Forest Research

# Opportunity Mapping for Woodland Creation to Reduce Diffuse Sediment and Phosphate Pollution in the Lake District

Samantha Broadmeadow
and Tom Nisbet

Forestry Commission England

WOODLAND TRUST

NATURAL ENGLAND

CUMBRIA WOODLANDS

The Research Agency of the Forestry Commission

Samantha Broadmeadow and Tom Nisbet

Centre for Forestry and Climate Change,

Forest Research, Alice Holt, Farnham,

Surrey GU10 4LH

Samantha.broadmeadow@forestry.gsi.gov.uk

Tom.nisbet@forestry.gsi.gov.uk

The Research Agency of the Forestry Commission

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# Executive summary

It is widely acknowledged that woodland has the potential to reduce soil erosion at source, limit the delivery of diffuse pollutants to watercourses and protect river banks from erosion. This study assesses the opportunities for woodland creation to help manage sediment problems within the Lake District National Park (LDNP) by identifying the main sediment sources and pathways of delivery to watercourses. The work builds on the Bassenthwaite Lake Study (Nisbet *et al.,* 2004) by extending the earlier work to the whole of the LDNP plus the associated Environmental Sensitive Area. The scope for woodland creation to reduce diffuse phosphate pollution is also considered.

This study has identified the following opportunities for woodland creation to reduce diffuse pollution based on the characterisation of observed bank erosion, modelled sediment and phosphorus sources, and the presence of major constraints.

- Over 85,000 ha of land with high risk of soil erosion.
- Over 1,550 km of river length with high risk of bank erosion, which is equivalent to almost 9,340 ha of riparian woodland.
- An additional 9,483 ha of riparian land at moderate risk of bank erosion; of which 5,036 ha is bordering land with a high vulnerability to soil erosion where woodland creation could both protect river banks and act as a buffer to trap sediment in runoff from the adjacent land.
- Over 24,700 ha of land subject to diffuse phosphate losses exceeding 100 kg/km$^2$/y. This includes over 12,200 ha of land at high risk of soil erosion and 2,054 ha of riparian land at high risk of bank erosion.
- 5,365 ha of potential new floodplain woodland.

It is recommended that regional stakeholders use the maps and spatial data prepared for this study to help target future woodland creation to aid diffuse pollution management. Further management recommendations are given at Section 8.

# 1. Background

This study was commissioned by the Woodland Trust, Natural England and Forestry Commission England in December 2009. It assesses opportunities for woodland creation to help manage sediment problems within the Lake District National Park (LDNP) by identifying the main sediment sources and pathways of delivery to watercourses. The work builds on the Bassenthwaite Lake Study (Nisbet *et al.,* 2004) by extending the earlier work to the whole of the LDNP plus the associated Environmental Sensitive Area (Map 1). The scope for woodland creation to reduce diffuse phosphate pollution is also considered.

The standing water habitats of the LDNP are of international importance for their ecological, aesthetic, recreational and cultural value, and many have been designated as Sites of Special Scientific Interest, Special Areas of Conservation and/or National Nature Reserves. These waters are very vulnerable to disturbance and highly sensitive to pollution. A key issue is the high level of soil erosion in some parts of the LDNP caused by a range of pressures, including overgrazing, land cultivation, drainage, and human trampling. Erosion has led to some scarring of the landscape and a loss of the soil resource. It has also been linked to high water turbidity and excessive sedimentation, with consequent damage to priority species and habitats. In addition, the eroded sediment is an important source of phosphate, which has contributed to enrichment of the standing waters and associated problems.

The condition of over two thirds of the standing open water SSSIs across the LDNP is assessed as being unfavourable and most of these sites are declining rather than recovering. A similar situation applies to the larger undesignated lakes such as Lake Windermere, as well as many of the smaller lakes/tarns. Floristic surveys and water quality monitoring have revealed widespread problems of siltation and eutrophication, which has badly affected several native plant and animal species, and may have contributed to the expansion of invasive alien species. Many river and lake water bodies have been assessed by the Environment Agency as being at less than good ecological and chemical status.

The Lake District Still Waters Partnership (LDSWP) was established in 2001 to try and tackle these threats through improved land management. The partnership of statutory and non-statutory organisations is helping to develop an integrated, whole-catchment approach to sustainable water management. Woodland creation forms a core element of this approach.

It is widely acknowledged that soils under woodland are generally well protected and are often improved in terms of soil structure and carbon content compared to more demanding land uses (Forestry Commission, 1998). The development and implementation of best practice as exemplified by the Forestry Commission's Forests

& Water Guidelines (Forestry Commission, 2003) means that the planting and establishment of new woodland could offer an effective approach to reducing sediment losses in the LDNP. Woodland has the potential to reduce soil erosion at source, to limit the delivery of sediment to watercourses, to protect river banks from erosion, and to encourage sediment deposition within the floodplain. Woodland can also reduce phosphate pollution through nutrient uptake and the trapping of soil-bound material.

Water quality is becoming an increasingly important driver of land-use policies. The issue of best use of land and in particular, land near to watercourses in the form of the riparian zone and wider floodplain is critical as this is where conflicts are often greatest between farming, water quality and natural-river processes. Persuading landowners to give up in-bye land for flood storage or buffer strips is difficult because of its value to farmers for certain activities at different times of year (e.g. for tupping, lambing and dipping). Additional grant aid is often required to persuade riparian and floodplain land owners to buy-in to schemes to establish woodland. Opportunity mapping has a key role to play in targeting limited financial support to areas where maximum benefit can be gained.

# 2. Policy context

There are several existing policies related to the creation of new woodland in Cumbria. These include:

- Cumbria Woodland Vision
- Regional Forestry Framework manifesto on woodland creation
- A Strategy for England's Trees, Woods and Forests
- Natural England's Upland Vision
- Biodiversity Action Plan
- Water Framework Directive
- Lake District National Park Landscape Character Assessment
- Combating Climate Change, A Role for UK Forests
- Defra Climate Change Plan

This mapping work is intended to fit alongside these and help provide further geographic focus for woodland creation.

# 3. Objectives

The primary aim of the study is to identify opportunities for woodland creation to reduce sediment and phosphate problems within the Lake District National Park and Lake District Environmentally Sensitive Area. There are three main objectives: to identify areas that are highly vulnerable to erosion and liable to deliver sediment to watercourses; to identify sources of diffuse phosphorus pollution; and to identify which of these areas/sources would be suitable for woodland creation to help control sediment and phosphate problems.

# 4. Study Area

The study area covers central, western and southern parts of Cumbria. The boundary is defined by the Lake District National Park extended to include all the land contained in the Lake District Environmentally Sensitive Area. It comprises over 2,500 $km^2$ of the Cumbrian Fells, sixteen major lakes and numerous tarns/small lakes (Map 1, Appendix 1). For the remainder of the report the project area is referred to as the National Park.

## 4.1 Landscape, geology and soils

Cumbria has a rich and varied geology which has resulted in a variety of landforms (Maps 2 & 3, Appendix 1). There are three broad zones, starting with the roughly triangular mountains in the north formed from the Skiddaw Group of sedimentary rocks, composed primarily of mudstones with occasional layers of coarser silt and sandstone. In the centre are the high peaks and rugged terrain of the Borrowdale Volcanic Group formed from volcanic lavas and ash flows some 450 million years ago. Finally, the southern foothills form a zone of Silurian slates, siltstones and sandstones known as the Windermere Group. These softer rocks are overlain with till, alluvium and lacustrine deposits.

The volcanic rocks of the central belt are relatively impermeable and despite higher gradients and stream power, are less erodible than the sedimentary rocks that lie to the north and south. Barlow *et al.* (2009a) reported that the softer sedimentary rocks were a greater source of fine sediment compared to the hard geology of the Borrowdale Volcanic Group. Soils range from humic rankers and raw peats on the high ground to stagnogleys and alluvial soils in the lowlands (Map 4, Appendix 1). They tend to become quickly saturated after heavy or prolonged rainfall, generating rapid surface runoff.

In common with other parts of the UK, landslips are a major source of sediment and often associated with large flood events. In 2005 there were an unprecedented number of shallow landslides across northern Cumbria, while more severe landslides followed the Borrowdale and Wasdale floods in October 2008 and the Derwent flood in November 2009 (Warburton et al., 2010). Work is currently underway in the Coledale valley within the Bassenthwaite lake catchment to assess the significance of landslide-derived flood debris in accentuating valley floor flood inundation (LDSWP, 2009).

## 4.2 Land use and land use practices

Agriculture in the National Park is based on a long tradition of hill sheep farming with some suckler herds, store cattle and dairying on the lowland fringes. Map 5, Appendix 1 illustrates the land use across the LDNP based on the Countryside Survey (Fuller *et al.,* 2002) and the same data is summarised in Figure 1.

The vegetation cover of the High Fells is predominantly unimproved grassland, with a rich mosaic of scrub, heaths and mires. Extensive areas of the fells have been scheduled as Sites of Special Scientific Interest due to their value for nature conservation. The soils and land of the Low Fells are better for farming and there is a higher proportion of improved grassland. Most of the National Park has Less Favoured Area Status and just 5% is used for arable cropping. There are extensive assemblages of broadleaf woodland which cover 8% of the park, with a further 3.5% under several large coniferous plantations. However, this woodland is unevenly distributed across the park.

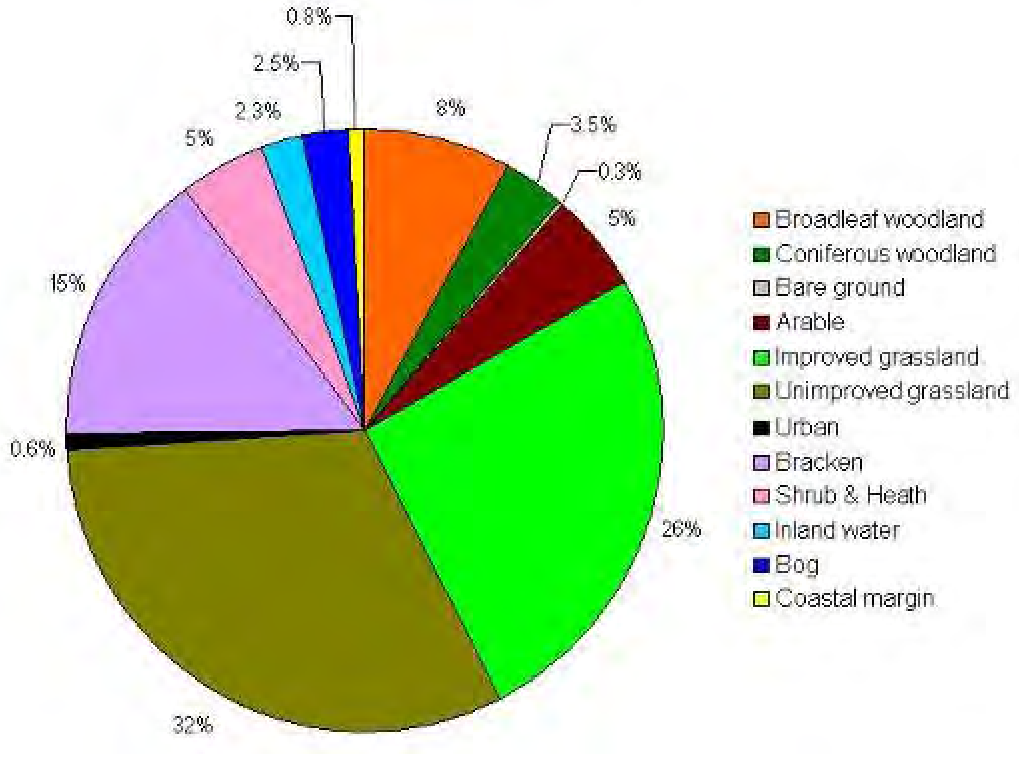



Figure 1 Land cover in the Lake District National Park, data from the CS2000

The majority of the eligible agricultural land within the Lake District Environmentally Sensitive Area (ESA) was entered into ESA agreements between 1993 and 2004. This scheme is now closed and agreements are expiring and being replaced by the Environmental Stewardship Scheme. The latter provides payments to farmers for adopting specified land management practices, which may or may not include restrictions on cultivation, stocking rates, fertiliser and pesticide use. Map 6, Appendix 1 illustrates the uneven distribution and density of grazing pressure across the National Park using a proxy data set of 'Grazing Livestock Units' derived from the Defra agricultural census (used to calculate the number of animals in each 1 km grid square as an input to the PSYCHIC model; see Section 5.2). The data set standardises livestock numbers both in terms of their manure production, so that a single cow is equivalent to 12.5 sheep, 5 pigs or 250 hens; and location, so that inputs are evenly distributed across each grid square for grazing animals but on a proportionate basis for housed animals. Full details of the approach are provided in Davison *et al,* (2008).

Sheep have been shown to increase soil compaction and overland flow (Carroll *et al.,* 2004). Barlow *et al.* (2009a) quantified the impact of livestock on fine sediment supply to Lake Windermere in a recent fluvial audit of the catchment. They estimated that 26% of the fine sediment was derived from poaching of stream banks by cattle and sheep, while a further 16% came from livestock damage to hill slopes. McDowell (2006) reported that sheep faeces represented a greater source of soluble reactive phosphorus compared to that of cattle.

The popularity of the Lake District for fell walkers also places the environment under great pressure. Over 8 million people use the National Park's paths annually and this has led to soil compaction and a significant loss of vegetation cover, resulting in soil erosion and sediment transport to watercourses. Since 2002 the National Park Authority and National Trust have led the 'Fixing the Fells' initiative to create durable path surfaces along 172 of the most popular routes.

## 4.3 Water Status and River Basin Management Plans

Across the National Park 52% of the 105 river water bodies assessed under the Water Framework Directive are considered to have a less than Good Ecological Status (GES) and no catchment was rated as achieving High Status. The pressures and risks affecting each river catchment are identified within the River Basin Management Plan (EA, 2008a and b) and Map 7 (Appendix 1) illustrates the risk of river water bodies failing to meet GES by 2015 due to diffuse pollution. Around 41% of water bodies are at risk of failing due to diffuse pollution from agriculture, with 21% affected by sediment delivery, 30% by pesticides from sheep dip and 28% by phosphorus.

A recent analysis of long-term physical, chemical and biological data collected from Lake Windermere between 1950 and 2007 revealed a significant reduction in water quality since 2000 (Maberly et al., 2008). In the last ten years the lake ecosystem has seen a significant switch in nutrient availability and trophic control, with a reduction in summer zooplankton numbers leading to a greater phytoplankton crop being produced per unit phosphorus. The reduction in zooplankton may be due to an increase in roach abundance, which in turn could be an indirect symptom of climate change since roach are thought to be favoured by higher water temperatures. Maberly *et al.* (2008) suggest that as a consequence, the phosphorus loading to the lake must be reduced even further if the lake is to achieve GES. Bassenthwaite Lake is another important water body at risk from nutrient enrichment associated with elevated inputs of fine sediment from the wider catchment (Hatfield & Maher, 2008).

Many of the rivers and lakes across the National Park are under serious threat from an increasing number of invasive alien species. Eutrophication encourages the growth of Himalayan Balsam and Japanese Knotweed, which have become more frequent invaders. These vigorous weeds crowd out native plants so that when they die back in the winter the stream banks are left bare and vulnerable to erosion. Poor water quality in the lakes has contributed to the rapid growth of exotic pond weeds such as *Crassula helmsii,* which is now well established in Derwent Water, Bassenthwaite Lake, Grasmere, Coniston and others.

# 5. Methods

## 5.1 Identification of constraints to new woodland creation

The first step was to identify constraints to woodland planting where the creation of woodland was either not possible or very unlikely to be suitable due to existing land use, land ownership or the presence of vulnerable assets (Maps 8 & 9, Appendix 1). For this project the absolute constraints were considered to be:

- Urban areas, including villages, towns and cities
- Roads and railways
- Scheduled Ancient Monuments and an additional Roman well/fort designated as a World Heritage Site due to its association with Hadrian's Wall
- Sites in the English Heritage Register of Parks and Gardens of special historic interest
- Existing woodland
- Lakes and tarns
- National grid infrastructure – gas pipelines and electricity overhead cables requiring cleared wayleaves 5.3 m wide under 400kV lines.

In a landscape as spectacular as the Lake District National Park woodland creation would only be appropriate after careful consideration of scale, design and species choice. This is as true for the rolling farmland of the low-lying valleys as for the rugged mountain peaks and wild, open high fells. Planting applications would be subject to the normal assessment, consultation and approval process. A number of key factors that would influence the nature of woodland creation are shown in Map 10, Appendix 1 and include:

- Sites scheduled or recognised for their nature conservation or geological importance
- Cultural landscapes; the Lake District National Park has the largest concentration of Common Land in Britain, and possibly Western Europe
- Land within the EA flood defence infrastructure, such as behind raised flood banks
- Land above 450 m, where altitude will dictate the growth and type of woodland or scrub that would be appropriate.

The sources of these data sets and the processing required in their preparation for mapping are detailed in Appendices 2 and 3.

A number of other important factors would affect woodland creation, not least the interests of landowners and tenant farmers, but also including:

- Landscape
- Public access
- Historic environment features not covered by statutory designations
- Other nature conservation features e.g. County Wildlife Sites and Regionally Important Geological Sites.

These are not considered further here but would be addressed at the local level when considering individual planting applications.

## 5.2 Identification of soils within the Lake District National Park which are highly vulnerable to sediment loss and sources of diffuse phosphorus pollution

The propensity of soils across the National Park to erode and transfer sediment to water bodies was predicted using the Phosphorus and Sediment Yield Characterisation in Catchments (PSYCHIC) model (Davison *et al.,* 2008). The model was developed by ADAS as a tool to identify areas where diffuse pollution mitigation measures may have the greatest effect.

PSYCHIC is a process-based model of suspended sediment (SS) and phosphorus (P) mobilisation and delivery to watercourses. The model predicts annual soil loss risk based on a consideration of suspended sediment mobilisation by raindrop impact and runoff shear, sediment transport capacity and landscape connectivity to local watercourses. The model is sensitive to a number of soil management, crop and animal husbandry decisions, as well as to environmental factors such as climate, soil type and slope. It uses easily available national data sets to infer all necessary input data as 1 $km^2$ grids. The model has been widely used by the EA both as a first step in catchment characterisation (Collins and Anthony 2008) and as a tool to investigate potential mitigation measures (Haygarth *et al.,* 2002).

The original model output in terms of predicted sediment delivery to watercourses is shown in Map 11, Appendix 1. The dominant soil association was identified for each 1 km grid cell and the range of predicted sediment loads used to classify soils in terms of their vulnerability to erosion (Map 12, Appendix 1). Figure 2 displays the range and extreme values for the individual $km^2$ grid cells as a box and whisker plot. The bar illustrates the median value, which is enclosed by a box that defines the first and third quartiles; the outliers are represented by asterisks. The median rates of sediment loss for most soil associations in the National Park are close to the average value for England and Wales (128 kg $ha^{-1}$ $yr^{-1}$) determined by Collins and Anthony (2008). However, several soil associations are vulnerable to far greater sediment losses where subject to pressure from certain land use activities and there is close connectivity to watercourses. Four soil associations stand out with high outliers and are classed as highly vulnerable to erosion; these are Skiddaw 311b, Bangor 311e, Manod 611c, and Brickfield 713f . Another four soils (Malvern 611a, Wilcocks 1 721c, Conway 811b and Winterhill 1011b) with intermediate values are classed as moderately vulnerable, while the remainder are assigned to the low vulnerability class.

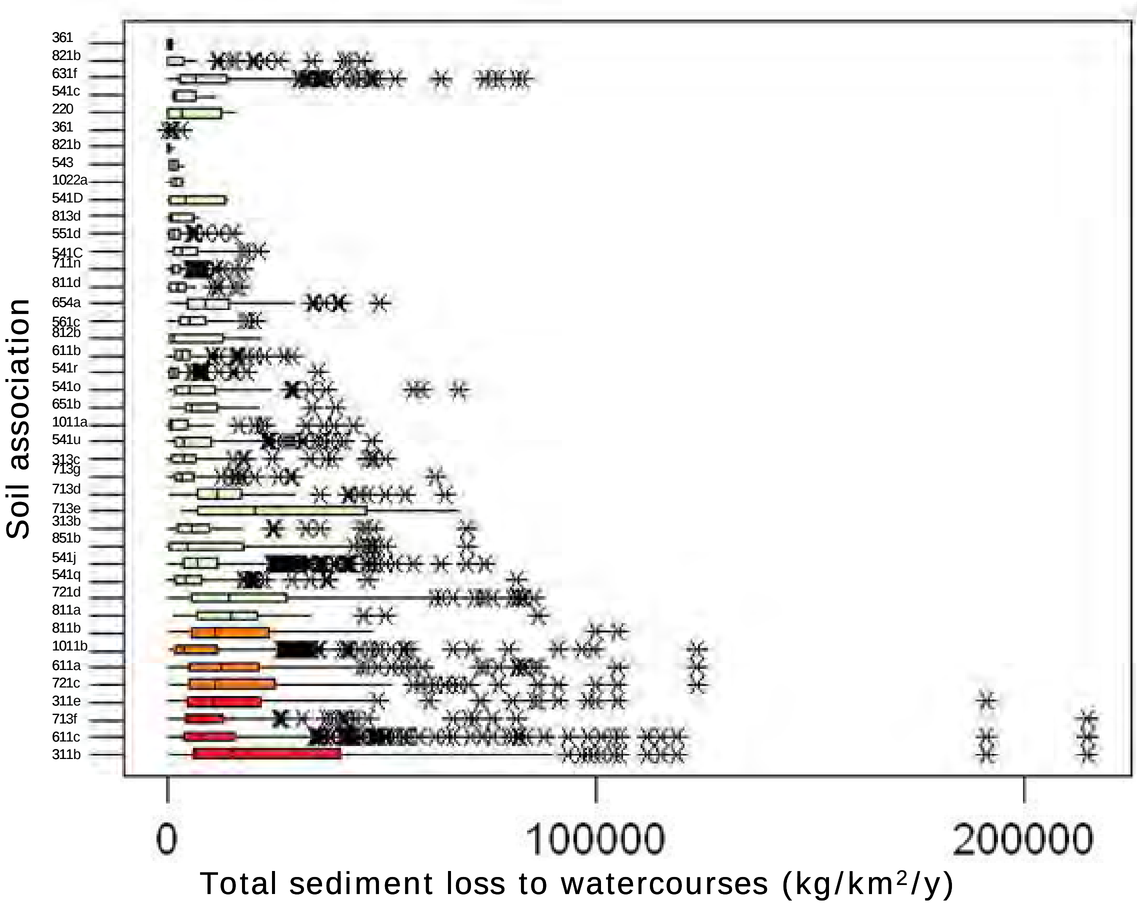



Figure 2 Box and whisker plot of the range of values for predicted sediment loss to watercourses for each soil association across the Lake District National Park

PSYCHIC was also applied to the National Park to identify areas of high phosphorus loss to watercourses. The model considers the sources and mobilisation of both dissolved and particulate phosphorus (P). Rates of application of manure (and hence phosphorus) to agricultural land were derived from the Manure Management Database (Davison et al 2008), which uses livestock numbers, and on manure type from Defra's Agricultural Census to determine livestock unit grazing pressure (Map 6, Appendix 1). Dissolved P sources from animals (the excreta from grazing animals plus the managed manure from housed animals) were attributed to the proportion of grass and arable land within each 1 km grid cell. Fertiliser inputs were inferred from crop type based on the agricultural census, assuming applications were in line with the Survey of Fertilizer Practice. Losses from hard standing and incidental loss from managed manure and fertiliser applications were estimated as a function of hydrologically effective rainfall using specific coefficients for dairy and beef cattle. Dissolved P concentration in runoff is dependant on soil P stocks (soil Olsen P), while the particulate P associated with eroded suspended sediment was estimated from soil total P, the quantity of suspended sediment mobilised and particle size distribution. Map 13, Appendix 1 shows the modelled output of diffuse P losses to watercourses.

## 5.3 Identification of soils that are highly vulnerable to stream bank erosion

Soil vulnerability to bank erosion was assessed using a combination of observed and predicted data, which were integrated using GIS to derive a refined map showing areas at greatest risk of erosion. Map 14, Appendix 1 displays the distribution of actively eroding stream/river bank observed in the recent fluvial audits of the catchments of the Bassenthwaite Lake (Orr *et al.,* 2003) and Windermere Lake (Barlow *et al.,* 2008a). The first project surveyed the entire main river and a number of minor watercourses in the Bassenthwaite Lake catchment, while the second evaluated the key tributaries of Lake Windermere. In order to fill the gaps, the distribution of observed erosion was related to riparian soil type, as in the previous study at Bassenthwaite Lake (Nisbet *et al.,* 2004), and this relationship then used to predict the risk of bank erosion. However, the surveyed area only provided data for 14 of the 37 soil associations found in the riparian zone of the wider National Park (that is land within 30 m of the Environment Agency's Detailed River Network data set), leaving around 25% of the park unclassified.

The relationship between observed bank erosion and soil type is displayed in Figure 3. As at Bassenthwaite Lake, the soil associations formed three distinct groupings. The most vulnerable soil associations were Ellerbeck 541u, Malvern 611a and Brickfield 2 713f, which represented 53% of the observed bank erosion. A second group of four soil associations (Denbigh 1 541j, Alum 561c, Manod 611c and Conway 811b) were classed moderately vulnerable and together accounted for a further 35% of the observed erosion. The remaining seven soil associations were placed in the low vulnerability class.

Map 15, Appendix 1 shows the distribution of riparian soil vulnerability to bank erosion across the National Park. The potential area for riparian woodland to protect banksides was defined as a 30 m wide zone on either bank of the EA DRN dataset. This width was selected as the zone where woodland was most likely to influence the stability of the river channel and banks through rooting and the provision of large woody debris. The downstream limit for the transition between riparian and floodplain woodland was arbitrarily set as either the upper extent of the EA Main River data set or the EA Flood Zone. This had the advantage of removing the need to consider the potential restriction on planting riparian woodland along such designated reaches due to possible adverse impacts on flood conveyance and river access for maintenance work.

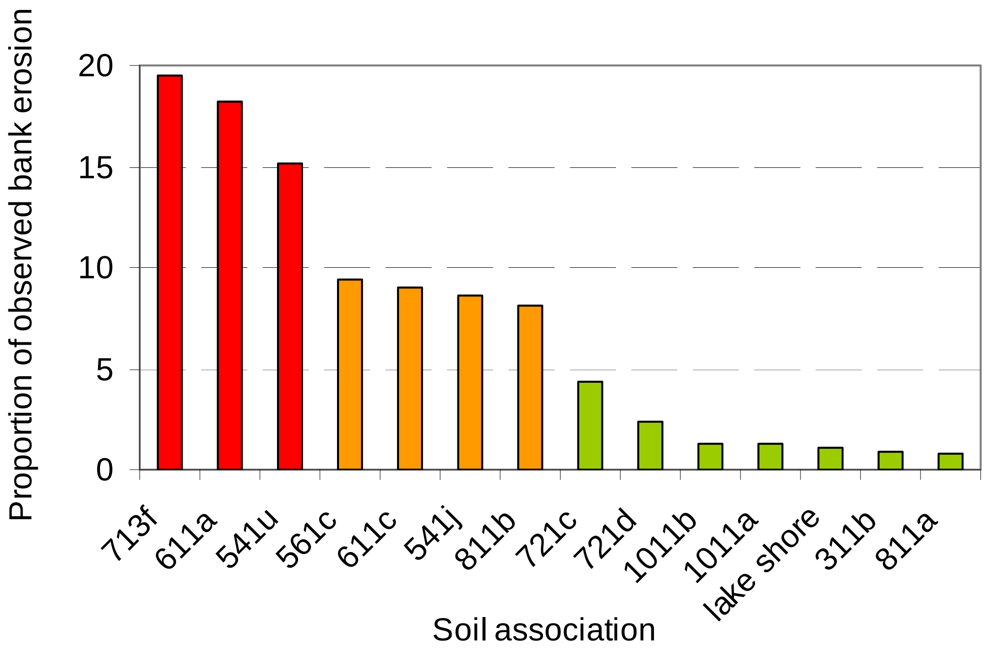



Figure 3 Relationship between observed bank erosion and riparian soil associations. Red – high risk, orange – medium risk and green - low risk of erosion.

## 5.4 Identification of areas of potential new floodplain woodland

Stream channels are often straightened, dredged or embanked to increase channel conveyance of flood flows and reduce the risk of flooding. Inevitably, this results in less sediment deposition on the floodplain and greater siltation downstream within river channels and lakes. The recent fluvial audit of the Windermere catchment reported that many kilometres of river length have been modified to prevent flooding of adjacent land. Restoring these reaches would allow the floodplain to function naturally and help retain significant quantities of alluvial sediment. Planting floodplain woodland would enhance sediment capture by increasing hydraulic roughness, which would ‘slow the flow’ and promote sedimentation and retention. The disconnection of some rivers from their floodplains in the Windermere catchment is thought to be contributing to the continued accumulation of fine sediment within the lakes (Barlow *et al.,* 2008a).

One of the recommendations of the Windermere Catchment Action Plan commissioned by the EA is the restoration of river and floodplain connectivity (Barlow *et al.,* 2008b).

To this end it is suggested that existing hard bank protection and embankments should be breached or removed to create new wetlands on the floodplain. Floodplain woodland would be highly suited to such sites and as well as promoting sediment removal, could provide benefits for managing downstream flood risk and contributing to BAP targets for restoring wet woodland.

The identification of potential areas of new floodplain woodland drew heavily on a companion study that mapped opportunities for woodland to reduce flooding within the River Derwent catchment (Broadmeadow and Nisbet, 2010). The first step was to use the Environment Agency Flood Map to define the extent of the Flood zone (Map 16, Appendix 1). Next, consideration was given to the protection of vulnerable assets such as buildings, roads and railways that could be placed at risk from the backing up of floodwaters upstream of any planted floodplain woodland. Ideally, individual assets should be buffered against the expected rise in flood level based on a detailed topographic assessment of their position with respect to the zone of enhanced inundation. However it was not practical to do this at the scale of the National Park and instead, fixed buffers were created around the main features. Although the extent of the backwater effect will be dictated by the gradient of the floodplain, modelling studies have shown that it usually does not extend beyond 300-400 m upstream (Thomas and Nisbet, 2006; Nisbet and Thomas, 2008). A longitudinal buffer of 500 m length was therefore selected downstream of urban areas and 300 m for roads and railways. The narrower buffer for the latter was based on the assumption that these assets were more likely to be built on embankments and thus better protected from flooding. Buffer areas are not required upstream of vulnerable assets since the backing up effect only applies to woodland located below them. It is important to note that isolated farms and buildings within the floodplain have not been buffered. Individual proposals for planting would need to consider the impact on these and ensure they are not placed at greater risk of flooding.

It should be noted that at the time of writing, Natural England and the Environment Agency are currently working on River Restoration Visions for river systems with nature conservation designations (the Derwent, Kent and Eden). The aim is to identify opportunities and scope for potential river restoration projects. This will include areas suitable for tree, shrub and woodland planting or establishment via natural regeneration. Realisation of the opportunities identified by this project will be dependant upon extensive future consultation.

# 6. Results

## 6.1 Constraints to new woodland creation

Table 1 lists the extent of the absolute constraints identified in the National Park for which spatial data was available. A total area of 47,683 ha is affected, leaving over 200,000 ha of the National park deemed potentially suitable for woodland creation. The principal constraint is existing woodland, which covers around 11% of the area, while urban settlement and open water together account for another 5%.

| Potential constraint | Area (ha) | % of National Park |
|---|---|---|
| Rail | 425 | 0.2 |
| Road network | 2,564 | 1.0 |
| National Grid Gas pipeline | 289; *(98 km)* | 0.1 |
| National Grid overhead cable wayleaves | 1,176; *(28 km)* | 0.5 |
| Lakes | 6,121 | 2.4 |
| Existing woodland | 29,262 | 11.4 |
| Urban areas | 6,893 | 2.7 |
| Scheduled monuments | 1,488 | 0.6 |
| Historic parks and gardens | 1,206 | 0.5 |
| **Combined total area of all constraints for which spatial data is available** | **47,683** | **18.5** |

Table 1 Constraints to woodland creation in the National Park

The areas influenced by a range of other factors that will affect scale, structure and species choice of woodland creation are listed in Table 2. Some 91,759 ha or 36% of the National park is covered by these designations, while high altitude would be a consideration in 16% of the area.

| **Other factors** | **Area (ha)** | **% of National Park** |
|---|---|---|
| SACs | 37,716 | 14.6 |
| SSSIs | 45,522 | 17.7 |
| Common Land | 68,417 | 26.6 |
| **Combined total area of all factors for which spatial data is available** | **91,759** | **35.6** |
| Land above 450 m | 41,149 | 15.9 |

Table 2 Other factors that may limit the scale, structure or species choice of new woodland creation.

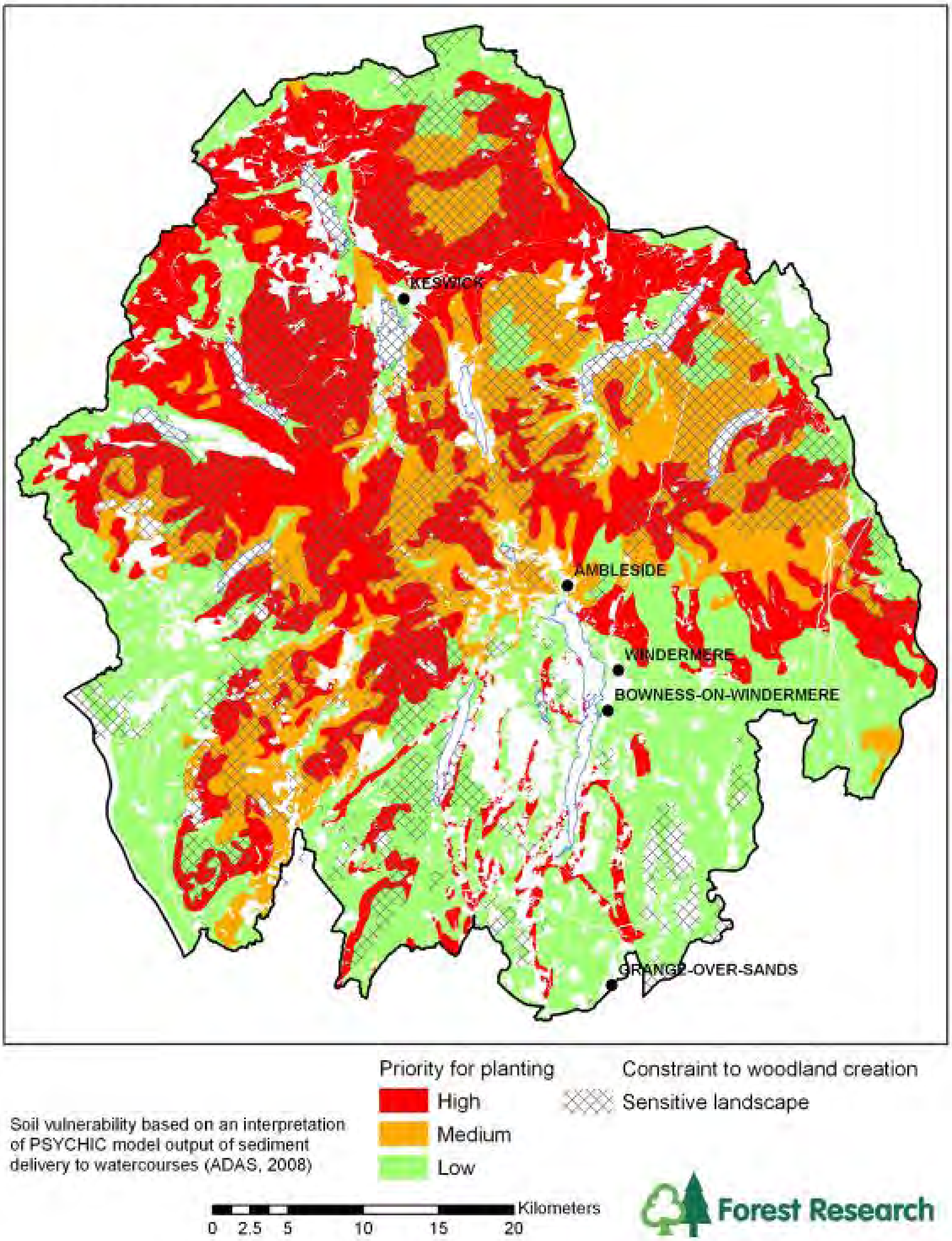
## 6.2 Opportunities for woodland creation in the wider catchment to reduce sediment loss

Map 17 overlays soil vulnerability to erosion with the identified constraints and landscape sensitivities to determine the priority areas for targeting woodland planting in the wider catchment to reduce sediment delivery. Over 85,000 ha (33%) of the National Park comprises highly vulnerable soils that are free from constraints and this land is ranked a high priority for planting (Table 1). Around half is situated within a sensitive landscape. A further 47,500 ha of moderately vulnerable soils are free from constraints and considered to be a medium priority for woodland creation to tackle the sediment problem.

| **Soil vulnerability to erosion** | **Soil Association** | **Area (ha and %) within National Park** | **Area (ha and %) free from constraints within National Park** |
|---|---|---|---|
| High | 311b, 611c, 713f and 311e | 97,427 [38%] | 85,217 [33%] |
| Moderate | 721c, 611a, 1011b and 811b | 54,427 [21%] | 47,540 [19%] |
| Low | others | 97,622 [38%] | 77,200 [30%] |

Table 3 Classification of soils by their vulnerability to deliver sediment to watercourses.

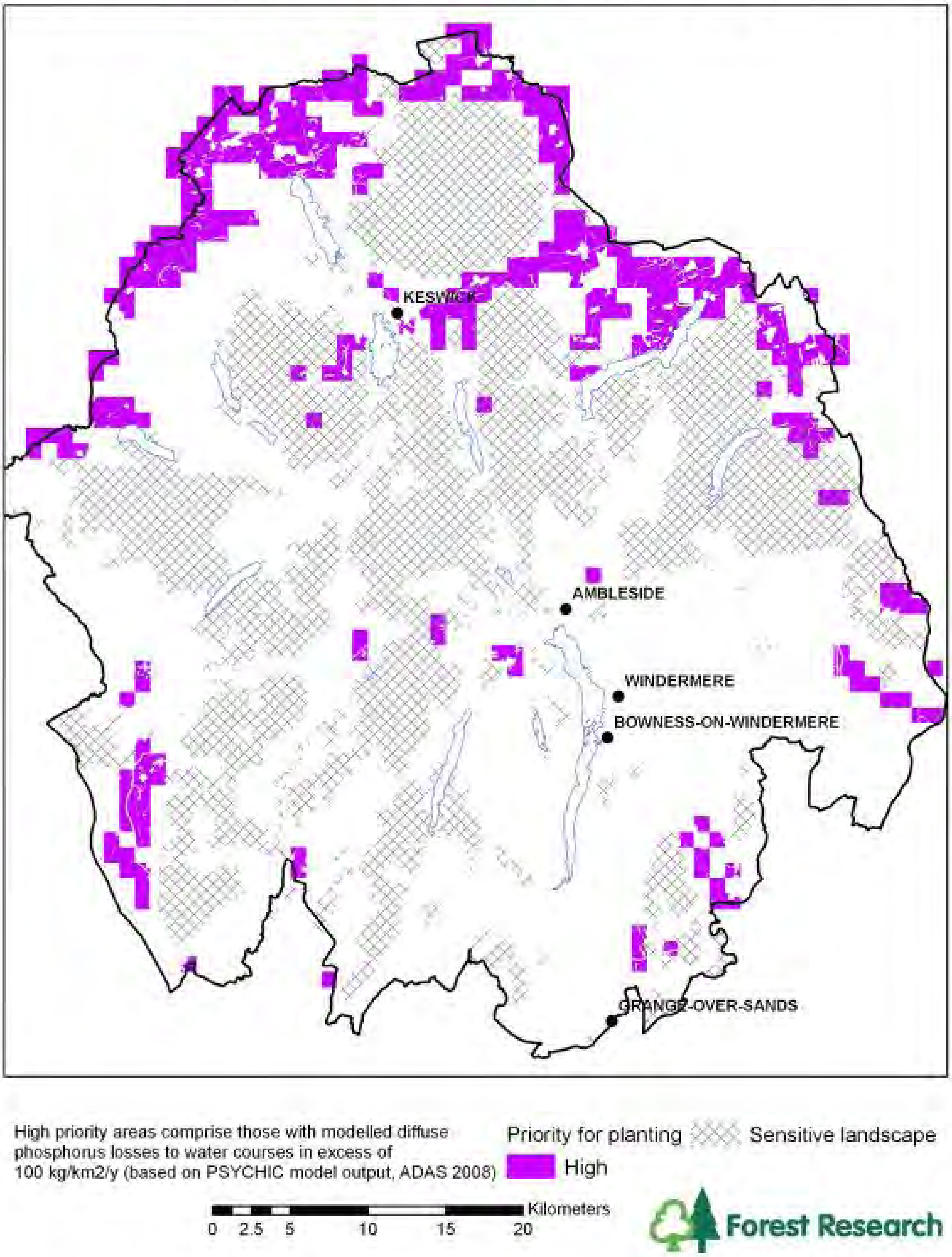
# Map 17 Priority areas for woodland creation in the wider catchment to reduce sediment delivery to watercourses



## 6.3 Opportunities for woodland creation in the wider catchment to reduce diffuse phosphorus pollution

The modelled diffuse phosphorus losses to watercourses are greatest in the north of the National Park (Map 13, Appendix 1) and appear to be closely associated with the density of cattle and manure spreading, rather than overall grazing pressure (Map 6, Appendix 1). The highest losses occur on the lower ground of the Vales of Glendermackin, along the River Eamont and in the Allerdale district around Embleton. Other hot-spots include along the boundary of the ESA scheme around Waberthwaite in the west and Whinfell and Orton to the east. A total of 28,021 ha of land have predicted diffuse P losses exceeding 100 $kg/km^2/y$ and is free from the mapped constraints. This area was classed as a high priority for new woodland to help reduce P losses to watercourses (Map 18). Some 5,098 ha of the high priority land lies within 30 m of a stream or river and therefore potentially available for the establishment of riparian woodland buffers.

# Map 18 High priority areas for new woodland creation to reduce diffuse phosphorus pollution



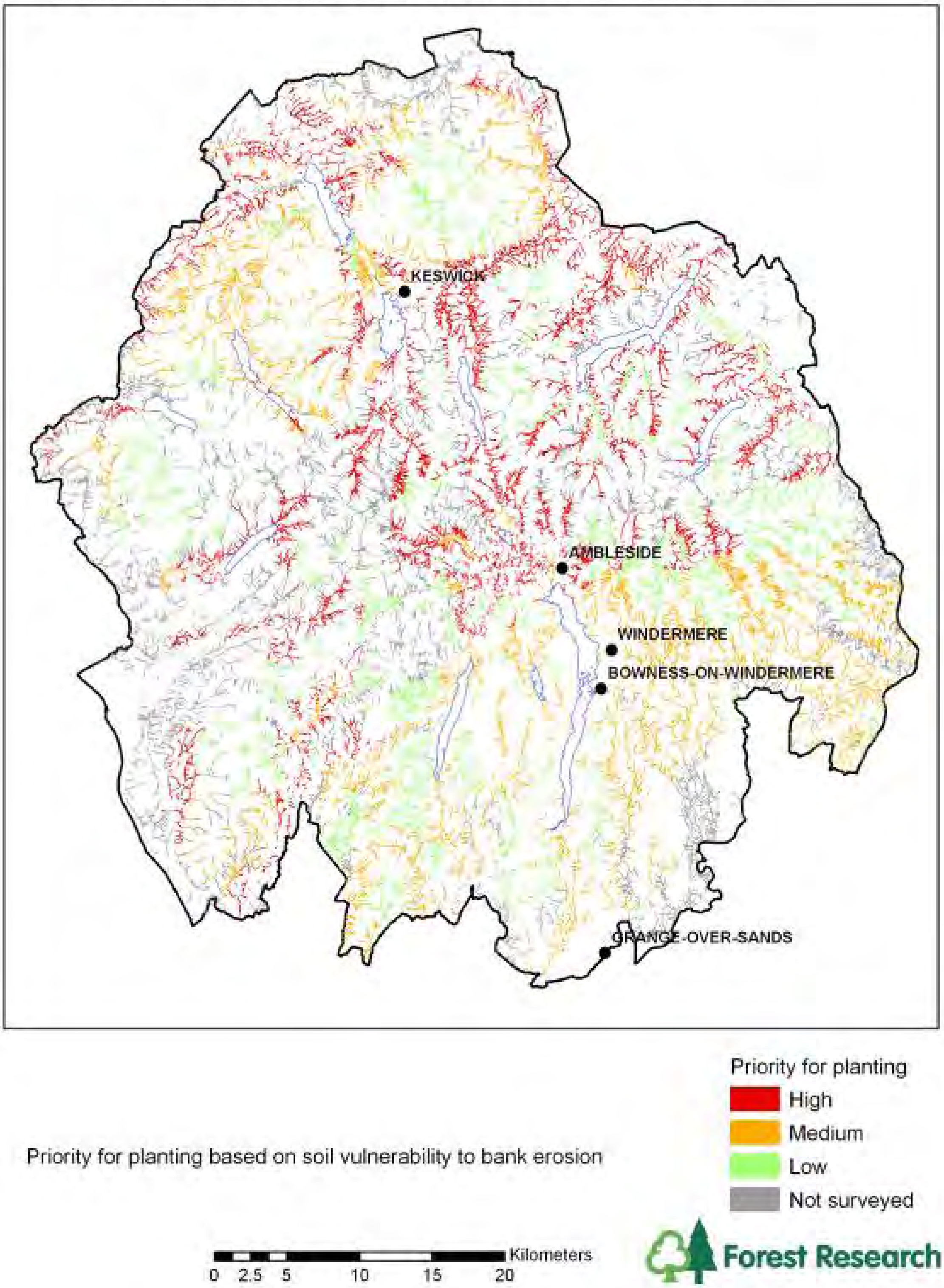
## 6.4 Opportunities for woodland creation to reduce bank erosion

Map 19 shows the distribution of high, medium and low priority riparian zones for woodland creation based on soil vulnerability to bank erosion and the mapped constraints. The area where it was not possible to classify the soils is also displayed for information. A total area of 9,336 ha of riparian soils are classed as a high priority for planting to reduce bank erosion, equivalent to approximately 1,556 km of stream length (Table 4). Only a relatively small proportion of this land is affected by other sensitivities. A similar area of 9,483 ha, or 1,581 km stream length, of riparian land is identified as medium priority.

| Soil vulnerability to bank erosion | Soil Association | Riparian area (ha and %) free from constraints within National Park |
|---|---|---|
| High | 541u, 611a, 713f | 9,336 (3.62%) |
| Moderate | 541j, 561c, 611c, 811b | 9,483 (3.67%) |
| Low | 311b, 721c, 721d, 811a, 1011a, 1011b, lake shore | 8,149 (3.12%) |
| Not surveyed | Others | 10,618 (4.12%) |

Table 4 Classification of riparian soils by their vulnerability to bank erosion. Area figures assume a riparian corridor width of 30 m.

## Map 19 Priority areas for riparian woodland creation to reduce stream bank erosion




Priority for planting based on soil vulnerability to bank erosion

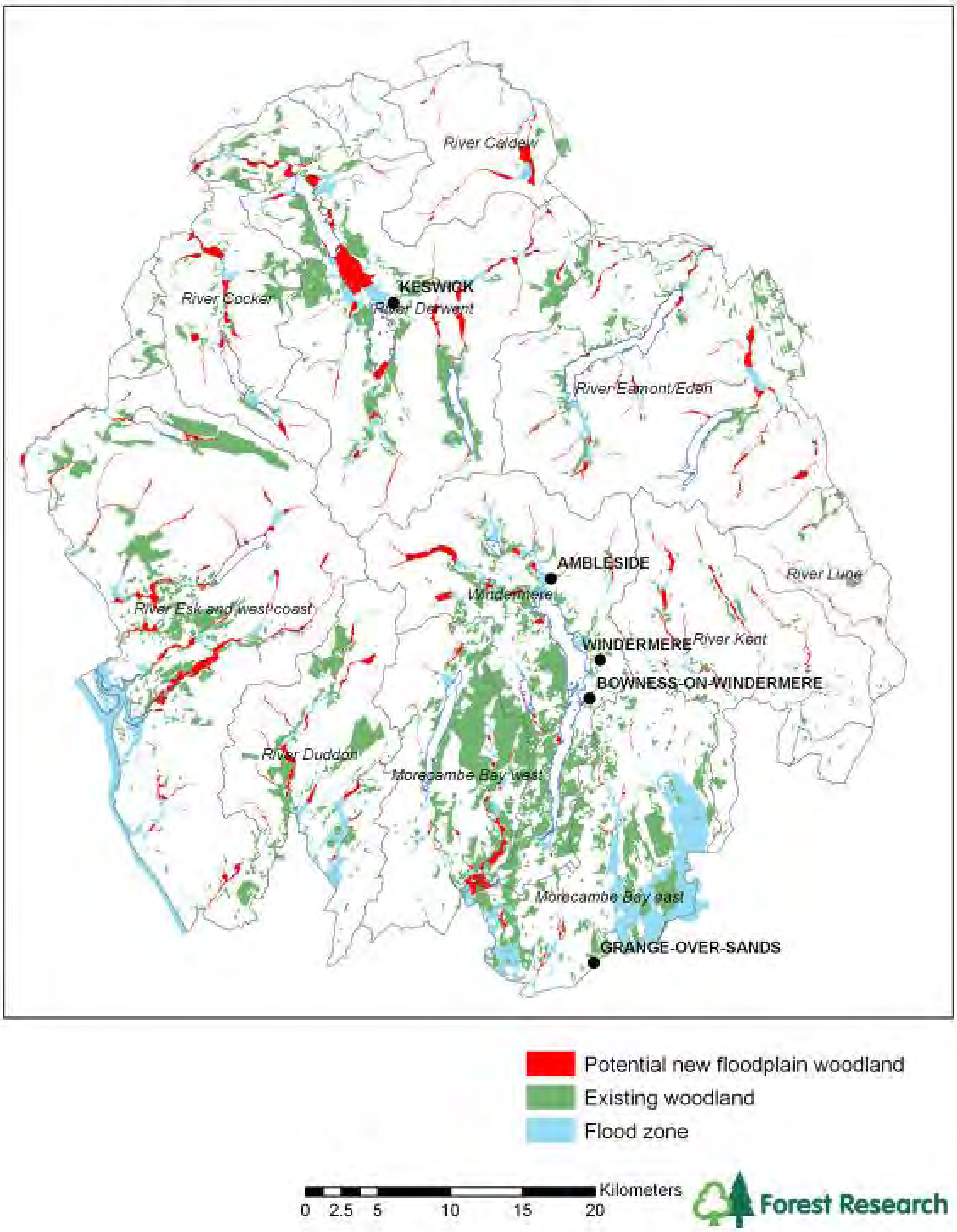
## 6.5 Opportunities for restoring floodplain woodland to help reconnect the river channel with the floodplain to enhance sediment and nutrient retention, as well as assist flood management.

Map 20 shows the area of the Environment Agency's designated floodplain within the National Park that was identified as having potential for new floodplain woodland. A total of 5,365 ha are free from the mapped constraints to woodland creation.

Several other pieces of relevant work have been completed or are underway in the region. These also identify and will help prioritise specific locations for potential floodplain and riparian planting. They include:

- Orr *et al.,* (2004) identified possible sites for woodland creation to reduce sediment supply to Bassenthwaite Lake, particularly in the Newlands Valley, bottom end of Newlands Beck and Gleneramackin, and St John's Beck.
- Hatfield and Maher (2008) estimated that while Newlands Beck provided just 10% of water inputs to Bassenthwaite Lake, it contributed around 80% of the total sediment load.
- Barlow *et al., (*2008b) identified priority sites in the Windermere Catchment for the restoration of river and floodplain connectivity.
- Natural England and the Environment Agency are currently working on detailed River Restoration Visions for the Derwent, Eden and Kent river systems.

# Map 20 Potential new floodplain woodland to enhance sediment storage on the floodplain and reduce downstream inputs to lakes

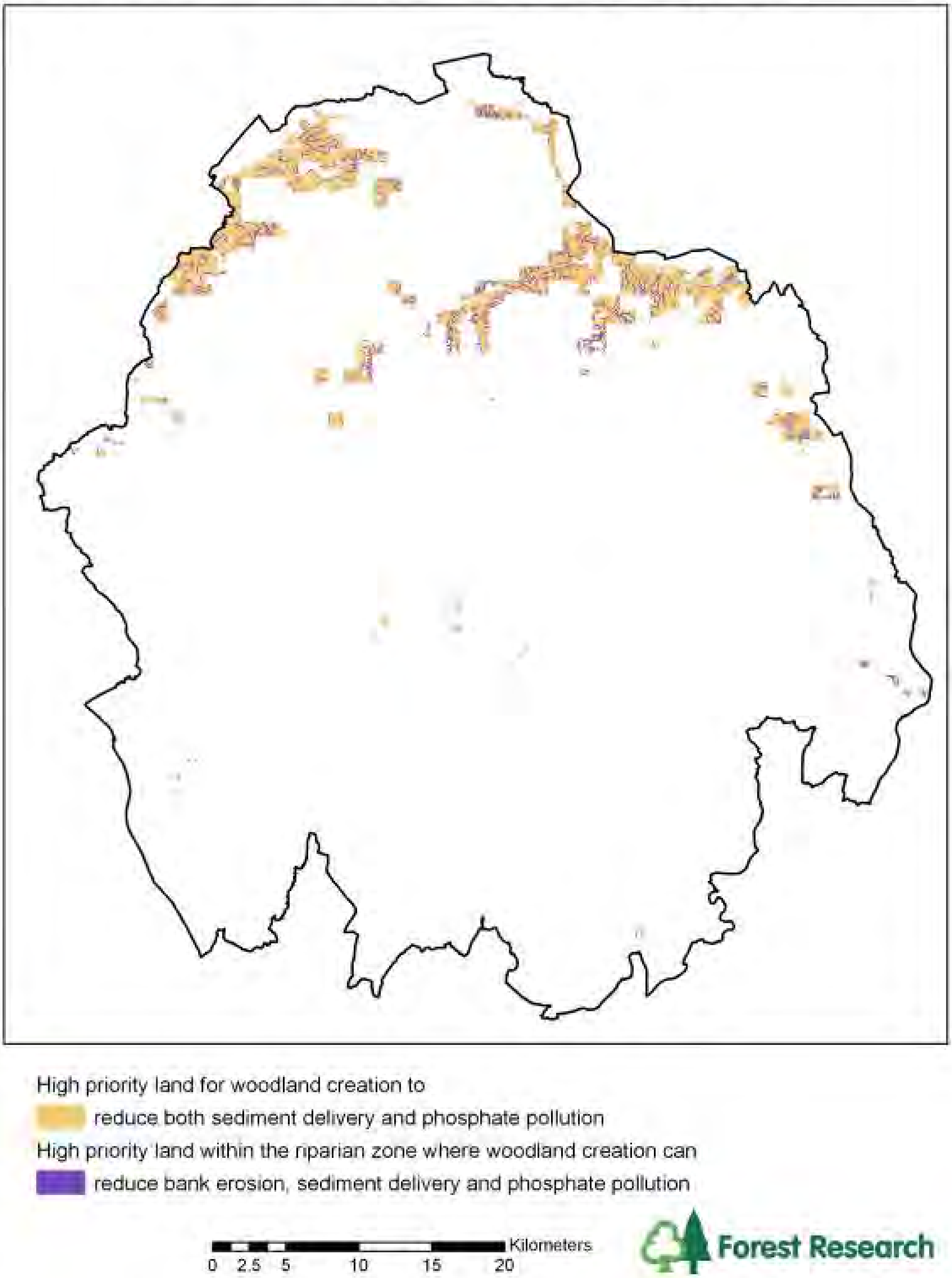


## 6.6 Opportunities for woodland creation to best reduce diffuse sediment and phosphate pollution

Map 21 illustrates locations within the National Park where woodland creation could address diffuse pollution from both sediment delivery and phosphate. There is a combined area of 12,267 ha of land with soils that are highly vulnerable to erosion and responsible for large P losses exceeding 100 $kg/km^2/y$.

Some 2,273 ha comprises riparian land where woodland creation could provide further value for sediment control from vulnerable stream banks and/or losses from the wider catchment.

# Map 21 Opportunities for woodland creation that would address both diffuse sediment and phosphate pollution



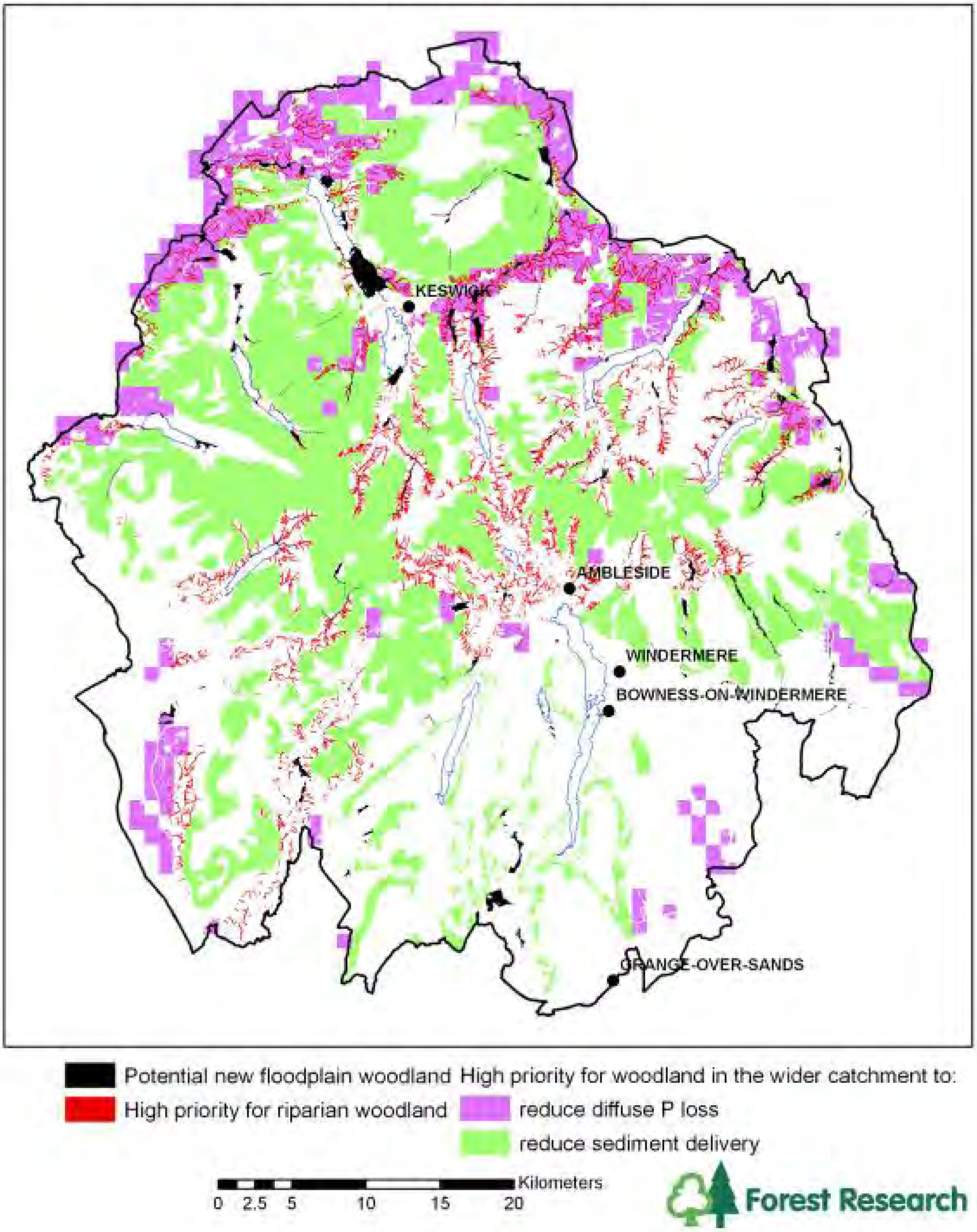
# 7. Conclusions

This study has identified the following opportunities for woodland creation to reduce diffuse pollution based on the observed and predicted bank erosion, modelled sediment and phosphorus sources, and the presence of major constraints.

- 85,217 ha of land at high risk of soil erosion, comprising extensive areas of shallow peaty soils on the high fells plus deeper, seasonally waterlogged, loamy soils on the valley bottoms
- 1,556 km of river length at high risk of bank erosion, equivalent to almost 9,336 ha (assuming a width of 30 m) of riparian land
- An additional 9,483 ha of riparian land at moderate risk of bank erosion;, of which 5,036 ha is bordering land with a high vulnerability to soil erosion where woodland creation could both protect river banks and act as a buffer to trap sediment in runoff from the adjacent land.
- 24,729 ha of land subject to diffuse P losses exceeding 100 $kg/km^2/y$, including 12,267 ha of land highly vulnerable to soil erosion and 2,054 ha of riparian land at high risk of bank erosion
- 5,365 ha of potential new floodplain woodland.

Map 22 shows all of high priority land in the wider catchment, riparian zone and floodplain for woodland creation to reduce diffuse pollution. This covers an extensive area of the National Park and reflects the sensitivity of the soils and watercourses to ground disturbance and nutrient runoff. It is recommended that regional stakeholders use this and the other maps to help target the best sites where woodland creation can provide the greatest benefit. However, success will depend on increasing the value of and improving the synergy between available incentives to secure land use change. The establishment of one or more demonstration woodlands is recommended to provide a local evidence base and help communicate the need for a more integrated, whole catchment based approach to water management.

Map 22 Combined map showing high priority areas for woodland creation in the wider catchment, riparian zone and floodplain to reduce diffuse sediment and phosphous pollution



# 8. Recommendations

There is no intention to cover the whole of the National Park in trees. It is recommended that stakeholders use the maps to try to devise and target schemes that will reduce diffuse pollution, satisfy landowner and farmer interests, and further other policy aims covering aspects such as biodiversity, landscape, historic environment and public access. The Cumbria Woodland Vision (FC, 1999) provides useful guidance on these matters.

The term “woodland creation” should be interpreted very broadly to include everything from commercial conifer woodland managed for timber production to various types of native woodland reserve. New native woodland may vary from high forest to open wood-pasture systems, including low growing montane scrub, wet willow carr and even individual trees along river banks. Woodland creation may be achieved through new planting and/or natural regeneration, with structure and species choice tailored to local conditions and the aims listed above.

Woodland creation should not be viewed in isolation. Other habitats can also play a valuable part in reducing diffuse pollution, such as the role of dwarf shrub heath (heather and billberry), especially where this supports a bulky moss layer, to intercept surface runoff and any associated sediment. Often, a mosaic of different habitats will best meet the range of local objectives.

With regard to tackling the serious threat posed by diffuse sediment and phosphate pollution of watercourses, a range of woodland options are possible, including:

(i) larger scale planting or natural regeneration schemes on soils with a high vulnerability to erosion or nutrient leaching,

(ii) targeted planting of woodland or natural regeneration along runoff pathways such as swales [vegetated shallow channels that intersect and retain surface runoff during wet periods], across the mid-slope and in riparian buffers, to encourage soil infiltration and retain sediment and nutrient pollutants,

(iii) targeted planting or natural regeneration along actively eroding stream sides or reaches with a high risk of bank erosion (perhaps in some cases extending further back from the river edge to allow for future channel migration), and

(iv) planting and restoration of floodplain woodland to increase “hydraulic roughness” and so encourage pollutant deposition and ‘slow the flow’. This should comprise relatively open woodland with trees and shrubs with many low branches and multiple stems to maximise roughness and delay flood flows.

It is recognised that it may be difficult to agree woodland creation in some of the identified areas, particularly where productive farmland is involved. Incentive schemes should be operated and reviewed accordingly.

# 9. Acknowledgements

We would like to acknowledge the support of a number of partners in undertaking this work. The study was funded by Natural England, the Woodland Trust and Forestry Commission England, with assistance from Cumbria Woodlands. Data was supplied from ADAS and we are grateful for permission to use the outputs from their Phosphorus and Sediment Yield Characterisation in Catchments (PSYCHIC) model. The authors are especially grateful to Jean Johnston, Sian Thomas, Heather Swift and Jim O'Neill for their valuable comments on an earlier version of this report.

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# Appendix 1 List of Maps

Map 1 The project area: the Lake District National Park and Environmentally Sensitive


*(The following maps also appear in the main text of the report*)

# Appendix 2 GIS data sources used in the project

Basic physiographic data layers:

| Source | Name | Content | Date |
|---|---|---|---|
| ADAS | ADAS Grazing Livestock Units<br>ADAS Land Cover<br>ADAS PSYCHIC Diffuse Phosphorus and Total sediment reaching watercourses via all pathways | 1 km modelled data of sediment and phosphorus mobilisation and delivery to watercourses. | 2004 |
| Ordnance Survey | OS Colour Raster<br>OS Strategi<br><br>Land-Form PROFILE Plus | OS map images<br>Digital data for mapped features e.g. roads<br>Digital terrain model at 1:10 000 scale, from which can be derived slope, land form, water flow direction, drainage networks, river catchments and topographic wetness index | |
| National Soils Resources Institute | NATMAP | National digital soil association data from which can be derived:<br>Hydrology of Soil Types (HOST),<br>Standard Percentage Runoff,<br>Poach Class,<br>Vulnerability to structural degradation leading to accelerated runoff | |
| Countryside Survey CEH | Land Cover 2000 | Vegetation cover (20 broad habitat classes) based on the interpretation of aerial photographs | 2002 |
| English Heritage | National Monuments Record | Scheduled Monuments<br>Registered Parks & Gardens | 2010<br>2010<br>2010 |

| | | | |
|---|---|---|---|
| | | Listed Buildings<br>World Heritage Sites<br>Registered Battlefields | 2009<br>2008 |
| Environment Agency | National Flood Zone Map<br>Flood defences<br>Land benefiting from flood defences<br>Water Framework Directive consultation spatial data and data base<br>Detailed River Network<br>Main Rivers<br>ECSFDI Priority Catchments | | 2008 |
| Forestry Commission | National Inventory of Woods and Trees | Existing woodland | 2002 – updated with new planting annually |
| Orr et al 2004 | BASS GIS | Observed bank erosion and bare ground (from aerial photographs) in the Bassenthwaite Lake Catchment | 2004 |
| Barlow et al 2009 | Windermere Fluvial Audit | Observed location of sediment sources and sinks in the Windermere Lake catchment | 2009 |
| British Geological Survey | Geology | | |
| Mc Hugh et al | Connectivity index | Sediment transport capacity resulting from slope shape and drainage pattern | 2002 |
| Natural England | National Character Area Map<br>Site of Special Scientific Interest<br>Special Areas of Conservation<br>National Nature reserves<br>Local Nature Reserves<br>Environmentally Sensitive Area Scheme | Landscape character<br>Site boundaries, name and details<br><br><br><br>ESA scheme boundary and agreements | 2005<br><br><br><br><br>2002 |
| RSPB | Reserves and Important Bird | The RSPB may object to | |

| | | | |
|---|---|---|---|
| | Areas | expanded tree cover within their reserves | |
| Defra | Lake District National Park<br>Agricultural Land Classification<br>Registered Common Land | Boundary<br><br>Boundary and name | |
| Forestry Commission Spatial Data Repository | Gas National Grid pipeline<br>Electricity National Grid<br>Overhead cable<br>Ministry of Defence Estate | <br><br><br>Site boundary, names and function | |

# Appendix 3: Pre processing required to generate spatial data for the constraints to woodland creation

## SSSIs, Special Areas of Conservation and Special Protection Areas

There are 144 SSSIs in the Lake District National Park. Each site citation, available on line http://www.english-nature.org.uk/special/sssi/search.cfm was read to determine the character of the habitat and ascertain whether woodland creation would be acceptable. There were 125 sites classed as solely open habitats where woodland may be less appropriate. There were 13 sites of extensive upland habitat where it was considered that some expansion of woodland cover may be more acceptable.

## Scheduled Monuments

The register of Scheduled Monuments including linear antiquity and World Heritage Sites were all buffered by 30 m, in accordance with the Forest and Archaeology Guidelines

## Register of Historic Parks and Gardens of special historic interest in England.

The spatial data for the Registered Historic Parks and Gardens was obtained from the English Heritage web site (8th March 2010).

## Existing Woodland

Existing high canopy woodland was identified using the National Inventory of Woods and Trees interpreted forest types: conifer (including felled and ground prepared for planting), mixed, coppice and broadleaf. This was considered to present a constraint to new woodland creation.

## Urban areas

Urban Area + 500 m buffer: All urban areas were excluded. In addition, floodplain within the 500 m buffer was excluded if adjacent or downstream of the settlements that intersected the floodplain.

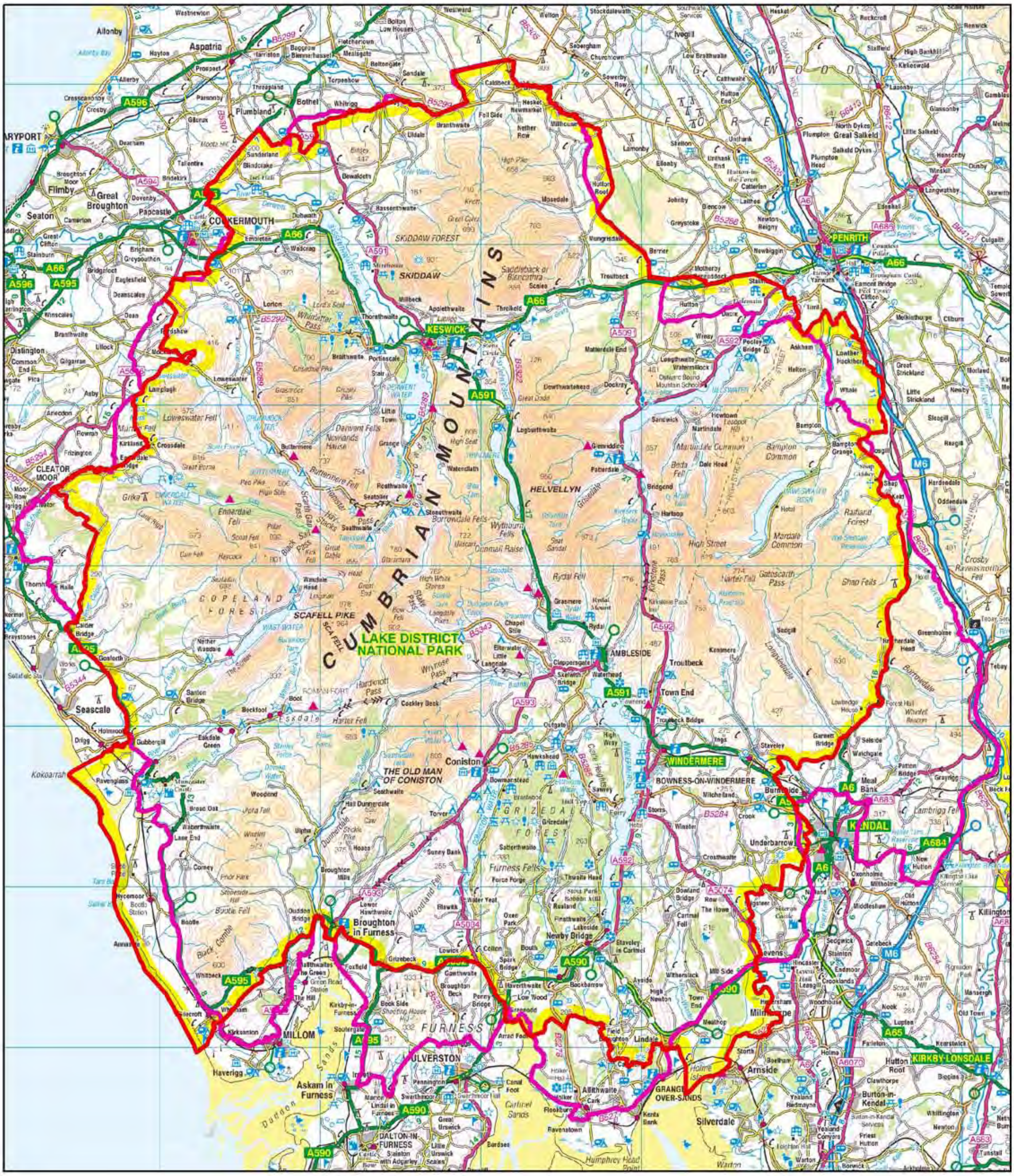
## Roads

Spatial data for the road network is available as OS50k polyline features, which were buffered to create polygons approximate to the actual size of feature in the landscape:
A Roads + 50 m buffer
B Roads + 20 m buffer
Minor roads + 5 m buffer.
The buffered roads were amalgamated using the UNION tool and dissolved to create a single feature for the road network.
The road network + buffer: As with the urban areas, a 300 m wide buffer was created around the road network; areas of floodplain within 300 m downstream of a road were excluded as potential new woodland.

## Rail

The railways were available as OS 50k polyline features, which were buffered by 20 m to create a polygon approximate to the actual size of the feature in the landscape. It was assumed that rail tracks were raised above the floodplain on embankments and thus it was decided not to delineate an additional linear buffer along them. However this would need to be verified on an individual site by site basis.

# Map 1 The project area: Lake District National Park and Environmentally Sensitive Area




National Park

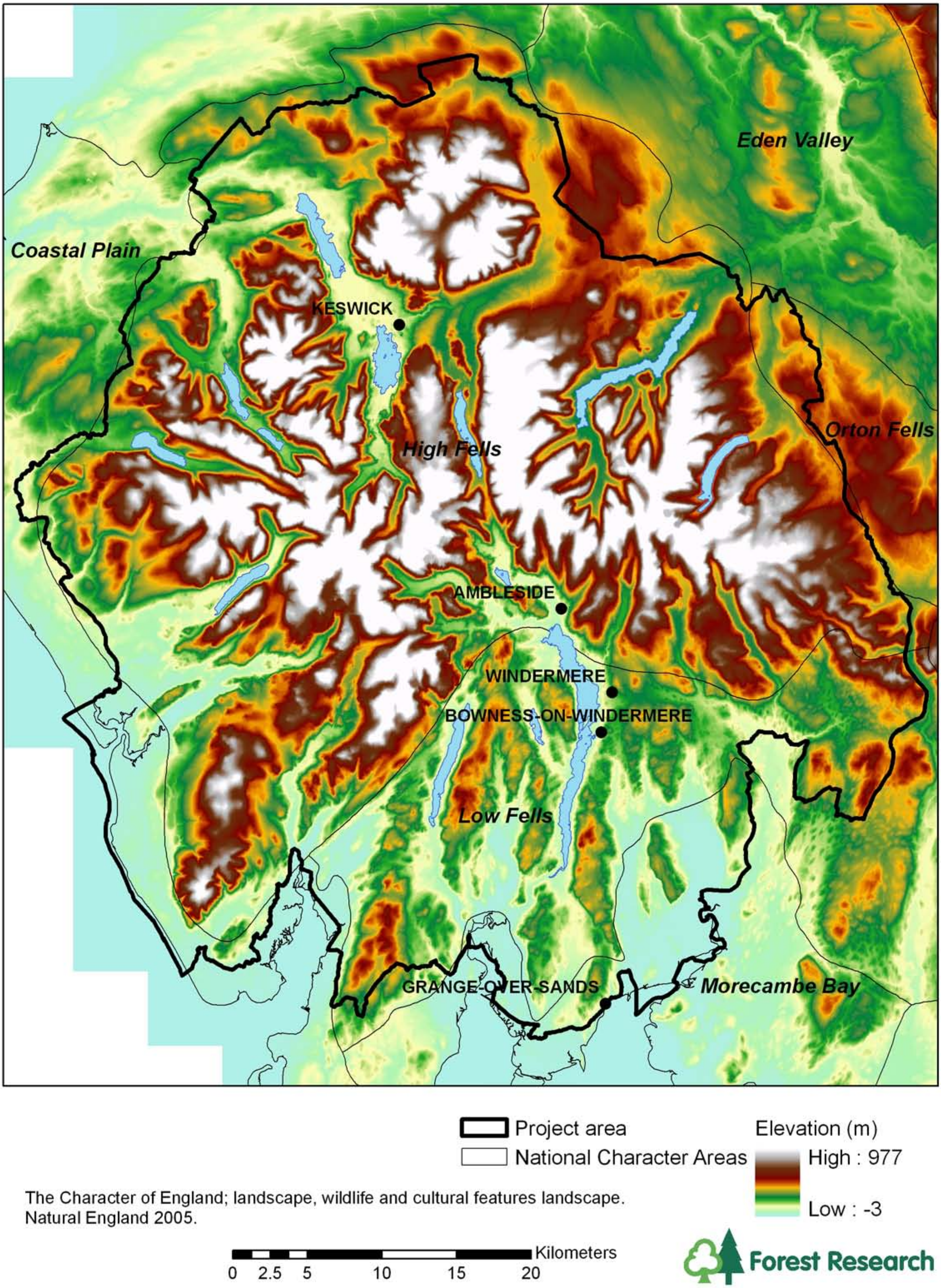
Environmentally Sensitive Area



0 2.5 5 10 15 20 Kilometers

Forest Research

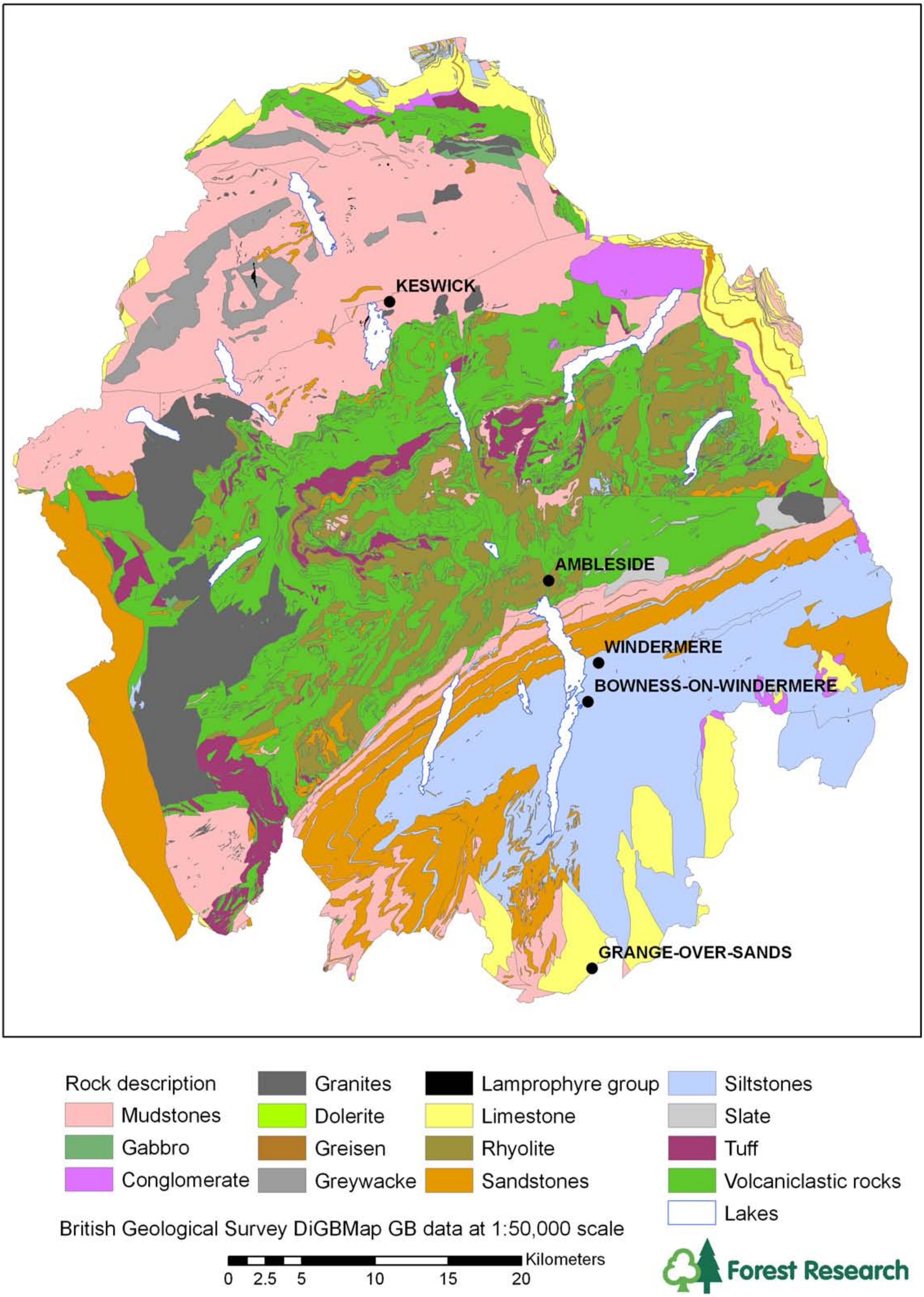
# Map 2 Elevation and Landscape




The Character of England; landscape, wildlife and cultural features landscape.
Natural England 2005.

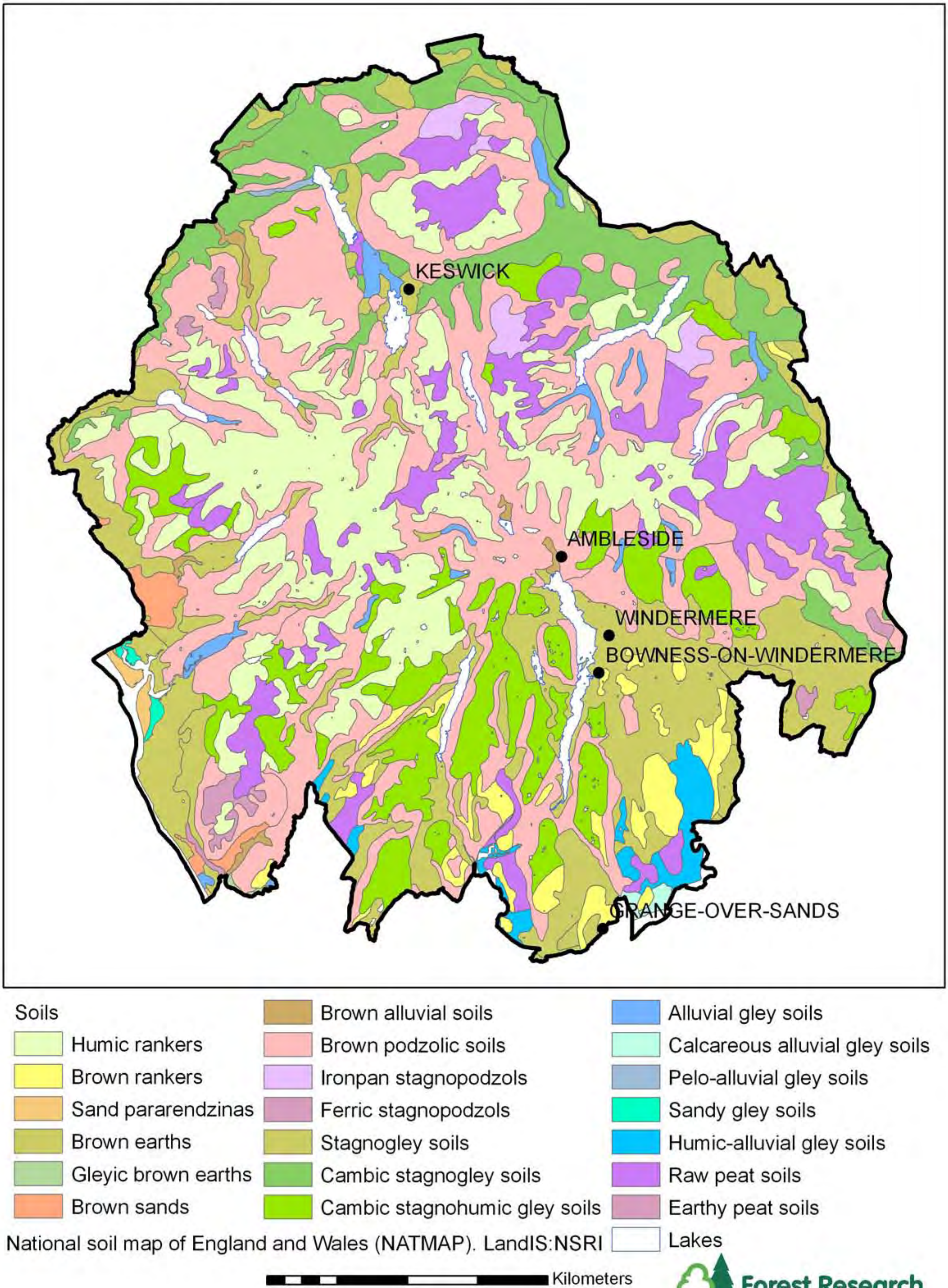
Forest Research

# Map 3 Geology




Forest Research

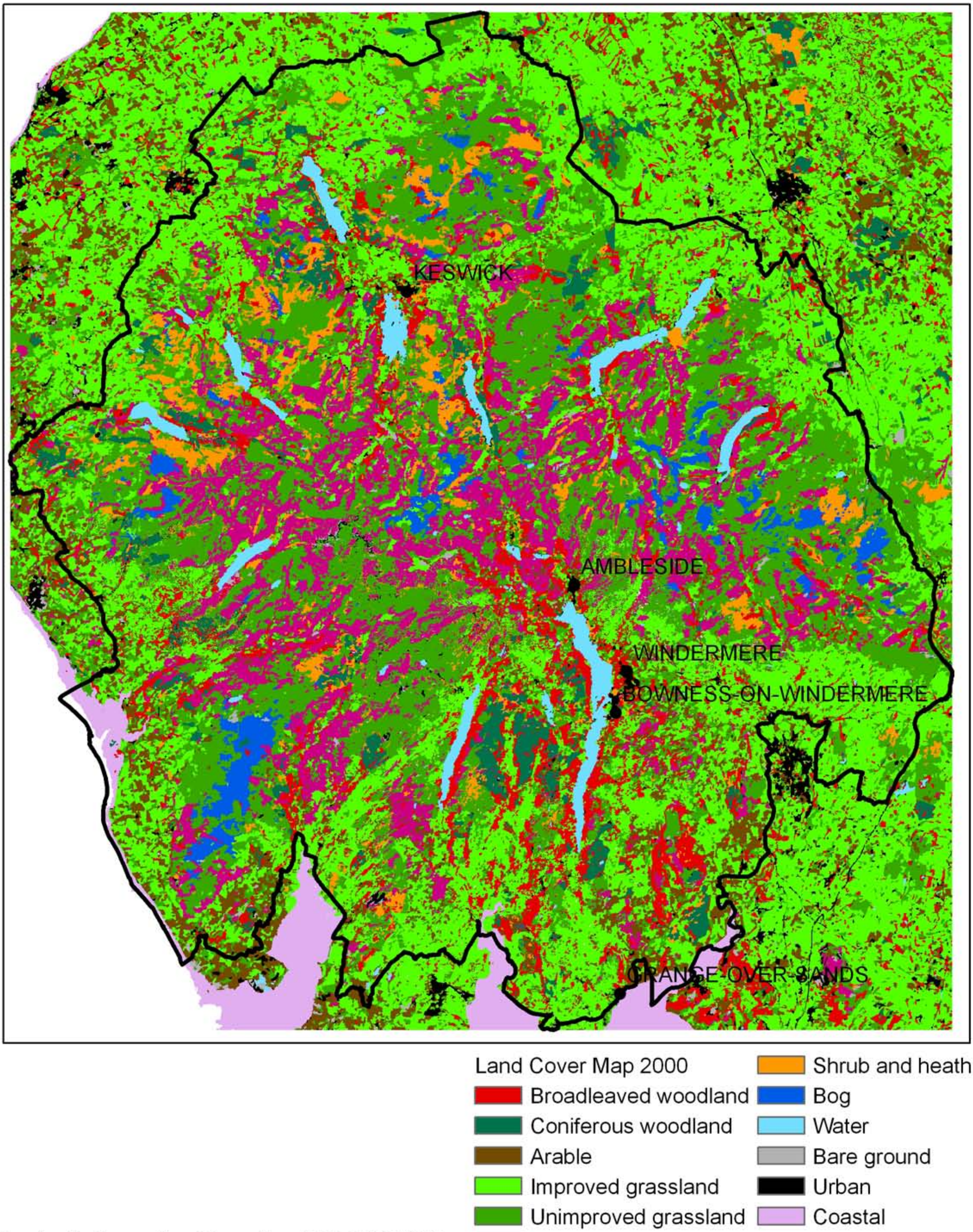
# Map 4 Soils




National soil map of England and Wales (NATMAP). LandIS:NSRI

Forest Research

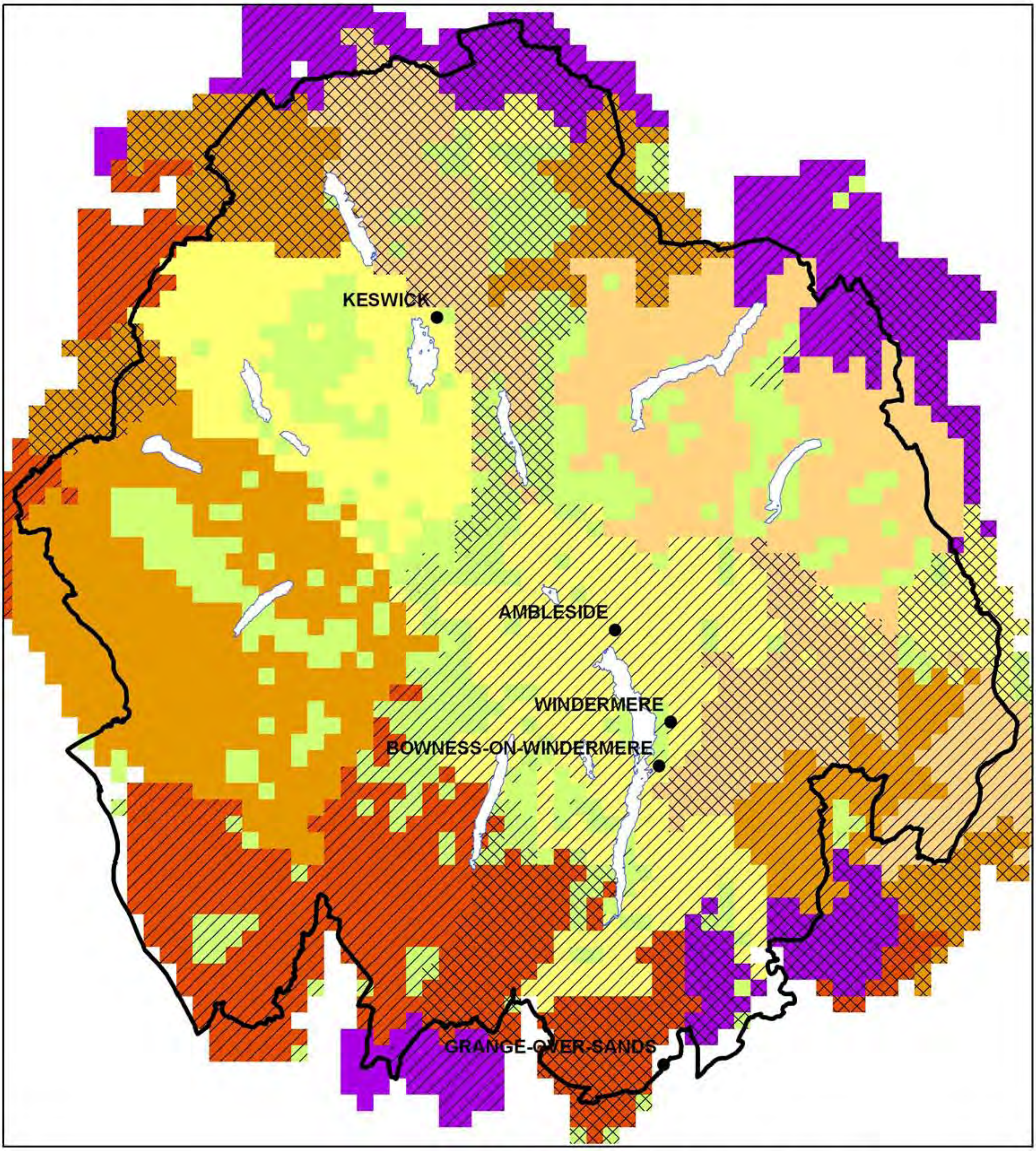
# Map 5 Land use - Countryside Survey 2000




Countryside Survey, Land Cover Map 2000. CEH (2002)

Forest Research

# Map 6 Land use - grazing pressure

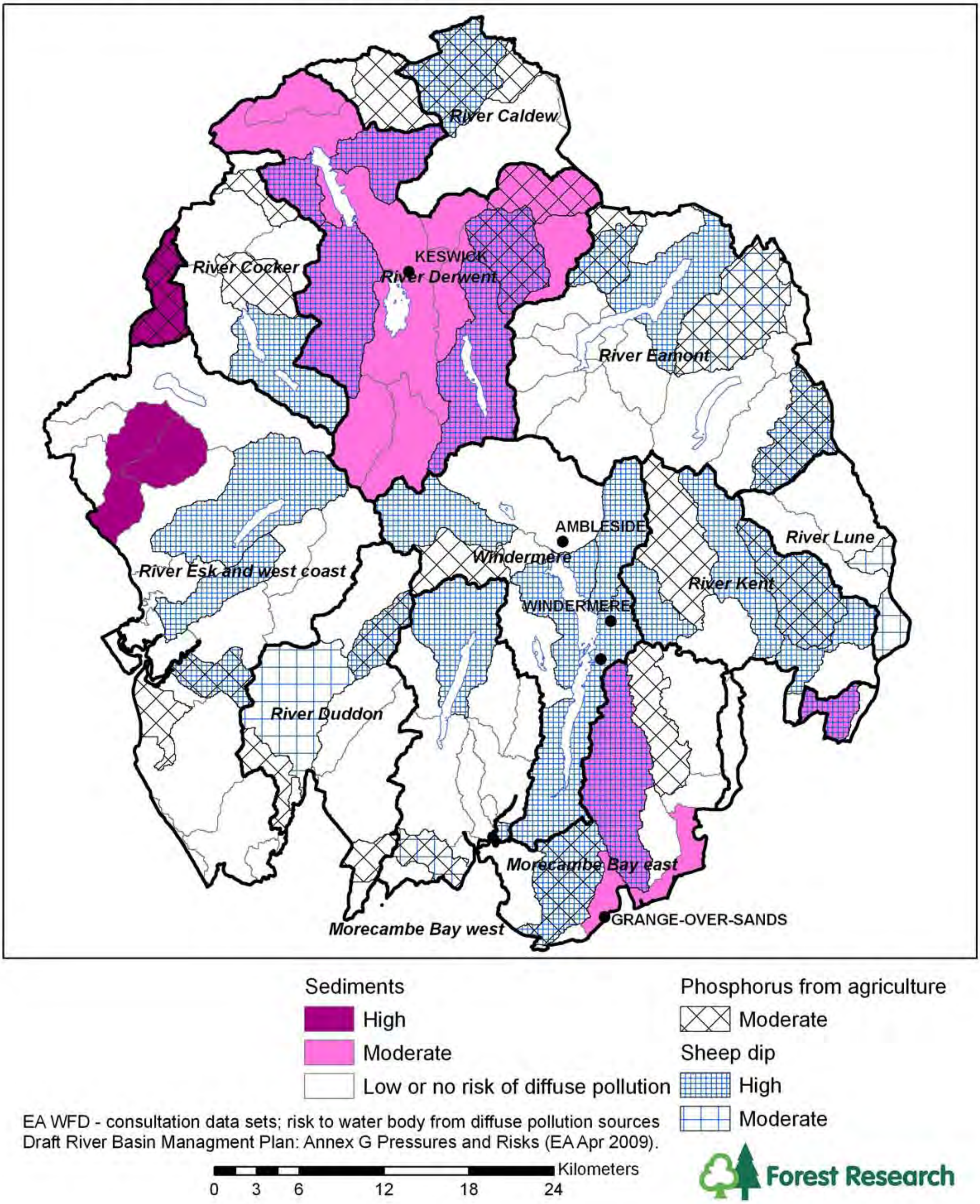



| ADAS Total livestock units | Sheep units |
|---|---|
| 0.0 - 0.5 (units/ha) | < 0.32 (units/ha) |
| 0.5 - 1.54 | 0.32 - 0.44 |
| 1.54 - 1.65 | 0.44 - 0.59 |
| 1.65 - 2.06 | |
| 2.06 - 2.25 | |
| 2.25 - 3.31 | |

ADAS Land use database.
ADAS PSYCHIC - Phosphorus and sediment yield characterisation in catchments (2008)

0 2.5 5 10 15 20 Kilometers

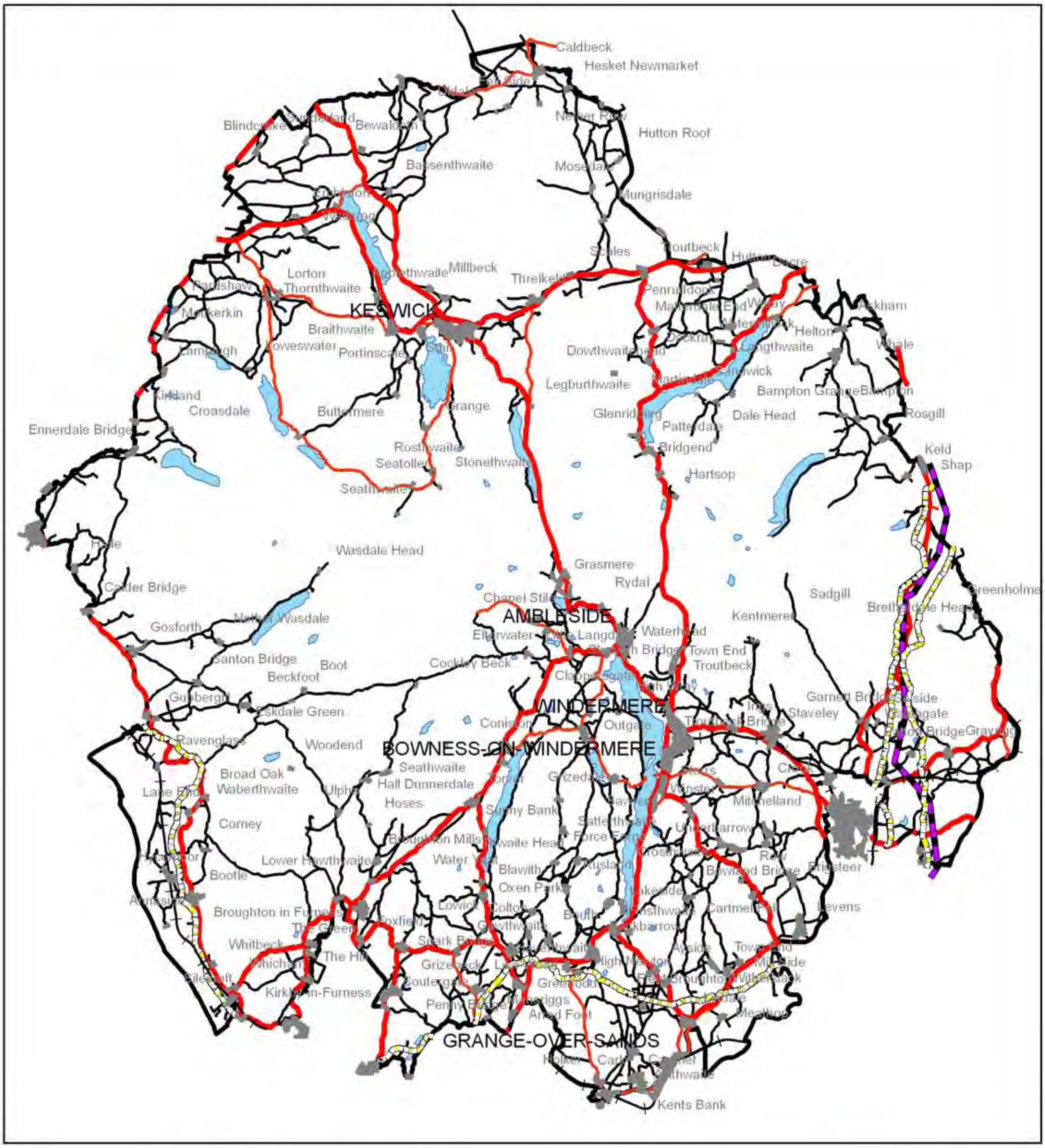
# Map 7 Risks to waterbodies failing to achieve good ecological status by 2015 due to diffuse pollution from sediments, phosphorus from agricultural sources and sheep dip.




EA WFD - consultation data sets; risk to water body from diffuse pollution sources
Draft River Basin Managment Plan: Annex G Pressures and Risks (EA Apr 2009).

Forest Research

# Map 8 Urban Infrastructure

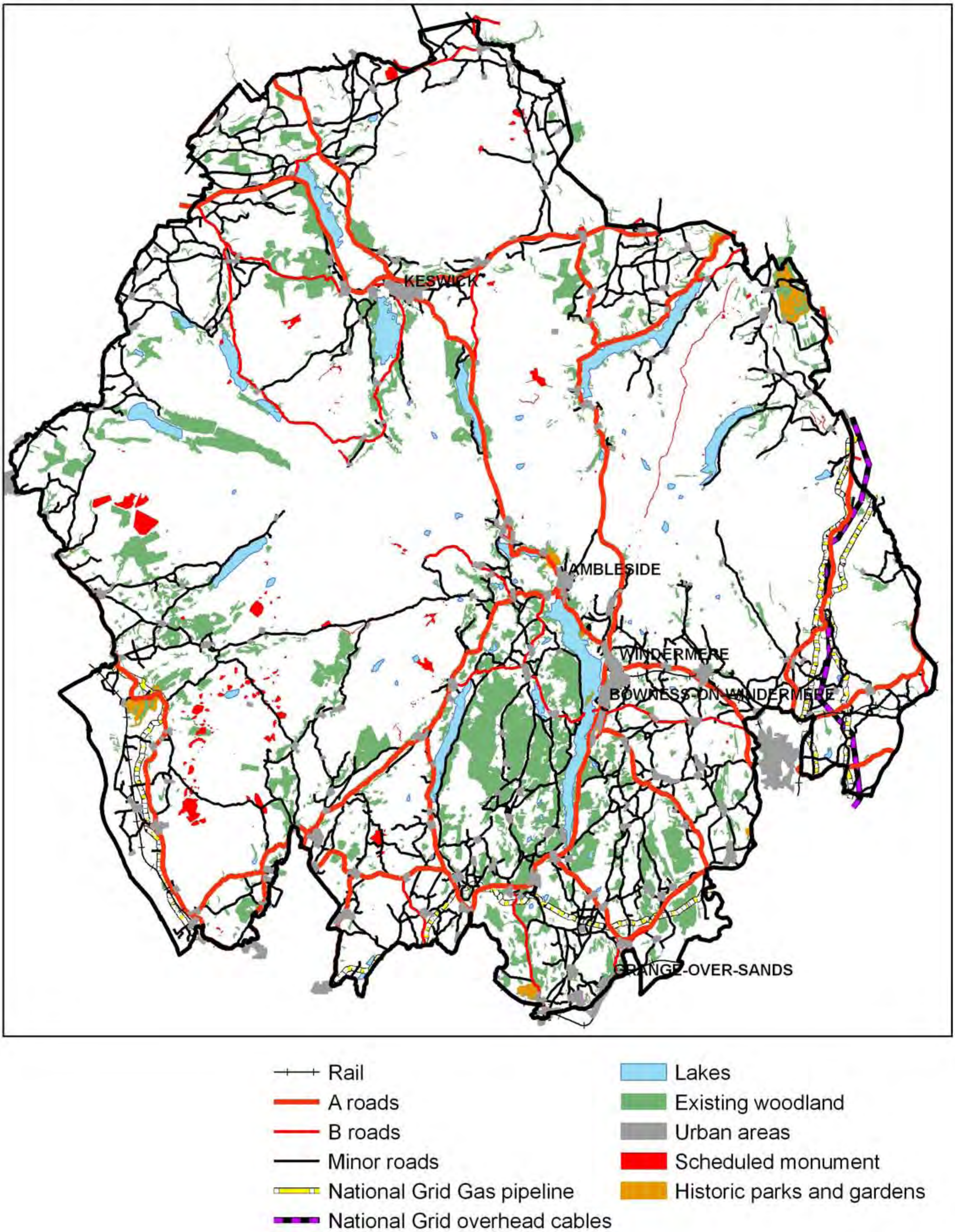



Urban areas
Rail
National Grid: Gas pipeline
National Grid: Electcity overhead cables
A roads
B roads
Minor roads
Lakes

0 2.5 5 10 15 20 Kilometers

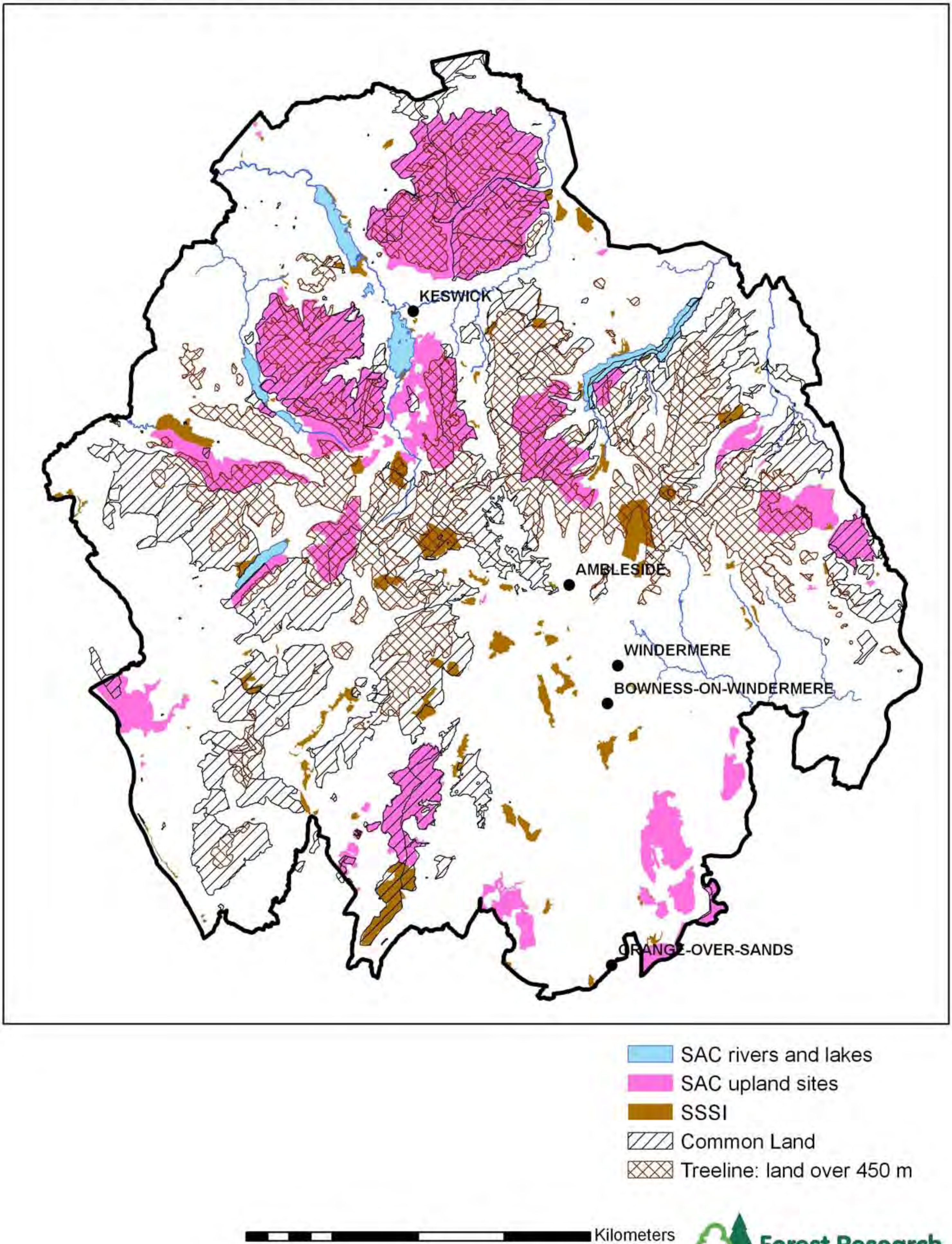
Forest Research

# Map 9 Some constraints to woodland creation



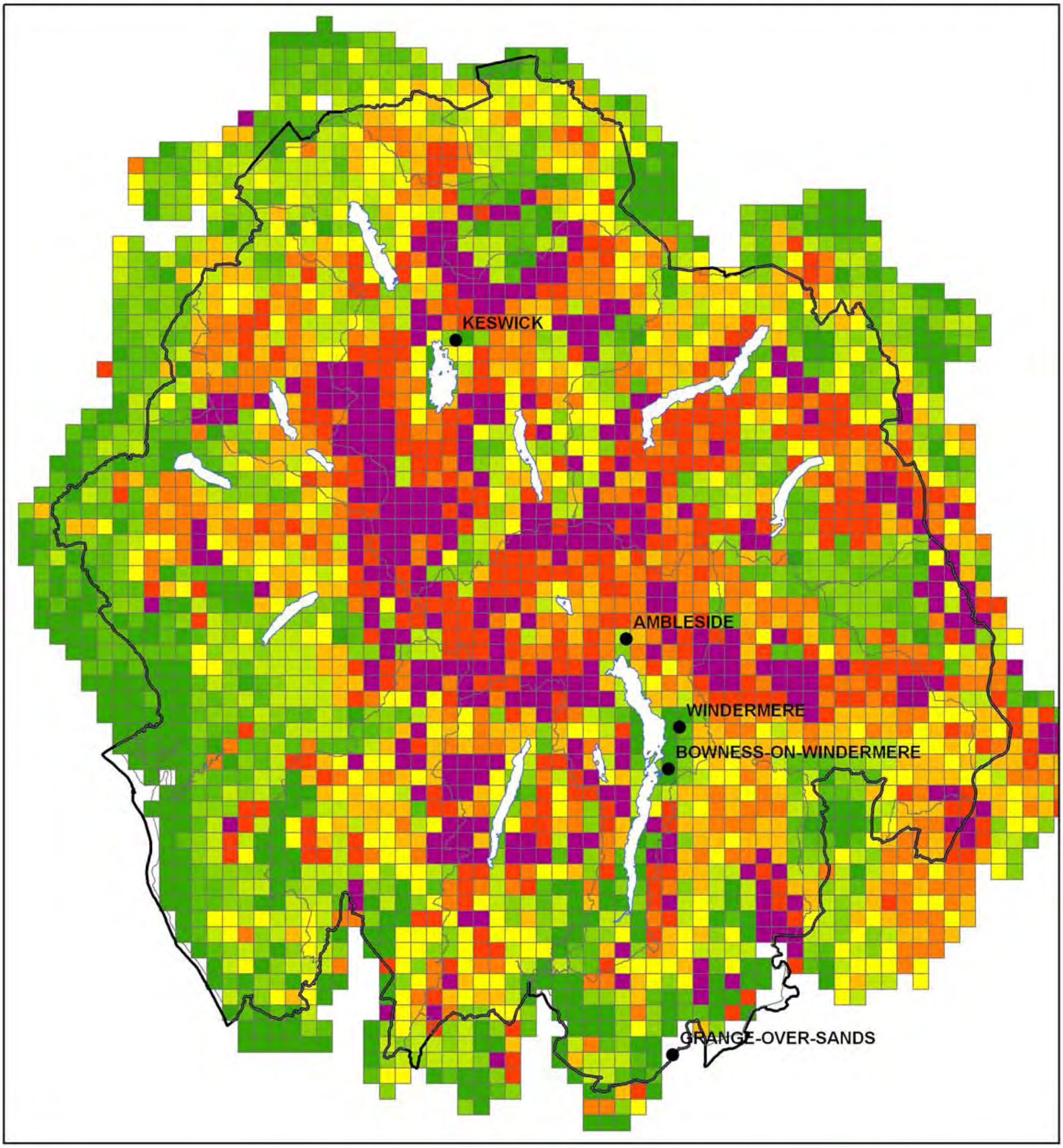

Forest Research

# Map 10 Other factors to be considered when planning woodland creation




Forest Research

# Map 11 Modelled sediment loss to watercourses




Total sediment reaching watercourses via all pathways

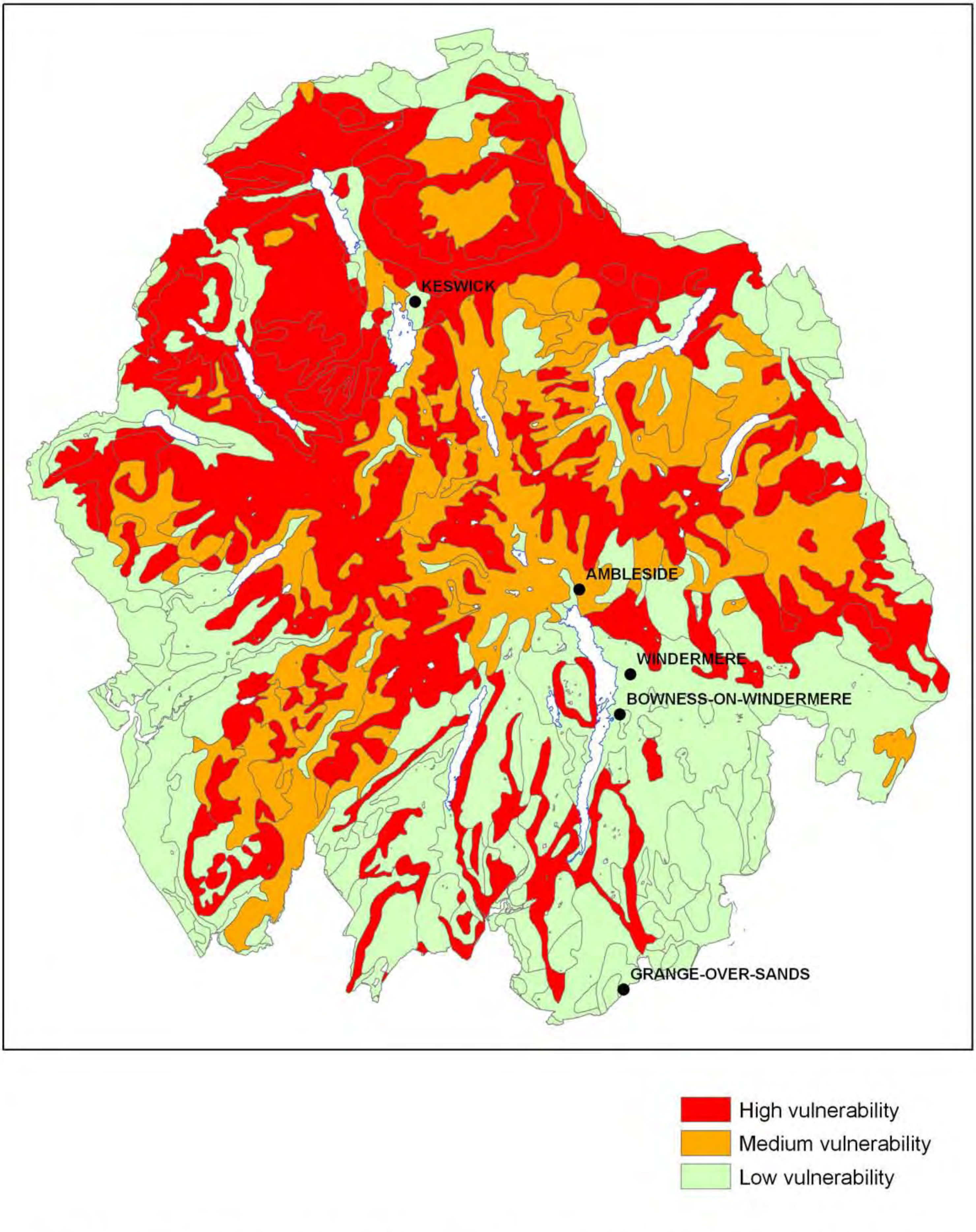
- 0 - 1.1 (tonnes / km2 / y)
- 1.1 - 2.2
- 2.2 - 3.6
- 3.6 - 5.4
- 5.4 - 7.7
- 7.7 - 11.2
- 11.2 - 16.0
- 16.0 - 26.7
- 26.7 - 214.6

Created by - ADAS (2008) Phosphorus and sediment yields charcaterisation in catchments (PSYCHIC). DEFRA & CEH.

Kilometers
0 2.5 5 10 15 20

Forest Research

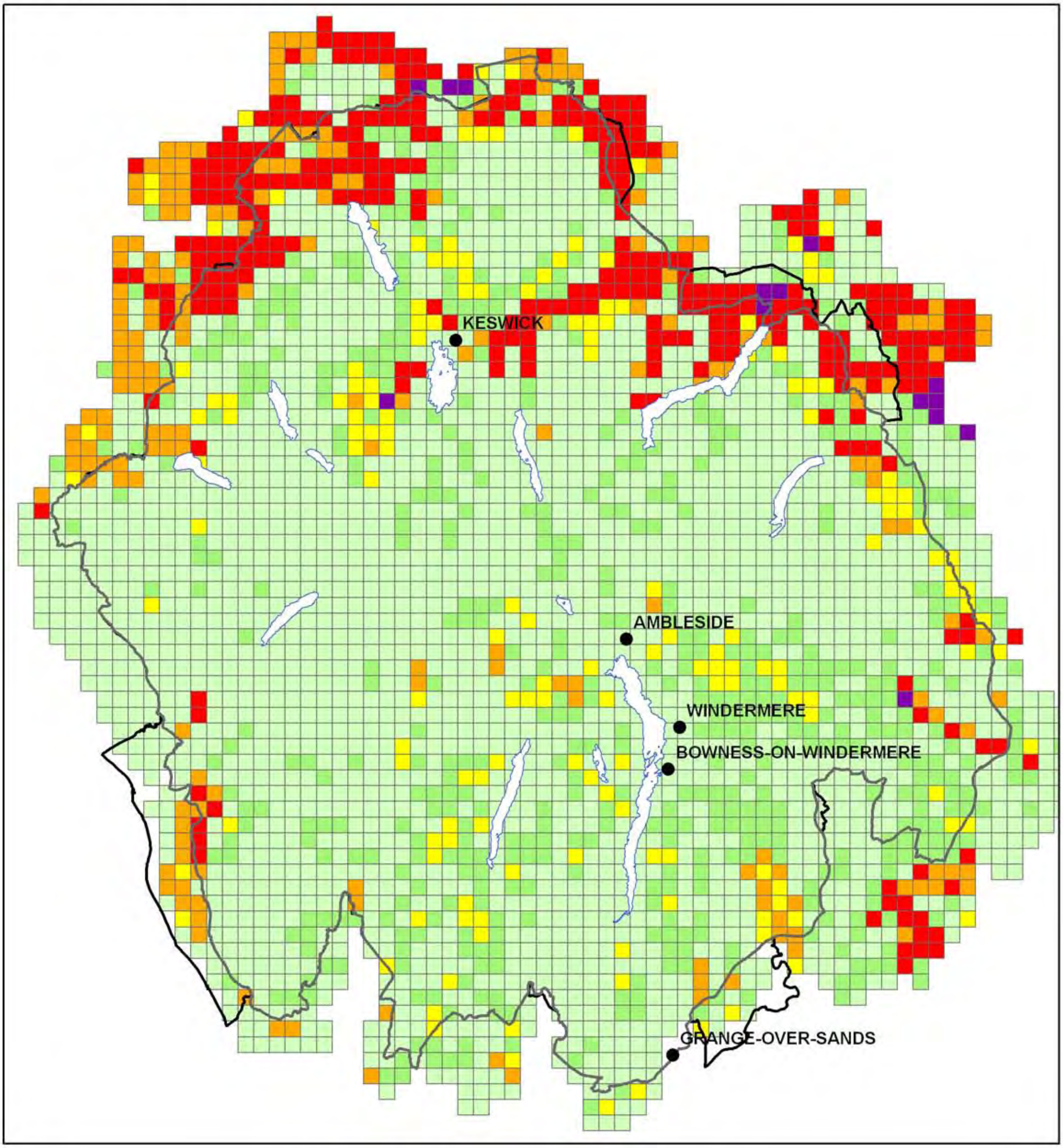
# Map 12 Vulnerability of soils to sediment loss




Based on ADAS (2008) Phosphorus and sediment yields charcaterisation in catchments (PSYCHIC). DEFRA & CEH.

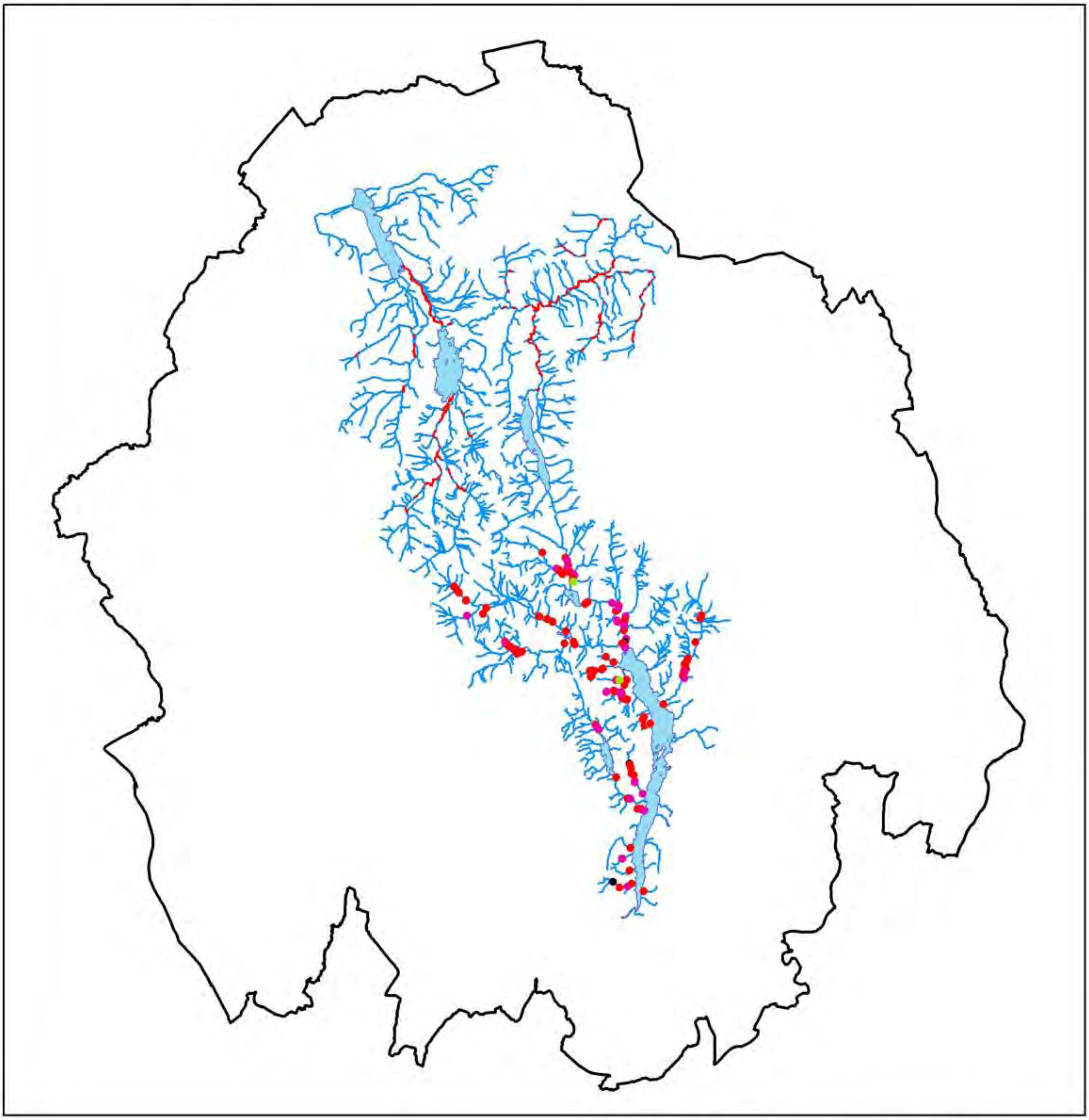

Forest Research

# Map 13 Modelled diffuse phosphorus loss to watercourses




Created by - ADAS (2008) Phosphorus and sediment yields charcaterisation in catchments (PSYCHIC). DEFRA & CEH.

# Map 14 Distribution of observed stream bank erosion in Bassenthwaite and Windermere lake catchments



Bassenthwaite
Eroded reaches

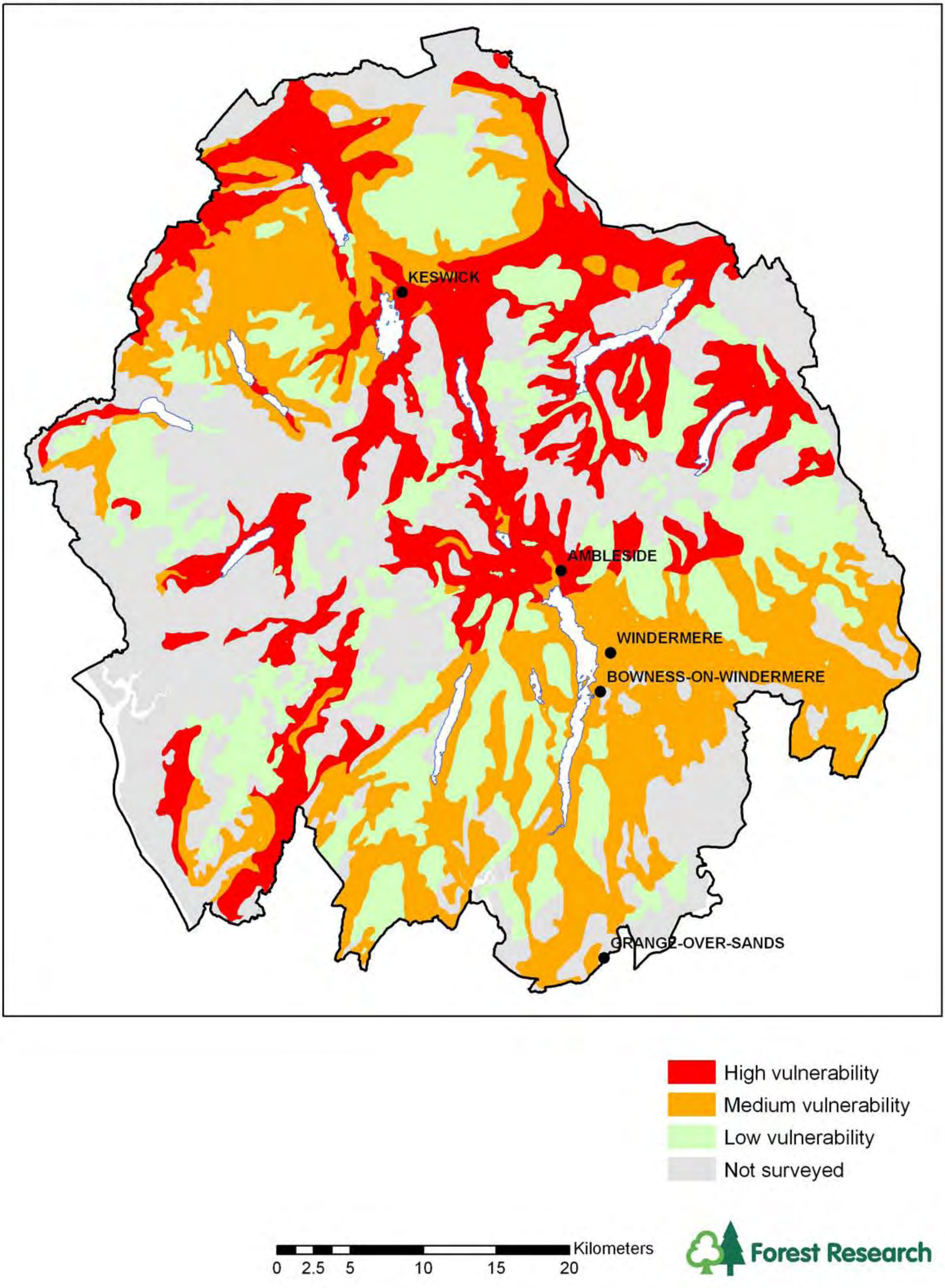
Windermere
Sediment sources
- Bank erosion
- Fallen tree/wall
- Footpath
- Poaching

Spatial data set sources: Bassenthwaite Lake Geomorphological Assessment: Phase 2 (2004); prepared by Orr et al., at Lancaster University for the EA.
Windermere Fluvial Audit (2009); prepared by JACOBS Engineering UK Limited on behalf of the EA and Windermere Catchment Restoration Programme.
No comparable data was avaliable for the other river catchments.

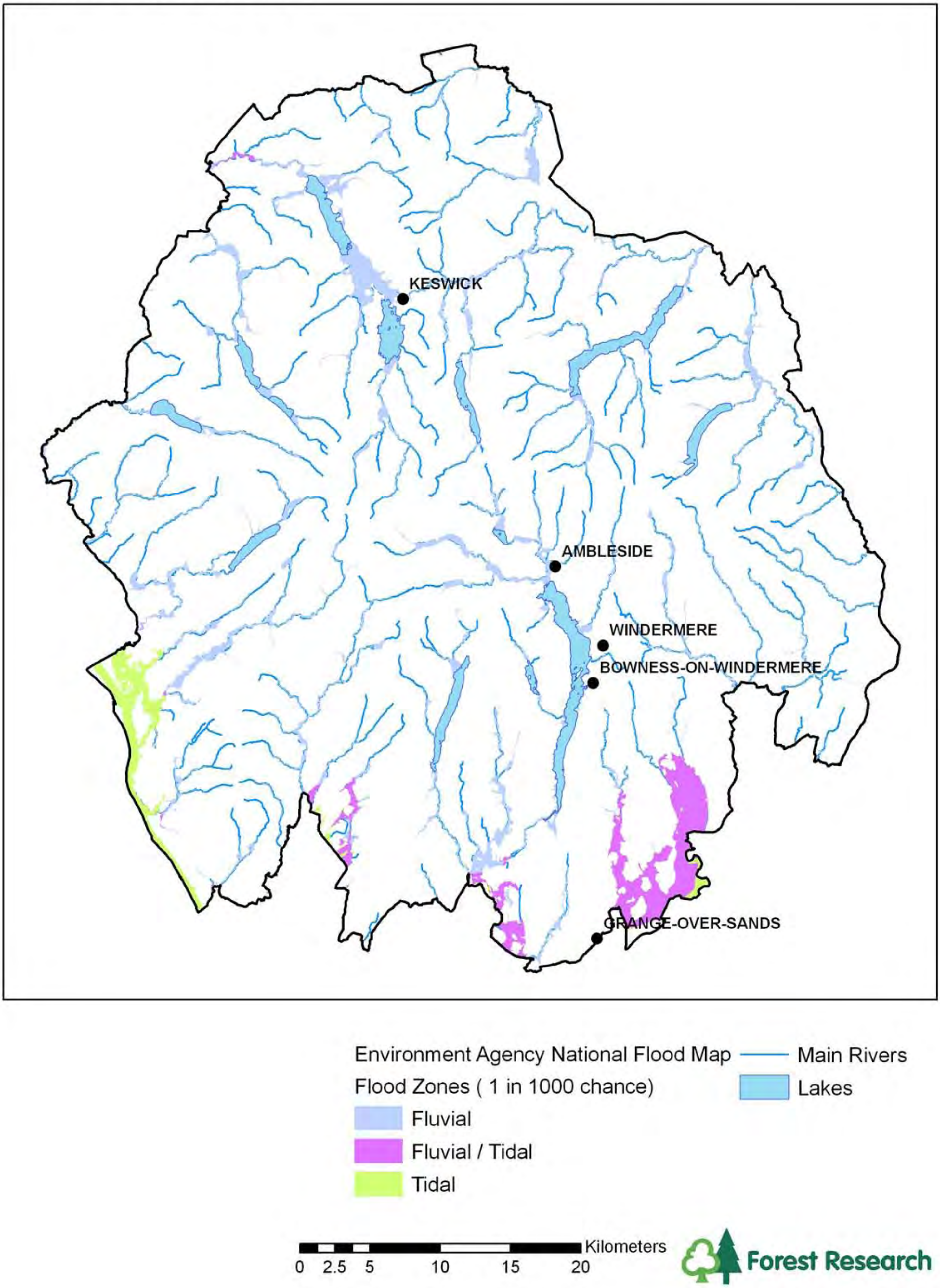
Kilometers
0 2.5 5 10 15 20

Forest Research

# Map 15 Vulnerability of riparian soil to stream bank erosion

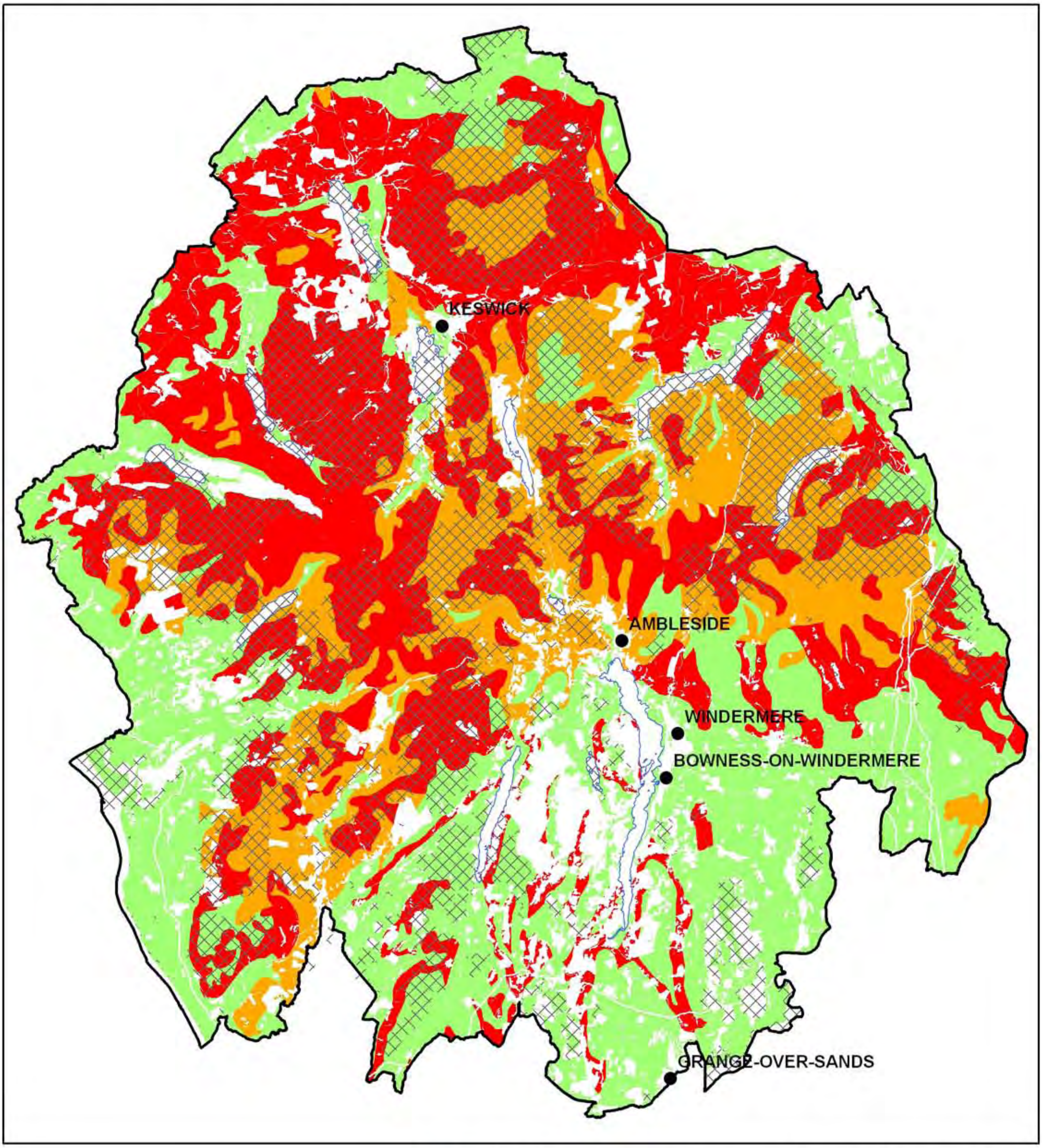


# Map 16 Environment Agency Flood Zone and Main Rivers




Forest Research

# Map 17 Priority areas for woodland creation in the wider catchment to reduce sediment delivery to watercourses




Priority for planting
- High
- Medium
- Low

Constraint to woodland creation
Sensitive landscape

Soil vulnerability based on an interpretation of PSYCHIC model output of sediment delivery to watercourses (ADAS, 2008)

0 2.5 5 10 15 20 Kilometers

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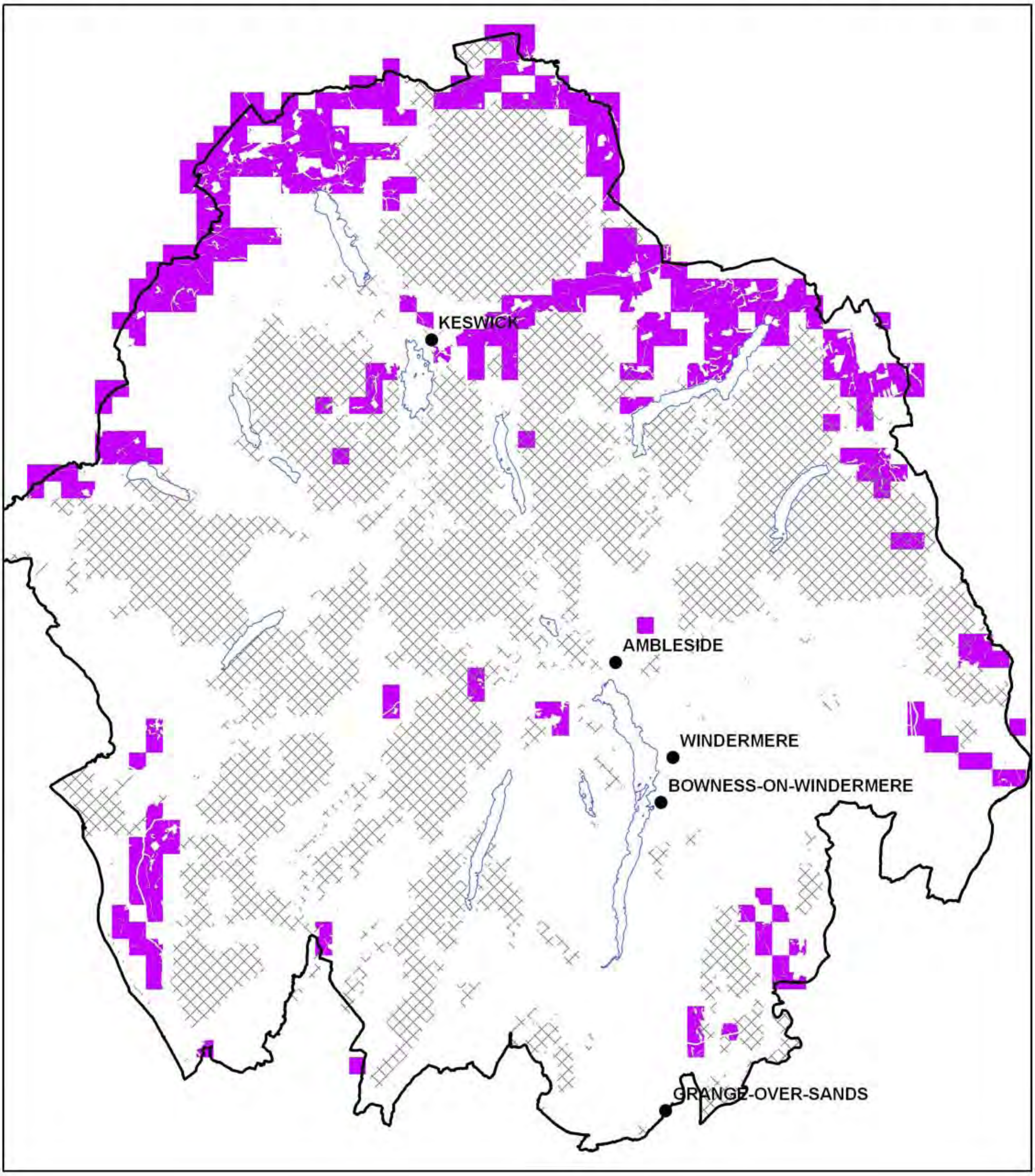
# Map 18 High priority areas for new woodland creation to reduce diffuse phosphorus pollution




High priority areas comprise those with modelled diffuse phosphorus losses to water courses in excess of 100 kg/km2/y (based on PSYCHIC model output, ADAS 2008)

Priority for planting: High

Sensitive landscape

0 2.5 5 10 15 20 Kilometers

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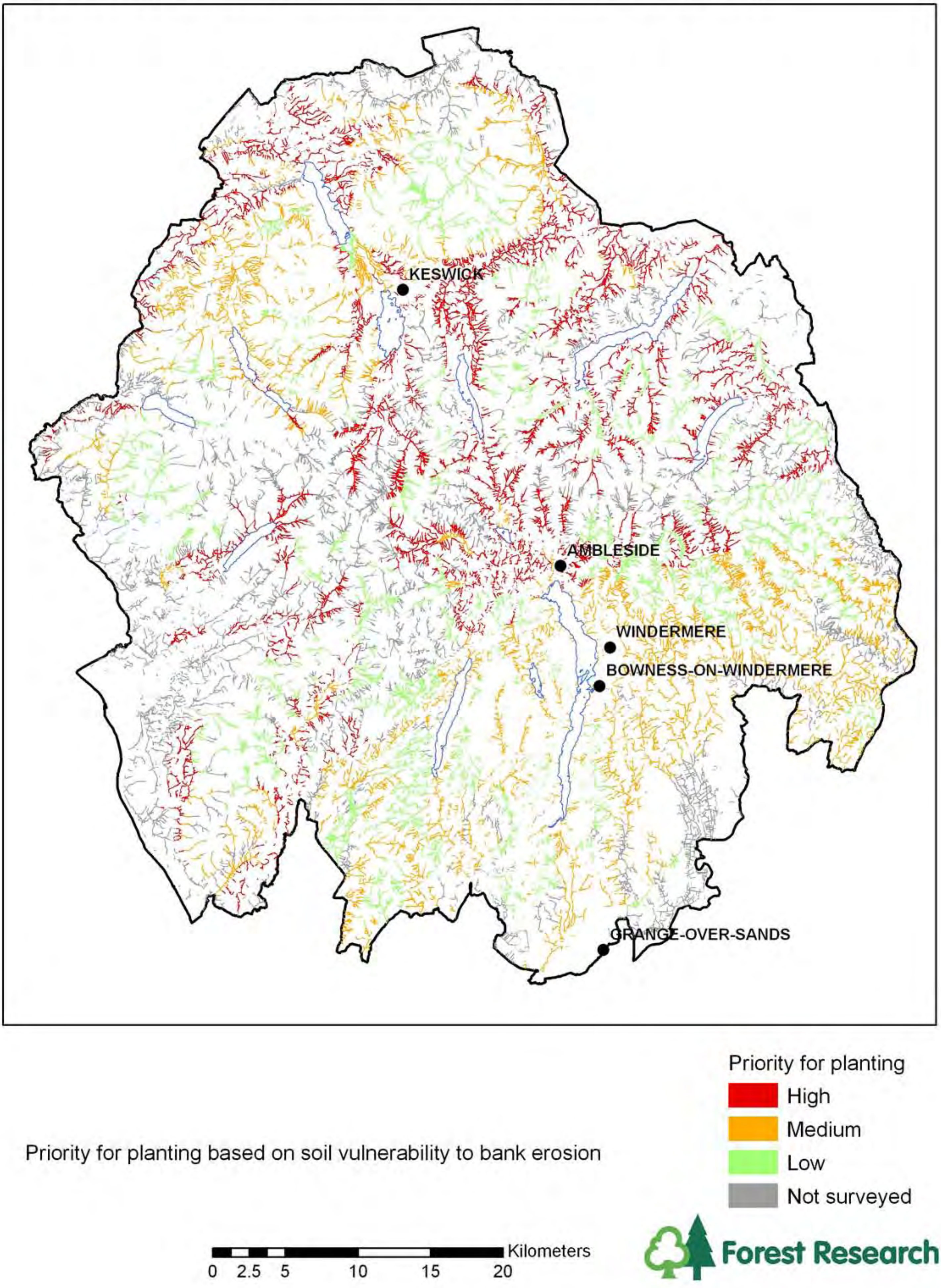
# Map 19 Priority areas for riparian woodland creation to reduce stream bank erosion




Priority for planting based on soil vulnerability to bank erosion

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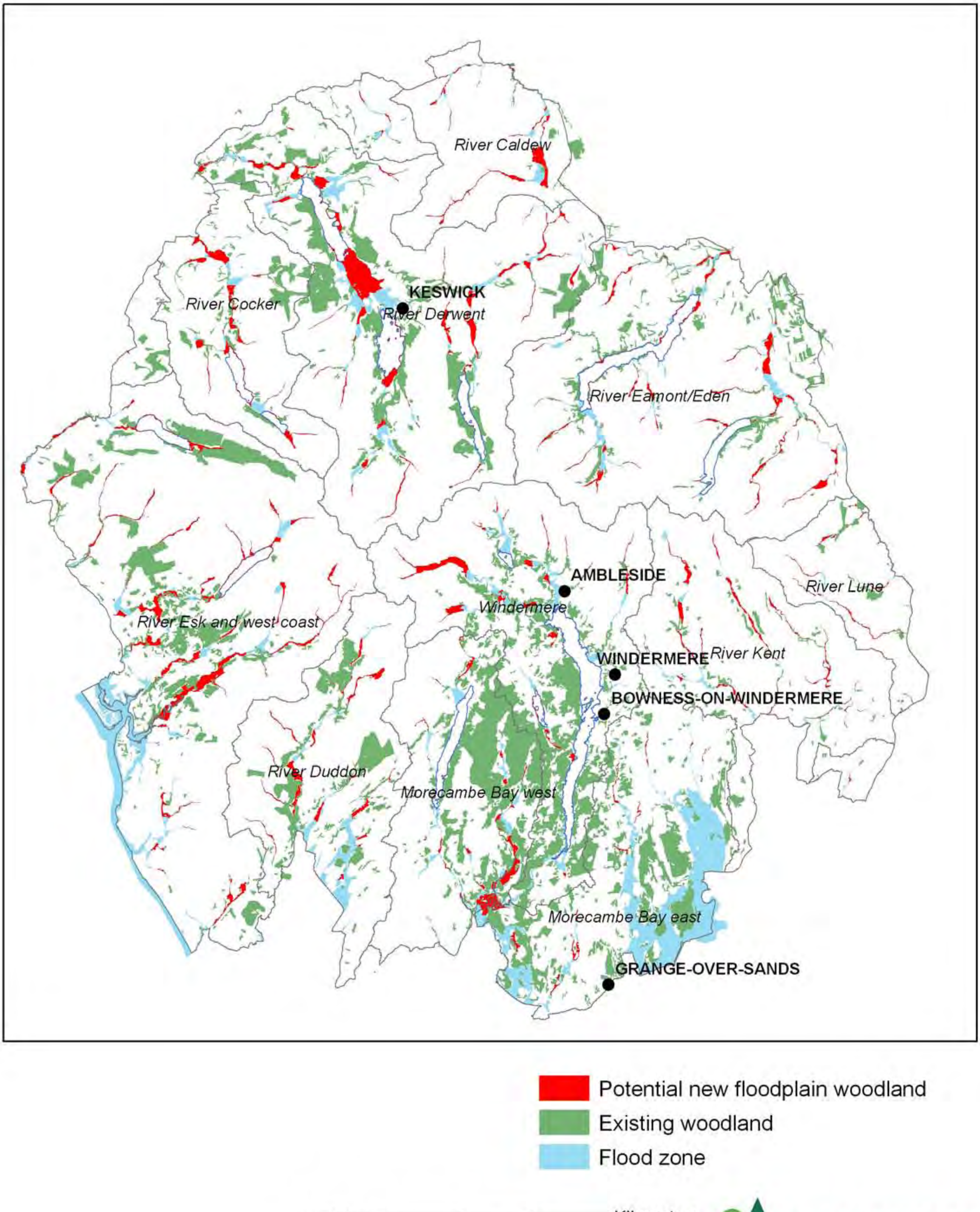
# Map 20 Potential new floodplain woodland to enhance sediment storage on the floodplain and reduce downstream inputs to lakes

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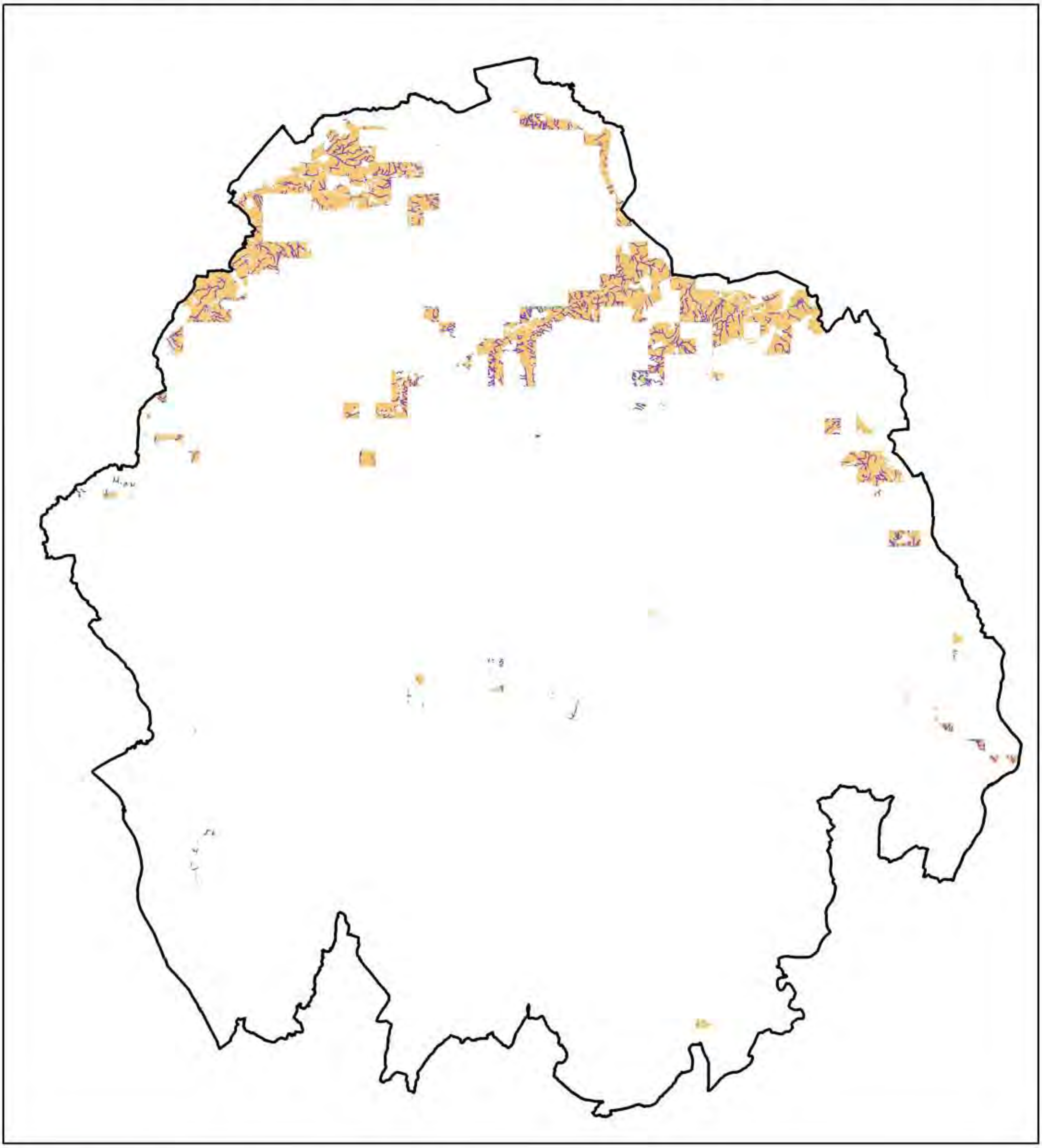
# Map 21 Opportunities for woodland creation that would address both diffuse sediment and phosphate pollution



High priority land for woodland creation to

reduce both sediment delivery and phosphate pollution

High priority land within the riparian zone where woodland creation can

reduce bank erosion, sediment delivery and phosphate pollution



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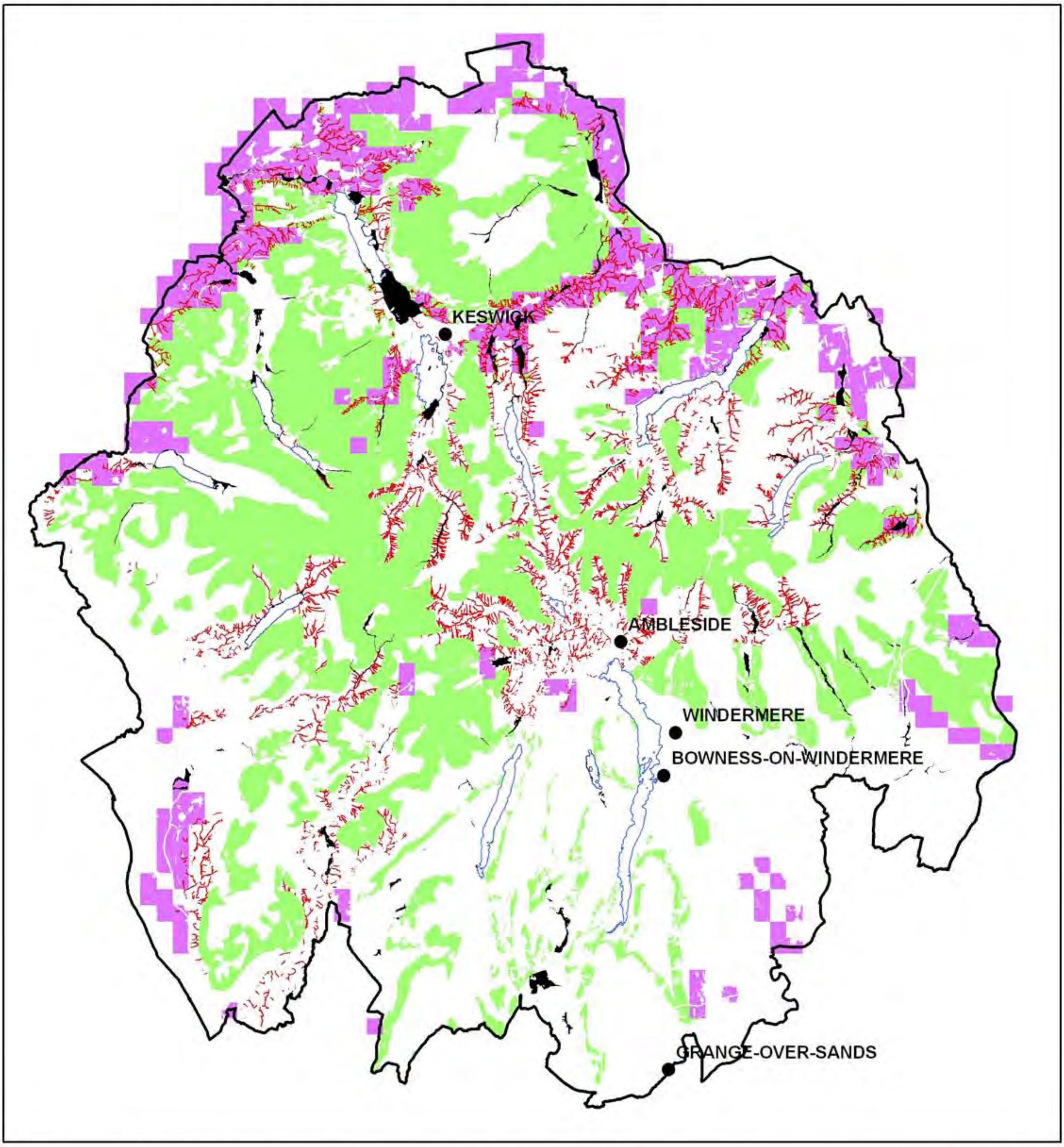
# Map 22 Combined map showing high priority areas for woodland creation in the wider catchment, riparian zone and floodplain to reduce diffuse sediment and phosphous pollution




Potential new floodplain woodland
High priority for riparian woodland

High priority for woodland in the wider catchment to:
reduce diffuse P loss
reduce sediment delivery

Kilometers
0 2.5 5 10 15 20

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