planted woodland and are influenced by environmental constraints and key silvicultural factors:

- Tree growth benefit
- Initial stability
- Initial weed competition (relative to tree growth).

These are discussed below. Species choice is also a key silvicultural factor although outwith the scope of this guide.

Tree growth benefit:

Initial growth benefit: likely growth rate of the species on the site in the establishment phase (~ 5 years) when cultivated soils are looser and weeds more prevalent. Faster growing species on suitable sites include birches, alders, ash, willows, poplars, aspen, larches & Sitka spruce. Slower growing species on most sites include oaks and intermediates such as rowan, pines & Norway spruce.

Later growth benefit: likely growth rate of the species on the site after the establishment phase. This is a reflection of the species' inherent suitability for the site when transient constraints such as initial plant exposure and weed competition have passed.

Initial stability:

The likelihood of trees remaining upright in the establishment phase (~ 5 years) owing to root anchorage and stem strength relative to crown weight and exposure.

Initial weed competition:

The likelihood of physical competition by fast growing pioneer weeds, especially broadleaved weeds, outgrowing and 'swamping' young trees in early establishment, with rushes a problem in later establishment on wetter sites.

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Environmental constraints:

Limiting factors established for the protection of the wider environment, especially the avoidance of pollution and potential damage to the water environment such as the risk of nitrogen and phosphorus leaching into surface or ground-water. These tend to be set by legislation with Codes of Practice in support.



The optimum application rate for any one site will be a combination of the likely Tree initial growth benefit and the counter-balancing dis-benefits including Environmental constraints, and the relative financial costs.



Higher compost application rates may not improve tree performance owing to water-logging on wet sites, initial tree instability on dry but looser sites and weed competition on all sites and, cumulatively, by rushes on wet sites.

Compost requirement for sites within NVZs

The main environmental impact of using compost will be release of nutrients, particularly phosphate, into ground and surface waters. Application of compost in excess of the maximum total nitrogen loading for agriculture will need to be agreed with the relevant regulator, and will need to be justified by environmental benefit such as improved tree growth and health.



The current (2013) NVZ rules set an upper limit of **500 kg total N / ha** applied wholly in compost in any 24 month period.

The quantity of compost supplying 100 kg of total Nitrogen is shown approximately in **Tables 9** (by volume) and **10** (by weight), for a range of compost characteristics.



An application of **500 kg total N / ha** would be **60 - 240 tonnes / ha compost**, depending on the compost total nitrogen content (Table 10 for 100 kg N, x 5).

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Table 9. Approximate volume (m³) of compost to supply 100 kg total nitrogen

Bulk Density	Total nitrogen %	Moisture content		
		High 45% dm	Medium 55% dm	Low 65% dm
Low 0.5 t/m ³	Low 1%	97	79	67
	Medium 1.25%	77	63	54
	High 1.50%	64	53	45
Medium 0.7 t/m ³	Low 1%	49	40	34
	Medium 1.25%	39	32	27
	High 1.50%	33	27	23
High 0.9 t/m ³	Low 1%	30	24	21
	Medium 1.25%	24	20	17
	High 1.50%	20	16	14
Key	Compost tonnage	Low	Medium	High

Table 10. Approximate tonnage of compost to supply 100 kg total nitrogen

Bulk Density	Total nitrogen %	Moisture content		
		High 45% dm	Medium 55% dm	Low 65% dm
Low 0.5 t/m ³	Low 1%	48	40	33
	Medium 1.25%	39	32	27
	High 1.50%	32	26	22
Medium 0.7 t/m ³	Low 1%	35	28	24
	Medium 1.25%	28	23	19
	High 1.50%	23	19	16
High 0.9 t/m ³	Low 1%	27	22	19
	Medium 1.25%	22	18	15
	High 1.50%	18	15	12
Key	Compost tonnage	Low	Medium	High

Further information on NVZs is in the [Regulatory regime](#) section of this guide.

Compost requirement for sites outside NVZs

There is relatively little information on the optimum quantity of organic amendments, including compost, for tree growth on reclaimed soils. This is because the optimum application rate will be a balance between what is desirable for various individual characteristics within the context of avoiding environmental harm through over-application. In achieving the balance the trends influencing the optimum application rate will be towards higher or lower rates depending on the relationship between each individual SFM characteristic and its target (**Table 11**):

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Table 11. The influence of SFM characteristics on compost application rates

SFM characteristic	Target	Usual influence on application rate	
Organic matter content	Achieve minimum of 10%		Higher
Total nitrogen	Achieve minimum of 1500 kg / ha		Higher
P, K & Mg content	Achieve minimum of Index 2, 2 & 1	Lower or	Higher
Soil chemistry, other	Achieve minima (see Table 1) ⁸⁹	Lower	
Contaminants above limits	Application rate must not exacerbate	Lower	
Soil wetness	Lower application on wetter soils	Lower	
Likely prevalence of weeds	Lower application on weedy sites	Lower	
Tree species / woodland NVC	Lower application for pioneers	Lower	
Impact on water environment	Lower application if NO ₃ and P ₂ O ₅ sensitive	Lower	

The extent of the combined *Influence* that the various *SFM characteristics* have on the compost application rate can be assessed by a combination of calculations and *trends*.

- **Calculations** can be made by adjusting the SFM laboratory analysis results for moisture content, bulk density (expected, after cultivation), estimated stone volume and expected tree rooting depth as shown in the [Soil analysis](#) section and Table 6. This will give an estimate of the quantity of organic matter, total nitrogen, other nutrients and any contaminants in the receiving SFM. The results may be surprising: for example great variations in total nitrogen may be found on apparently similar sites. A similar method can be used to calculate the contribution that would be made by an application of, say, 100 tonnes of compost. However, the result of these rather complex calculations will be an *estimate* since the variables are themselves variable or estimates.
- **Trends** can be used to adjust an application rate initially determined by calculation. Alternatively, trends can be used to adjust application rates known to have been effective on similar sites, although this simpler approach is limited by the availability of data on growth.

Results from Forestry Commission field trials planted between 2008 and 2011⁹⁰, enabled an assessment of the broad scale of organic amendment application in the form of green compost for fairly typical conditions in [Central Scotland](#) represented by the four broad "[Simple soil categories](#)" (**Table 12**).

⁸⁹ Achievement may be an evolving process taking time (months or years) following initial reclamation, so a judgement is required of likely changes that will ensue

⁹⁰ Wall, M. (2013). Soil status and amendment needs on forest reclamation sites: case studies. TDJR105. Technical Development, Forest Research

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Table 12. Approximate compost application rate ranges likely to include the optimum by simple soil category in Central Scotland (fresh tonnes / ha)

Soil Category	Tonnes / ha										Limiting factor	
	100	150	200	250	300	350	400	450	500	550		
Firmer/drier	*	*										Stability & weeds
Looser/drier	*	*										Stability
Firmer/wetter	*	*										Growth & weeds
Looser/wetter	*	*										All above
Application Range	Inlier =						Outlier =					
Application trend	Higher =		Drier >>>>				& / or >>> Firmer				Less fertile >>>	
Application trend	Lower =		Wetter <<<<				& / or <<< Looser				More fertile <<<	

Note: * Based on very limited information for Low application rates of < 200 t/ha (fresh weight)

The 'optimum' compost application rate will:

- Enable prolonged and healthy **growth of trees that can compete with weeds** unaided **within 5 years** ('establishment'), using the **minimum quantity of amendment**
- **Avoid excessive weed competition and early tree growth** (which causes stem bending and tree toppling) and associated tree deaths
- **Avoid pollution** of the water environment, particularly with phosphate, which can lead to eutrophication of water bodies.

This assessment gives a higher compost application rate range for firmer and drier soils, reflecting better stability and utilisation of nutrients and organic matter in aerobic conditions. In wet, anaerobic conditions, applications beyond the optimum will provide no growth benefit, but may contribute to pollution risk over time.



Firmer/drier sites are likely to benefit from applications of around **200 to 450 tonnes / ha** (fresh weight) of compost with wetter sites perhaps **100 to 300 tonnes / ha**. Position within the range using the SFM characteristics (Table 11).

This compost application rate guidance must be treated as approximate because:

- It results from a very **narrow range of trials**
- It is an **empirical judgment** from as yet incomplete results over quite different sites
- **Differences can take time** to emerge and are likely to become greater in the later establishment phase and immediately afterwards
- Tonnage dose rates are a very **approximate measurement** of quantity, because moisture content, and the content of (for example) total nitrogen, can vary between batches.

An application rate specification will normally be based on the desired soil physical improvement (due to the organic fraction of compost) and the expected major nutrient supply of the amendment, following laboratory analysis of representative amendment batches.

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Different composts have different nutrient characteristics, so analysis of the source to be used is recommended in order to allow determination of an appropriate application rate.

Organising and managing operations

It is important that one person is in overall charge of operations, who will ideally have also been involved in the planning stage. The 'project manager' will need to ensure co-ordination of the work activities of the various disciplines involved in the scheme for reclamation using quality compost, particularly:

Operational specifications (what, how much, where)
Operational resources (contracts / direct working)
Operational management (safety, co-ordination, monitoring)

These are considered below.

Operational specifications

The **specifications** will be used to define the exact location, extent and nature of the reclamation scheme for costing, tendering (if applicable) and management of the operations (**Appendix 6**). They comprise:

- Accurate, scale **maps, plans and diagrams** showing detail of work required and any hazards
- Detailed **statement of specification** by type e.g. enabling, access, storage, drainage, cultivation (including method), supervision, safety & environment, monitoring and recording.
- **Bill of Quantities** stating amount of work by type and quality of materials e.g. aggregate and compost
- **Supporting documents** including outline health and safety risk assessment, site safety rules (with relevant emergency contact details), environment risk assessment, pollution precautions & contingency plan and CDM Regulations responsibilities.

The **CDM Regulations**⁹¹ and the associated Approved Code of Practice governing health and safety management on construction projects apply to earth moving and other land reclamation works. Although they do not normally cover forestry ground preparation, in practice the procedures adopted on a reclamation site will cover the whole operation and the staff or contractors involved. A project is notifiable to HSE if it lasts more than 30 days or involves more than 500 person days of construction. The Regulations provide for clearly identified responsibilities of the roles of Client (e.g. land owner or manager), CDM Co-ordinator (to advise the client, on notifiable projects only), Designer (e.g. of scheme, specifications) and the Principal contractor.

⁹¹ The Construction (Design and Management) Regulations 2007 <http://www.hse.gov.uk/construction/cdm/legal.htm>

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A wide range of site related issues need to be considered when designing a scheme and drafting the specifications, some examples of which are summarised in **Table 13**. Note that additional factors may on occasion be relevant, such as a neighbouring land use of SSSI or nature reserve. If the site is located in a Nitrate Vulnerable Zone, this will be of overriding importance.

Table 13. Key factors to consider for application of compost to land and incorporation for reclamation to forestry

Factor	Implication	Action
Local Community	Potential local concerns e.g. noise, disruption, change	Consider advance community engagement programme
Access	Existing or potential for HGV access required	Check feasibility
Utilities	Constraints to area and access e.g. buffers and crossings	Check & consider implications
Watercourses	Constraints to area and method e.g. drainage and buffers	Check & consider implications
Slope	Constraints to area and method e.g. avoid steep slopes	Check & consider implications
Current use	Constraints to area and method e.g. existing woodland & unsuitable areas / habitats	Check & consider implications e.g. net areas available for compost
End use	Method specification e.g. higher intensity/cost for production forestry, lower for amenity	Consider implications e.g. net areas available for compost and quantity required
Timescale	Constraints on timing e.g. availability of sufficient compost and <u>duration of winter weather restrictions</u>	Plan operations with regard to weather windows
Receiving soil characteristics	Constraints on method and compost quantity	Consider soil survey requirements & mitigation of soil constraints e.g. de-compaction by cultivation
Completed soil specification	Affects method and compost quantity	Consider operational requirements
Aftercare	Establishment of reclamation vegetation / crop will require maintenance operations e.g. seeding, planting, weeding, protection	Ensure robust specification & suitable provision



Prepare a clear specification comprising maps, diagrams, tables and text covering all requirements in sufficient detail to ensure that the desired results will be delivered.

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Avoid over-specification that will unnecessarily limit options on site but do include statements describing **required quality of work**. The specification should be designed to support costing / tendering and control of the contract / direct-working operation.

Operational resources

The organisation responsible for the implementing the reclamation scheme may have the ability to carry out some or all of the operations itself by **direct working**. However, implementation will frequently require appointment of **contractors**, usually one main contractor who may then subcontract specific elements of the work, hire equipment and source materials.

Each organisation will have its own **procurement**, tendering and contract completion procedures but issues to consider include:

Contractor



Allow sufficient time (e.g. 6 months) for the procurement and contract appointment process to be completed in relation to the required seasonal / weather conditions⁹².

Quality compost

Compost is a crucial resource that justifies careful specification and control. Measures to monitor supply and maintain the quality of compost include:

- ⚠ Source **quality green compost** accredited to PAS 100 standard⁹³
- ⚠ Specify key **characteristics** that may be appropriate for the site e.g. pH, moisture content, bulk density and nutrient content (Appendix 6)
- ⚠ Check **variability** e.g. using certificates of analysis for three batches in the preceding six months
- ⚠ Check **quality** e.g. supplier to test batches every 15 loads
- ⚠ Measures to maintain correct **moisture content** e.g. blending with drier compost and sheeting
- ⚠ Maintain **records of deliveries** e.g. running total, delivery/supply notes with date and batch weight.



Include procedures to ensure that the correct quantity and quality of compost is acquired and delivered

Operational management

The precise roles of those involved in the reclamation scheme will vary, but there should be one person, such as a **project manager**, having the role of ensuring that the

⁹² Larger public sector contracts may need to be advertised in the Official Journal of the EU under Directive 2004/18 'Public Sector Directive' concerning procurement of public works, supply and service contracts

⁹³ Suppliers are listed by the Organics Recycling Group of the Renewable Energy Association <http://www.organics-recycling.org.uk>

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scheme is completed as smoothly as possible. For example, if the work is let to a main contractor, the landowner may appoint a project manager to liaise with the contractor and to ensure that all activities on site are co-ordinated. The main issues that need to be managed at a site level include:

External liaison e.g. neighbours and local authority
Site liaison e.g. co-ordinate risk assessments and contractors
Site monitoring e.g. environment and specification delivery

These are considered in **Table 14**:

Table 14. Key issues that a project manager will need to manage at site level

Issue	Requirement	Comment
External liaison		
Planning consent (may not apply to forestry works)	Ensure conditions are met	Agree variations with planning authority
HGV access	Roads authority aware of works	Establish contact in case of issues arising
Neighbours and local community	Give prior information and contact in case of issues	Good and timely liaison can prevent problems
Utilities	Minimise disruption and avoid risks	Ensure appropriate action e.g. via contractor etc
Site liaison		
Inter-contract logistics	Correct sequence or overlap of contracts	Monitor progress manage delays e.g. use a 'gant chart'
Safety	Ensure risk assessments are in place / exchanged	Co-ordinate for landowner or land manager
Site monitoring		
Environment	Ensure pollution plans and controls are effective	Anticipate effects of bad weather & check controls
	Operations to comply with best practice & legislation	See 'Regulatory Regime' section, page 16
	Ensure an environmental risk assessment is in place	Refresh as required. Check controls e.g. silt traps
Quality of work	Ensure specifications are delivered or agree changes	Based on contract requirements
Quality compost	Ensure correct quality and quantity is used	Based on contract requirements
	Ensure good practice for storage, handling & use ⁹⁴	See Quality compost section at page 13
Completion of work	Site left tidy & snagging / remedial work completed	Also needed to close off contracts

⁹⁴ WRAP & EA (2013). Quality Protocol, Compost. End of waste criteria for the production and use of quality compost from source-segregated biodegradable waste & Defra (2009). Protecting our water, soil and air: a code of good agricultural practice for farmers, growers and land managers (CoGAP)

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Cultivation specifications and methods

Loose tipping

Compost will usually need to be mixed into an existing ground surface, which will therefore exhibit a degree of firmness or compaction. However, the recommended method for forming a new surface soil is by 'Loose tipping' of the SFM (**see box**) so that it is aerated and not compacted.

Loose tipping is achieved by tipping the SFM intended for the final 1m surface from dumpers in loads suitably spaced across the site ('block tipping') and levelling by excavator, working from the side of the strips of loose surface soil being created. The orientation of equipment can be adjusted providing that the principal of avoiding compaction is met. Machinery should travel on the overburden, which should also have been ripped to achieve a degree for de-compaction to aid drainage. If appropriate, the specification may include two or more SFM layers such as a 'sub soil' and higher quality 'topsoil'. In this case, the SFM for the different layers are tipped adjacent and the excavator used to level the lower one and cover with the upper one. Multilayer loose tipping will clearly be significantly slower and therefore more expensive. *Machinery should not traverse loose tipped soil, because this is likely to cause re-compaction and other soil structure damage that will not be readily rectified.*

In cases where a **compost application** is to be mixed into the loose tipped SFM, this can be achieved by block tipping the compost spaced across the site in the appropriate proportions to the SFM tips. The excavator is then used to spread and incorporate the compost over, and into, the surface of the levelled SFM.

An alternative method is to mix compost into the SFM at the source / stockpile location during dumper loading, whereby the loading excavator adds buckets of SFM and compost in the appropriate sequence and proportion such as one bucket compost after five of SFM etc. However, this will result in compost being mixed to the full 1m final soil depth unless the SFM is to be loose tipped as a multilayer.

Loose tipping is fully described in the Forest Research publication BPG 004.⁹⁵

⁹⁵ Moffat, A (2006). Loose Tipping. Best Practice Guide for Land Regeneration, BPG Note 4. Forestry Commission Forest Research

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If planning compost application before the SFM is placed on site, then use loose tipping methods. Otherwise, plan on the basis of the existing ground surface.

Whether soils are deep cultivated or loose tipped, areas on sloping ground must be provided with appropriate engineering soil stability and erosion control features including berms, taps and swales (**Appendix 7**).

Cultivation specifications

Land reclamation operations are likely to be carried out by civil engineering companies, potentially on a 'one-off' basis. The level of detail required for contracts is likely to be far greater than is usual for forestry operations, where contractors specialise in types of forestry operations for which a standard form of practice is accepted as normal. Specifications should include the end result required, the quality and handling of compost and also the types of machinery and techniques that will be appropriate. They should also anticipate problems that might arise by incorrect practice so as to 'close loopholes', for example tracking machinery over cultivated ground, or attempting to use wheeled dumpers in soft conditions. The problem with very detailed specifications is that flexibility suffers and it is difficult to cover for all eventualities, so wherever possible try to allow for flexibility that will not translate into extra cost.



Specifications for tendering and contracts need to be relatively detailed and should anticipate and mitigate risks of inappropriate practices.

Specifications need to be matched to implementation method, whether contract or in-house, the site characteristics, ancillary work and so on. However, an outline guide to requirements for common routine features is given in Appendix 6, although this is not a complete list.

The enriched nutrient status of the completed cultivation is likely to encourage very vigorous weed growth in the first season (see [Forestry operations](#) section).



Consider including grass seeding as an element of the cultivation work.

Cultivation methods

For [existing ground surfaces](#), there are a variety of methods for using excavators for deep, complete cultivation and subsequent incorporation of compost, most of which differ only in detail.

The methods involve:

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- **Primary cultivation** to prepare the ground, and then
- **Secondary cultivation** to incorporate the compost as a second operation.

Operational staff can adjust methods to suite their precise conditions, machinery and operator preferences to achieve the best balance between logistics, work rate and quality of work. Common methods generally involve digging and cultivating a series of **trenches** positioned side by side along a **strip**. The strips then build up across the site.

The focus in this guide is on the principal components of an effective system (**Table 15**).

Table 15. Principal components of an effective excavator complete cultivation method

Component	Objective	Method	Comment
Primary cultivation			
Organise work in straight strips suited to excavator reach	Ensure uniform dimensions for efficiency	Strips are one effective full depth reach wide. Allow slight overlap to avoid compact 'walls' between strips	Strips length can vary to fit the cultivation cell length. Build up adjacent strips across the cell width
Position excavator on uncultivated ground and dig trenches in sequence in front or to the side	Cultivate adjacent to machine progressively along the strip	Trenches are one bucket-width wide	Excavator can work within + along, or adjacent + along the strip
Complete dig to 1m depth	De-compact the whole specified soil profile	As above	Soil volume will increase or 'bulk up', raising the surface by 10 - 20 cm
Remove oversize rocks & obstructions	Achieve specification e.g. < 20 cm rocks in upper 50 cm & < 30 cm in lower 50 cm profile	Place obstructions to side of strip for subsequent disposal. If required, 'chase back' and cut steel rods etc e.g. 20 cm below cultivation	Specification may allow burying below trench
Sequence of trenches	Move spoil from working trench continually along the strip	Fill each trench by digging out next trench	Spoil from first trench taken to other end of strip to fill final trench
Dig in layer-depths suited to compaction	Scrape-excavate in layers to break up compact SFM.	Draw bucket edge across trench surface e.g. to 15 cm (6") depth	Length and depth of scraping can be varied to suit conditions
	Dig-excavate in looser soils for efficiency	Fill bucket from single dig-action	Digging to bucket depth is faster in looser soils

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Replace dug soil in trench	Aid de-compaction and fill trench before starting next	Drop soil from bucket into final position	Suit drop-height to achieve desired effect
Partial inversion	Efficiently de-compact the whole soil profile but avoid burying the surface soil	Place upper excavation spoil aside then replace over lower spoil when filling trench	Two stage process, worthwhile if upper soil is clearly better, but slower
Full inversion	Efficiently de-compact the whole soil profile	Place excavated spoil directly into previous trench thus inverting profile	One stage process is faster, suited where surface can be buried
Surface levelling	Leave an even completed surface e.g. max rise / fall 10 cm	Rake with excavator bucket on completing trenches in each strip	Avoid re-compacting by machine tracking
Secondary cultivation			
Tipping compost	Tip uniform load on fresh cultivated ground at set intervals	Tip from hard ground in centre of marked section to be treated. Can space-tip larger loads	Regular tip intervals determined by load size in relation to application rate ⁹⁶
Mixing compost	Intimate mix of compost to set depth e.g. 30 cm	Spread evenly over surface, then turn over surface with bucket, repeating as required	Bucket teeth, riddle bucket or stone forks desirable for good effect. Also breaks-up clods
	Minimise pollution risk	Incorporate all compost tips by end of day	Most important on wet, sloping sites near watercourses



Select a method for primary cultivation, and secondary cultivation to incorporate compost, that is appropriate for ground conditions, application rate and available equipment, and plan drainage taps, referring to guidance in this section.



Complete the cultivation operations on each discreet area at the end of the working day, to avoid potential run-off pollution and any overnight rainfall impeding subsequent working.

Primary cultivation

Two basic systems for **primary cultivation** are side-strip (**Figure 3**) and the **centre-strip** (**Figure 4**) in which the excavator works on uncultivated ground to the side or in the centre of the desired strip:

⁹⁶ e.g. 3 tonne load & 300 tonnes / ha = 1 load per 1/100th ha (1: 100m² = 1 load in 20 m for 5 m wide strip)

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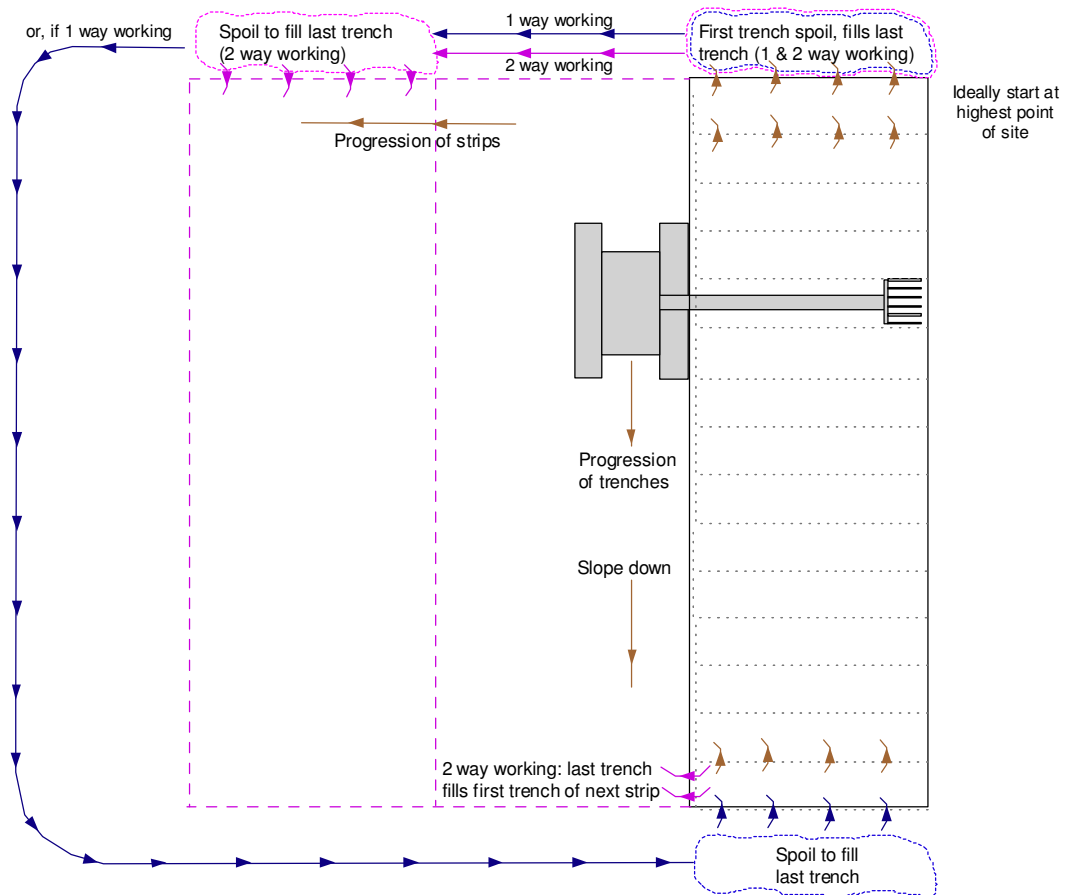


Figure 3. Primary cultivation by side strip method

To aid breaking of clods and achieve a more friable cultivated soil, especially on heavier soils:



Strip soil from the trenches in layers by drawing the excavator bucket evenly across the ground surface in the trench, and drop back from a height.

Drop and spread the spoil from a height (e.g. 1 m) when replacing each bucket load too further aid clod break-up. A stripping depth of 15 cm is standard but this can be increased for more friable soils.

Full and partial inversion

The basic primary cultivation method involves **full inversion** whereby the top layer of each trench is stripped and placed it into the bottom of the previous trench, thus effectively 'inverting' the profile. Whilst this is acceptable in homogenous SFM and for burying potentially troublesome surface vegetation, it is not always desirable.

Partial inversion is an alternative whereby the top layer of soil is first removed from the trench and placed nearby, whilst the lower layer is cultivated. The top layer is then placed on top of the cultivated lower layer. This can be achieved using the centre strip cultivation method whereby the upper layer of each trench is removed and then replaced in the same trench after the lower layer has been cultivated *in situ*.

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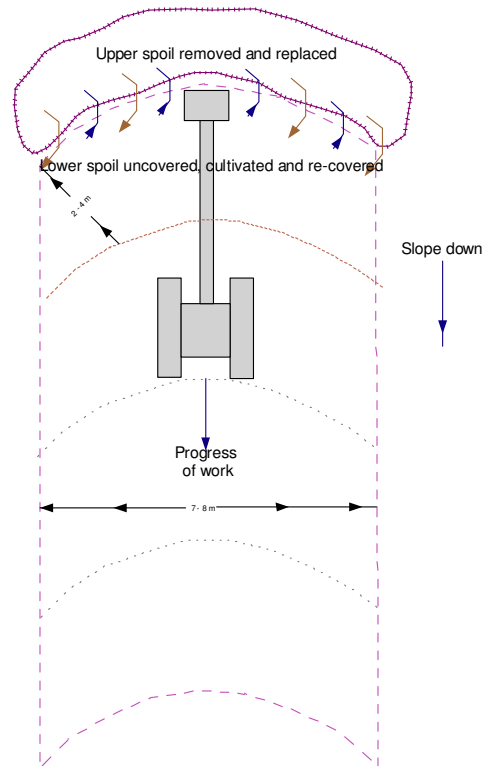


Figure 4. Primary cultivation by centre strip method with partial inversion⁹⁷

Partial inversion can also be achieved with the Side-strip method whereby the spoil is moved into the adjacent trench (**Figure 5**):

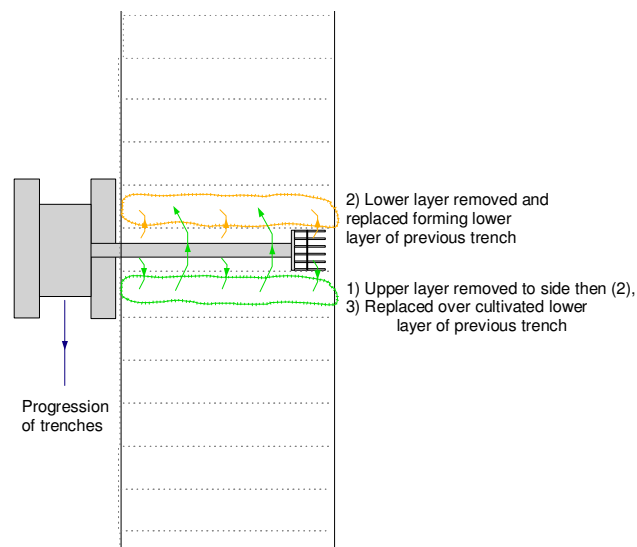


Figure 5. Partial inversion by the side strip method

⁹⁷ After Reynolds, C. (1999). Total cultivation of compacted soils on reclamation sites. Technical Note 30/98. Technical Development Branch, Forestry Commission Forest Research

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Use a **partial inversion** technique if the soil surface layer is better quality than the lower layer and it is desirable not to bury it during cultivation.

Secondary cultivation

The **incorporation of compost** into the ground following primary cultivation involves a degree of re-cultivation of the soil and thereby improves the breaking of clods. Secondary cultivation of compost using the Side-strip method is shown at **Figure 6**:

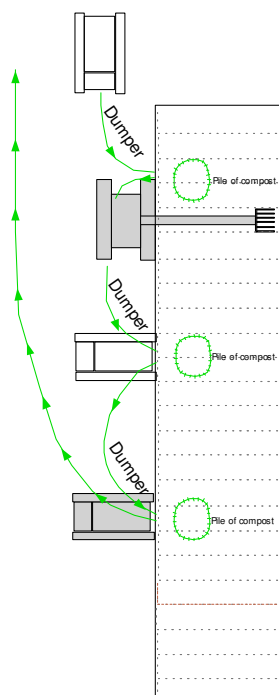


Figure 6. Compost supply for secondary cultivation

The dumper tips full or part loads of compost from uncultivated ground onto the cultivated ground, at regular intervals that will be conveniently within reach of the excavator for spreading.



Calculate the number and spacing of part loads to be tipped onto cultivation strips (see **Figure 7**).

The number of full or part loads is calculated according to the application rate, strip dimensions and load size e.g.:

- Application rate 300 tonnes / ha = 300 tonnes / 10,000m²
- Load size 3 tonnes = 3 tonnes / 300 tonnes = 1/100th ha = 100m²
- Strip 5m wide so 100m² = 100 m² / 5 m = 20m length
- Load tipped in (e.g.) 3 piles = 6 ³/₄ m spacing

Figure 7. Calculating compost load tip amount and spacing

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Compost is spread evenly over the surface from the piles placed regularly by the dumper and incorporated into the surface layer according to the specification (e.g. 30 cm or 50 cm) using the excavator, which will ideally be fitted with a stone fork or bucket with long teeth. Use of a stone fork enables the compost to be 'folded' into the upper layer and sifted back upwards to aid intimate mixing.



Calculate the length of cultivation strip per compost load, and plan for full or part loads to be tipped in piles conveniently within reach of the spreading excavator e.g. every 10 m for a reach of 5 m.

Drainage taps

The cultivation operation should include installation of drainage 'taps' as work progresses, to ensure that water collecting within the base of the cultivated ground can drain out to the ground surface, or more commonly to into the edges of drains ('swale') and berms (**Figures 8 and 9**):

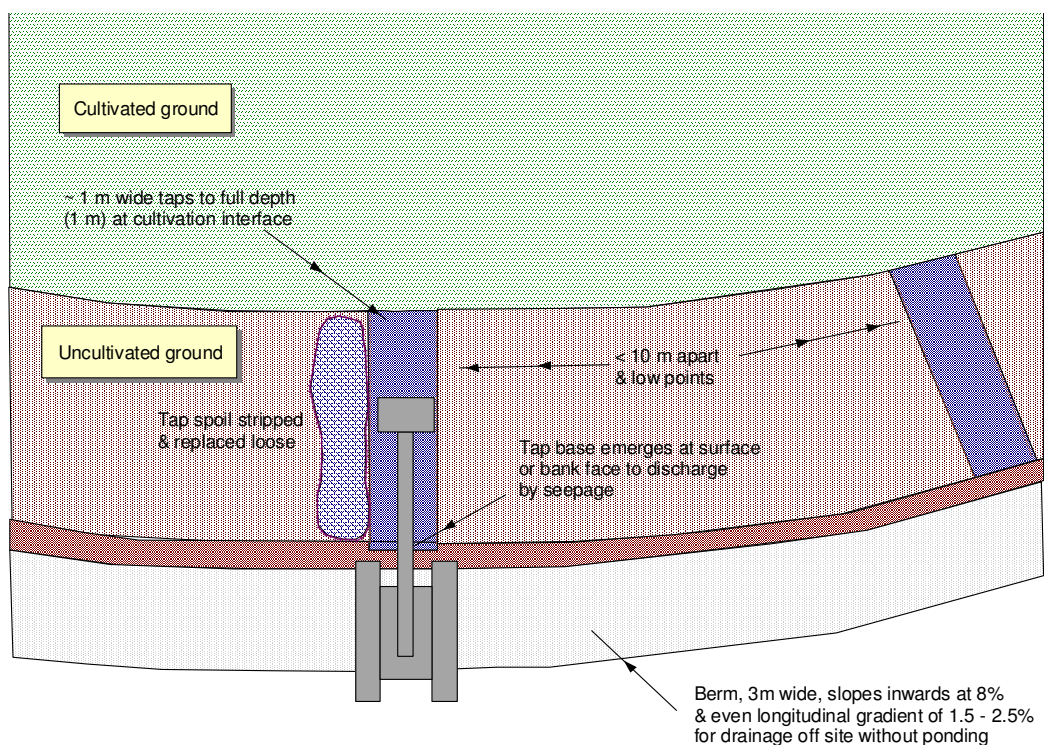


Figure 8. Drainage tap plan (example meets drainage berm)

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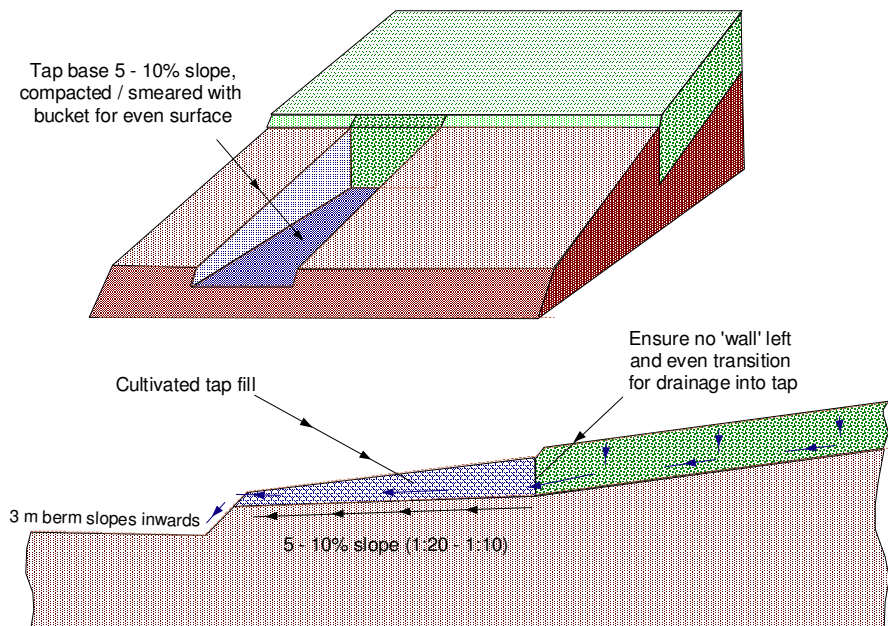


Figure 9. Drainage tap view (example meets drainage berm)



Install drainage 'taps' as required at the lower edge of cultivation areas to ensure drainage from the cultivated profile out through uncultivated ground.

Machinery

Efficiency is dependent on the use of the correct specification of equipment for the site conditions, an obvious example being that wheeled machinery is unsuited to soft, wet conditions. Aspects of machine specification are considered in **Table 16**:

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Table 16. Aspects of machine specification for primary and secondary cultivation

Machine	Specification	Comment
All	Skilled & accustomed	Required for efficiency and to achieve a quality result
Compost supply		
Loader	8 - 12 tonne 360° excavator	Can be wheeled if working on hard standing, but tracked machine may have other uses on site
	5 - 10 tonne front loader	Wheeled. Rapid loading may exceed requirements ~ 0.8 m ³ - 1.6 m ³ bucket
	Scraper edge bucket	1m ³ + bucket. Flat / grading edge rather than teeth
Dumper	5 - 9 tonne class	Compromise between load and ground damage
	5 - 10 tonne payload	Match to supply rate needed for cultivation
		Load volume may limit payload e.g. 10 m ³ ~ 6 tonnes
	Tipping	Front or rear tipping essential for efficient compost layout
	Tracked or wheeled	Tracked for soft / wet and wheeled for firm conditions
Cultivation		
Excavator	14 - 25 tonne 360°, long carriage	600 mm track (or 700 mm tracks for very wet / soft ground). Heavier machines confined to firm sites
	Min 6 m effective reach	Effective reach will affect strip width
	Bucket ~ 1m ³ , 1 m wide	'Square' section, 10 - 15 cm teeth at min. 15 cm centres for digging. Avoid oversized buckets for machine capacity
	Stone fork, 1m+ wide	~ 5 cm * 60 cm long tines at min 15 cm centres for cultivating compost. A slotted bucket is not a substitute



Ensure that machine specifications are matched to site conditions, method adopted and anticipated logistics

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Cultivation work rates and costs

For planning purposes work rate **time** can be expressed broadly in two ways:

Basic time - actual time spent doing the specific task excluding machine maintenance and operator rest / other work

Standard time - Basic time with an allowance for 'Rest and Other Work'⁹⁸.

Conventional work study allowances are operation and machine type dependent but are likely to have a 25% to 35% effect.



There is a reduced risk of underestimating the time or cost of a job if Standard time is used, so it is important to know the context in which figures are applied.

Forecasting the work rate (productivity or 'output') of the cultivation and amendment supply / mixing system for logistics and cost planning can be achieved by the following steps:

- a) Estimate the cultivation and mixing work rate
- b) Estimate the compost loading and haulage work rate
- c) Apply machine and operator hourly costs to give total work rate and cost.



For planning purposes calculate to combined operation work rate and cost, for example by applying or adjusting Steps a) to c).

Step a). Cultivation and mixing work rate

The rate at which machine ground cultivation will progress across a site (the 'work rate' or 'output') is dependent on several **key factors** and as such it is not possible to give precise guidance. The main influencing factors are described in **Table 17**:

⁹⁸ Work Study term. Rest allows for brief stops / interruptions to the working cycle 'on the job', and Other Work allows for refuelling and daily maintenance, both expressed as a % of basic time. Meal breaks and breakdowns are excluded

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Table 17. Main factors and degree of influence on excavator cultivation work rate

Ground Condition	Factor & effect	Work rate Up / down	Influence on work rate
Ground conditions			
Wet	Softer ground is easier to dig	Up	High
	Reduced mixing quality - clay clods will not readily break up	Down	Low
	Machinery bogging	Down	Low
Compact	Hard / dry compact ground is harder to dig	Down	High
	Use of layer stripping to break up		
Friable	Easier to dig and mix with compost Layer stripping not required	Up	Medium
Steep	Reduced manoeuvrability and slewing ability	Down	Low
Boulders	Time to remove to one side then bury / dispose of	Down	Low
Machine specification			
Size	Larger machines may dig faster with larger bucket and more power	Up	Medium
	De-bogging downtime may increase (subject to track width)	Down	Low
Bucket	Fitness for purpose improves speed and quality of cultivation e.g. 6" teeth / tines	Up	Low
Skill	Skilled & accustomed operators will work faster and give improved quality	Up	Medium
Cultivation specification			
Depth*	<u>1 m standard</u> . Deeper is slower, shallower may not be faster. Interacts with foregoing factors	Up	Low
Method*	Strip & trench layout / length, layer stripping, partial / full inversion may affect work rate dependent on other factors	Up / Down	Medium
Application rate*	Adding more compost may take longer but good mixing may be faster	Up / Down	Low

Note: * Effects deduced empirically as insufficient work study data

An indication of cultivation work rates from work studies in central Scotland is at **Table 18:**

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Table 18. Indicative compost cultivation work rates (from studies, to 1m initial depth)

SFM >	Hard spoil	Soft clay		
Compost (tonnes / ha) >	300	340	450	300
Excavator (tonnes) >	23	13	13	23
Ha / basic hour	0.016	0.013	0.023	0.046
Basic hours / ha	63	77	43	22
Ha / standard hour*	0.013	0.010	0.018	0.036
Standard hours / ha*	77	100	56	28
Machine	Hitachi PC210LC 1 m ³ riddle bucket 9.0 m reach	Hitachi 130 LCN 0.85 m ³ bucket 8.0 m reach	JS 130LC 0.80 m ³ bucket 8.0 m reach	Hitachi PC210LC 1 m ³ riddle bucket 9.0 m reach
Trial	ADL 2010	DQY 2012	DQY 2009	DQY 2010

Note: * Standard hour here includes an allowance of 1.265, 10% 'rest' and 15% 'other work' i.e. Basic hour + 26¹/₂%



Cultivation work rates are likely to lie within the broad limits of **0.01 to 0.04 hectares per hour (Standard time)**, although they should be similar in similar conditions.

Step b) compost loading and haulage work rate

The application of compost within the cultivation operation also requires **loading and haulage** of compost from the stockpile to the cultivation strip. Planning will need to include allowance for these elements (**Table 19**):

Table 19. Main factors and degree of influence on system efficiency for loading and haulage of compost on site

Factor	Influence on system
Loading (by excavator or front loader)	
Loader size - loading suits smaller excavator than cultivation (8 - 10 tonne)	Low
Loader type - front loader can be quick, but excavator may have more uses on site	Low
Use bucket with scraper edge (not teeth)	Low
Intermittent task (except in larger operations)	Medium
Operator may cover second task e.g. hauling to dump site (except in larger operations)	Medium
Haulage (by heeled or tracked tipping dumper)	
Higher travel speed reduces time between loading and dump site	High
Tip to offload	High
Rubber tracked machines reduce damage to soft ground and are less likely to bog	High
Wheeled machines are unsuited to soft routes	High
Larger machine load may increase rate of delivery, but should be matched to optimum	Medium
Match loads to those required for cultivation strip (e.g. 5 tonnes for 5 or 10 tonne strips)	Medium
Larger machines may increase ground damage and cost	Medium
May be intermittent task (depending on outward / return time)	Medium
If intermittent task, operator may also load	Medium

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In practice the combined system is likely to require fine tuning on site to ensure the most efficient system for the individual circumstances of the operation. However, for initial planning purposes:



A rule of thumb for loading compost by excavator is approximately 4 m³ per basic minute⁹⁹ i.e. **3 m³ per standard minute** (2 tonnes at 0.65 tonnes / m³ density).

Where the loader and dumper will be driven by the same operator:



A rule of thumb for operator swapping between loader and dumper machines is **one standard minute** per move i.e. 2 standard minutes per cycle.

An initial estimate of the work rate of the compost loading and delivery system can be calculated for planning purposes, for example as shown in **Table 20**:

Table 20. Estimation of work rate of compost loading and delivery

Element	Calculation	Minutes	
		Basic Time (BM)	Standard Time (SM) (BM * 1.265)
		Loading	
Load 5 m ³	= 5 m ³ / 4 m ³	= 1.25	= 1.6
		Haulage (return)	
Travel 200m each way = 400 m	Mean speed of 4 kph* = 67 m per BM	400 m / 67 m = 6	= 7.6
		Other	
Tip load			= 0.6
Swap machines (2x)			= 2.0
Total time per load			11.8
Loads per hour			5.1
Work rate			26 m³ / hour

Note: * Return journey unloaded is likely to be faster. Use separate out/return calculations if a noticeable difference is expected e.g. in rough terrain with a full load

Step c) Apply machine and operator hourly costs to give total work rate and cost
The cost of the supply of compost is included in the calculation, which will vary by location:

⁹⁹ Saunders, C.J. & Wall, M. (2014). Dalquhandy compost cultivation trials. Technical Development Report TDJR110. Forest Research

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A rule of thumb for cost of PAS100 compost delivered to site within a 30 mile radius of the depot is **£10 / tonne delivered** (2013), although this will vary by location and specification. Local estimates should be obtained for planning.

The operation work rates can be converted to operation cost relatively simply (**Table 21**). Note that where a machine or operator has to be dedicated to the task, the hours per hectare will be that of the slowest element (cultivation in this example). However, the calculation stages will vary depending on logistics, such as the number of dumpers required to supply compost to one cultivation machine. For example, if one dumper can supply two cultivation machines then that element cost will be halved.

Table 21. Apply machine and operator hourly costs to give total (example)

Element	Unit cost (£/hour) (a)	Quantity (b)	Work rate (ha / Shr) (c)	Work rate (Shr / ha) (d) = 1 / (c)	Unit Cost (£/ha) (a) * (b) * (d)
Cultivation					
Excavator 15T	£60	1	0.025	40	£3,600
Operator	£30				
Compost					
Application rate	£10 / tonne	500 tonnes / ha			£5,000
Excavator 10T	£20	1	-*	(40)*	£800
Dumper 5T	£15	1	0.052**	(40)*	£600
Operator	£20	1	-*	(40)*	£800
Total (£/ha)					£10,800

Note: * Assumes dedicated to the combined operation full time: otherwise a reduction may be applicable. Operator covers both machines in this case

** Convert m³ delivered / hour in Table 20 to ha supplied / hour i.e. 26m³ compost delivered per hour / 500 m³ per ha compost. In this case one dumper is sufficient, and could actually supply two cultivators if applicable, so reducing costs.



Total reclamation cost per hectare will comprise individual operation costs plus all site overheads and charges etc and may be considerably higher than the unit cultivation cost.

Forestry operations

It is important that foresters are aware of the characteristics of soils reclaimed using quality compost so that the silvicultural benefits are maximised whilst the potential problems are minimised (**Table 22**). Reclaimed soils will usually have a poor soil structure and may still be poorly drained and have unusual chemistry. However, the application of quality compost will provide a marked initial nutrient boost, particularly of available nitrogen, which can cause problems if not anticipated.

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Table 22. Key issues for planting and establishment on sites reclaimed with compost

Issue	Implication	Comment
Ground preparation		
Ground is already cultivated	Mounding is not advisable or necessary	Wet sites might benefit <u>but</u> machinery compaction risk and cost likely to preclude
Drainage already installed	Additional surface drains usually unnecessary. Avoid compaction by machines	Armoured drain, berm & swale spacing may differ from forestry drain norm
Grass seeding	Ideally sow grass seed to minimise initial annual weed growth	Physical competition by grass is much less than broadleaved weeds
Planting & protection		
Fallow period	Preferably avoid fallow owing to vigorous weed growth in 1 st season	Annual weed growth can be limited if site is grass seeded early
Planting date	Normal constraints apply but loose soil can dry / re-wet quickly	Consider wind-scorch and desiccation risk
Plant type	Sites may justify more expensive plug plants over bare root transplants	Bushy bare roots can be difficult to plant properly in heavy, wet clods
Species	Fast, pioneer species will reduce weed risk but may also topple after 2 - 3 years if exposed	Slower growing climax species will be at risk from weeds for longer
Protection	Tubes aid chemical and strimmer weeding, give protection against voles and weeds smothering soft conifers	Tubes also protect against hares (75 cm) and rabbits (60 cm). Taller tubes (120 cm) can be more liable to vandalism / wind toppling
	Taller (120 cm) tubes can exacerbate etiolation and poor stem strength. Use shorter tubes except where some protection from Roe deer is needed	Exterior deer fencing may also be advisable.
Establishment, weeding & maintenance		
Weeding	Expect vigorous early annual / pioneer weed growth. Chemical weeding alone may not suffice, allow for strimming etc	Allow for 3 - 4+ years weeding. Excessive 'arable' weeds can swamp trees and tubes, especially in first year; less thereafter
	Expect rush infestation on certain wet sites, spreading within 2 - 3 years onwards. Readily swamp trees over winter, especially softer species	Very difficult to control chemically and may need strimming, so consider tubes as trees are otherwise difficult to see and easily damaged
Staking	Potential very rapid stem / crown growth in first two years. Can lead to stem drooping / lodging or snapping at root collar. Consider additional staking of faster growing species	Flush of major nutrients in first two years that will then subside, but tree instability may occur soon thereafter, especially on windy sites
Beating up	Apply normal practice for replacement of dead trees	Initial survival should be good, but weeds and etiolation are threats

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The nutrient enrichment of soils reclaimed with compost need a robust establishment specification and often probably also an extended maintenance period



Plan to overcome possible problems of excessive early stem growth and prevalence of weeds. Post planting care is crucial. Do not get caught out!



Consider species choice to include slower growing trees, tubes for protection from animals and weeds, grass seeding and selective remedial staking

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Forestry for biomass

Reasons for considering establishment of trees for biomass on sites reclaimed using compost include:

Fast growth is expected & desirable for short rotations
Close tree spacing benefits biomass yield and site
Extensive crop root growth will aid soil development
Crop biomass value may offset maintenance costs
Crop biomass can have a high biodiversity value
Biomass crops can evolve into woodlands

However, the inherent characteristics of reclaimed sites are likely to pose particular challenges for growing single stemmed or coppiced trees as a short rotation crop to be harvested for biomass, as compared to conventional woodlands.



Ensure that all relevant factors are considered, and that production costs and harvesting commitments are justified by realistic expectations of the benefit.

Short Rotation Coppice and Short Rotation Forestry are the two systems designed with the primary aim of growing woody biomass from trees for energy. The short duration of the crop capitalises on the fact that trees have their highest annual increment in the early years. Crops of fast growing species grown on short rotation will therefore maximise volume production on a year by year basis. Conventional forestry accepts a reduction in total volume inherent in longer rotations as a trade-off for higher value timber yield such as saw-logs.

Short Rotation Coppice (SRC) is a highly intensive system requiring good site conditions and ongoing site management (weeding) to achieve its potential over rotations of typically 3 - 4 years.



Reclamation sites are by their nature not ideal for SRC where biomass production as a crop to be harvested is the main aim.

Short Rotation Forestry is less specialised as it uses standard forestry techniques and equipment and is more robust because it is less demanding of operational conditions



The SRF system is likely to be more suited to objectives on reclamation sites, providing that the slightly longer rotation of 10 - 15 years can be accommodated.

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For example, SRF is more adaptable to changing management priorities and opportunities because it can be grown-on longer, or to maturity, if desired.

The main attributes of the SRC and SRF systems for optimum effectiveness are summarised in **Table 23**. Note that SRC can be grown in less suitable conditions than tabulated but costs and productivity will suffer greatly, and also that SRF can use conifer species such as Sitka spruce, although calorific content (as opposed to timber volume) may not be optimum:

Table 23. Indicative comparison of SRC and SRF biomass production systems

Characteristic	SRC Optimum	SRF Optimum
Crop		
Usual Species	Willow (Poplar in best conditions)	Birch, ash, alders, sycamore, aspen, sweet chestnut
Rotation	3 years (initial 4 years)	10-15 (-20) years
Volume production, solid	10 m ³ / ha p.a. (6-15) ^{100 101}	10 m ³ / ha p.a. (6-12) ¹⁰²
Tonnage Production	8 a.d. tonnes / ha p.a. (4-10) ¹⁰³	8 a.d. tonnes / ha p.a. (5-10)
Plants	Clones (rods / cuttings)	General forestry (bare root / plug)
Planting machinery	Specialised SRC	General forestry Manual / mechanised
Weeding	Intensive (100%), Chemical	Extensive (30-50%), Chemical & / or physical
Susceptibility to deer / rabbits	Very	Moderately
Genetic base & susceptibility to pests & diseases	Narrow More susceptible	Broad Less susceptible
Regeneration	Coppice	Coppice & singling or re-planting
Ground prep cost on Brownfield land (e.g.)	Additional to SRF (De-stoning)	High (complete cultivation & organic amendment)
Plants, Planting & Establishment cost	~£1,500 / ha	~£1,500 / ha

¹⁰⁰ Impacts of the Production of SRC on Poorer Quality land. AEA (2007)

¹⁰¹Tubby, I. & Harrison, A. (2002). Establishment and Management of Short Rotation Coppice. Forestry Commission

¹⁰² McKay, H (Ed). (2010). Short Rotation Forestry: Review of growth and environmental impacts. Forest Research Monograph 2. Forestry Commission

¹⁰³ a.d. = air dry, c 30% moisture content (wet basis)

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Site conditions		
Slope	Level or gently undulating / sloping	Ideally < 15% (1:6) Potentially up to 30% (1:3)
Soil	Moderately to very fertile	Low to high fertility
Surface soil stones/rocks	Absent / few	Not sensitive or Absent / few if mechanised planting
Drainage	Good	Good to seasonally poor
Harvesting and utilisation		
Harvest	Winter only	Year round / Subject to nesting & local restrictions
Harvest equipment	Specialised SRC	General forestry
Access for harvest	Good	Good to poor
Woodfuel type	Chip	Chip (log processed to chip) or log
Woodfuel storage	Heap Short term unless air dry	Chip - Medium term (air dry) Log - stack to air dry
Woodfuel drying	Heap ventilation under cover	Chip - heap, covered Stack - outdoor or covered
Haulage (from site)	Grain wagon / curtain-sider	Timber wagon - large volumes Flatbed - smaller volumes
Harvesting cost to forest road	~£14 / a.d. tonne	~£12 / a.d. tonne (round timber)

* a.d. = air dry, c 30% moisture content, wet basis

Using quality compost to reclaim land for forestry and woody biomass

Future work

This guide draws particularly on experience gained in Central Scotland by Forestry Commission from 2008 to 2013 in forestry field trials, partly supported by WRAP, and from 2011 in operational reclamation schemes. Although this provides a body of evidence on which to base guidance, it is inevitably limited by conditions, practice and timescale. Further recommended investigation to develop improved guidance is:

- Determination of major nutrient needs of tree crops on reclaimed land in the British Isles and improved guidance on compost application rates
- Determination of optimum compost application rates for a wider range of soil types and climates that balance tree growth, soil improvement, weed competition, environmental impact and cost
- Optimum compost application rate and depth for poorly draining, clay rich soils that are seasonally waterlogged
- Work study to provide improved work-rate (cost) information for a wider range of soils, equipment and cultivation methods
- Potential for modifying compost nutrient content to match site needs, especially reducing available phosphate, enabling higher application rates with consequent soil structure improvements; for example for use in Nitrate Sensitive Zones
- Determination of the potential for enhancing the role of forestry biomass production on sites reclaimed with compost by reducing SRF spacing and rotation lengths.



A shortened 'field booklet' (or e-booklet) extract from this more detailed guide would extend the application of the best practice in reclamation using compost, especially if readily updated.

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Technical Development

Technical Development helps develop, evaluate and promote safe and efficient equipment and methods of work, maintains output information, advises on forest operations and provides related specialist services

The list of products/manufacturers in this report is not comprehensive, other manufacturers may be able to provide products with equivalent characteristics. Reference to a particular manufacturer or product does not imply endorsement or recommendation of that manufacturer or product by Forest Research.

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Appendix 1

Summary of the specification values of BSI PAS 100

Parameter	Recommended limits ¹⁰⁴	PAS100 Example*	Units
	PAS100 Specification ¹⁰⁵		
Pathogenic micro-organisms			
Salmonella Spp	Absent		MPN in 25g sample dry weight
Escherihia coli	< 1,000		CFU / g fresh mass
PTEs / Contaminants			
Zinc	<400		mg/kg dm
Copper	<200		mg/kg dm
Lead	<200		mg/kg dm
Nickel	<50		mg/kg dm
Chromium	<100		mg/kg dm
Cadmium	<1.5		mg/kg dm
Mercury	<1		mg/kg dm
Arsenic	<10		mg/kg dm
Selenium	<6		mg/kg dm
Boron	<3		mg/kg hot water soluble
Physical contaminants			
Glass, metal, plastic & other non-stone fragments > 2mm	0.25% (0.12% plastic)		% mass / mass air dry sample
Stones > 4 mm	8% (10% in mulch)		% mass / mass air dry sample
Other			
Microbial respiration rate	16		Mg CO / g organic matter / day
Germinating weed seeds or propagule growth	0		Mean number / litre compost

¹⁰⁴ *Moffat, A. (2006). Use of Sewage Sludges and Composts in Forestry. Information Note 79. Forestry Commission. ** Schedule 'B' - Detailed specification for ground preparation and drainage works for the establishment of community woodland on a restored inert landfill at Greenoakhill, Broomhouse, Glasgow. Forest Enterprise Scotland (unpublished, 2011)

¹⁰⁵ PAS100:2011 Specification for composted materials. BSI (2011)

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Typical analysis for green compost comparison

Parameter	Recommended limits ¹⁰⁶	PAS100 Example ¹⁰⁷	Units
pH	6.5 - 8.7*	7.6*	
Elec. Conductivity	< 2,000 (<3,000 reduced rate)*	693*	uS/cm (1:5 water extract)
Bulk Density	500 - 700**	617**	Kg/m ³
Dry matter	45% - 70%*	55.5%*	% DM by weight
Moisture content	30% - 55%*	45% - 70%	% by weight
Organic matter	>25%*	33%*	DM, kg OM (loi)
C:N	15:1 - 20:1*/**		ratio
N, Total	1.0 - 2.0%**	1.7%*	% N DM
N, Nitrate	<200**		mg/l Water extractable
N, Ammonium	<25**		mg/l Water extractable
Phosphorus	0.15 - 0.30%**		% w/w ds
(as P ₂ O ₅)		0.24%*	% w/w ds
Potassium	0.75 - 1.50%**	0.78%*	% w/w ds
(as K ₂ O)	0.90 - 1.80%**		% w/w ds
Magnesium			Kg MgO
Sulphur			Kg SO ₃

¹⁰⁶ Recommended limits column:

* Moffat, A. (2006). Use of Sewage Sludges and Composts in Forestry. Information Note 79. Forestry Commission.

**Schedule 'B' - Detailed specification for ground preparation and drainage works for the establishment of community woodland on a restored inert landfill at Greenoakhill, Broomhouse, Glasgow. Forest Enterprise Scotland (unpublished, 2011)

¹⁰⁷ Example column:

* Source: Scottish Water, Pod Soil Booster specification

**Source: NRM Ltd. Analysis of AD / CLO and Compost from 2011 Forestry Field Trials i/d 20658-30574, 2/11/11

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Appendix 2

Regulatory regime: supplementary information

Code of Practice for the Agricultural Use of Sewage Sludge

The 'Sludge Code' or 'Code'¹⁰⁸ was published by the Department of the Environment in 1989, was updated in 2001 and complements the Sludge (Use in Agriculture) Regulations 1989 (SI 1989, No. 1263) which covers GB. Although the code relates to the use of sewage sludge on land, the principles are relevant to use of compost.

Amongst other objectives, the Code is intended to ensure that use of sludge avoids public nuisance and water pollution and safeguards the health of humans, animals and plants. The Code provides for prior soil sampling and gives maximum soil concentrations of PTEs, some of which (Zn, Cu, Ni) increase with pH (alkalinity).

Maximum permissible concentrations of PTEs in soil after application of sewage sludge¹⁰⁹

Parameter	Soil Maximum (mg / kg dm)				Maximum addition ^e (kg / ha)	Max. in Compost ^f (mg / kg dm)
	5-5½	5½-6	6-7	>7*		
PTE	5-5½	5½-6	6-7	>7*		
Zn	200	200	200	300	15	400 ^f
Cu	80	100	135	200	7.5	200 ^f
Ni	50	60	75	110	3	50 ^f
PTE	For pH ↑ & pH 5.0 and above ↓					
Cd	3				0.15	1.5 ^f
Pb	300				15	200 ^f
Hg	1				0.1	1 ^f
Cr ^b	400				15	100 ^f
Mo ^{bc}	4				0.2	
Se ^b	3				0.15	
As ^b	50				0.7	
F ^d	500				20	

^a Increased permissible concentrations for pH>7 only apply in soils >5% calcium carbonate

^b Not limited by Directive 86/278/EEC on environment protection when sewage sludge is used in agriculture

^c May be naturally higher although not causing problems, in which case take expert advice

^e Maximum average annual rate of PTE addition over 10 years

^f Upper limit in compost. PAS 100: 2011. Specification for composted materials, for general use. Aqua Regia test

Whilst the Code relates to use of sewage sludge, the principles and chemical limits are relevant to other organic soil amendments.

¹⁰⁸ Code of Practice for Agricultural use of Sewage Sludge [as at 2013, DEFRA]

¹⁰⁹ <http://archive.defra.gov.uk/environment/quality/water/waterquality/sewage/documents/sludge-cop.pdf>

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Code of Practice for the use of sludge, compost and other materials for land reclamation 2010

Published by the Scotland and Northern Ireland Forum for Environmental Research, this code covers accepted practice in application of compost, anaerobic digestate, sewage sludge and others. The Code provides for a site assessment process that considers a wide range of factors including physical features, contaminant levels and sample analyses.

The Code recommends that organic amendments should **not** be applied:

- to sites that are subject to flooding or where the permanent ground water table is less than 1 m depth
- within 20m of surface water or 50m of a drinking water supply
- within 100m of a dwelling without a site specific risk assessment
- to ground greater than 25 degrees slope (1:4)
- to ground between 15 degrees and 25 degrees where in liquid form

It is recommended that organic matter should be incorporated to 40 cm depth and also that plant growth trials may be beneficial in determining appropriate application rates.

The Code provides Guideline Values for application of organic material. In the case of soil formation for non-food crop production, landfill cap and colliery spoil reclamation the guideline value is 100 - 500 tonnes dry solids / ha. The rate will depend on the nature of the organic amendment, condition of the land and the contaminant concentration in both the organic amendment and soil. Rates at the lower end of the range should be used for organic matter less than 25% dry solids.

The Code states that:



'Higher than normal rates of organic matter application should only be considered if it can be demonstrated that they are both beneficial and necessary for planned end use'.

and



'Applications in excess of that needed for sustainable ecological improvement could be considered as a waste disposal rather than a land reclamation operation'.

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Appendix 3

Example Scoping site assessment protocol to determine site suitability for tree growth and potential need for amelioration

The **scoping site assessment** is a brief site visit process that can give a reasonable general understanding of potential woodland performance on a previously un-visited site upon which further management decisions can be based. The survey can be followed by a more detailed **site assessment** (e.g. Appendix 4) if the site is considered further for reclamation.

This scoping site assessment method is intended to be simple, so it inevitably involves professional judgement based on varied, inter-related visual evidence, considered as a whole rather than independently.



The site assessments require a basic level of understanding of trees, vegetation, soils and drainage but are not intended to be a substitute for expert site investigation, for which further detailed guidance is available¹¹⁰.

The scoping site assessment aims to link site conditions at a precise location to potential tree performance and to provide sufficient information to understand whether further reclamation was likely to be required.



In cases where chemical contamination or physical features such as mineshafts are known or expected to pose a health and safety risk, then a preliminary **site investigation** should be discussed with a suitable specialist minerals agency and this can include soil sampling and other features of the site assessment.

It is helpful for the **scoping site assessment** to gather information on previous **historical site uses**, particularly former industrial processes. Ordnance survey mapping at 1:10,650 and smaller is available commercially from the first series mapping of c. 1860 onwards and this can provide an excellent time-line for the site though the latter part of industrial revolution e.g. 1858, 1891, 1910, 1922, 1938, 1954, 1968, 1982 etc.

The scoping site assessment is essentially a **walkover** during which general points of interest are noted, for example on a map. During the walkover, specific attention should be paid to any indications of contamination such as unexplained 'bare' patches, waste dumping or discolouration of water.

¹¹⁰ Greenspace Establishment on Brownfield Land: the Site Selection and Investigation Process. Doick, K & Hutchings, T. (2007). FC Information Note 91

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The walkover will be coupled with more detailed assessment at [point locations en route](#). The point locations should be chosen to represent as far as is visually evident 'typical' conditions on the site. The number of points will therefore depend partly on site variability.

Provisional point locations can be marked on a map in advance of the site visit according to anticipated suitability of soils for tree growth from historical maps and current aerial photography.

Once the walkover is underway, the site condition can be reviewed and an exact location chosen for each point so as to represent typical conditions as far as can reasonably be visually determined. This is an empirical judgement. Clearly, the soil and tree growth assessment subsequently made relates to the precise point location and its immediate vicinity, but this should be able to be taken within reason as representative of the site. An initial site walkover may be needed to enable a good choice of point location.

A c 500g [soil sample](#) is collected at each point location using a steel core tool, spade or trowel (for surface samples only). Each soil sample should represent the entire likely current rooting depth, which is usually to a barrier formed by an underlying hard, compacted SFM layer.

If possible, supplementary samples of the underlying SFM should also be obtained from convenient points on the site, such as existing cuttings and excavations (if any) because it is likely to be utilised as part of any reclaimed soil profile. If the opportunity to readily sample the subsoil SFM does not arise then this will be recorded as an uncertainty for possible future determination.

An [assessment of key characteristics](#) relevant to soil reclamation for tree growth is made at each point location. These are summarised below.

A simple scoring system of Good (*satisfactory*), Medium (*borderline*) or Poor (*unsatisfactory*) is used, whereby a tendency towards a need for reclamation is indicated by the key '**reclamation indicators**': tree health and present rooting factors.



A **Poor** classification in **Tree Health** is a strong reclamation requirement indicator.

A **Poor** classification in any of the four **Root-able soil** parameters is a strong reclamation requirement if replacement of the existing tree cover is justified for other reasons.

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A **Medium** classification indicates a possible need for reclamation but should be considered in the context of the site as a whole. For example, a 'medium' soil depth of 50 cm can be sufficient to support healthy woodland in some situations.

The characteristics assessed at each point location are summarised below. Those that would indicate a tendency towards a reclamation requirement are highlighted (thus):

Characteristics assessed at point locations with reclamation indicators highlighted

Characteristic Assessed	Reason	Categories (Reclamation Indicator)	Method
Reclamation requirement indicators			
Tree health and growth	Key indicator of soil suitability	Good Medium Poor	Visual assessment. <i>Ideally record species, age, growth rate, deficiencies as supporting evidence</i>
Rootable depth (including humus layer)	Key for tree growth & stability	Good (> 50 cm) Medium (< 50 cm) Poor (< 25 cm) <i>Qualifiers: Actual cm</i>	Pit / core to compact root barrier
	Assess soil volume supplying nutrients	<i>Qualifiers: Humus layer And/or Topsoil And/or Subsoil/SFM Record Actual layers in cm Water-logging</i>	-do-
Rootable soil category (simple)	Assess mineral / organic character	Good (friable, few stones) Medium (friable, stony) Poor (stony, clayey) (/ peat) <i>Qualifiers: Sand, Stony, Clay, Humus, Peat</i>	Visual assessment of pit / core
Rootable soil BD (bulk density)	Confirmation of rootability	Good (<1.3 g / cm ³) Medium (1.5-1.7 g / cm ³) Poor / compacted (>1.7 g / cm³)	Weight for core volume. Assume approximate. <i>Cannot be precise w.r.t. stones & wetness</i>
Rootable soil Status	Determine soil quality supporting current growth (N P K Mg, Organic matter, Bulk Density & other key characteristics)	Good (compliant**) Medium (largely compliant) Poor (largely non-compliant)	Laboratory analysis
Supplementary information			
Ground vegetation (exclude heavily shaded ground)	Indicates soil conditions: compaction, drainage organic matter & fertility	Good (vigorous) Medium (reasonable) Poor (sparse) <i>Qualifiers: Wet, Varied/Unvaried, Indurated</i>	Visual assessment. <i>Ideally identify main characteristic vegetation at micro-site as supporting evidence</i>
SFM (physical character below present rooting zone)	Assess physical potential to cultivate & ameliorate	Good (potentially friable) Medium (workable) Poor (rocky, heavy clay) <i>Qualifiers: Stony, Heavy Clay, Indurated</i>	Visual assessment of pit / core

Notes: * OM = Organic Matter ** Refers to FC Minimum standards (Table 2)

The physical character of the SFM below the present rooting zone is **supplementary information** because it is relevant to any proposed reclamation specification. Similarly,

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the ground vegetation at the sample location is supplementary because it may be influenced by a wide range of factors including canopy.



The scoping site assessment method, as outlined, will not cover some less common site types, such as deep peat, although such sites would probably not be reclamation candidates for ecological or other reasons. However, the process can be adjusted to suit.



The scoping site assessment method can be supplemented by an initial assessment of the influence of ecological, social and landscape factors on any future reclamation requirement for the site as a whole.

For example, an infertile, compacted site supporting a priority acid heathland habitat may have a greater overall benefit if left untouched.

Following a scoping site assessment, the reclamation planning process, if initiated, may then involve a more detailed [site assessment](#), including mapping and sampling of soil conditions across the site. An example of a detailed site assessment specification is at **Appendix 4**.

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Appendix 4

Example Site assessment protocol to determine site suitability for tree growth and potential need for amelioration

Site characteristics

History: previous use(s), how long has site been in the present form

Location: relation to surroundings, distance to nearby housing, farmland, woodland, drainage courses, etc.

Type of site: spoil heap, landfill, demolition site, quarry, etc

Ground conditions: loose tipped, graded by bulldozer, landscaped, ploughed, drained, etc

Type of material: topsoil, subsoil, mainly sandy/gritty/gravelly/stony, clay, shale spoil, slag, quarry waste, organic material

Landform and slopes: steep on conical coal bings, undulating, fairly level, or a combination such as steep sides with flat top etc.

Existing vegetation

Ground cover: % Vegetation cover/% bare ground

Dominant vegetation types: grass-dominated, marshy, shrubs, small trees, large trees, etc

Trees: existing tree species & growth/health & trees naturally colonized or planted

Soil characteristics

Horizons: identify horizontal layers in the soil with distinctly different colour and/or material

For each horizon record - colour, texture, stoniness (visual estimate of volume), presence of roots and earthworms

Other factors: soil drainage, compaction and depth at which it occurs, potential tree rooting depth. This could be limited by compacted or other impermeable/hard layer, water table, landfill cap etc.

Soil sampling for analysis

Number and location of samples: these should be representative of the site and soil forming materials (SFMs); as a guide, 3 samples per hectare or per specific SFM would be a minimum. Each sample should be a composite of 5 sub-samples. The sample depth should be 5 to 15 cm in profiles with no significant horizon development. If two or more distinct horizons of significant thickness are present, they should be sampled separately.

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Analysis: pH in water; organic matter (by loss on ignition); total nitrogen; extractable phosphorus, potassium, magnesium. Analytical results to be assessed by comparison with published guidelines.

Use analytical data to calculate existing content of plant nutrients in SFM, adjusting for bulk density and stone content if necessary to give kg of nutrient per hectare to rooting depth (e.g. 30 cm).

N.B. Coal and coal shale contain carbon and nitrogen that is not available to plants and is sometimes referred to as "fossil" C or N. Samples taken from coal mine spoil heaps and some other sites can contain varying amounts of coal or shale and the analytical techniques used will not distinguish between fossil and non-fossil sources. The results can therefore be over-estimated and this should be taken into account.

On some sites the SFM may need to be analysed for potentially toxic elements and/or other chemical parameters, but this would require expert advice. Such sites would most likely be determined when assessing the site characteristics, i.e. from site history and field observations.

Assessment of site suitability for trees

A site can be assigned to one of the following four categories of suitability for tree establishment as a further aid to overall site assessment. In each category, one or more of the factors could have a limiting effect. In Class 1 little or no intervention would be required to achieve good tree growth and young stock could be planted directly into the ground. In classes 2 to 4 there are increasing limitations and amelioration required. This classification does not take account of factors such as the need for rabbit or deer fencing, fire protection, etc, or the availability of machinery.

Class 1: High suitability – very good vegetation cover over all or most of site; healthy plants and trees; no or few restrictions to access and potential management operations; very good or good soil conditions and potential tree rooting depth; little or no need for amelioration/intervention

Class 2: Moderate suitability – good vegetation cover but some areas with poor cover; generally healthy plants and trees but some areas showing stress or poor growth/health; some restrictions on access/management due to steep slopes, obstacles, landform, etc; adequate soil conditions and potential tree rooting depth, may be sub-optimal in some areas; some areas could benefit from amelioration/intervention depending on cost/benefit analysis.

Class 3: Low suitability – generally low vegetation cover, although some areas may be good; generally poor growth and health of plants and trees, some indications of

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stress, nutrient deficiency, disease, etc; access and management restricted by very steep slopes, unstable ground, etc; generally poor or sub-optimal soil conditions and potential tree rooting depth; amelioration is essential and may include ground works (e.g. re-grading, drainage, de-compaction, etc), and the application of amendments such as compost and/or fertilizer.

Class 4: Very low suitability – very little vegetation cover; good growth only in some tolerant plant species; severe restrictions to access/management; very poor soil conditions (e.g. very high stone content, severe compaction at surface, very low or high pH, very low plant nutrient content, excessive toxic element content, etc.); amelioration is essential but will be costly and difficult.

Assessment of compost application rate

Use overall site assessment, including analytical results, to determine required application rate of compost.

Main benefit is organic matter content acting as a soil improver. Slow release nutrients an added bonus. Nitrogen and phosphorus content are the limiting factors for compost application rates.

Andrew Hipkin, Soil Consultant, 21st March 2013

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Appendix 5

Relating soil analysis results to field conditions

The analytical data can be used to calculate the amount of nitrogen, organic matter, and other components within areas of soils and SFMs in the field, for example to give kg of nutrient per hectare to a 50 cm rooting depth.

Laboratory analysis figures relate to a subsample that has usually been air dried and sieved to remove stones and other material (including organic matter) > 2mm and the results are expressed as a weight per weight of sample (or % by weight). This needs converting to a volume of soil present within areas in the field. For this purpose bulk density (fresh soil), moisture content (fresh soil) and stone content (in the field) can be determined accurately, but in practice, given the amount of variability in the field, it is sufficient to use informed estimates.

Table a. Typical approximate field bulk densities (BD)¹¹¹

	BD (g/cm ³)		BD (g/cm ³)
Peat	0.1 - 0.3	Agricultural, plough horizons:	
Peaty topsoil	0.9	Light soils	0.8 - 1.4
Grass & woodlands, surface horizons	0.8 - 1.2	Heavy soils	1.4 - 1.7
Clay loam subsoil	1.5 -1.7+	subsoil horizons	1.5 - 1.8
Reinstated soils/SFMs, compact clay	1.5		

Compaction and a lack of oxygen are the main soil factors preventing root penetration. Root penetration ceases at a bulk density greater than 1.8 g cm⁻³.

Table b. Examples of approximate total stone content in the field (> 2 mm)

SFM	Location	Estimated stone volume
Coal mine tip, residue from process	Heathland	40%
Coal mine tip, spoil from shaft	Limerigg	70%
Waste oil shale	Addiewell	50%
Clay SFM from opencast coal site	Dalquhandy	20%
Building /washed sand mix (50/50)	Merchant	25%
Builders aggregate	Merchant	80%

Source: Wall, M. (2014). Soil status and amendment needs on forest reclamation sites: case studies. Technical Development Report TDJR105. Forest Research

It is feasible to calculate constituents of soil, such as nitrogen or organic matter, that are likely to be contained within a volume of soil/SFM in the field from a laboratory analysis result. Calculations require complex mathematical formulae including conversion of the various measurables into equivalent units.

¹¹¹ From Hipkin, A. Pers. Comm. (2014)

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A **simplified estimate** of the constituents of soil present in the field uses:

- the dry matter lab sample result
- the field moisture content
- an estimated field bulk density (weight per volume)
- a reduction for estimated stone volume
- a calculated factor to allow for differences in units and
- a relevant soil depth.

An illustrative example is the conversion of a value for % total nitrogen obtained from lab testing to a theoretical amount of total nitrogen in the field as shown in **Table c.**

Table c. Converting figures from laboratory to site soil volume, illustrative examples

a. Figure for air dry <2mm part	b. Convert from (a) in dry to (a) in wet weight	c. Convert from weight to volume	d. Exclude volume of stones in soil	e. Factor	f. Volume of soil & stones / ha (m ³)	g. Quantity on site
0.280% TN	100%-39%	1.41	100%-20%	$\times 10^7$	0.50	9,633 ¹¹²
0.105% TN	100%-19%	1.63	100%-28%	$\times 10^7$	0.13	1,253 ¹¹³
0.100% TN	100%-24%	1.43	100%-32%	$\times 10^7$	0.10	739 ¹¹⁴
Accurate	Approximate	Approximate	Estimate	Fixed	Fixed	Approximate
Lab result (mg/kg or %)	$\times 100\%$ -m.c.% (wet basis)	\times Bulk density (g/cm ³)	$\times 100\%$ -Stone vol.% (vol/vol%)	$\times 10^7$	\times Soil depth (m)	Kg N / ha

a. 0.280% is $\times 0.00280$ etc

b. Approximate measurement. % sample not water-m.c. of the bulk density sample, but will vary over the site

c. Approximate measurement. Core taken from soil *in situ* i.e. compacted, or loose if cultivated

d. Approximate Estimate. Vol. of stones in lab sample can be measured: vol. of rocks & boulders in the field cannot

e. Converts from g/cm³ to Kg/m³ ($\times 1,000$) and m² to ha ($\times 10,000$)

f. Depth to which the sample applies, which is the depth to which the presence in the soil relates

The end result is highly dependent on the estimates used. For example, if the soil depth is estimated as 50 cm but in fact is only on average 40 cm, then the result will be incorrect by 25%¹¹⁵. The need to use estimates and approximate measurements for what can be very variable factors has important implications for interpretation of laboratory soil analysis results.



The **simplified estimate** process involves several stages and a number of figures that in practice can only be set very approximately, so the result will be similarly approximate.

¹¹² Dalquhandy 2011, Compost at 2,000kg / ha TN mixed in clayey subsoil

¹¹³ Humber Bridge, Ferriby, soil developed over c 60 to 90 years on boulder clay in chalk quarry


¹¹⁴ Rubble at former factory site, Barrhead

¹¹⁵ (50 cm-40 cm)*100/40 cm

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Appendix 6

Outline contract specifications for reclamation to forestry with compost

Item	Specification	Possible exclusion 	Comment
Compost			
Quality	Green Compost to PAS 100 (General Purpose)	No amendment for nutrients & pH	Approve specification used See 'Example of Additional compost characteristics' table below
Screening	0 - 20 mm to 0 - 40 mm	No compost that excludes a fine fraction e.g. no 10 - 30 mm	Fine fraction includes much of the nutrient value
Delivery	Handling	No excessive compacting of loose compost to increase load weight	Handle with care. May be denser than planned owing to settling / pressure in load
	Inspection	Not over wet or dry, unfriable, no stones, plastic, glass or green plant material & not 'self-heating'	Visually check each load for consistency
Handling at site	Handle with care, avoid compaction	Machinery must not traverse compost or contaminate it with mud etc	Avoid loss, contamination on-site with SFM or stones, water-logging & run-off pollution
Storage	Location of accessible, free draining (5 - 10% slope), hard standing of sufficient size	No storage where water-logging or mud will spoil quality	As above & ensure space for un/loading e.g. 3 m around windrows, each < 3 m high & with 50% slopes
	Minimise wetting	No loose heaps or surfaces, extracting from mid windrow	Windrows with 'pointed' top, 'seal' surface by light bucket pressure
Records	Delivery notes include date, weight & batch reference Daily & cumulative total	No payment for undocumented loads	Quantity and quality of compost delivered is a key control point


Note. Includes extracts from Forest Enterprise Scotland, Scottish Lowlands FD. Greenoakhill Specifications. Bending, N. (unpublished, 2011). May be adjusted to suit local circumstances

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Item	Specification	Possible exclusion 	Comment
Machinery			
Machinery	See ' Cultivation methods '	& Table 15	
Surface Drains¹¹⁶			
Contour berms (bench terraces)	<p>See Appendix 7</p> <p>3 - 4 m wide</p> <p>Slight side-slope into hill (e.g. 1:12, ~8%)</p> <p>Equal cut/fill</p> <p>Cut/fill slopes <1:2 (~50%)</p> <p>Gradient 1:40 - 1:60 (~1½% - 2½%).</p> <p>Feed seamlessly into drains</p>	<p>Variation in longitudinal slope (causes erosion / ponding).</p> <p>Erodible surfaces, especially at interface with main drains</p>	<p>Less erodible than open cross-drains, intercept surface water shed down-slope, conveying to collecting drains</p> <p>Compact e.g. by traversing</p>
	Location as restoration plan	n/a	<p>Plan spacing at 8 m (for more erodible / wetter SFM) to 20 m vertical intervals e.g. for 1:20 (5%) slope = 160 - 400 m for 1:40 (2½%) = 320 - 640 m apart</p>
Earth drains	<p>Location as restoration plan</p> <p>Discharge through vegetated buffer areas sufficient to capture silt e.g. > 10m buffer (> 20 m if watercourse bed > 2 m wide)</p> <p>Cross sectional shape appropriate to conditions e.g. 0.9m deep, 1:2 side slopes</p> <p>Longitudinal slope 1:100 - 1:30 (1% to 3.5%), ideally 1:50 (~2%) facing up-valley</p>	<p>Variation in longitudinal slope (causes erosion / ponding).</p> <p>No cultivation within 2 m</p> <p>Do not connect to natural watercourses except through buffer areas</p>	<p>Use armoured drains in erodible SFM and if drainage required for steeper slopes (> 1:30, 3.5%)</p> <p>Follow Forests and Water: UK Forestry Standard Guidelines</p> <p>(see 'Regulatory regime')</p>
Armoured drains	<p>See Appendix 7</p> <p>Location as restoration plan to collect from berms, swales & earth drains</p> <p>Dig by grading bucket from side as smoothed 'U' shape e.g. 0.8m * 2.4m</p> <p>Surface of pitched stone e.g. 20% 4-10 cm & 80% 15-22 cm cobbles on geotextile, 25 mm layers of 6 mm-dust aggregate above and below</p>	<p>Stone armouring to be pitched onto the grit layer over the geotextile lining firmly by hand as 'cobbles', not loose tipped and firmed by excavator etc</p>	<p><u>Use where made / loose ground conditions, steepness or flow rate risks erosion</u></p> <p>Gradient may need to exceed normal limit (3.5%) on reclaimed areas</p> <p>Transverse retaining cills e.g. Stone 45 cm ↕ * 25 cm ↗ * 50 cm ↘ embedded over the geotextile at 1 m fall (max. 10 m run), in shallow 25 cm ↴ trench</p>

¹¹⁶ Forest Enterprise Scotland, Scottish Lowlands FD Restoration Schedule (unpublished, 2007), Scottish Lowlands FD Specifications, Greenoakhill. Bending, N. (unpublished, 2011) & Forestry Commission, Forestry Training Services guidance. Bending, N (unpublished 1999)

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Item	Specification	Possible exclusion 	Comment
Surface Drains (continued)			
Swales	<p>See Appendix 7</p> <p>Shallow, wide, convex with smooth rounded edges</p> <p>e.g. 45 cm * 3 m, smoothed 1:3 (33%) slope, longitudinal slope 1% to 3.5% (ideally ~ 2 %)</p>		Substitute for conventional 'V' or 'U' earth drains to minimise erosion on reclaimed soils
Silt traps	<p>Pond or excavation along drain for sediment capture</p> <p>Works by slowing water flow for sedimentation, so size is dependent on peak flow rate</p>	<p>Exclude locations that cannot be reached for dredging by excavator</p> <p>Avoid deep, steep-sided excavations & minimise risk to public</p>	Often best located prior to filtration through buffer areas adjacent to natural watercourse, especially if designed as a 'natural' pond
Cultivation with compost			
See also ' Cultivation work rates and costs ' & Tables 16 to 21			
Compost supply	Load into dumpers from central stockpile	No compaction or contamination with SFM / stones	Compost must not be 'spoiled'
	Remove from stockpile sequentially & leave 'sealed' surface each day	No random digging from stockpile	Maintain integrity of stockpile to shed water etc
	Take to cultivation strip by tipping dumper	No wheeled dumpers except in suitable hard routes	Relate load capacity to cultivation logistics (see ' Cultivation methods ')
	Tip compost from uncultivated onto cultivated ground in whole or part loads	No trafficking of cultivated ground. Tip onto un-composted ground only	Achieve specified compost tip size and spacing (see ' Cultivation methods ' & Figure 6)
Cultivation	See ' Cultivation methods '	& Table 15	
	Remove obstructions from cultivation depth e.g. oversize rocks / masonry & steel	Obstructions to be buried below cultivation depth or disposed off working area.	If required, steel rods etc to be 'chased back' and cut off e.g. 20 cm below cultivation depth
Grass seeding	Seed cultivated ground as soon as practicable (e.g. DoT Verge mix)	Exclude unsuitable conditions (e.g. freezing or vey wet weather)	Information readily available from seed merchant web-sites
Records	Map & dates of work on individual planting blocks	n/a	Good records are necessary for effective site management

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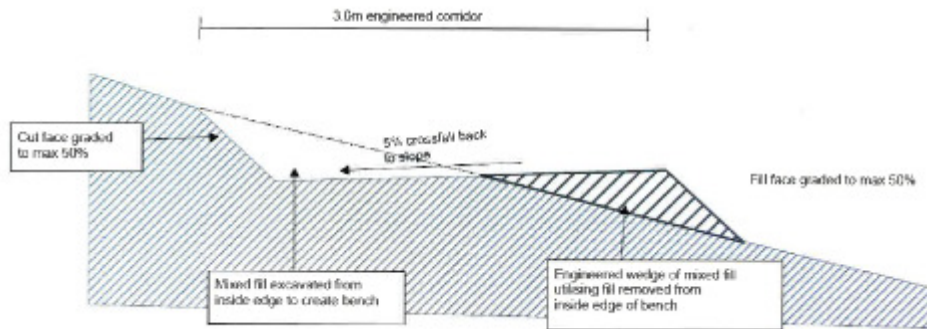
Example of Additional compost characteristics*		
Characteristic	Specification	Comment
pH	6.5 - 8.7	
Conductivity	< 2,000 uS/cm	1:5 soil/water solution
Moisture content	30% to 55%	Wet basis
Bulk density	0.50 to 0.70 g/cm ³	
Organic matter content	40% to 70%	Weight of dry solids
C:N ratio	15:1 to 20:1	
Total nitrogen	1.0%- 2.0%	Weight of dry solids
Ammonium nitrogen	< 25 mg/l	Fresh, water extractable
Nitrate nitrogen	< 200 mg/l	Fresh, water extractable
Total phosphorus	0.15% - 0.30%	Weight of dry solids
Total phosphorus (as P ₂ O ₅)	0.35% - 0.70%	Weight of dry solids
Total potassium	0.75% - 1.5%	Weight of dry solids
Total potassium (as K ₂ O)	0.9 % - 1.8 %	Weight of dry solids

Note *. From Forest Enterprise Scotland, Scottish Lowlands FD. Greenoakhill Specifications. Bending, N. (unpublished, 2011). May be adjusted to suit local circumstances

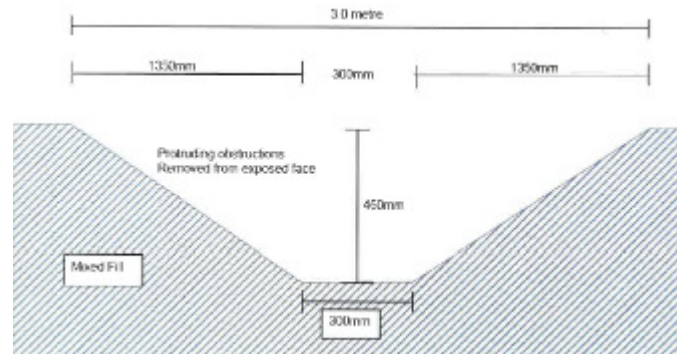
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Appendix 7

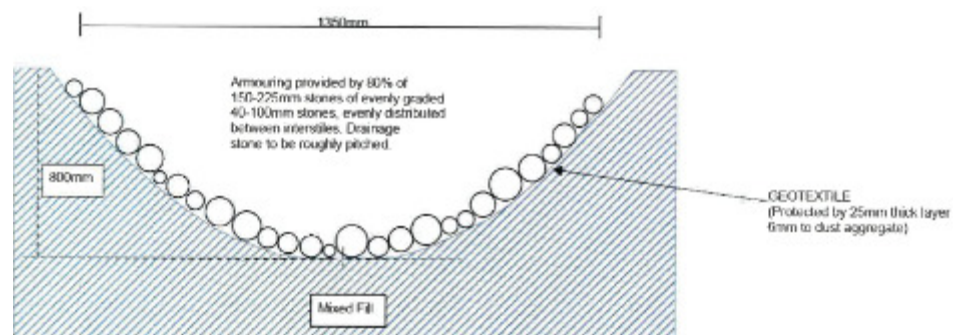
Example diagrams of Contour berm, Swale and Armoured drain



Contour berm



Swale



Stone armoured drain

From Forestry Commission Scotland Schedule 'B' - Detailed specification for ground preparation and drainage works for the establishment of community woodland on a restored inert landfill at Greenoakhill, Broomhouse, Glasgow, January 2011. After Bending, N. & Waters, G. (2011).