# Sustainable Forestry and the Protection of Water in Great Britain

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## Background

Approximately 12% (2.8 million hectares) of the land area of Great Britain is under woodland or forest cover. More than half of this has been created in the last century and ownership is roughly two-thirds private and one-third public. Most of the expansion involved afforestation with evergreen species, predominately Sitka spruce (*Picea sitchensis*), in upland areas, which also formed the main water gathering grounds for the water industry. Stream waters were generally pristine in nature and of high conservation and fishery value, making them very vulnerable to disturbance. During the 1970's and early 1980's it became apparent that forestry could have a major impact on both water quantity and quality, highlighting the need for improvements in forestry practice. This contributed to the wider shift in policy on sustainable development and led to the introduction of a range of supporting measures.

This paper briefly describes the regulatory instruments and incentives that are designed to achieve sustainable forestry in Great Britain, summarises the main water issues, and then details developments in best planning and management practice to conserve the quantity and quality of water resources.

## Forestry Regulation

It is government policy to encourage the sustainable management of existing woods and forests, and an expansion of tree cover to increase the many diverse benefits that forests can provide. Implementation is achieved by a range of regulatory instruments and incentives, which are primarily operated by the Forestry Commission. These are outlined in Table 1.

The principal regulatory instrument for the protection of freshwaters is the Forests and Water Guidelines. They were first published in 1988 with the aim of advising forest owners and managers how forests influence the freshwater ecosystem and how operations should be carried out in order to protect and enhance the water environment. The Guidelines apply equally to the state and private forestry sectors and it is a condition of approval for forestry grants and plans that all operations meet the required standards. A joint committee conducts regular reviews with representatives from the water and forestry regulatory authorities and conservation agencies. Since their introduction there have been two revisions, in 1990 and 1993, to ensure that the Guidelines continue to reflect the results of recent research and experience. A fourth revision is currently underway.

## Effects of Forestry on the Freshwater Environment

The basis of the Guidelines is the recognition that forests and forestry operations can have a marked effect on both the quantity and quality of water moving through forest stands. Good forest management can help to conserve water resources, counter diffuse water pollution and enhance aquatic and riparian habitats. In contrast, poor planning and management can exacerbate water shortages, contribute to local flooding, lead to increased acidification, and increase soil and stream erosion, turbidity, sedimentation, and pollution. These can damage wildlife and fisheries, and increase costs of treatment for drinking water.

The following is a brief summary of the main forest and water issues in Great Britain:

**Water yield**

*Evergreen forest*

Water yields from catchments containing closed canopy evergreen forest are usually less than from moorland or grassland catchments due to higher interception losses. Interception increases with forest height and canopy development and is greatest in the wetter and windier parts of Great Britain. Though assessments of the degree of reduction in a given catchment cannot be exact, research suggests there may be a 1.5-2.0% reduction of potential water yield for every 10% of a catchment under mature evergreen forest.

The drier and less windy climate in the lowlands reduces the interception loss, but tree transpiration rates may be higher due to roots reaching deeper soil water reserves. The net effect of a mature evergreen forest can be a marked reduction in the limited water yields that characterise these areas, amounting to as much as 70% or more. This can have important implications for the quantity and quality of lowland groundwater resources and the maintenance of river flows.

*Deciduous woodland*

Evaporation from deciduous woodland is generally much less than from evergreen forest due to reduced interception losses during the leafless period. Studies have shown that groundwater recharge under beech and ash woodland on chalk can be expected to be similar or slightly higher than that under managed grassland. However, recharge under deciduous woodland on drier sandy soils is likely to be reduced compared to grass due to greater transpiration losses sustained by deeper rooting. Another exception concerns short rotation coppice crops of poplar and willow, which can sustain very high transpiration rates on moist or wet soils, resulting in a 50% or greater reduction in water yield for a fully established crop.

**Base Flows**

Summer base flows in rivers can often be critical for wildlife, water supply, or the disposal and self-purification of effluent. Research suggests that the reduction in water yield associated with upland evergreen forests has a limited effect on these flows. Indeed, the cultivation and drainage of wet soils prior to planting can significantly increase base flows, an effect that may persist throughout a complete rotation. Base flows may be reduced in headwater catchments by the continued growth of a forest or temporarily increased by tree felling, but they appear to be relatively unaffected by forestry in larger catchments. The situation is different in the lowlands, where large areas of evergreen forest can be expected to result in a significant decline in summer base flows. This is because of the greater potential reduction in water yield and the fact that base flows tend to form a much larger proportion of annual run-off. Deciduous woodland is generally considered to have a small effect on base flows.

## Flood Flows

*Evergreen forest*

Forestry can have a range of effects on flood flows, depending on the type and scale of forest operation. The ploughing and drainage of a catchment can result in a significant increase in peak flows - of the order of 15-20%, decreasing to 5% after 20 years - and a decrease in the time to peak of up to one-third. The impact of smaller-scale drainage treatments depends on the location of the site with respect to the catchment outlet. Quicker run-off from sites close to the catchment outlet will help to reduce overall peak flows, while the opposite is likely to be the case for more distant sites.

Forest establishment and growth generally appear to have a small effect on peak flows, with the impact of clearfelling often being difficult to detect. The main exception concerns lowland forests, where the greater reduction in water yield is expected to reduce peak flows, with benefits for flood control. This is enhanced by the drier, organically richer soils under forests, which can receive and hold more rainwater.

*Deciduous woodland*

The effect of deciduous woodland on flood flows remains uncertain. One potentially significant factor is the ability of woodland to improve rainfall infiltration in soils damaged by poor agricultural practice. Soil compaction due to overstocking and repeated cultivation has been implicated in recent flooding events and research is underway to determine the extent to which woodland planting could help to reduce rates of run-off and so assist flood control.

Floodplain woodland is increasingly recognised as having an important role to play in attenuating flood peaks, as well as providing many other environmental benefits. Flood flows are able to spread out over natural floodplains and the presence of a diverse woodland structure, e.g. in the form of multiple woody dams on the woodland floor, is expected to aid the retention and delay the release of flood waters. Strategically placed floodplain woodland may therefore offer a means of assisting downstream flood defence. However, several concerns remain to be investigated such as the effect of the backing-up of floodwaters on local housing, river access for maintenance, a reduction in engineered flood control, and an increased risk of large woody debris blocking downstream structures.

## Acidification

Acidification remains a problem in a number of acid sensitive areas of the UK, resulting in damage to fisheries and increased costs for water treatment. Forestry is recognised as a contributory factor due to the ability of forest canopies, particularly evergreen, to capture more acid pollutants from the atmosphere. The increased capture, often termed scavenging, is a function of the stand structure which creates turbulent air mixing. The effect therefore becomes more important as trees grow and the height of the stand increases. The enhanced capture of mist, which can contain large concentrations of sulphur and nitrogen, is greatest at high altitude because of the increased duration of cloud cover and high wind speeds.

**Sedimentation and turbidity**

Good forest management minimises soil disturbance and compaction, and protects the soil resource. Forest planting can therefore help to reduce the higher rates of soil erosion that are often associated with more intensive land uses, such as arable cropping. The bare cultivated soils associated with autumn sown winter cereals are particularly at risk of erosion by heavy rainfall or strong winds. Strategically placed woodlands in the form of shelterbelts or riparian buffer zones can help to reduce soil losses from such sites.

Conversely, poor forest management can lead to large quantities of sediment entering surface waters. There have been instances where cultivation, drainage, harvesting, road building and a lack of adequate road maintenance have caused unacceptable turbidity levels and siltation, seriously disrupting water treatment works, water supplies and fisheries. The financial consequences of such incidents can be very great. Sediment can also have a high nutrient, metal or pesticide content, which can contribute to the enrichment and contamination of downstream waters, particularly reservoirs and lakes where the sediment may remain for a considerable period of time.

**Nutrient Enrichment**

Forestry can affect nutrient enrichment in a number of ways. Firstly, the application of phosphate and nitrogen fertilisers that are required to achieve the satisfactory establishment of forests on certain soil types can lead to significant leaching losses. Nutrient releases following large-scale felling operations, windblow or wildfire can also present a problem for receiving waters. The main concern is with upland waters that are naturally nutrient-poor and where biological activity is usually phosphorus limited. In extreme cases, phosphorus enrichment can produce excessive algal growths, resulting in wide fluctuations in dissolved oxygen and fish death.

The situation is different in the lowlands where the generally higher nutrient status of soils means that woodlands rarely require fertiliser applications. Nutrient inputs tend to be much lower compared with agriculture and thus woodland planting on ex-agricultural land may help to protect water quality within sensitive areas such as Nitrate Vulnerable Zones. The main exception concerns evergreen forests, which can enhance the capture of nitrogen pollutants from the atmosphere and concentrate nitrate levels in groundwater.

High nitrogen inputs can result where forests are downwind of local pollutant sources, such as intensive pig- and poultry-rearing units.

**Pesticides**

The low usage of pesticides in forestry and strict controls to minimise the risk of contamination means that forest planting can help to offset the greater pollution threat from more intensive land uses such as agriculture. In particular, forestry can play an important role in reducing diffuse pollution in surface water supplies and groundwater protection zones.

**Chemicals**

Woodland planting on badly designed landfill sites can lead to tree rooting disrupting the protective clay cap. The resulting inflow of rainwater increases the volume of leachate and thus the risk of contaminating local groundwaters and streams. Conversely, the higher water use associated with some types of forest can reduce this problem. Planting restored mineral workings and contaminated land has both potential positive and negative effects that will vary depending on the nature of the site. For example, increased acidification of inadequately buffered materials can lead to the greater mobilisation of some metal pollutants, while the ability of forests to accumulate soil organic matter may enhance the retention of others. Lower leachate volumes would also be beneficial on such sites.

**Fuel oils and lubricants**

The primary concern arising from the use of fuels and lubricants during forest operations is the risk of spillage leading to water pollution. Both the accumulation of small spills during routine handling and larger accidental spills can lead to serious contamination of soils and drainage waters. All oils, and in particular diesel, can quickly migrate through the soil and small quantities are sufficient to taint drinking water supplies and disrupt water treatment processes. Oils can have a toxic effect on freshwater life and can prevent the transfer of oxygen through the water surface, causing aquatic animals to suffocate. Bio-oils are less persistent in the environment, but can still pose a risk of pollution through accidental spillage or mis-use.

**Shade and Shelter**

The structure and composition of riparian vegetation can have a dramatic impact on the aquatic environment. A key factor is the degree of shade. On one hand, too much shade leads to bare, eroding banks; wider, shallower channels; and reduced productivity of fish and aquatic invertebrates. On the other hand, too little shade can result in a lack of shelter; more extreme temperature fluctuations, including the risk of lethal high temperatures for fish during summer months; and contribute to excessive weed growth. A cover of relatively open, native woodland is thought to provide the best combination of shade and shelter. Riparian woodland also forms an important edge habitat between agricultural land and the aquatic zone and can be a key wildlife corridor linking other woodland habitats. In addition, it can help to control diffuse pollution from the adjacent land by retaining sediments, nutrients and pesticides in drainage waters.

## Catchment Management Planning

The Guidelines address the above issues either at the catchment or site level. Catchment issues include the effects of forestry on water yield, base flows and flooding, the contribution of forestry to acidification and eutrophication, and the design of riparian buffer areas. Catchment management planning is increasingly driven by European Union legislation such as the Water Framework Directive, which requires the production of river basin management plans and action to achieve good ecological status for all waters. The sensitivity of any water catchment to forestry will depend on the quality of freshwater habitats and the requirements of water users, and must be identified and taken into account at the planning stage. The following summarises the Forestry Commission’s approach to addressing the main catchment scale issues:

### Water Yield & Base Flows

The potential reduction in water yield from evergreen forests is likely to be a problem where the supply is being, or is planned to be, fully exploited. This is increasingly the case in many catchments as the demands on water resources continue to grow. In the uplands, this may include catchments used for the generation of hydro-electricity, impoundment for water supply or river regulation. Areas draining to heavily exploited groundwater aquifers or rivers with an identified low flow problem are most at risk in the lowlands. Also in many catchments the needs of river ecology, fisheries and other water uses have to be considered in addition to the demands for supply.

Developments in forest design have helped to mitigate the impact of existing forests on water yield and base flows. The introduction of forest plans and the publication of the UK Forestry Standard have driven the conversion of evergreen plantations into more mixed age forests with increased species, structural diversity, and open space. Research has shown that water yields from young forests, felled areas and deciduous woodland are likely to be similar or even lower than from grassland catchments, and therefore the creation of a more diverse forest should help to even out the effects of forestry at a larger catchment scale. A more mixed aged forest is also expected to be more resilient to the damaging effects of major storms and wildfire, which can bring about marked short-term changes in water yield, as well as water quality.

Proposals for new planting of evergreen species pose the greatest threat to water supplies and early consultation with the water regulatory authority is recommended to clarify whether there is likely to be a problem. Water use models are available to estimate the likely impact on water yield, although further work is underway to improve confidence in predictions. There is an increasing need to assess the impact of climate change and how this will interact with forest evaporation. Where there is a risk that new planting will exacerbate water shortages it is unlikely that forest grants would be approved.

Broadleaved woodland presents a smaller threat to water resources, and may even enhance supplies in some areas. One exception is the large-scale planting of short rotation coppice crops of poplar and willow and in such cases it is recommended that sensitive locations be avoided.

**Peak Flows**

A well managed mixed aged forest is considered to have little effect on flood flows at a larger catchment scale. The greatest opportunity for forestry to assist flood control is through the planting and restoration of floodplain and riparian woodland. Unfortunately, there is a lack of data to quantify the effects on flood flows and to resolve outstanding concerns. This topic is a priority for future research.

**Acidification**

Reduction in the emission of acid pollutants is the only way of solving the general problem of surface water acidification. The European Union has agreed to further sulphur and nitrogen pollutant reductions by 2010, but these will not protect all parts from acidification. The increased capture of acidic pollutants by forests poses a risk of delaying the recovery of acidified waters or even leading to further acidification in the most sensitive areas. Large-scale new planting of evergreen species represents the greatest threat while the replanting of existing forests can also be a cause for concern.

The critical loads approach is used to identify which areas of Great Britain are most at risk. A critical load is defined as the maximum load of a pollutant that a given ecosystem can tolerate without suffering adverse change. For fresh waters, critical loads can be calculated which, provided they are not exceeded, should ensure the maintenance of water chemistry suitable for the protection of populations of fish and other freshwater biota. Proposals for new planting or restocking in 10 km grid squares where critical loads are exceeded may be required to undertake a more detailed catchment-based critical loads assessment to determine the susceptibility of individual waters. Factors to be considered include the size of the planting scheme, species mix, altitude, the proportion of forestry already in the catchment, soils, geology, and the sensitivity of local water uses. Deciduous woodland poses less of an acidification threat due to the smaller scavenging effect, but the impact of larger planting schemes requires consideration. Where forest scavenging is predicted to result in the total acid deposition exceeding the freshwater critical load, approval of forest grants or forest plans is unlikely until there are further reductions in pollutant emissions.

The short-term release of nitrate that may follow the large-scale harvesting of some forest sites can pose an additional acidification threat within acid-sensitive areas and there may be a need to carry out a separate site impact assessment. Factors to be considered include catchment size, the timing of felling operations, species mix, local soils and geology, and the presence of fish. Sites believed to be at risk require the size of felling area to be reduced and the adoption of management practices designed to minimise nitrate losses. Other restrictions include avoiding whole-tree harvesting where critical loads are exceeded due to the longer-term threat of soil and water acidification presented by the greater removal of base cations in harvested produce.

**Nutrient Enrichment**

Waters vary in their sensitivity to nutrient enrichment, with nutrient-poor waters most at risk of damage. Aerial phosphate fertiliser applications present the greatest threat and must be carefully planned to ensure that phosphate losses from consecutive applications in a given catchment do not exceed environmental quality standards in receiving lakes or reservoirs. Applications exceeding a total area of 50 ha in any three-year period may pose a problem, depending on soil properties, size of the catchment and the characteristics of the water body. Sites considered to be at risk may be required to undertake a more detailed site assessment based on modelling nutrient loads using phosphorus export coefficients.

**Design of Riparian Buffer Areas**

A buffer area is required both in existing forests and new planting to protect the riparian and aquatic zones from disturbance by forest operations on the adjacent land. In the same way, the planting of riparian woodland within agricultural areas can be used to control diffuse pollution and improve freshwater habitats. Key aspects of the design of the buffer area are width, choice of species, and structure.

The desired width of the buffer area depends on a consideration of its principle functions: water quality protection, moderation of shade and temperature, maintenance of riparian and aquatic habitat diversity and ecological integrity, and landscape improvement. These are related to site sensitivity and a balance is sought between benefits and costs. In terms of providing adequate protection for the aquatic zone, a width of 20 m on either side is thought to generally suffice for larger watercourses with a channel more than 2 m wide. For smaller streams, practical constraints mean that the minimum buffer widths should be 10 m on either side for channels 1-2 m wide and 5 m on either side of channels up to 1 m wide. Where the natural riparian zone exceeds these widths, the dimensions of the buffer area are correspondingly increased, up to twice the minimum recommended width. Greater widths are considered where there is scope for restoring native floodplain woodland. Steep ground that is dissected by numerous streams is a special problem, since it may not be possible, or desirable in terms of landscape design, to establish buffer areas alongside the smallest of streams.

It is recommended that the vegetation within the buffer should preferably be native to the location and soils. Natural regeneration is the favoured means of establishing native tree and shrub species when an appropriate seed source exists and any regeneration by evergreen species is manageable. Where natural regeneration is unsuitable, planting relies on stock raised from local seed sources. Densely shading trees are interspersed with lighter foliaged trees such as birch, willow, rowan, ash, hazel, aspen and bird cherry.

The general aim is to establish and maintain an open woodland canopy by creating an intricate mosaic of five vegetation habitat types: open ground, occasional large trees, trees with open glades, scrub thicket and closed canopy woodland. Together these provide the structural diversity that is attractive to woodland fauna and to the plants that flourish in semi-woodland conditions. It is recommended that about half of the length of a watercourse overall is left open to sunlight, with the remainder being under dappled shade from trees and shrubs. The level of shade should be sufficient to allow the development of a more or less continuous cover of ground and bankside vegetation.

**Site Planning and Operational Guidance**

Good site planning is an essential part of any forest operation. The UK Forestry Standard requires a methodical approach, which involves consideration of available techniques and resources, the potential environmental impacts of the work, and consultation with appropriate bodies to assess the sensitivity of the area and the existence of any legal requirements. Usually there will be a need for a detailed site assessment and the production of a well annotated map (site plan) showing pertinent information, particularly site constraints.

The Guidelines describe a range of specific measures that should be taken to minimise the impact of forest operations such ground preparation, managing riparian vegetation, road construction and maintenance, harvesting, the application of pesticides and fertilisers, and the storage and handling of chemicals and fuel oils. Common aspects are the need for meticulous planning and supervision of operations, the adoption of less disruptive practices, the careful matching of machinery to site conditions, varying the scale and timing of operations according to site sensitivity, the use of a wide range of protective measures, and the drawing-up of a contingency plan in case of the accidental spillage of chemicals or oils.

**Monitoring and Quality Control**

Monitoring is an essential part of assessing compliance with the standards of environmental protection and practice that are set out in the UK Forestry Standard and Forests and Water Guidelines.

A set of UK Indicators of Sustainable Forestry has recently been published to provide information about the present state, and trends over time, of woodlands and their management. There are seven indicators covering the condition of the forest environment, five of which deal with freshwaters: water yield and stream flows, water quality, surface water acidification, river habitat quality, and pollution incidents.

The Forestry Commission routinely assesses compliance with the requirements of the Guidelines at a local level. Grant approvals, felling licences and forest plans are checked at various stages of development to ensure that the standards are being met. Operations may be suspended where there is a serious departure from good practice, and failure to remedy the situation can result in grants being withheld or reclaimed, or in prosecution for suspected illegal felling.

The Forestry Commission also conducts national audits, which include regular assessments of performance in meeting the guidelines and an annual survey of compliance with approved forest plans. The results of the latter are published in the Forestry Commission's Annual Report, together with statistics on grants paid, grants reclaimed, felling licences granted, cases of illegal felling, and instances where Restocking Notices have been issued. Occasionally, independent assessments are commissioned to evaluate the performance of particular instruments and mechanisms.

Research has a key role to play in assessing sustainable forest management, including evaluating and developing standards and indicators, and measuring the effectiveness of best management practices. The Forest Research Agency collaborates with the water regulatory authorities and other research agencies in undertaking such work. A number of partnerships have been formed to help steer long-term catchment studies that are designed to quantify the impact of the different stages of the forest cycle on water yield, stream flows and water quality. Other shorter-term catchment-scale studies have been carried out or are ongoing to test the efficacy of the Guidelines in practice. These include assessments of the impact of forest cultivation and drainage, fertiliser application, road construction and clearfelling in two public water supply catchments in West Scotland, and the impact of forest cultivation, drainage and fertiliser application in a pristine catchment supporting a high value salmonid fishery in North Scotland. Results from these are published in official reports and in the wider scientific literature (see Bibliography).

Finally, the UK Woodland Assurance Standard was introduced in 1999 as a means of providing independent certification for forest management. The UKWAS incorporates the requirements of the UK Forestry Standard but is more detailed in addressing specific aspects of forest management or types of operation. It is a voluntary scheme developed by a wide range of stakeholders in UK forestry, including the Government, private forest and woodland owners, the wood processing sector, people who work in forests, and environmental and community groups. Owners whose woodland management is audited, or inspected, to the UKWAS Standard by independent auditors accredited by the Forest Stewardship Council (FSC) may use the FSC's internationally recognised trademarks on their products.

## Conclusions

A wide range of regulatory instruments and incentives are in place in Great Britain aimed at achieving sustainable forest management for multiple objectives, including commercial timber production. At the core of these are the UK Forestry Standard, the UK Indicators of Sustainable Forestry and the set of supporting guidelines. Results from monitoring and research suggest that these measures provide a sound basis for conserving the quality and quantity of water resources.

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Table 1 Summary of regulatory instruments and incentives to achieve sustainable forestry in the Great Britain

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| The UK Forestry Standard | Introduced in 1998 with the aim of setting criteria and standards for the sustainable management of all forests and woodlands in the UK. |
| Forest Guidelines | These describe the concepts and processes of good forest design, management and operational planning. The series includes Forests and Water, Forests and Soil Conservation, Forest Nature Conservation, Forest Landscape Design, Community Woodland Design, Lowland Landscape Design, Forest Recreation, and Forests and Archaeology. |
| National Forestry Strategies | To inform regional strategies on how best to achieve sustainable land use in existing woodlands and identify the needs and opportunities for new woodland planting. |
| Indicative Forestry Strategies | To identify those areas at a regional level where significant planting is to be preferred or where there are particular environmental sensitivities that must be addressed before approval can be given for grant aid. |
| Local Forestry Frameworks | To resolve local issues by considering the available evidence and the views of interested parties. |
| Forestry Grant Schemes | To provide funding for the establishment and management of woodlands provided that the standards of environmental protection and practice set out in published guidelines are met. |
| Felling licences and Forest Plans | Deal with approval for felling and provide a set of maps and documents that outline the felling, thinning, and restocking work to be carried out on a property over a 20-year period |
| Environmental Assessment | Introduced in 1988 and requires those who propose to carry out a forestry project involving afforestation, deforestation, road works or quarrying that may have a significant effect on the environment to apply for consent from the Forestry Commission. |
| Public Register | To provide details of all new planting and felling applications and allow people to find out about developments in their local area and to make comments if they wish. |
| Consultation | Requires the Forestry Commission to consult with local authorities and a number of statutory bodies before determining applications for forest grants or for a felling licence. |