Forestry Commission

Practice Guide

Managing forests in acid sensitive water catchments

FOREST SERVICE

Forestry Commission

Practice Guide

Managing forests in acid sensitive water catchments

Forestry Commission: Edinburgh

This publication is also available on our website at: www.forestry.gov.uk/publications

First published by the Forestry Commission in 2014

ISBN: 978-0-85538-911-6

Forestry Commission (2014).
Managing forests in acid sensitive water catchments
Forestry Commission Practice Guide
Forestry Commission, Edinburgh. i–iv + 1–24pp.

Keywords: acid deposition; acidification; catchments; ecology; ecosystem services; forestry; water quality.

FCPG023/FC(ECD)/MLG-2K/AUG14

MIX
Paper from responsible sources
FSC® C115556

Enquiries relating to this publication should be addressed to:

Forestry Commission
Silvan House
231 Corstorphine Road
Edinburgh EH12 7AT
0131 334 0303
publications@forestry.gsi.gov.uk

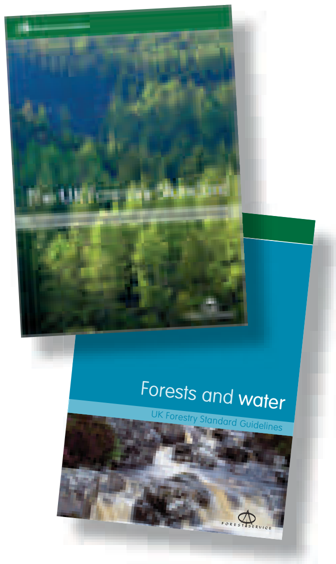
In Northern Ireland, to:

Forest Service
Department of Agriculture and Rural Development
Dundonald House
Upper Newtownards Road
Ballymiscaw
Belfast BT4 3SB
02890 524480
customer.forestservice@dardni.gov.uk

The Forestry Commission will consider all requests to make the content of publications available in alternative formats. Please send any such requests to the Diversity Team at diversity@forestry.gsi.gov.uk or call 0131 314 6575.

Contents

Introduction



The quality of water draining large parts of the uplands of the British Isles has been profoundly affected by atmospheric pollution since the onset of the industrial revolution. Of primary concern has been the widespread acidification of rivers and lakes by the deposition of sulphur and nitrogen compounds derived in part from the combustion of fossil fuels. Acidification has resulted in marked ecological changes in affected waters, including the elimination of many aquatic plant and invertebrate species (Figure 1), the decline or complete loss of fish, and a reduction in the density and distribution of animals such as certain amphibians and birds.

Growing recognition of the adverse environmental impact of atmospheric pollution led to international controls on acidic emissions being introduced in the 1980s. While these have resulted in dramatic reductions in the emissions of sulphur and, to a lesser extent, nitrogen gases to the atmosphere, the response of acidified waters has been slow and many areas remain impacted. The objective of the EU Water Framework Directive is to achieve what it defines as 'Good Ecological Status' in all water bodies by 2027, but the recovery time for waters to respond to emission reductions is hard to predict due to the complexity of factors involved. In some cases, full biological recovery is expected to take decades and Good Ecological Status may not be achieved until after 2027. Consequently, there is an urgent need to implement other measures to promote the recovery process, including measures within areas of forestry.

Forestry is known to affect the acidification of waters, principally due to the ability of forest canopies to capture more acid sulphur and nitrogen pollutants from the atmosphere than shorter types of vegetation. As a result, it is important to manage forestry within vulnerable areas to ensure acidification is not exacerbated and opportunities for improvement are realised. The UK Forestry Standard (UKFS) and its supporting Guidelines on *Forests and water* requires that: 'Where new planting or restocking is proposed within the catchments of water bodies at risk of acidification, an assessment of the contribution of forestry to acidification and the recovery process should be carried out; details of the assessment procedure should be agreed with the water regulatory authority'. This guidance, agreed by the relevant forestry, water and nature conservation authorities in the UK, describes how to meet this requirement, including the need to undertake a critical load assessment where new planting or restocking is proposed within the catchments of water bodies that are failing or at risk of failing Good Ecological Status due to acidification, and a site impact assessment where felling is planned.

Figure 1 Freshwater invertebrates such as mayflies are very sensitive to changes in water acidity.

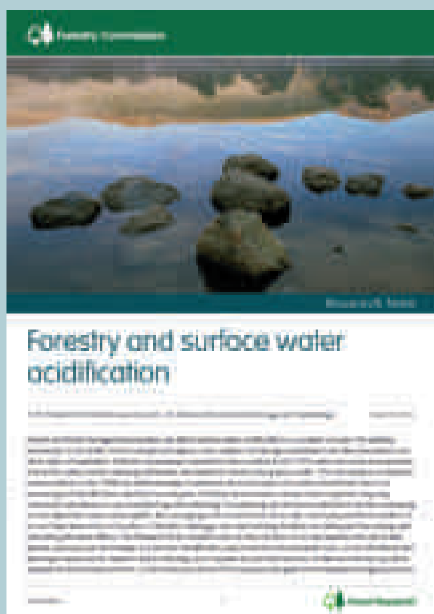
The Practice Guide provides detailed advice on how to undertake these assessments to ensure forestry does not cause adverse impacts. It also describes measures that can be taken to promote biological recovery of acidified waters. The guidance applies to those involved in managing, planning and regulating woodland creation and the felling and restocking of existing forests within vulnerable areas. It relies on early dialogue with the local water regulatory authority (see Useful sources of information) and water companies (where appropriate) to discuss the assessment process, the availability of relevant chemical, biological and fisheries data and information, and possible mitigation measures.

The regulatory authorities have agreed that some flexibility should be allowed in implementing the detailed guidance to reflect local factors, providing that changes are supported by scientific evidence and agreed between forestry and water regulators, or in the case of designated sites, with nature conservation agencies. This flexibility includes avoiding the need to undertake assessments for very small planting proposals or the restocking of small woodlands (e.g. <2–5 ha), and excluding areas where it is agreed that the scale or nature of existing forestry does not pose a threat to water bodies. Nature conservation agencies may require that greater precaution and more detailed assessment be undertaken for any planting proposal which might affect individual Natura 2000 sites or SSSIs/ASSIs through existing consultation arrangements, based on the conservation agencies' evidence of site vulnerability to acidification. The relevant regulatory authorities may provide additional guidance at the country level to aid implementation, including on water sampling and analysis. Water and forestry regulators may adopt a strategic approach and undertake regional-scale water sampling campaigns of failing and at risk water bodies to narrow down which sub-catchments are at risk from a forestry effect.

The Practice Guide is divided into two main sections. The first deals with how to undertake a critical load assessment for new planting and forest restocking, including the collection and analysis of water samples, and how to use the results to calculate critical load and exceedance values. The second section considers how to undertake a site impact assessment for forest felling. The steps involved in undertaking both assessments are summarised in separate decision trees (Figure 3 and Figure 7). Advice in both sections will need to be followed when formulating or reviewing a forest management plan, or when applying for a felling licence where no plan exists.

Forestry and surface water acidification

The science underpinning this Practice Guide is described in the Forestry Commission Research Note 'Forestry and surface water acidification'. The Note considers the various ways that forests and forestry management practices can affect surface water acidification, including the role of tree species, planting scale and design. It covers the identification and protection of vulnerable areas, use of critical load and site impact assessments, research and monitoring, and measures to promote recovery. The Note also defines failing and at risk water bodies, and explains the nature of the 'critical loads approach'.



How does the approach relate to previous guidance?

This Guide provides advice on managing the acidification issue detailed in the UKFS Guidelines on *Forests and water*. There are a number of significant changes to the previous method, most notably in the way that areas at risk from a forest acidification effect are identified. The new approach takes advantage of the Water Framework Directive classification of water body status to allow impacted waters to be better targeted. The Directive's acidification status replaces the use of the UK freshwater critical loads exceedance map to define potential acid sensitive areas. The critical loads exceedance map (*Forests and water guidelines*, 4th edition) was a rather blunt tool due to its coarse 10 km grid scale, and it necessitated both exceeded and adjacent squares to be considered as being at risk. Other important changes have been made to the methodology applied in catchment-based assessments to reflect the most recent research and experience.

While our understanding of the impact of forestry on acidification has greatly improved, uncertainty remains about the rates and extent of recovery of aquatic ecosystems and interactions with future climate and land-use change. This is particularly the case concerning the role of nitrogen, with conflicting model predictions on the risk of soils becoming increasingly nitrogen saturated and leading to nitrate release and renewed acidification. These issues continue to be investigated in a number of research programmes, the results from which will be used to update or revise this guidance as appropriate.

Where does the guidance apply?

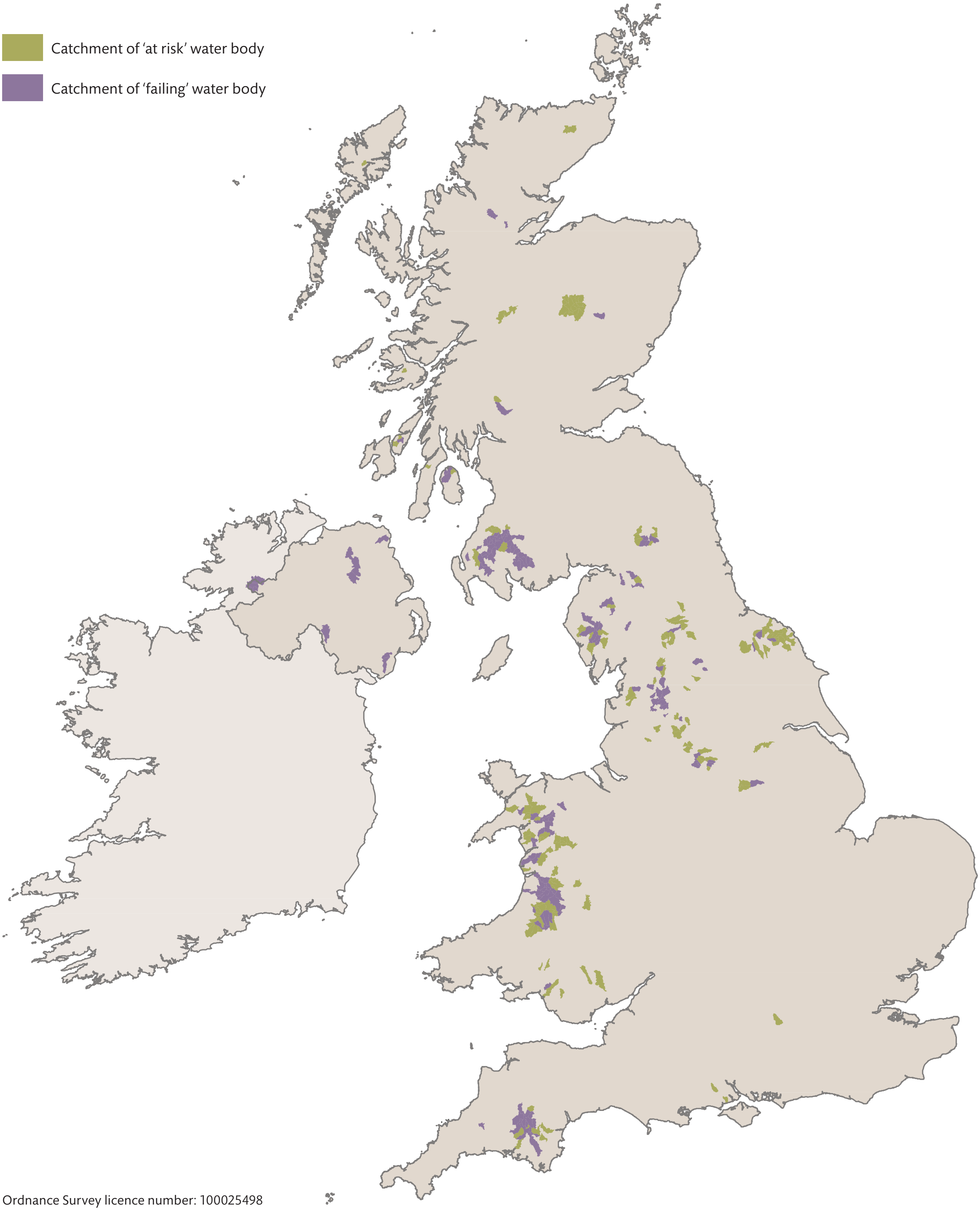
The Practice Guide applies to the areas of the UK that are vulnerable to acidification, which are defined as the catchments of river and lake water bodies identified by the water regulatory authorities as failing or at risk of failing Good Ecological Status due to acidification. Failing water bodies are those where the acidity of out-flowing waters exceeds Water Framework Directive chemical standards for pH or acid neutralising capacity. It is important to note that the definition of 'at risk water bodies' differs from that of the Water Framework Directive. In this Guide, the term applies to water bodies that are failing for fish or other aspects of freshwater biology and data suggests that acid deposition is a contributing factor. It also includes water bodies lying upstream or adjacent to those failing due to acidity but where data are lacking to confirm their condition. Figure 2 shows the distribution of failing and at risk water bodies across the UK as of July 2013. An updated digital map showing the boundaries of these water bodies is available using the link in Figure 2.

Measures to promote recovery

The UKFS Guidelines on *Forests and water* specify three guidelines (WG1, WG2 and WG3) for undertaking assessments of the impact of forestry proposals on surface water acidification at the catchment or site level. These are described in the following sections, along with measures to reduce the effects of new planting or restocking within vulnerable areas.

The Guidelines also outline a range of forest management measures that are concerned with promoting the biological recovery of acidified waters and ensuring that certain forestry management practices do not inadvertently enhance the risk of acidification (WG4, WG5, WG6, WG7 and WG8). These apply to the catchments of water bodies that are either failing or at risk of failing Good Ecological Status due to acidification and are set out below.

Figure 2 Catchments of river and lake water bodies in the UK failing, or at risk of failing, Good Ecological Status due to acidification caused by acid deposition (Reference date: July 2013)*. For the latest digital maps showing catchments vulnerable to acidification, see: www.forestresearch.gov.uk/tools-and-resources/catchments-vulnerable-acidification.



*The water regulatory authorities continue to monitor the condition of all UK water bodies, which may lead to changes in those classed as failing or at risk of failing from acidification, e.g. as some recover due to emission reductions. The digital map will be updated at least every six years to coincide with the review of Water Framework Directive River Basin Management Plans. Note that there are no catchments failing, or at risk of failing, in the Shetland Isles.

- WG4 – On soils classified as at high risk of increased soil and water acidification, regardless of water body status, avoid short rotation forestry or coppice, and the harvesting of whole trees, forest residues and tree stumps (see Useful sources of information).

- WG5 – Co-ordinate the phasing and timing of felling of conifers in riparian zones to promote the ecological recovery of watercourses.

  Box 1 lists a number of good practice measures that can be taken to improve the design and management of the riparian zone, which can have a profound effect on the quality of riparian and aquatic habitats, and thus on freshwater life.

- WG6 – Limit the planting of alder to less than 10% of the area within riparian zones.

  Alder is not suitable for larger-scale riparian planting because of its ability to contribute to acidification through nitrogen fixation and nitrate release. There is also an issue of alder's susceptibility to infection by Phytophthora.

- WG7 – Avoid filling trenches, created for mounding on restock sites, with fresh brash.

  Filling cultivation trenches with fresh/green brash can promote nitrate leaching to water and thereby acidification. Similarly, 'mulching' fresh brash (breaking and incorporating/mixing with the soil) after harvesting can accelerate nitrate leaching and thus should also be avoided.

- WG8 – For water-bound roads and tracks, avoid using material resulting in metallic, sulphide-rich or strongly acidic, polluted water run-off.

  This forms a General Binding Rule (GBR) in Scotland (GBR22a) under the Water Environment (Controlled Activities) (Scotland) Regulations 2005 (as amended). GBRs are an integral part of the water regulatory framework in Scotland and have a legal status.

!

The riparian zone is defined as the area of land adjoining a river channel, including the river bank but not the wider floodplain. Riparian vegetation can directly influence the condition of the aquatic ecosystem, for example by providing shade, leaf litter input and stabilising river banks.

Box 1 Good practice measures underpinning WG5

- Accelerate the clearance of dense-shading, riparian conifer stands to open out streamsides. On wind-firm sites consider leaving the occasional conifer tree in the riparian zone to provide some shade and large woody debris inputs until the new riparian woodland becomes established.
- Adjust forest management plans to prioritise the removal of remaining streamside conifer stands from those stretches/reaches of streams and rivers where dense shading is constraining the movement of fish to other stretches with better water quality.
- Encourage more active management of cleared riparian zones to facilitate quicker establishment of an open canopy of native riparian woodland, providing 50% dappled shade. This includes controlling conifer regeneration.
- Where possible (subject to landscape and related constraints), extend conifer clearance beyond the minimum buffer widths recommended for watercourses (see the UKFS Guidelines on *Forests and water*), such as to incorporate steep side slopes and boggy source areas and flushes. This includes leaving a minimum buffer width of 10 m along small streams (channels <1 m wide) where these are accessible to and have the potential to support fish.
- Work with other landowners, fishery groups and water regulatory authorities to identify forestry barriers (e.g. poorly designed culverts) to fish movement that may be constraining the recolonisation of previously impacted reaches. Where appropriate, plan for their replacement to improve access.
- Encourage the expansion of native riparian woodland into treeless areas to improve habitat conditions for fish.

How to carry out a critical load assessment

The UKFS Guidelines on *Forests and water* provide the context for undertaking critical load assessments, specifically:

- Where the area of new planting or restocking could contribute to increased acidification or delay recovery, undertake a catchment-based critical load assessment (WG1).

- Avoid new planting or restocking where catchment assessments based on critical load calculations and relevant supporting information indicate this will lead to deterioration in water body status or prevent recovery to good status (WG2).

A critical load assessment is a method for assessing the susceptibility of freshwaters to acidification and is applied at the catchment scale (the catchment comprises all of the upslope land that naturally drains to an individual stream or lake).

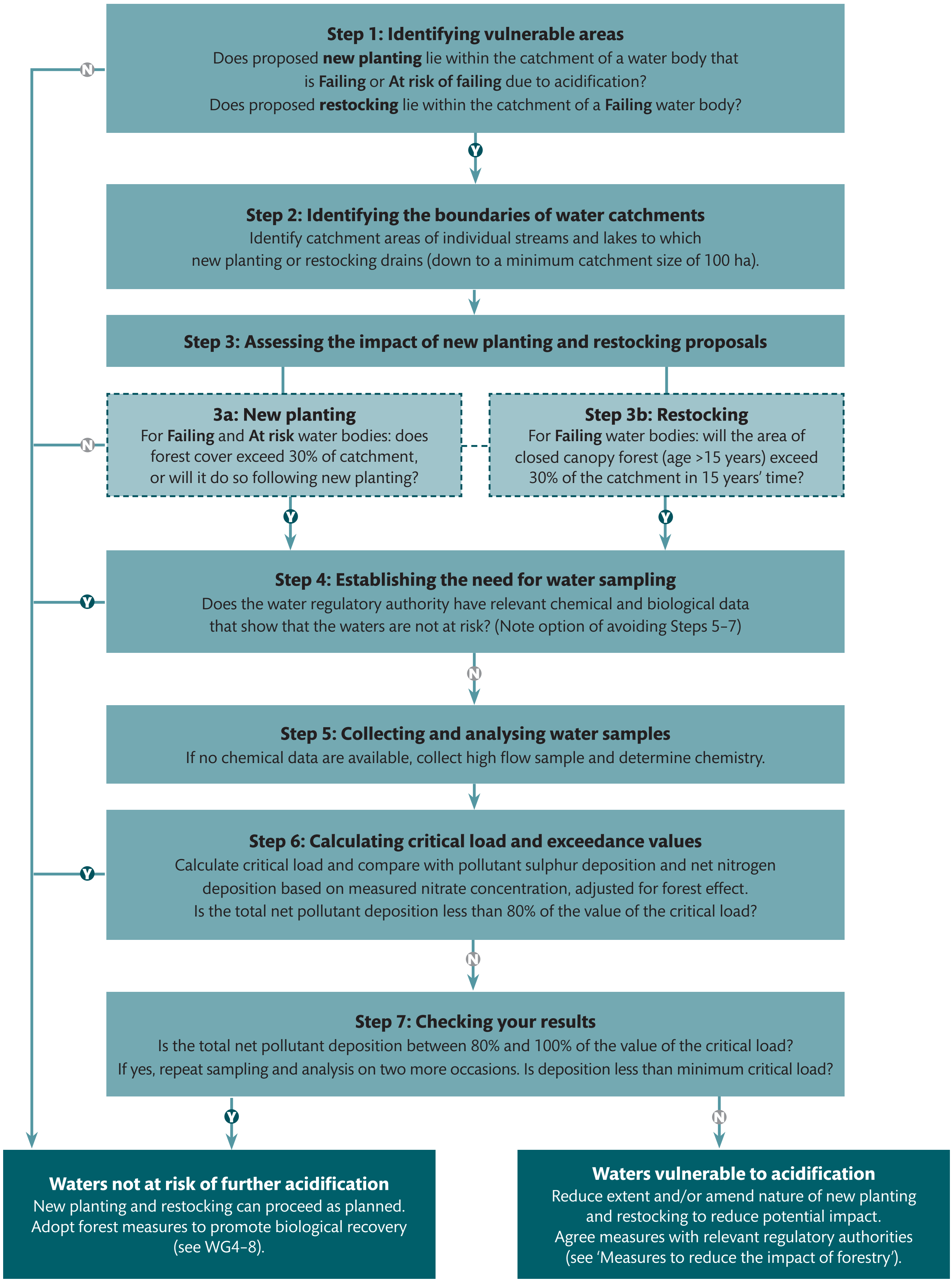
A critical load is defined as 'the highest deposition of acidifying compounds that will not cause chemical changes leading to long-term harmful effects on the ecosystem structure and function'. In the case of freshwaters, this equates to the amount of buffering available to neutralise inputs of acidity from atmospheric pollution, which if exceeded would lead to surface water acidification and damage to freshwater life. Streams, rivers and lakes integrate all of the major acidification and neutralising processes within their catchment area and thus provide a useful reference point for determining the critical load, based on a measurement of water chemistry. This rationale defines the 'catchment-based' term.

As noted earlier, forest canopies can capture more sulphur and nitrogen pollutants from the atmosphere than shorter vegetation and thus changes to the nature of forest cover in a catchment will affect the risk of the critical load being exceeded. New planting represents a change in land use and potentially poses a significant risk of contributing to critical load exceedance by permanently increasing pollutant scavenging. Critical load assessments for new planting are therefore required for both failing and at risk water bodies.

In contrast, chemical conditions are expected to improve following restocking of existing forests due to the replanted trees being exposed to much lower pollution levels than during the previous rotation, which will reduce the scavenging effect. There are also opportunities to enhance the recovery process through forest redesign and management. Since restocking is less likely to lead to critical load exceedance, a catchment-based assessment is only required for restocking sites within failing water bodies.

Figure 3 summarises the steps involved in undertaking a catchment-based critical load assessment for new planting or restocking. The criteria used to determine the need for an assessment differ between the two and are described below. Note that the regulatory authorities have agreed that forest managers have the option of avoiding the need to collect samples and calculate critical load exceedance if they assume that the area is vulnerable to a forestry acidification effect and can agree and implement specific measures (see 'Measures to reduce the impact of forestry') to minimise the potential risk of new planting or restocking contributing to acidification.

Figure 3 Decision tree for undertaking a catchment-based critical load assessment (see guidance on Steps 1–7 on pages 8–13).



Step 1

Identifying vulnerable areas

Use the online map (link in Figure 2) to determine whether the proposal lies within the catchment of a water body that is:

- **Failing** Good Ecological Status due to acidification (for new planting and restocking).
- **At risk of failing** Good Ecological Status due to acidification (for new planting only).

If this is the case, check the current status of the water body with the water regulatory authority to confirm that it remains failing or at risk (see Box 2).

Step 2

Identifying the boundaries of water catchments

Identify the catchment area of the nearest stream or lake (as shown on a 1:25 000 OS map) that the proposed new planting or restocking drains to by drawing the boundaries of the catchment. For a stream, start at the **outlet**, i.e. the point of intersection/confluence with the next stream below (point '**O**' in catchment **A** in Figure 4 and 5). For a lake, start at the **outflow**. From either side of the outlet or outflow, draw a line upslope perpendicular to the next contour, then continue these two lines across consecutive contours until the highest points are reached (see arrows in Figures 4 and 5). This process continues by following the edge of the natural drainage basin to link up consecutive high points, until the two lines meet, completing the catchment.

The catchment areas of all streams and lakes potentially affected by the proposed new planting or restocking need to be similarly determined, including the catchments of larger streams and rivers that are joined downstream (see catchments **C** and **D** in Figure 4 and 5). These are identified by following the same process as above, using the outlet or outflows of consecutive confluence points, and incorporating all upstream land draining to them. The process stops when either the sea is reached or it becomes apparent that the area of forest cover is very unlikely to exceed 30% of the catchment, or downstream water bodies are not acidified.

There are two exceptions to identifying catchment areas. The first is that it is not necessary to identify the catchments of small streams or lakes with areas <100 ha (see stream '**X**' in Figure 4). Where this is unclear, the boundaries need to be drawn and the catchment area checked. The second is, when proceeding downstream, it is not necessary to calculate the catchment area at a confluence point if the 'stream order' (see Glossary) does not change. For example, the joining of a lower order stream to a higher order stream does not cause the receiving stream to change its order and therefore a catchment assessment is not required for the receiving stream (only for the tributary stream) at this point (e.g. see the confluence point marked '**Y**' in Figure 5).

!

The assessment of whether forest restocking poses a risk of water acidification should be undertaken when developing or reviewing a forest management plan or, if there is no plan, when applying for a felling licence.

It is also worth checking to establish whether a site impact assessment may be required for felling as there may be advantages in co-ordinating both assessments (especially with respect to water sampling).

Box 2 Checking water body status with the water regulatory authority

There are a number of reasons why water bodies may no longer be Failing or At risk of failing:

- It is possible that the status of a particular water body may have improved since 2011 (Figure 2 is based on 2009–2011 data).
- Further investigations by the water regulator may have determined that some of the water bodies that were originally classed as being at risk are not impacted by acid deposition.
- At risk water bodies may only be at risk within headwater areas and thus new planting proposals in lower parts of the water body catchment may not pose a problem (due to local variation in soils and geology). Many water bodies drain catchments larger than 10 km^2 and headwater streams tend to be more acid sensitive than the larger rivers they drain into.
- The water regulator may have collected or know of reliable local data on freshwater macroinvertebrates and/or on fish populations within the failing or at risk water body that could indicate whether the site is acidified.

Figure 4 Identifying water catchments* for new planting proposals to determine which require a critical load assessment (CLA).

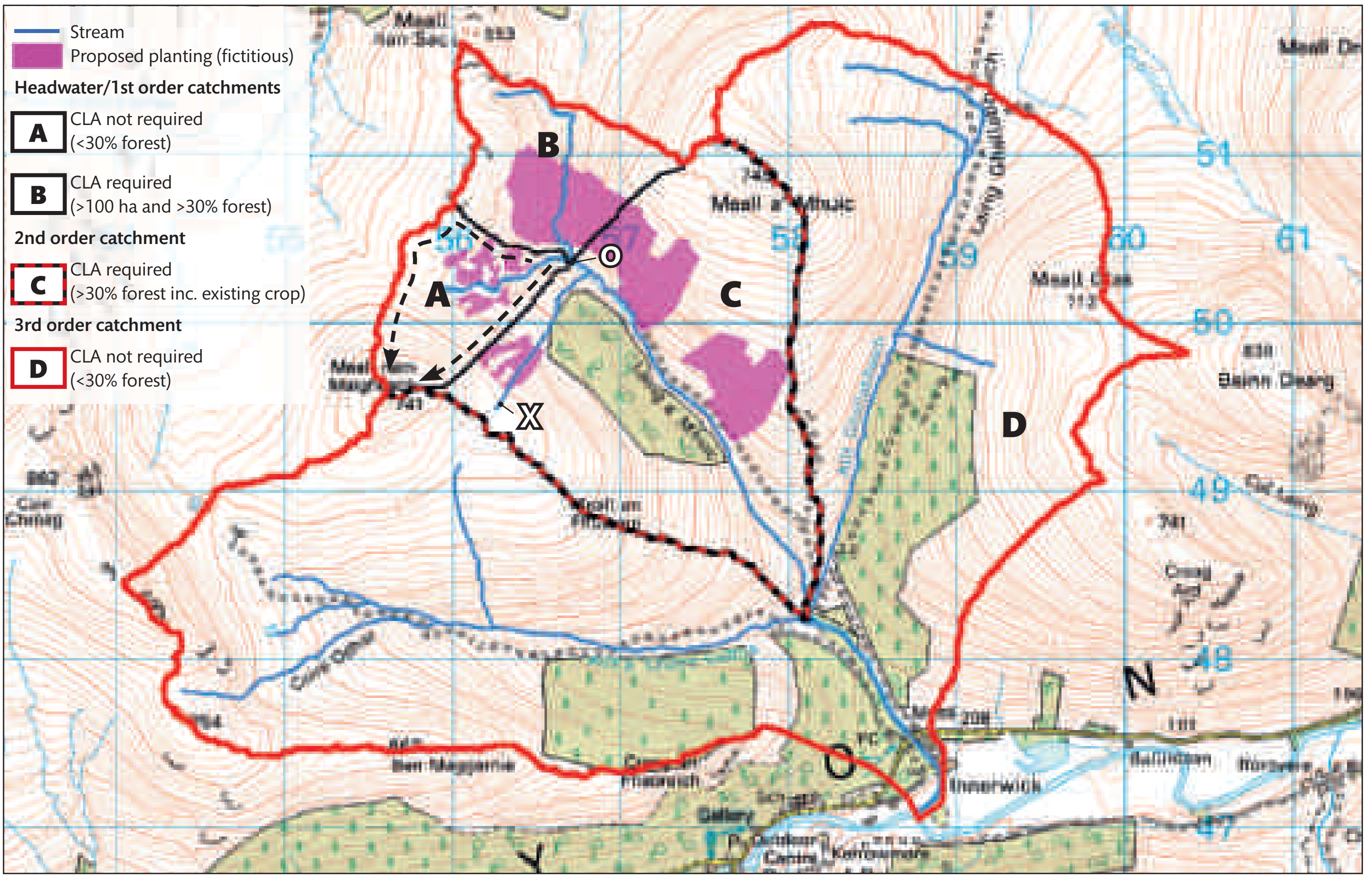
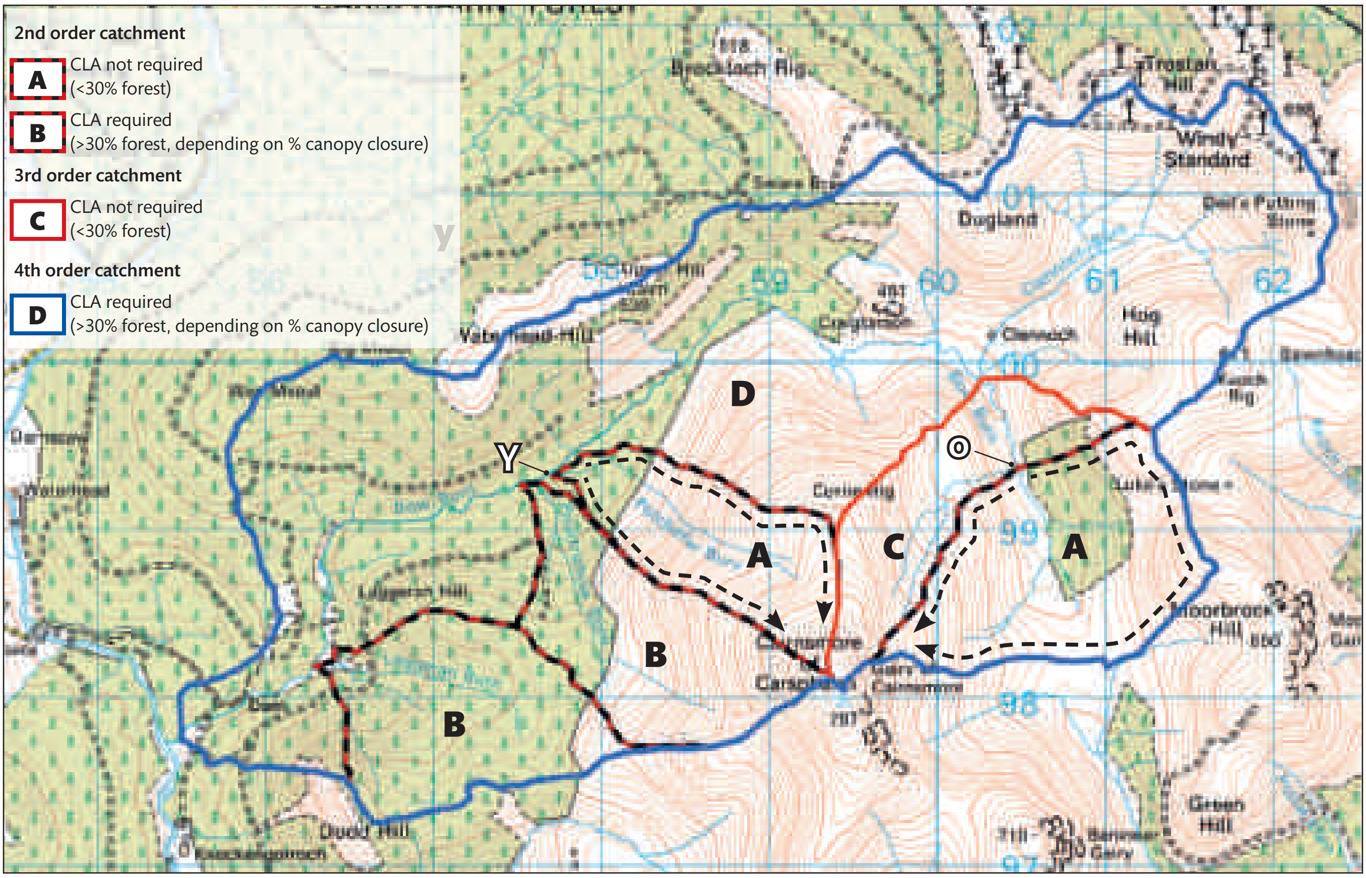


Figure 5 Identifying water catchments* for proposed restocking of existing forest to determine which require a critical load assessment (CLA). All first order catchments are <100 ha and thus not delineated.



*If you are uncertain about the identification of stream or lake catchments, check with the local water regulatory authority or forestry authority.

Step 3a

Assessing the impact of new planting proposals

Calculate the percentage area of new planting (both coniferous and broadleaved but excluding open space) within all appropriate downstream catchments to which the area drains (note that the catchment area of a lake includes both the land and the lake surface). As noted in Step 2, catchments with areas less than 100 ha do not require a separate calculation and instead are incorporated into the catchment of the next confluence downstream.

If the area of forest to be planted exceeds 30% of any of the catchments or the existing area of forest already exceeds this threshold (or will do so when combined with the new planting), proceed to Step 4 to determine if it could contribute to critical load exceedance.

If woodland planting will not lead to the 30% cover figure being exceeded it is unlikely to contribute to critical load exceedance and pose a risk of acidification. Planting can therefore proceed as planned.

Step 3b

Assessing the impact of restocking proposals

> **!**
>
> In catchments where there are forests in multiple ownership, the combined effect of restocking in different forest management plans will need to be assessed (or estimated where no plan exists).

Estimate the proportion of closed canopy forest cover (both coniferous and broadleaved) expected in 15 years' time within all identified catchments downstream of the forest area. Catchments with areas less than 100 ha do not require a separate calculation and instead should be incorporated into the catchment of the next confluence downstream.

If the area of closed canopy forest cover will exceed 30% in any of the catchments, proceed to Step 4 to determine if the planned restocking could contribute to critical load exceedance.

If restocking will not lead to the 30% closed canopy cover figure being exceeded it is unlikely to contribute to critical load exceedance and pose a risk of acidification. Restocking can therefore proceed as planned.

Step 4

Establishing the need for water sampling

Check with the water regulatory authority about the availability of water chemistry data for the site in question – if they have confirmed that it is necessary to determine the critical load. Appropriate chemical data to allow the calculation of critical load may already be available and so remove the need for a water sampling exercise. Where no chemical data exist, there will be a need to collect at least one water sample per site. If sampling is required, the approach and chemical analyses should be agreed with the water regulator. Seek a contractor and agree costs.

Note that there is an option of bypassing the water sampling and critical load calculation by assuming the area is vulnerable to a forestry acidification effect. This option may be expedient where the scale and nature of the proposed planting or existing forest cover breaches the 30% threshold by a small or modest margin. In such cases, it may be relatively easy to agree and implement specific measures to minimise the risk of forestry contributing to acidification (see Measures to reduce the impact of forestry on page 14).

Step 5

Collecting and analysing water samples

Sample the stream, river or lake draining each catchment that exceeds the forest cover threshold. Sampling points should be located upstream but reasonably close to the outlet/confluence point with the next stream, river or lake, or downstream but close to the outflow of a lake. Precise locations will need to allow for access and health and safety considerations, and sampling details should be agreed with the water regulatory authority.

It is likely that a contractor will have to be appointed to undertake the work and the cost of carrying out the sampling and chemical analysis, as well as for calculating the critical load and exceedance, agreed and paid for by the applicant or forest owner (see 'Analysing the samples' and 'Step 6' below). The local office of the forestry regulator should be able to advise on potential contractors and laboratories, as well as give a guide to the likely costs involved.

When to collect samples

!

The person carrying out the sampling should be agreed with the water regulatory authority and could include suitably trained forestry and water regulatory staff, fishery groups or contractors. For high flow sampling, they should be based locally as they will need to respond at short notice after heavy rainfall.

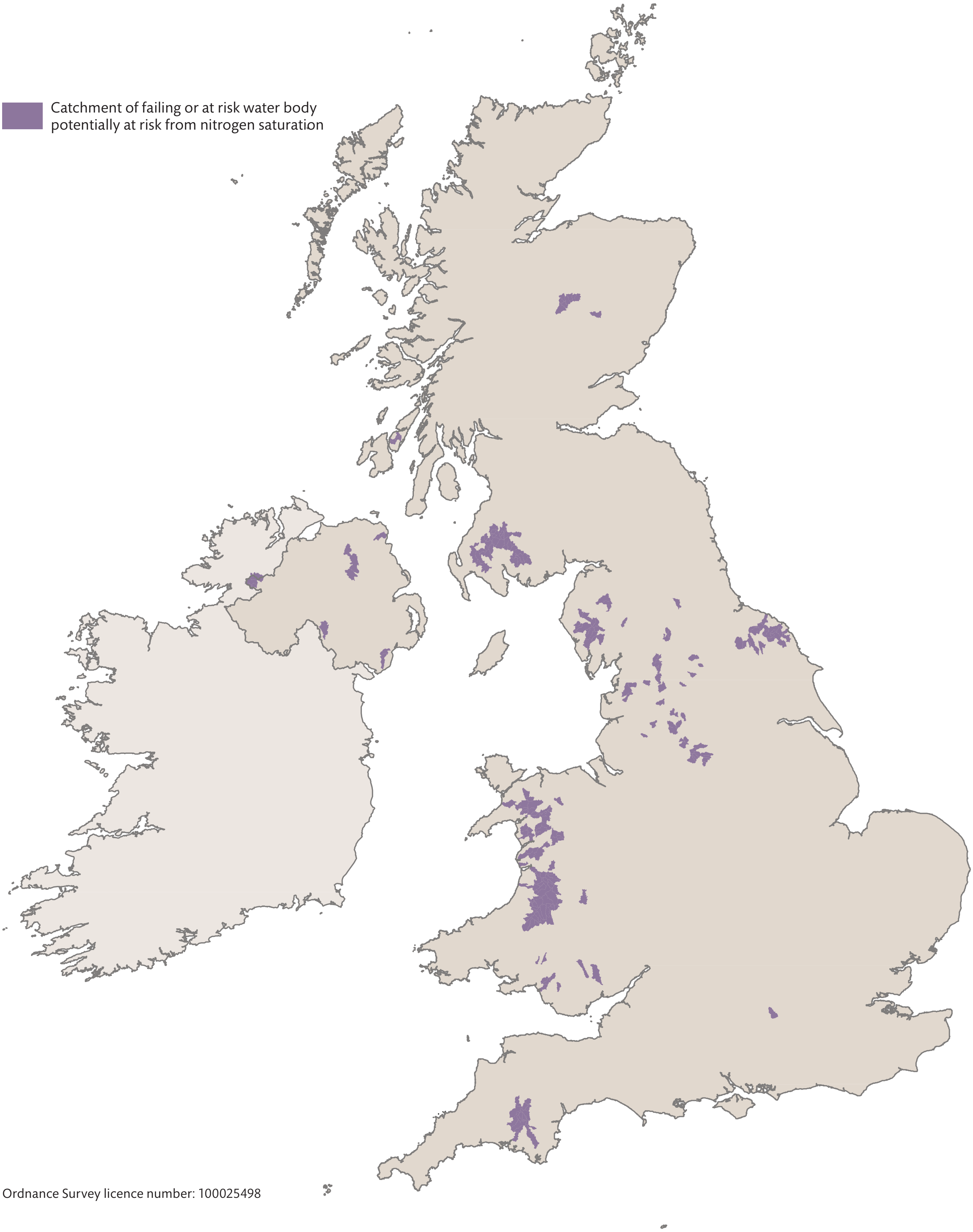
Collect water samples from streams or rivers at 'high flow', when conditions tend to be most acidic. 'High flow' should generally be taken to mean a 'spate' following heavy rainfall but not a real 'flood'; flows need to be at least above average. Such flows can occur at any time of the year but are most common during winter and spring periods. They will usually only last for a matter of hours to, at most, one or two days following significant rain events. The water regulatory authorities can advise on when flow conditions are suitable for sampling; they operate a network of flow gauging stations and 'real-time' data may be accessible via their website. Extreme events such as periods of major snow-melt or heavy rainfall after a prolonged dry period should be avoided as these can result in atypical water chemistry, affecting the critical load calculation.

In areas showing signs of 'nitrogen saturation' and a seasonal release of nitrate to waters outside the growing period (Figure 6), sampling should generally be restricted to the period January to March inclusive (when nitrate concentrations are likely to be highest). Where this is not feasible, an allowance should be made (see Appendix 1), guided by the water regulatory authority, for the potentially lower nitrate concentrations in waters when sampled at other times of the year (particularly during the summer, when plant/biological uptake of nitrogen from soils is greatest).

Larger lakes (surface areas greater than 50 ha) can act to dampen variability in inflowing streams and therefore outflows can generally be sampled under any flow condition. However, summer and autumn periods should be avoided within areas at risk of nitrogen saturation due to seasonal reductions in nitrate concentrations (see Figure 6), or an allowance made for this factor as per rivers.

In some cases it may be possible to sample streams and rivers at any flow and time of year provided that this is timed to coincide with the sampling of a comparable 'local' established, long-term monitoring site. Chemical knowledge of these 'analogue' sites could potentially be used to calibrate the sample data for a new site and provide an estimate of annual mean chemistry. Work is ongoing to evaluate this approach.

Figure 6 Catchments of river and lake water bodies in the UK failing, or at risk of failing, Good Ecological Status due to acidification and potentially at risk from nitrogen saturation (Reference date: July 2013)*.



Ordnance Survey licence number: 100025498

*Note that there are no catchments failing, or at risk of failing, in the Shetland Isles.

How to collect samples

Sampling needs to follow a standard protocol to avoid the risk of contamination and ensure a valid sample is obtained. The laboratory undertaking the chemical analysis (see below) should provide, or specify, appropriately labelled sample bottles and instructions on how samples need to be taken. Where uncertain, seek advice from the water regulatory authority. It is important that, once collected, samples are delivered to the laboratory for analysis in accordance with their protocols for sample storage and delivery. This will include keeping the samples cool (but not frozen) in a fridge until delivery. The preference is for samples to be placed in a cool box or bag and sent via a courier for next-day delivery.

Analysing the samples

The water regulatory authority may be able to analyse the water samples but, failing this, an alternative competent laboratory should be contacted. Water samples need to be filtered according to the laboratory's protocol and analysed for calcium (0.02 mg per litre), magnesium (0.02 mg per litre), sodium (0.02 mg per litre), potassium (0.02 mg per litre), chloride (1.0 mg per litre), sulphate (0.2 mg per litre), and nitrate (0.01 mg per litre) to appropriate detection limits (shown in brackets). Sample pH should also be determined, although it is not part of the critical load calculation or site impact assessment. Water analyses should be completed within two weeks of the samples being received by the laboratory.

Step 6 Calculating critical load and exceedance values

Use the water chemistry data to calculate the critical load and determine whether this is exceeded by acid deposition using the method described in Appendix 1. If acid deposition is less than the critical load, new planting or restocking is unlikely to pose a risk and should be able to proceed as planned.

If the critical load is found to be exceeded, the catchment stream, river or lake will be at risk of further acidification and the proposed new planting or forest restocking has the potential to exacerbate the problem. Unless measures can be agreed to reduce its impact (see next section), it is unlikely that new planting will be approved until acid deposition falls below the critical load. For existing forests, exceeding the critical load will mean the extent of restocking will have to be curtailed or its nature amended to reduce its impact; measures will need to be discussed in detail and agreed with the regulatory authorities.

Where the critical load exceedance calculation generates a close result (acid deposition is less than but within 20% of the critical load value), there is a need to check the result (see Step 7).

Step 7 Checking your results

For close results (see above), collect high flow samples on another two occasions and determine chemistry as described under Step 5. Calculate the critical load for each sample and compare with the original result. Select the lowest critical load value from the three samples and determine whether this is exceeded by acid deposition. Very close results (acid deposition is within ±5% of the lowest critical load value) should be discussed with the water regulatory authority, who may be able to draw on local freshwater biology data to inform the decision as to whether new planting or restocking can proceed as planned.

Measures to reduce the impact of forestry

New planting proposals

Where the critical load is exceeded for a new planting proposal, the main option is to try to offset its impact by reducing the scale of planting so that it falls below the 30% forest cover threshold in the catchment(s) concerned. Changing forest type (e.g. from coniferous to broadleaved) or tree species appears to have little impact on pollutant scavenging by forests. However, a switch to broadleaves does have the potential to reduce nitrate leaching within nitrogen saturated areas, although the magnitude of this effect remains uncertain at present. Planting nitrogen-fixing species, such as alder, which could promote nitrate leaching, should be limited to less than 10% forest cover. In situations where an existing forest cover contributes to the new planting exceeding the 30% threshold, it is possible that this could be mitigated through forest redesign changing the age distribution (so that a smaller area is at closed canopy when the planted area reaches this stage), by introducing more open space or by adopting other measures (see below).

Restocking proposals

Where the critical load is exceeded for a restocking proposal, the main scope for reducing its impact within the catchment is to amend the forest management plan, or its equivalent, in terms of the mix of crop age and area of open space so that the proportion of future closed canopy forest cover falls below the 30% threshold for the catchment. While this could succeed in catchments with intermediate levels of forest cover, it is unlikely to work in extensively (>50%) forested catchments. Additional measures that could help in such circumstances include converting conifer stands to broadleaves, or to continuous cover forestry or low impact silvicultural systems. While these options are not expected to reduce pollutant scavenging, both could help to reduce the risk of nitrate release from the soil and thereby effective nitrogen deposition. Where none of these measures are possible, deforestation may be the only option to ensure water quality is protected. Such a decision may be subject to an Environmental Impact Assessment.

Liming

Liming has been extensively used in the past in some countries to protect endangered populations of fish and other aquatic life from acidification, especially when the effects of acid deposition were greatest. The use of liming has been more restricted in the UK, where there has been a greater focus on refining and better targeting applications to aid the recovery of fish populations in acidified streams. This includes the liming of stream source areas and stream channel gravel beds to enhance conditions in the most acid sensitive headwaters. A number of trials of these techniques are under way in Wales and southwest Scotland to assess their effectiveness in practice. Where liming occurs, it will be very difficult to undertake catchment-based critical load or site impact assessments due to the altered water chemistry. In some situations it may be possible to draw on baseline stream chemical data collected prior to liming treatments, but otherwise an alternative method of assessment will need to be discussed with the water regulatory authority.

It is not possible to justify a wider use of liming forest streams to ameliorate acidification until the benefits are shown to outweigh the costs and risks, especially when natural recovery appears to be under way, albeit slowly. Similarly, liming is not an appropriate mitigation method to allow new planting or restocking to proceed within areas where the catchment-based critical load is exceeded.

How to carry out a site impact assessment

The method involves determining the scale of planned felling within the catchments of water bodies failing or at risk of failing Good Ecological Status due to acidification (Figure 2). Where felling exceeds 20% of individual catchments in any three-year period, water sampling and chemical analysis of the catchment stream or lake outflow is required to assess whether the short-term release of nitrate that can follow the large-scale harvesting of some forest sites could have an adverse impact on the freshwater environment. The determination does not rely on the critical loads approach that is applied to new planting and restocking, but instead uses a simpler assessment of whether there is sufficient acid neutralising capacity (ANC) in waters to buffer the acidity associated with any nitrate released. Figure 7 summarises the steps involved in undertaking a site impact assessment for clearfelling.

> **!**
>
> The UKFS Guidelines on *Forests and water* (WG3) states that: 'where an area to be felled will exceed 20% of the acidified catchment in any three-year period, undertake a site impact assessment'.

Figure 7 Decision tree for undertaking a site impact assessment for felling (see guidance on Steps 1–6 on pages 16 and 17).

Step 1

Identifying vulnerable areas

Use the online map (link in Figure 2) to determine whether the proposed felling lies within the catchment of a water body that is **Failing** or **At risk of failing** Good Ecological Status due to acidification.Ifthisisthecase,checkthestatusofthewaterbodywitht he water regulatory authority to confirm that it remains failing or at risk (see Box 2, page 8).

Step 2

Identifying the boundaries of water catchments

As in Step 2 of the method for determining whether a critical load assessment is required, identify and calculate the catchment areas of all streams and lakes potentially affected by the proposed felling, including the catchments of larger streams and rivers that are joined downstream (see Figure 5). These are identifiedbyusingtheoutletoroutflowsofconsecutive confl uence points, and incorporating all upstream land draining to them, including 'nested' smaller catchments. Catchments with areas less than 100 ha do not require a separate calculation and instead should be incorporated into the catchment of the next confl uence downstream. The process stops when either the sea is reached, it becomes apparent that the area of forest cover and therefore of potential felling within the catchment is very unlikely to exceed 20%, or downstream water bodies are not acidifi ed.

Step 3

Assessing the impact of felling proposals

For each of the individual catchment areas exceeding 100 ha in extent identifiedinStep2, determine the proportion (including broadleaves) planned to be felled within any three-year period. All proposed felling needs to be included in the calculation, including that on neighbouring forest land under different ownership (this is more likely to arise as catchment size increases). Where the scale of felling exceeds 20% of a catchment there is a need to revise plans to bring it within this threshold or undertake a chemical assessment of the risk of the larger-scale felling causing damage (Step 5). The forestry regulator will advise on revisions to plans in cases of multiple ownership.

!

The assessment of whether forest felling poses a risk of water acidification should be undertaken when developing or reviewing a forest management plan or, if there is no plan, when applying for a felling licence.

Where an assessment is also required for forest restocking, there may be advantages in co-ordinating both assessments, especially in respect of water sampling needs.

The need for larger-scale (>20% of catchment) sanitary felling to control forest pests or diseases has to be considered alongside the legal requirement to protect the water environment. If there is insufficienttimetoundertakeasiteimpactassessmentorlittlescope to vary the level of felling required, effort should focus on adopting other management measures to limit the risk or impact of nitrate leaching. Early contact should be made with the water regulatory authority as well as the forestry authority to agree how to proceed.

In addition to the measures listed at the end of this section, consideration should be given to whole-tree harvesting, reseeding or early replanting to speed up revegetation and restore nitrate uptake. The UKFS Guidelines on *Forests and water* recommend avoiding whole-tree harvesting on soils classifiedathighriskofincreasedsoilandwateracidifi cationduetothe longer-term threat posed by the removal of base cations in harvested produce over consecutive harvesting cycles (WG4). However, it may be appropriate as a one-off action to help mitigate the short-term impacts of larger-scale felling, providing the risk of ground damage and erosion can be controlled.

Step 4

Establishing the need for water sampling

Check with the water regulatory authority about the availability of water chemistry data for the site in question. Appropriate chemical data to allow the calculation of acid neutralising capacity may already be available and so remove the need for a water sampling exercise. Where no chemical data exist, there will be a need to collect at least one water sample per site. If sampling is required, the approach and chemical analyses should be agreed with the water regulator. Seek a contractor and agree costs.

Step 5

Collecting and analysing water samples

Water sampling and analysis for a site impact assessment follows the same general approach as described for a catchment-based critical load assessment, including the need to sample streams and rivers under high flow conditions. Sample each catchment stream, river or lake that exceeds the felling threshold. Use the guidance in Step 5 of the previous section on when and how to collect samples and on analysing the samples.

Step 6

Calculating acid neutralising capacity

There are two ways of calculating acid neutralising capacity. The first is to separately sum the base cation (calcium, magnesium, sodium and potassium) and strong acid anion (chloride, sulphate and nitrate) concentrations measured in µeq per litre in the sampled water and then subtract the latter from the former (µeq = microequivalent – a unit used to express the amount of a chemical dissolved in water). Alternatively, where the laboratory is able to analyse water samples for Gran alkalinity and dissolved organic carbon (DOC), acid neutralising capacity can be calculated using the Cantrell* method:

ANC = Alkalinity (µeq per litre) + (4.5 x DOC (mg per litre))

A threshold of 30 µeq per litre has been set for high flow samples to protect salmonid fish from any acid pulse generated by felling. Based on the results:

- If the calculated ANC is greater than 30 µeq per litre, felling can proceed as planned.
- If the calculated ANC is less than or equal to 30 µeq per litre, the stream, river or lake is considered to be at risk from the planned scale of forest harvesting within the catchment.

In the latter case, the area to be felled in any three-year period needs to be reduced to below 20% of the catchment, unless it is agreed with relevant regulatory authorities that constraints such as tree stability or site conservation require a larger felled area and other management measures (see below) can be implemented to reduce the risk of nitrate leaching and acidification.

*Cantrell et al. (1990). Evaluation of acid neutralizing capacity data for solutions containing natural organic acids. *Geochimica et Cosmochimica Acta* 54.

Measures to reduce the impact of felling

A number of forest management measures can be used to minimise nitrate leaching following felling, including removing brash from riparian buffer zones to encourage revegetation and nitrate uptake, and avoiding filling trenches created for mounding on restock sites with fresh brash. These are covered by the following numbered guideline points from the UKFS Guidelines on *Forests and water*:

- Avoid filling trenches, created for mounding on restock sites, with fresh brash (WG7)

The filling of cultivation trenches with fresh brash can promote nitrate leaching to water and thereby acidification. Similarly, 'mulching' brash (breaking and incorporating/mixing with the soil) after harvesting can accelerate nitrate leaching and thus should also be avoided.

- Keep streams and buffer areas clear of brash as far as practicable; avoid felling trees into watercourses and remove them and any other accidental blockages that may occur (WG39)

Note that the removal of trees and accidental blockages from watercourses should be confined to locations where these pose a local flood risk or prevent fish movement. Otherwise:

- Retain large woody debris within streams unless it is clear that it forms a barrier to fish or poses a flood risk; design and manage riparian woodland to sustain the delivery of large woody debris to small watercourses (<5 m wide) (WG84)

Useful sources of information

Forestry Commission publications

- The UK Forestry Standard (FCFC001)
- The UK Forestry Standard Guidelines – Forests and soil (FCGL006)
- The UK Forestry Standard Guidelines – Forests and water (FCGL007)

Research

- Forestry and surface water acidification (FCRN016)

Other publications

- Guidance on site selection for brash removal (Forest Research)
- Stump harvesting: interim guidance on site selection and good practice (Forest Research)

Websites

Forestry Commission

- www.forestry.gov.uk/ukfs/water
- www.forestry.gov.uk/felling
- www.forestry.gov.uk/eia
- www.forestry.gov.uk/grants
- www.forestry.gov.uk/publicregister

Other forestry authorities

- Forest Service (Nothern Ireland) – www.dardni.gov.uk/forestry
- Natural Resources Wales – www.naturalresourceswales.gov.uk

Water regulatory authorities

- England: Environment Agency – www.environment-agency.gov.uk
- Scotland: Scottish Environment Protection Agency – www.sepa.org.uk
- Wales: Natural Resources Wales – www.naturalresourceswales.gov.uk
- Northern Ireland: Northern Ireland Environment Agency – www.doeni.gov.uk/niea

Other websites

- Joint Nature Conservation Committee (JNCC) – jncc.defra.gov.uk
- Met Office – www.metoffice.gov.uk
- UK National Focal Centre on Critical Loads Mapping and Modelling – cldm.defra.gov.uk
- UK Upland Waters Monitoring Network – awmn.defra.gov.uk
- Countryside Survey – www.countrysidesurvey.org.uk
- Natural England – www.naturalengland.org.uk
- Scottish Natural Heritage – www.snh.org.uk

Appendix 1 – Calculating critical load exeedance

The calculation of critical load uses the 'steady-state water chemistry model' (SSWC) derived by Henriksen*. The method assumes a steady-state situation where outputs balance inputs; the model is unable to predict the timescale for reaching equilibrium conditions (see Forestry Commission Research Note *Forestry and surface water acidification* for further information).

The SSWC involves a chemical mass balance calculation to estimate the buffering that is available in a water sample to neutralise acid inputs. It is based on the principle that the 'non-marine' concentration of base cations measured in water reflects the net weathering processes in the soils and rock of the catchment it drains, and thus the available buffering. The 'marine' component is calculated by assuming that all chloride present in the water is of marine origin and using established chloride to base cation ratios in seawater to deduct the proportion of each present as a neutral, marine salt. A further deduction is made for the component of non-marine base cations that are being leached from catchment soils due to acid deposition to derive the inherent, pre-industrial concentration. This is estimated using a set of empirical equations.

The total available buffering is then adjusted to allow for the level required for protecting salmonid fish. This level or critical threshold is represented by an appropriate value of acid neutralising capacity (ANC), which is a measure of the sum of base cations minus the sum of strong acid anions in the water. A value of ANC 20 μeq per litre is applied to high flow samples. Where annual mean chemistry data are available, a value of 40 μeq per litre is used instead.

Subtracting the critical ANC value from the estimated pre-industrial concentration of non-marine base cations gives the actual amount of buffering that is available to neutralise acid inputs. The last step is to convert the resulting non-marine base cation concentration to a critical flux or load by multiplying by the annual volume of run-off/discharge from the catchment. The latter is estimated using a general relationship between annual rainfall and evaporation, which assumes that 15% of rainfall is lost to evaporation within the UK uplands. An annual rainfall value is therefore required for the general locality and preferably should be the mean of several years. Ideally a longer-term (e.g. 10 year) mean should be selected; the water regulatory authority may be able to provide rainfall data free of charge. The 15% value for evaporation only applies to the wet uplands of western Britain and should be increased for drier parts of the UK. In such areas (where annual rainfall is <1000 mm), use can be made of standard maps and 1 km^2 values of 'effective rainfall', which the water regulatory authority may also be able to provide free of charge.

Having calculated the critical load from the water sample, the final stage is to compare this with the acid deposition load received by the catchment. The UK National Focal Centre for Critical Loads Mapping and Modelling produces three-year average acid deposition values for different land covers on a 5 km grid across the UK, based on a combination of measurements and modelling (http://pollutantdeposition.defra.gov.uk). The latest available three-year dataset for a 100% forest cover should be used as a precautionary approach to allow for model uncertainty and local variability.

The Focal Centre generates total deposition values for both sulphur and nitrogen for each 5 km grid square but only those for sulphur are directly applicable. This is because much of the nitrogen deposited on the land is either taken up by the vegetation or immobilised in the soil. Instead, the effective acidifying load of nitrogen deposition is estimated from the component that is leached to water as nitrate. This is determined by multiplying the measured nitrate concentration in the sampled water by the annual run-off value for the catchment.

*Henriksen *et al.* (1992). Critical loads of acidity: Nordic surface waters. *Ambio 21.*

Outline of the steady-state water chemistry model

Critical load = ($[BC]_o^*$ – [ANC limit]) x Q

Critical load is expressed in keq H per hectare per year calculated from other parameters.

$[BC]_o^*$ = non-marine base cation concentration in streamwater prior to acidification being the sum of:

Sodium (Na) + potassium (K) + calcium (Ca) + magnesium (Mg)

Non-marine components calculated based on the chloride ratio in seawater (Na: 0.858, K: 0.018, Ca: 0.037, Mg: 0.198)

[ANC limit]= Critical concentration appropriate to target organism:

Value of 20 µeq per litre (for high flow chemistry) or 40 µeq per litre (for mean chemistry) selected from literature for brown trout

Q = Run-off (rainfall/1.15).
Annual rainfall (mm) is obtained from the local water regulatory authority; advice on adjusting the 1.15 factor in drier parts of the country (<1000 mm annual rainfall), such as by using annual effective rainfall values, is also available from the local water regulatory authority

Calculation of non-marine base cation concentration prior to acidification:

$[BC]_o^* = [BC]_t^* - F (([SO_4]_t^* + [NO_3]_t) - ([SO_4]_o^* + [NO_3]_o))$

$[BC]_t^*$ = Current non-marine base cation concentration measured in sampled streamwater (µeq per litre)

F = F factor, representing fraction of extra acid anions leached from soil due to hydrogen and aluminium. Calculated as: $\sin [90 \times ([BC]_t^* /400)]$ (unitless)

$[SO_4]_t^*$ = Current non-marine sulphate concentration measured in sampled streamwater (µeq per litre)

$[SO_4]_o^*$ = Original non-marine sulphate concentration, calculated as:
$(15 + (0.16 \times [BC]_t^*))$ (µeq per litre)

$[NO_3]_t$ = Current nitrate concentration measured in sampled streamwater (µeq per litre)

$[NO_3]_o$ = Original nitrate concentration (assumed to be zero)

Calculation of critical load exceedance:

Clex = $S^*dep + ([NO_3] \times Q) - CL$

Clex = Critical load exceedance (keq H per hectare per year)

S*dep = Non-marine sulphur deposition (keq H per hectare per year)
(part measured, part modelled, obtained from UK National Focal Centre)

$[NO_3]$ = Nitrate concentration measured in streamwater (µeq per litre).
In nitrogen saturated areas this is multiplied by 3 for new planting of conifer and by 1.5 for new planting of broadleaves (adjusted for % cover in catchment)

Q = Run-off (rainfall/1.15) (as above)

CL = Critical load (keq H per hectare per year)

Since woodland planting could lead to increased nitrate leaching (due to deposition scavenging) in areas prone to nitrogen saturation, the nitrate concentration is multiplied by a factor of three for new planting of conifer forest in these cases (weighted linearly by the proportion of forest cover represented by the new planting in the catchment). Alternatively, the nitrate concentration could be taken from sampling and analysing a nearby forest stream (avoiding the need to apply a multiplier), which is likely to be the best option where new planting is proposed in catchments with >30% cover of existing forest. Figure 6 identifies the failing and at risk water bodies thought to be most at risk of nitrogen saturation and therefore where the nitrogen multiplier applies, but details should be checked with the local water regulatory authority.

A smaller multiplier of 1.5 should be used for new planting of broadleaves to reflect the lower susceptibility of broadleaved woodland soils to nitrogen saturation. The use of a modifier does not apply to catchments known to be significantly impacted by nitrogen run-off from agriculture or human habitation. This is likely to include catchments with more than 15% cover of improved grassland and arable. Information on the extent of agricultural land within catchments is available from the Countryside Survey (www.ceh.ac.uk/data).

No enhancement of nitrate is recommended for assessing restocking proposals since ongoing changes to forest design and felling practices are expected to reduce the risk of nitrate leaching from existing forests. However, as noted above, uncertainty remains about the future course of nitrogen saturation across all sensitive areas, regardless of forest cover. This guidance will therefore be kept under review and updated if the results of ongoing research and monitoring show evidence of a general increase in nitrate leaching.

The estimated nitrogen deposition value is added to that of sulphur for the 5 km grid square in which the catchment lies to give the total net annual acid deposition. Where a larger catchment straddles two or more 5 km grid squares, an average value should be taken.

If the total sulphur and estimated nitrogen deposition exceeds the calculated critical load then the catchment stream, river or lake is at risk of further acidification and the proposed new planting or forest restocking has the potential to exacerbate the problem. In contrast, if the total deposition is less than the critical load, new planting or restocking is unlikely to pose a risk and can proceed as planned.

A caveat to the above rule is where the calculation generates a close result and there is a risk of an incorrect assessment due to associated uncertainties. To allow for this, where the total net acid deposition is less than but within 20% of the critical load value, the assessment should be repeated for a second and a third time, involving the collection of additional samples. Where assessments are repeated, the lowest value of the critical load should be taken and the decision based on the end result. Results that are very close to zero (±5%) should be discussed with the water regulator, who may be able to draw on fish and freshwater macroinvertebrate data to help inform the outcome.

Glossary

Acid deposition The process by which acid pollutants, primarily sulphur and nitrogen compounds derived in part from the combustion of fossil fuels, deposit from the atmosphere to the ground. This can be in particulate form as aerosols or gases (dry deposition), or through direct input in aqueous solution or suspension, as rain and snow (wet deposition) or cloud water (occult deposition).

Acid neutralising capacity (ANC) A measure of the overall buffering capacity of a solution against acidification. Often calculated as the sum of strong base cations minus the sum of strong acid anions.

Acidification A continuing loss of acid neutralising capacity manifested by increasing hydrogen ion concentrations and/or declining alkalinity; the term may be applied to waters or soils.

At risk water bodies Water bodies defined by the Water Framework Directive as failing for fish or other aspects of freshwater biology and data suggest that acid deposition is a contributing factor. It also includes water bodies lying upstream or adjacent to those failing due to acidity but where data are lacking to confirm their condition.

Base cation A positively charged ion such as calcium, magnesium, sodium and potassium that increases the pH of water when released to solution by mineral weathering.

Brash The residue of branches, leaves and tops of trees, sometimes called 'lop and top', usually left on site following harvesting.

Buffer An area of land which protects the watercourse from activities on the adjacent land, such as by intercepting polluted run-off. The buffer area will usually include the riparian zone and may extend into the adjacent land.

Buffering capacity A measure of the ability of a soil to resist a change in pH.

Catchment area The area of land from which precipitation drains to a defined point in a river system, or to a lake or reservoir.

Chemical mass balance calculation Calculation of a chemical reaction or process whereby the chemical mass of reactants and products must balance due to the law of conservation of mass.

Confluence The junction of two streams or rivers.

Continuous cover forestry A silvicultural system whereby the forest canopy is maintained at one or more levels without clearfelling.

Critical load (of acidity) The highest deposition of acidifying compounds that will not cause chemical changes leading to long-term harmful effects on ecosystems.

Environmental Impact Assessment A statutory requirement under the EU Environmental Impact Assessment Directive 85/337/EEC (as amended by 97/11/EC and 2003/35/EC). This introduced a Europe-wide procedure to ensure that environmental consequences of projects are evaluated and public opinion is taken into account before authorisation is given.

Failing water bodies (see also At risk water bodies) Water bodies defined by the Water Framework Directive where water quality fails to meet the chemical standards for pH or acid neutralising capacity for achieving Good Ecological Status.

Flushes Areas of wet ground over which water flows without being confined to a definite channel.

Forest management plan (woodland management plan) A plan which states the objectives of management together with details of forestry proposals over the next five years and an outline of intentions over a minimum period of 10 years. Forest management plans allow managers to demonstrate that relevant elements of sustainable forest management have been addressed, and can be used to authorise management operations as required for grant aid.

Good Ecological Status One of five classes of ecological status under the Water Framework Directive, the others being high, moderate, poor and bad. Good Ecological Status is where elements of aquatic biology such as fish and invertebrates are only slightly changed from their reference conditions as a result of human activities, and the environmental quality standards are achieved for relevant physico-chemical quality elements.

Gran alkalinity A method of determining the alkalinity of a water sample using an acidimetric titration in two pH ranges (4.5–4.0, and 4.0–3.0) devised by Gran*.

Headwater A tributary stream of a river close to or forming part of its source.

High flow A stream or river in spate conditions following heavy rainfall; water flow remains within the channel and thus not high enough to cause a flood.

Liming The addition of a base material to soils or waters, typically calcium and magnesium carbonate, for the purpose of neutralising acidity.

Low impact silvicultural system An alternative silvicultural system to clearfelling that minimises the environmental impact of forestry operations, including group selection, shelterwood, small coupe felling, coppice and minimum intervention.

Macroinvertebrates Relatively large (visible to the eye) invertebrate animals such as beetles, snails, mussels, shrimps and insects (larval and nymph stages) that usually live in, on or near the bottom of streams, rivers and lakes.

Nitrate leaching The removal of nitrate in solution from the soil via water movement, with the potential to contaminate surface water and groundwater.

Nitrogen saturation A state in soils where the availability of ammonium and nitrate exceeds the total combined plant and microbial nutritional demand, leading to the increased leaching of ammonium or nitrate below the rooting zone.

pH A logarithmic index for the hydrogen ion concentration in an aqueous solution, used as a measure of acidity. A pH below 7 is considered to be acidic and one above 7 alkaline.

Restocking Replacing felled areas by sowing seed, planting, or facilitating natural regeneration.

Riparian Relating to or situated adjacent to a watercourse or water body.

Scavenging (of pollutant) A function of the greater air turbulence and mixing created by tall forest canopies, which increases the rate at which air pollutants are deposited onto trees.

Short rotation forestry The practice of growing single or multi-stemmed trees of fast-growing species on a reduced rotation length primarily for the production of biomass.

Steady-state water chemistry model A form of critical load model that assumes a state of equilibrium between acid deposition inputs and soil and water chemical conditions, allowing the use of a simple mass balance calculation to determine whether catchments are able to maintain acid neutralising capacity in surface waters above a defined threshold for protecting freshwater life.

Stream order A method of classifying stream size, starting in the headwaters and assigning the smallest perennial streams a value of one or 'first order'. It takes the joining of two first order streams to form a second order stream, two second order to form a third order stream, and so on down the river system.

UK freshwater critical loads exceedance map A UK map showing the exceedance of critical loads of total acidity for freshwater ecosystems based on water samples collected from acid sensitive areas on a 10 km x 10 km grid.

Vulnerable areas Areas of land with base-poor, slow-weathering soils and rock subject to sufficiently high levels of acid deposition to cause surface water acidification and the receiving water body to fail Good Ecological Status.

Water body The basic water management unit defined under the Water Framework Directive for which environmental objectives are set. Water bodies can be parts of rivers, lakes and estuaries, stretches of coastal water or distinct volumes of groundwater.

Water Framework Directive An EU Directive that came into force in December 2000 with the aim of establishing a common framework for Community action on water policy. It commits European member states to achieve good qualitative and quantitative status of all water bodies through a process of river basin management planning.

Water regulatory authority In Scotland, the Scottish Environment Protection Agency (SEPA); in England, the Environment Agency; in Wales, Natural Resources Wales; and in Northern Ireland, the Northern Ireland Environment Agency.

*Gran, G. 1952. Determination of the equivalence point in potentiometric titrations, Part II. *Analyst*, **77**.

Atmospheric pollution in the form of acid deposition has been dramatically reduced since international controls on emissions were introduced in the 1980s. However, acidification still affects acid-sensitive regions of the UK, damaging fisheries and causing adverse ecological changes in freshwaters. Forestry is known to influence the degree of acidification, principally due to the ability of forest canopies to capture more acid sulphur and nitrogen pollutants from the atmosphere than other types of vegetation. As a result, there is a need to manage forestry within vulnerable areas to ensure that it does not lead to increased acidification or delay the recovery of waters to Good Ecological Status. This Practice Guide describes the measures that can be taken to minimise adverse impacts and provides a methodology for determining whether new planting, restocking or felling proposals could pose a risk to freshwaters. It includes maps showing the locations of vulnerable areas and decision trees to guide those involved with woodland creation or the felling and restocking of existing forests in affected areas through the steps of catchment-based critical load and site impact assessments.

Forestry Commission

Silvan House
231 Corstorphine Road
Edinburgh
EH12 7AT

£6.00

www.forestry.gov.uk