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Opportunity Mapping for Woodland to Reduce Flooding in the Yorkshire and the Humber Region

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Executive Summary

Forests and woodland have long been associated with an ability to slow down run-off and reduce downstream flooding. There are three ways that trees can assist flood risk management; by reducing the volume of runoff, by promoting rainfall infiltration into the soil and reducing the rate of runoff, and by delaying the downstream passage of flood flows. This report considers opportunities for using woodland for flood mitigation within the Yorkshire and the Humber region in north England.

The ability of riparian and floodplain woodland to retard the passage of flood flows is believed to offer the greatest potential for flood management and therefore effort focused on identifying land suitable for planting these types of woodland. A range of GIS data sets were used to locate land vulnerable to flooding and unaffected by constraints to woodland planting. The approach built on previous work in the catchments of the River Parrett in Somerset and Bassenthwaite Lake in Cumbria. The main output is a series of maps showing opportunities for planting floodplain and riparian woodland for flood mitigation within the region. Areas were prioritised according to the scope for planting to generate added value for nature conservation and water quality. Floodplain sites were ranked by their potential to create an extended forest habitat network, while riparian zones took into account the risk of the adjacent land delivering sediment to watercourses.

The project also assessed opportunities for woodland planting to assist flood and water pollution management within the wider catchment. This used data sets that classified the catchment soils by their vulnerability to generate rapid surface runoff, degrade structurally and/or deliver sediment to watercourses. For example, 52% of the region’s soils are classed as at high or extreme risk of poaching by livestock. The result is a map ranking areas as low, medium or high priority for woodland planting.

Significant opportunities exist within the region to restore floodplain woodland for sustainable flood management. A total of 35,328 ha of the fluvial floodplain is potentially available for woodland planting, including 168 major sites with an individual area of >50 ha. The majority of these lie within the catchments of the River Derwent, River Swale, River Ure and central section of the River Ouse, where there is potential to help reduce the flooding of small towns and villages, as well as major towns such as York. Constraints mean that there is limited scope for planting sizeable areas of floodplain woodland in the catchments of the River Aire, River Calder, and River Don and Rother to reduce flood risk in the major urban conurbations along the Southern Pennine Fringe.

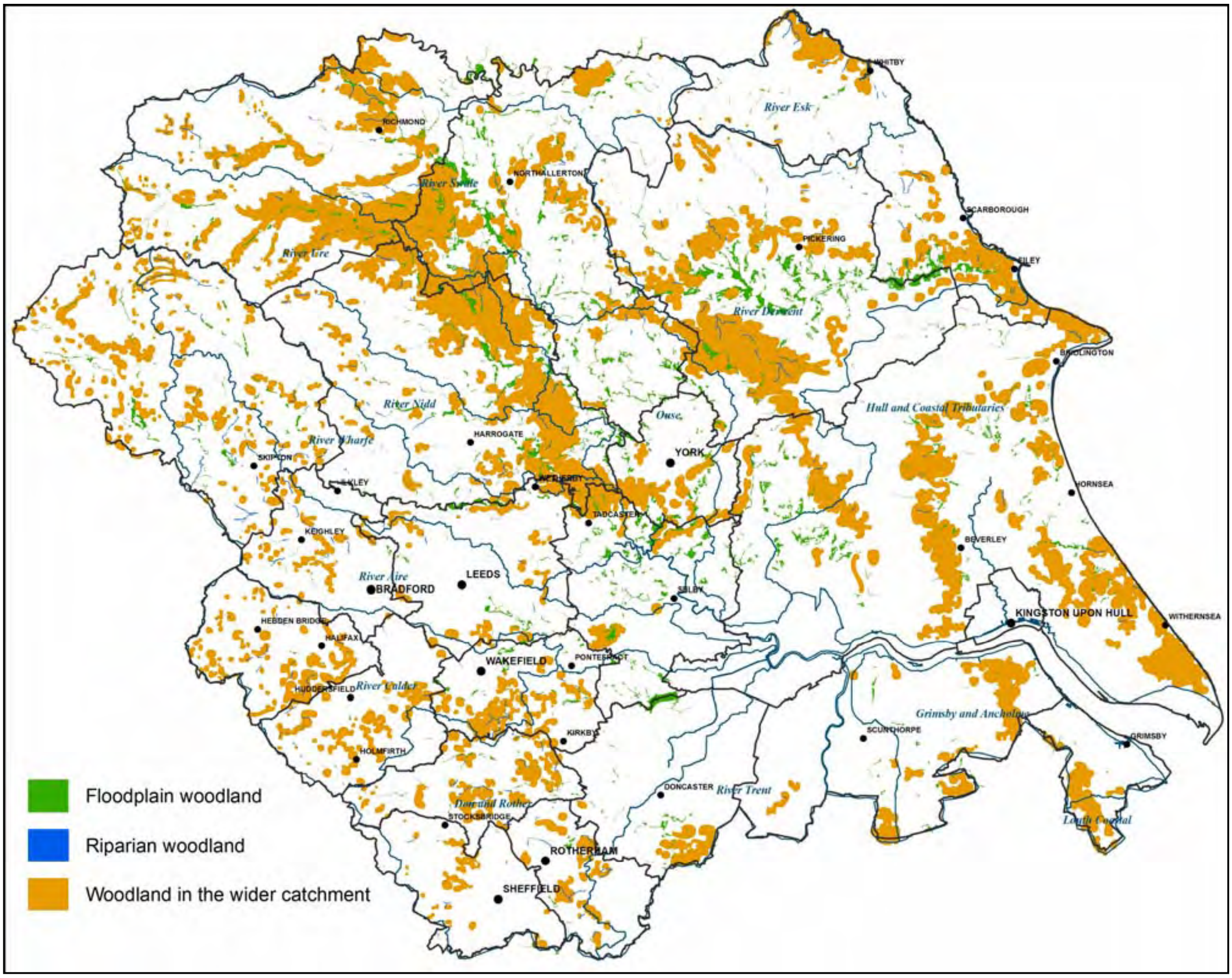
There are also many opportunities across the region for using riparian woodland to help reduce flood flows. A total of 18,730 ha are available for planting in the upper

reaches of most rivers, including those catchments in the Southern Pennine Fringe at high flood risk but with limited potential for planting floodplain woodland. Around 2,562 ha is adjoined by land at high risk of sediment delivery, where woodland creation could potentially benefit both flood risk management and diffuse pollution control. Some 997 ha lie within ECSFDI priority catchments, although most of this is located in the catchment of the River Derwent.

Finally, 65% of the land in the wider region is potentially available for woodland creation for multiple benefits, including flood reduction. Some 1,538 km^2 or 16% of the region is mapped as high priority for woodland planting on the basis of soil propensity to generate rapid runoff, soil sensitivity to structural degradation, and/or high risk of sediment delivery to watercourses. This land tends to be concentrated in the upper parts of river catchments and is most extensive within the River Ure, Swale, Derwent and Nidd catchments.

It is hoped that the opportunity maps will be used by regional stakeholders to promote the use of woodland in sustainable flood management and in so doing, help to meet the following objectives:

- Delivery of a sustainable flood risk management strategy for the region
- Delivery of reduced flood risk through effective and better integrated Catchment Flood Management Plans
- Delivery of flood alleviation for smaller communities where traditional methods of flood defence are not cost effective
- Delivery of the regional Biodiversity Habitat Action Plan targets for wet woodland and an enhanced forest habitat network
- Delivery of Regional and National Forestry Strategies, including climate change adaptation
- Contribute to a reduction in diffuse water pollution and an improvement in hydromorphology, thereby helping to meet EU Water Framework Directive targets for all water bodies to reach good water status by 2015
- Contribute to the England Catchment Sensitive Farming Delivery Initiative
- Develop partnerships to establish floodplain, riparian and wider woodland creation demonstration projects within the region as a way of developing a local evidence base and communicating the expected success of this option for flood and water pollution management



High priority areas with the greatest potential for woodland planting to reduce downstream flooding

1. Background

A series of severe floods in recent years has placed the issue of flood prevention and mitigation high on the public agenda. Flooding has been a longstanding problem in the Yorkshire Ouse basin, with major floods dating back to 1263. The flood record for the city of York suggests that both the frequency and magnitude of floods have increased from 1877 to the present day. The greatest rise appears to have occurred since the 1940s, with major floods in 1947, 1978, 1982 and 2000 (Lane, 2001). The extensive flooding in the autumn of 2000 proved to be the highest to date, affecting properties in York, Ripon, Selby and Barlby. More recently, severe thunderstorms in the summer of 2005 caused flooding in Helmsley and Thirsk, while the region was again badly affected by the widespread flooding of June 2007. Climate change is predicted to accelerate this trend due to wetter winters, more extreme storm events and a rise in sea level.

It is becoming increasingly clear that the problem of flooding can no longer be solved by building ever higher flood defences; the emphasis must also be on restricting development in the floodplain and pursuing 'softer', more sustainable methods of flood management. One aspect that has been attracting greater attention in the Governments 'Making Space for Water Strategy' is the potential for land use, and woodland in particular, to reduce flood risk (EA, 2007b). Forests and woodland have long been associated with affecting both the quantity and timing of stream flows (McCulloch and Robinson, 1993). Forestry provides a number of options for flood alleviation, principal amongst which is the ability of floodplain woodland to slow down flood flows and enhance flood storage (Thomas and Nisbet, 2006). Creating new floodplain woodland has been identified as one of seven priorities for action in the Forestry Commission's Regional Forestry Strategy for the Yorkshire and the Humber Region (Forestry Commission, 2005).

Woodland can also attenuate flooding due to the greater water use by trees and by the ability of woodland soils to intercept and delay the passage of rain water to streams and rivers (Thomas and Nisbet, 2006). These benefits can be maximised by targeting woodland planting onto the most sensitive soils or in key locations for intercepting and 'soaking-up' surface run-off generated from the adjacent ground. Examples include establishing woodland buffers along lower field edges, on infiltration basins/swales, or within the riparian zones of streams and rivers. Care is required to balance the water use benefit for flood flows against a potential reduction in summer low flows, through appropriate species choice and site selection (Nisbet, 2005).

The use of woodland for flood management has the potential to yield a number of other important benefits (EA,2007a), including improvements to water quality, fisheries, carbon sequestration, nature conservation, recreation, and landscape. Planting floodplain and riparian woodland would help to meet the UK Biodiversity Action Plan Target of creating 3,375 ha of wet woodland in England by 2010 (300 ha target within region).

This study was designed to assist Forestry Commission England (FCE) identify sites where the creation or expansion of woodland could be expected to reduce flood risk, while consistent with the established priorities for protected sites and designated landscapes. Around 500 ha of new woodland is planted each year within the region and the desire is to target future planting to areas where maximum public benefit can be achieved, including a reduction in flood risk. The work was GIS-based and followed the approach used by Nisbet and Broadmeadow (2003) in the Parrett catchment in Somerset. The methodology and results are described below.

2. Objectives

There were two main objectives:

1. To generate suitability maps identifying areas of fluvial floodplain and stream riparian zone within the Yorkshire and the Humber region where there is potential to create or expand floodplain and riparian woodland for reducing downstream flood risk.

2. To generate a suitability map identifying areas within the wider region where woodland planting is free of constraints and could benefit flood management by reducing rapid surface runoff, soil structural degradation and/or sediment delivery to watercourses.

3. Study Area

The Yorkshire and the Humber region covers about 15,000 km^2; the west of the region is defined by the upper catchments of the Yorkshire Ouse Basin, while to the east it is dominated by the Yorkshire Wolds and Holderness (Map 1). It is characterised by three distinct geomorphologic zones (Maps 2 and 3). The tributaries of the River Ouse rise in the western uplands of the Pennines and Yorkshire Dales, which are formed from carboniferous limestone and millstone grit and reach a maximum altitude of 730 m. To the north-east is the oolitic limestone and sandstones of the North York Moors and Cleveland Hills, and the chalk of the Yorkshire Wolds, which form the catchment of the River Derwent. In the middle and draining to the south is the lower-lying area of Permian and Triassic sandstones and mudstones that form the Vale of York, Humberhead levels and Holderness plains. Soils in the region vary from predominantly peat and lithomorphic soils in the uplands to surface and ground water gleys in the lower lying areas (Map 4).

The prevailing wind is from the west creating a gradient in precipitation. Annual rainfall ranges from around 1800 mm/y in the Pennines to 600 mm/y in the Vale of York. Land use is predominantly agricultural, with rough grazing dominating in the uplands and arable cropping in the lowlands (Map 5). Much of the latter relies on intensive drainage, managed in part by the Internal Drainage Boards. The average woodland cover across the region is 6.1%, which is lower than the national average of 8.4% (FC, 2005). The lack of trees is especially marked in the Lincolnshire and Yorkshire Wolds and Holderness, where woodland cover ranges from 0.3-3.4% (Map 6). The largest concentration of woodland is in the North York Moors National Park (13% forest cover).

The region suffers from both tidal and fluvial flooding, although the latter causes most problems. Urban surface water flooding is locally significant but groundwater induced flooding is rare. The wet soils and steep valleys that characterise the uplands naturally generate rapid runoff that is capable of transporting large amounts of sediment. When the sediment settles it can significantly reduce the capacity of river channels to convey flood flows and so raises the risk of local flooding. This can be a particular problem where the sediment accumulates under bridges or at culverts, leading to the backing-up of floodwaters.

The region has a number of large population centres and major road and rail links that are subject to flooding (Map 7). Cities at risk include Bradford, Leeds, Sheffield and York situated on the Rivers Calder, Aire, Don and Ouse, respectively. Many market towns are also at risk such as Knaresbrough, Ripon and Boroughbridge.

4. Methods

The approach to identifying opportunities for floodplain, riparian and wider woodland planting in the region to contribute to flood mitigation is described below:

4.1 Identification of suitable areas for restoring floodplain woodland

Since floodplain woodland is viewed as providing the greatest potential for flood mitigation, effort focused on identifying areas where its restoration was both feasible and desirable.

4.1.1 Extent of floodplain

The first step was to define the extent of the floodplain where woodland could interact with flood flows. The Environment Agency's indicative floodplain maps (2004) were selected for this purpose. These are based on detailed topographical surveys combined with modelled river flows and water levels, from which the extent of flood inundation is predicted (EA, 2006). Map 8 delineates both fluvial and tidal flood zones, with the fluvial floodplain defined for flood events with a 1% (Flood Zone 3) and a 0.1% (Flood Zone 2) probability of occurring in any year. The Flood Zone 2 was selected as the boundary of the floodplain to better represent the potential area at risk from inundation if new woodland was effective at raising upstream flood levels due to a backwater effect (see below). The tidal and combined tidal and fluvial zones were excluded since they were downstream of most sites that would benefit from a woodland induced flood lag effect. However, there may be scope for woodland within these zones to hold back and retard tidal surges for the protection of upstream sites, although this is not considered further in the report.

4.1.2 Constraints to new woodland planting

The next 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. The absolute constraints were considered to be:

- Urban areas, including villages, towns and cities
- Roads and railways
- Airports and military airfields
- Landfill sites (active and inactive)
- Scheduled Ancient Monuments
- World heritage sites
- Ministry of Defence land
- Grade 1 agricultural land
- Existing woodland
- Golf courses and campsites
- EA flood washlands

There are additional constraints that may not exclude the creation of new woodland but where the appropriate scale and design would require careful consideration on an individual site basis in consultation with the relevant agencies. This would be undertaken as part of the normal assessment and approval process for woodland planting applications. These constraints include:

- Sites scheduled or recognised for their nature conservation or geological importance
- Sites registered for their historic or cultural landscapes, such as Historic Battlefields, Historic Parks and Gardens
- Country parks
- EA flood defence infrastructure - raised flood banks

The sources of these data sets and the processing required in their preparation are detailed in Appendices 1 and 2. The combined data set created by the amalgamation of the individual constraints was used to remove areas of the floodplain that would be potentially unsuitable for planting woodland (Map 9).

Areas bordering flood defences were not included as an absolute constraint since although planting woodland is restricted within 10 m of flood banks, (because woodland can limit access for bank maintenance and possibly undermine flood banks due to rooting or windblow), floodplain woodland may be an acceptable, alternative land use in some areas, especially if flood banks were later removed to enhance flood storage. However, because floodplain woodland would have little effect on flood conveyance until the raised defences were removed, these areas would not be a priority for planting.

Sites identified by the Environment Agency as washlands were considered a potential constraint, partly due to concern that the presence of woodland could reduce flood storage (although the impact is likely to be small), but mainly because planting would have no benefit for flood conveyance. If planting was being considered for biodiversity gain, an important issue would be the timing, frequency and depth of flooding. Some tree species are more sensitive than others to inundation and care would be required in the design and management of these woodlands. Recent guidance on this issue is provided in FOWARA (2006).

The next step was to consider the protection of vulnerable assets such as buildings, roads and railways that could be at risk from the backing-up of floodwaters upstream of restored floodplain woodland. Individual assets would need to 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 practicable to do this at the scale of the whole region and therefore fixed buffers were created around main features. Although the extent of the backwater effect will be dictated by the gradient of the floodplain, modelling studies show that it usually does not extend beyond a distance of 300-400 m upstream. Consequently, for the initial stage of the mapping work a longitudinal fixed buffer of 500 m length was selected below all 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 were not retained in river reaches upstream of vulnerable features since the backing-up effect only applies to woodland located below them.

The buffers were incorporated into the floodplain using the UNION tool in the ArcView Toolbox. Working downstream, the floodplain fragments free from constraints were assessed and those lying within any buffer zones below urban areas, roads and railways were identified and deleted (Map 10). However, it is important to note that an allowance has not been made for the protection of isolated buildings and farmsteads and these would need to be assessed on an individual site by site basis during the planning and assessment phase of an individual application. The same applies to Listed Buildings, which have not been identified as part of the mapping exercise.

Sites and areas included in national heritage data sets such as Scheduled Ancient Monuments and Historic Battlefields were protected by a fixed 30 m buffer, as recommended by the Forestry Commission's Forest and Archaeological Guidelines. Wider buffer zones may be required to preserve the setting of these features, to be determined during site assessments. A number of areas are known to have concentrations of historic environment assets that are not included in national heritage data sets. These include designed landscapes, model farms and relict medieval field systems in the Southern Magnesium Limestone Ridge, Yorkshire Wolds, Vale of Pickering and Howardian Hills AONB. Further assessment of these features, including checking the relevant County Historic Environment Record and Historic Landscape Character maps, would be required on a site by site basis as part of the normal consultation process for assessing applications for woodland creation grant.

The efficacy of floodplain woodland in retarding flood flows and mitigating downstream flooding is dependant on the size of the woodland in relation to the scale of the floodplain (Thomas and Nisbet, 2006). Obviously, woodland spanning the entire floodplain will generate a greater impact compared to an isolated, small block of woodland on one side or on the margin of the floodplain. However, modelling shows that it is not necessary to plant a continuous stretch of woodland either across the full width or an extended length of the floodplain to achieve a significant delay in flood flows; a series of smaller blocks spread out along or across the floodplain may be just as effective at flood attenuation, depending on location (Nisbet and Thomas, 2008). Nevertheless, due to complexity of land ownership it would be difficult to co-ordinate the planting of a series of very small blocks and thus an absolute minimum area of 0.1

ha was adopted, and sites of less than 2 ha only retained if they presented an opportunity to extend existing woodland.

A related issue is the practicality of achieving a sufficient/sizeable area of woodland planting to have an impact on flood flows in the lower reaches of the main river system, where the width of the floodplain stretches to many kilometres. Consequently, those parts of the floodplain in the lower catchment that were over 1 km wide were excluded as priority areas for targeting the restoration of floodplain woodland (areas wider than 1 km were retained within middle and upper reaches). Finally, since the potential flood alleviation benefit only applies to downstream towns and cities, available planting sites near the outlet of the main rivers were also removed from consideration (Map 11).

The end result was a map showing areas within the EA Flood Zone 2 of the region that were potentially suitable for planting floodplain woodland for flood mitigation (Map 12).

4.1.3 Prioritising new planting sites for "added value"

Floodplain woodland offers a number of benefits or 'ecosystem services' in addition to potential flood reduction. These include improved water quality, nature conservation, fisheries, carbon storage, timber and wood fuel, and recreation. Most of these are site specific and therefore difficult to incorporate into the regional mapping exercise. One exception is nature conservation and the potential to link existing fragments of priority wet woodland habitat to create a more robust and valuable woodland habitat network. Spatial data sets were freely available to help assess which of the remaining floodplain areas offered the greatest potential to benefit woodland biodiversity in this way. This involved combining the data set of potential sites for new floodplain woodland (PNFW) (Map 12) with the habitat network data created by Roger Catchpole. It was assumed that the biodiversity gains would be greatest where new floodplain woodland included areas of existing woodland habitat network, particularly where the sites were large, closer together and with the potential to be linked along the river corridor (Map 13). These are the same principles that were applied in Roger Catchpole's previous work for English Nature on opportunity mapping for habitat networks for Natural England (2006). Areas with <30% existing woodland habitat network were identified as low priority for planting on the basis that these offered less potential to link up existing woodland/tree cover and may have greater value being retained as open wetland habitat. In particular, PNFW sites within the Mires, Fen and Bog, Heath and Grassland habitat network data sets that were likely to raise objections from Natural England, were classed as low priority due to the detrimental impact woodland would have on these important open habitats. The area with >60% existing woodland habitat network was considered to have the greatest potential for connectivity and thus classed as high priority.

The Convention on Civil Aviation (Annex 14) places restrictions on land use within a 13 km radius circular buffer zone around civil and military airports to limit the risk of bird strikes (DfT, 2001). The legislation states that local planning authorities are required to consult the person identified as representing the interests of the aerodrome before granting permission for any development within this zone that might endanger the safety of aircraft by attracting large numbers of birds. The presence of the bird strike zone does not prevent the creation of wetlands but it may affect the design or type of wetland habitat. For example, it may be preferable to plant wet woodland within washlands rather than open wetland since the latter is more likely to attract large flocks of wintering water-fowl. The PNFW sites located within the nine bird-strike buffer zones within the region are shown in Map 14. This map also displays the location of priority catchments under the England Catchment Sensitive Farming Delivery Initiative (ECSFDI), where the planting of floodplain woodland could confer additional benefits for diffuse pollution control (See section 4.3).

4.2 Identification of suitable areas for planting riparian woodland

Established riparian woodland can contribute to downstream flood alleviation through the action of woody debris dams, which impede water flow and promote out of bank flows, thereby reducing and delaying the flood peak. Additionally, riparian woodland can help to buffer/reduce sediment delivery from the adjacent land and so help control siltation and increase the flood storage capacity of river channels. Lastly, tree rooting acts to stabilise and strengthen riverbanks, reducing bank erosion and sedimentation.

The potential area for riparian woodland was identified as a 30 m wide zone on either bank of the OS 50k river network. This width was selected as the zone most likely to interact with and provide woody debris to the river channel. The preference was to exclude sections of the river channel that were too wide (>5 m) to establish stable debris dams but unfortunately no data were available on river channel width. Instead, the downstream limit for riparian woodland for flood reduction was somewhat arbitrarily set as the upper extent of river length classified as ‘Main river’. 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.

The next step was to identify constraints to planting riparian woodland due to existing land-use, ownership or the presence of vulnerable assets. A similar approach was adopted to that described in section 4.1.

To address the additional benefit of riparian woodland in reducing sediment delivery to watercourses, it was decided to overlay the area identified as being potentially suitable for planting with available information on soil erodibility. The work of McHugh *et al*., (2002) characterised erosion vulnerability and landscape connectivity across England and Wales to predict the rate of sediment delivery to watercourses (Map 15). This was based on data from field studies on the erodibility of upland, lowland grassland and arable soils, which was used to calculate the probability of erosion of a given magnitude occurring for different soil-slope combinations. These values were then combined with an index which defined the degree of connectivity between hillslopes and watercourses, to derive maps illustrating the risk of sediment delivery for different return periods. Unfortunately, the data for erosion potential, connectivity and sediment delivery are only available as 1 km^2 raster, which precludes identifying precise locations where riparian woodland would be most effective. Nevertheless, the data were considered sufficiently useful for prioritising potential areas for woodland planting for the dual benefit of flood risk reduction and sediment control. Land with an estimated sediment delivery rate to watercourses in excess of 0.1 m^3/ha/y was considered to pose a sedimentation or diffuse pollution pressure and therefore benefit most from riparian planting (Map 16). Map 16 also identifies the priority catchments under the ECSFDI where diffuse pollution is a major issue.

4.3 Identification of areas within the wider catchment where woodland could aid flood management

The potentially high water use of woodland, particularly for conifers, may help to reduce rainfall-runoff and the generation of flood flows. Research suggests that the effect is greatest at the headwater level and for smaller floods, and may be locally important (Nisbet and Thomas 2006). In practice, woodland planting in most locations in the catchment could be beneficial and thus the initial step was to identify land free from constraints to planting across the whole region (Map 17). The main constraints are as listed for the floodplain (section 4.1.2), but with additions for areas of open moorland and other land with commoners grazing rights, plus land above the natural tree line (set at 450 m AOD). The potential adverse impact of conifer water use on maintaining low river flows for water supply and ecology has not been assessed and would need to be considered on a site by site basis (Nisbet, 2005). Large scale conifer planting would not be recommended in areas where the water supply is being, or is planned to be, fully exploited.

Another benefit of woodland is the ability to protect soil from disturbance and improve soil structure due to greater inputs of organic matter and the action of tree roots. These conditions enhance soil infiltration and water storage capacity thereby reducing surface run-off and delaying the passage of rainwater to streams and rivers. The benefit for flood mitigation is likely to be greatest where woodland replaces more damaging land uses on sensitive soils that are likely to promote rapid run-off due to soil sealing and compaction. An analysis of where new woodland would be most effective at reducing surface run-off was made based on an assessment of the hydrological properties of the soil, the topography, the connectivity between hill slopes and watercourses, and the impact of current land management on erosion vulnerability. This involved the following data sets:

- The Hydrology Of Soil Types (HOST) (Boorman *et al*., 1995)
- Standard Percentage Runoff (SPR) and Poach Class based on the HOST classification
- Revised SPR values derived from the study 'Impact of land use and management on flooding (Packman *et al*., 2004)'
- Elevation and Slope - derived from the Ordinance Survey 10k Land-Form PROFILE plus digital terrain model
- Erosion Potential and Connectivity Ratio - from the Prediction of Sediment Delivery to Watercourses (McHugh *et al*., 2002)

Each of these are described below:

HOST: The HOST system was developed to classify soils according to their hydrological behaviour (Map 18). HOST is a conceptual representation of the hydrological processes in the soil zone. All soil types (soil series) in the UK have been grouped into one of 29 hydrological response models or 'HOST classes'. Allocation to a HOST class is by a hierarchical classification. Soils are first allocated to one of three physical settings:

- a soil on a permeable substrate in which there is a deep aquifer or groundwater (i.e. at >2 m depth)
- a soil on permeable substrate in which there is normally a shallow water table (i.e. at <2 m depth)
- a soil (or soil and substrate) which contains an impermeable or semi-permeable layer <1 m from the surface.

Each physical setting is sub-divided into response models, which describe flow mechanisms and identify groups of soils that are expected to respond in the same way to rainfall. Finally there are sub-divisions of some of these models according to the rate of response and water storage within the soil profile.

SPR: Calibrated values of SPR for each HOST class were derived from multiple regressions between the proportion of each response model within a number of UK river catchments and the SPR values derived from river gauging data. The SPR represents the percentage of rainfall that contributes to quick response runoff. HOST classes with a SPR >25% represent seasonally waterlogged and flashy soils that are likely to make a significant contribution to the generation of flood flows (Map 19).

Poach class: The HOST classification deals primarily with water movement but since the basis of the classification is the physical structure and configuration of the soil profile, it can also be used to underpin other physical and hydrogeochemical models. For example, Harrod (1998) used HOST to classify the vulnerability of lowland grassland soils to poaching by livestock (Table1). Poaching leads to surface compaction and waterlogging, increasing the risk of rapid surface run-off. Soils classed as 'moderate', 'high', 'very high' and 'extremely' vulnerable to damage are shown in Map 20.

HOST poach class	HOST classes	Vulnerability	Area (km^2)	% of region
1	1 – 5	Slight	3,430	22.2
2	6 – 8, 11, 6 – 20, 22	Moderate	2,030	13.1
3	10, 14, 21, 23	High	763	4.94
4	9, 13, 24, 25	Very high	5,153	33.4
5	12, 15, 26 - 29	Extreme	2,813	18.2

Table 1 Vulnerability of soils in the Yorkshire and the Humber Region to poaching as predicted by HOST class (Harrod, 1998).

Revised SPR values: A joint DEFRA/EA funded research programme reviewed the impacts of rural land use and management on flood generation. One output was a refinement of the Flood Estimation Handbook (FEH) rainfall-runoff model to account for the effects of soil degradation due to intensive agricultural practices. This involved reclassifying the SPR values for each HOST class by assigning an appropriate analogue HOST class to represent the degraded soil (Packman *et al*., 2004). The revised SPR values for the soils in the region are listed in Table 2. Soils considered to be most vulnerable to structural degradation-induced changes in SPR were brown earths (NATMAP vector codes 541, 542, 543, 571, 572, 581, 582) and brown sands (NAT MAP vector codes 551, 553, 554). The areas in the region identified as being most vulnerable to structural degradation by agriculture and therefore could most benefit from woodland planting are shown in Map 21.

HOST Class	Soil Series	Original SPR %	Amended SPR %	Poach Class	Area (km^2)	% of region	Physical Soil Description
0	Urban	-	-	-	1254	8.1	Unclassified
1	341, 342, 343fhi, 511cef, 571nr, 581	2.0	14	1	1030	6.7	Free draining over chalk
2	343ab, 511a, 544	2.0	14	1	685	4.4	Free draining over limestone
3	571fg	14.5	27	1	37	0.2	Free draining over soft sandstone
4	541fgq, 631a	2.0	15	1	1015	6.6	Free draining over consolidated rocks
5	511i, 541ru, 551, 631f	14.5	27	1	663	4.3	Free draining over sands or gravel
6	541xy, 571q	33.8	44	2	486	3.1	Unconsolidated, free draining over colluvium and loamy drift
7	512b, 543, 552, 641	44.3	44	2	310	2.0	Free draining over sands or gravel
8	512f, 532, 561	44.3	44	2	488	3.2	Unconsolidated, free draining over colluvium and loamy drift
9	22, 811bd, 812c, 813, 814, 831, 851	25.3	25	2	827	5.4	Unconsolidated, gleying < 40cm from surface
10	1011a, 811a, 812a, 821, 861	25.3	25	3	595	3.9	Unconsolidated, gleying < 40cm from surface
11	1022, 1024	2.0	2	2	43	0.3	Drained peat
13	512a	2.0	15	4	33	0.2	Impermeable layer within 100cm
15	311, 541o, 651, 652	48.4	48	5	766	5.0	Peat over permeable substrate
17	541j	29.2	47	2	14	0.1	Impermeable – hard, no gleying within 100 cm
18	572, 841	47.2	59	2	584	3.8	Slowly permeable, gleying within 40-100 cm
20	421	60	60	2	102	0.7	Impermeable (soft), gleying within 40-100 cm
21	92b, 431, 542	47.2	60	3	164	1.1	Slowly permeable, gleying within 40-100 cm
22	313	60.0	60	2	2	<0.1	Impermeable (hard), gleying within 40-100 cm
23	411	60	60	3	4	<0.1	Impermeable (soft), gleying within 40-100 cm
24	92c, 711cmnpu, 712afi, 713afg,	39.7	49	4	4128	26.7	Slowly permeable, gleying < 40cm from surface
25	711f, 712b	49.6	60	4	166	1.1	Impermeable (soft), gleying < 40cm from surface
26	721	58.7	59	5	1238	8.0	Peat over slowly permeable substrate
29	1011b	60.0	60	5	809	5.2	Raw Peat

Table 2 The hydrological properties of the soils of the region

Elevation and slope: Data on these aspects were derived from a Digital Elevation Model (Map 22). Land above 450 m AOD was excluded for potential woodland creation as being above the natural tree line, although this could shift in the future with climate change. Gradient was used to define five slope classes according to current DEFRA/NE Environmental Stewardship guidelines:

- Class 5 – very high sensitivity - slope >11°
- Class 4 – high sensitivity - slope 7 – 11°
- Class 3 – moderate sensitivity - slope 3 – 7°
- Class 2 - low sensitivity - slope 2- 3°
- Class 1 - very low sensitivity - slope <2°

Notable class boundaries include 3° as the critical angle at which rill erosion begins and 7° as the upper limit of land considered suitable for arable farming. Slopes <2° are defined as flat land, 2 - 3° as gentle, 3 - 7° as moderate, 7-11° degrees as steep; and >11° as very steep (McHugh *et al*., 2002).

It was recognised that there is a certain degree of overlap between some of these data sets. After careful consideration, it was decided to select those for SPR, revised SPR and sediment delivery to classify soils by their propensity to generate rapid surface runoff, degrade structurally and/or deliver eroded sediment to watercourses. The threshold values used to rank each factor were: <25%, 25-50% and >50% for SPR; <0.1 m^3/ha/y and >0.1 m^3/ha/y for sediment delivery; and low (SPR unchanged), moderate and high sensitivity to structural degradation based on the assessment of revised SPR values by Cranfield University and JBA Consulting in their report 'Catchments sensitive to land use change' (EA, 2008).

Erosion potential and connectivity ratio: See Section 4.2.

The individual sensitivity classes were then combined and the soil assigned a final ranking in terms of low, medium or high priority for woodland planting (Table 3). The distribution of priority areas across the region is shown in Map 23.

The final stage was to highlight the potential added value from targeting planting within areas at risk of diffuse water pollution. Four catchments within the region have been identified as priorities in England for trailing the Catchment Sensitive Farming Delivery Initiative (ECSFDI). These are the Yorkshire Ouse, Nidd and Swale, East riding of Yorkshire and North Lincolnshire, Yorkshire Derwent and River Esk catchments, all of which are subject to significant diffuse pollution pressures from agriculture. Capital grants (EWGS and HLS) are available to encourage best management practices within these catchments to reduce diffuse pollution and protect soil structure. Targeted woodland planting offers a number of specific benefits, including promoting good soil structure to minimise rapid surface runoff and erosion; reducing overall fertiliser and pesticide usage, and protecting watercourses from direct contamination by faecal bacteria, sediment and pesticides. Consequently, these areas are highlighted in Map23 for particular attention when considering opportunities for woodland planting.

Priority for new woodland planting	HOST original SPR value (%)	Sediment delivery (1 in 10 y event) $m^3/ha/y$	Sensitivity to structural degradation by land management based on revised SPR
Low priority	<25 <25 <25 <25 >25	<0.1 <0.1 <0.1 >0.1 <0.1	Low sensitivity Moderate sensitive High sensitivity Low sensitivity Low sensitivity
Medium priority	<25 >25 >25 >25 >50	>0.1 <0.1 >0.1 >0.1 <0.1	Moderate sensitive Moderate sensitive Low sensitivity Moderate sensitive Low sensitivity
High priority	<25 >25 >25 >50 >50 >50	>0.1 <0.1 >0.1 <0.1 >0.1 >0.1	High sensitivity High sensitivity High sensitivity Moderate sensitive Low sensitivity Moderate sensitive

Table 3 Classification of soils by their propensity to generate rapid surface runoff, degrade structurally and/or deliver sediment to streams.

5. Results

5.1 Opportunities for restoring floodplain woodland for flood mitigation

Across the region an area of 1,299 km^2 was identified as being at risk of fluvial flooding from a 1 in 1000 year event (Map 8). Extensive areas of floodplain exist in the Vale of Pickering, Humberhead levels, Vale of York and Vale of Mowbray.

A total of 20% of the fluvial floodplain was potentially excluded from tree planting due to the various constraints considered by the mapping exercise (Table 4, Map 9). The main constraints were urban infrastructure, land identified by the EA for washlands, and open-habitat SSSI's. Urban infrastructure had the greatest impact in the River Aire, River Calder and River Don and Rother catchments, removing most of the floodplain in the middle and upper reaches from consideration. Consequently, there is limited scope for using floodplain woodland to reduce flood risk in the major urban conurbations along the Southern Pennine Fringe (Maps 7-9). Only 3.1% of the fluvial floodplain in the region is covered by woodland.

A further 32% of the floodplain was excluded by the buffer areas that were created downstream of the built environment and roads to allow for the potential backing-up of floodwaters upstream of any planted sites. After allowing for the 21% removed due to the width of the lower floodplain exceeding 1 km, this left 27% (35,328 ha) of the fluvial floodplain in the region as possibly suitable for woodland planting. A total of 168 major sites were identified with an individual area of >50 ha (totalling 20,848 ha or 16% of the floodplain). The majority of these lie within the catchments of the River Derwent, River Swale, River Ure and central section of the River Ouse, where there is potential to help reduce the flooding of local towns and villages, as well as major towns such as York (Map 12). There were 484 medium (10-50 ha) and many small sites (<10 ha), which tended to follow the distribution of the larger sites.

Map 13 shows the result of combining the suitability map for floodplain woodland with Rodger Catchpole's forest habitat network data. Around 1,075 ha of the fluvial floodplain (644 sites) are classed as low priority for building an extended forest habitat network, with 294 sites or 363 ha as high priority. The high priority sites are fairly evenly distributed across the region, including 60 ha in the catchments of the River Derwent, River Don and Rother and River Calder. The lower Ouse and the coastal catchments are all rated low priority due to the minimal area of existing woodland habitat.

A total of 13,654 ha (38%) of PNFW lies within airfield bird strike zones, where woodland planting could help to reduce the risk of bird strikes by wildfowl (Map 14). There is also considerable scope for restoring floodplain woodland within priority catchments under the ECSFDI (21,190 ha). Planting here could provide additional gains for water quality by floodplain woodland promoting the trapping and retention of sediments and associated contaminants, as well as enhancing denitrification and nutrient uptake. However, 3,234 ha of this land (5,793 ha across whole region) occurs on Grade 2 agricultural land, which is less likely to be planted without appropriate higher level compensation.

5.2 Opportunities for planting riparian woodland to delay flood flows

Map 16 shows the land identified as being available for planting riparian woodland. Only 3,801 ha or 10% of the riparian zone as defined by this study was currently woodland, although this excludes stretches of watercourse fringed by scattered bankside trees or shrubs. The upper sections of most rivers have potential to create extended lengths of riparian woodland, totalling an area of 18,730 ha within the region. Some 2,562 ha of this adjoins land with a high risk of sediment delivery and therefore where woodland planting could benefit both flood management and the control of diffuse pollution. Areas range from 417 ha in the River Derwent to 107 ha in the Hull and coastal tributaries catchment. Diffuse water pollution by sediment delivery is a major issue in the region, with the River Ouse and its sub-catchments estimated to receive an annual sediment load of 124,152 t (Walling, 1999). As with PNFW, the combined gains for flood risk and water quality may be greatest within the ECSFDI Priority Catchments, with a total area of 10,211 ha of land available for planting riparian woodland (971 ha bordering land with a high risk of sediment delivery).

5.3 Opportunities for woodland planting in the wider catchment to aid flood management

A total of 35% of the region is potentially excluded from woodland planting due to the constraints listed in Table 4. The National Parks represent the single largest constraint, which are primarily upland moors designated for their cultural and conservation value. Over a fifth of the region lies within the Dark Peak, Yorkshire Dales and North York Moors National Parks, and while this does not exclude all tree planting there are restrictions on the location, scale and type of new woodland in order to preserve the special character of the landscape. For example, it is unlikely that any large scale planting of new conifer forest would be acceptable and thus there is little scope to maximise its water use effect on flood flows. The overlapping designation of SSSI's and Special Areas of Conservation (SAC) further preclude tree planting due to the high ecological value of the moors as predominantly open grassland and heath habitats. Common land is another overlapping constraint, covering some 5% of the region. The combined effect of these constraints is to potentially exclude a large part of the uplands from woodland planting.

The next most important constraint is urban infrastructure in the form of roads, towns and cities, which cover 13% of the area. The distribution is uneven and concentrated in the south west of the region in the Southern Pennine Fringe. All other constraints are relatively minor in area, including around 1% Grade 1 agricultural land and 0.8% by Scheduled Sites of Special Archaeological importance, including 2607 Scheduled

Ancient Monuments and 46 fragments of linear features of antiquity plus buffers (Roman and non-Roman roads and routes). A further 1% of the region is covered by landscapes of historic or cultural importance in which woodland creation may not be appropriate. This includes Registered Historic Parks and Gardens, Registered Historic Battlefields and World Heritage Sites. New planting within these areas would have to reflect the historic context of the site and be assessed on a site by site basis. Woodland covers 6.1% of the region.

Potential constraint	Area (ha)	Notes % of region or *Fluvial Floodplain*
Total area of all constraints for which spatial data is available: Across the region *Across the fluvial floodplain*	 544,646 *26,048*	 35% *20%*
SAC	138,125	8.9%: all this land also scheduled as SSSI
SSSI Across the region *across the fluvial floodplain*	 160,594 *3,926*	 10.4% *3%*
EA flood storage areas (washlands)	*11,677*	*9%*
Length of existing raised defences	1.2 km	15,828 ha of PNFW would require some modification to existing flood defences
National Parks	315,206	20.3%
RSPB reserves	1,480	413 ha; also scheduled as SSSI
Historic and cultural landscapes World Heritage Sites Country Parks Register of Historic Parks and Gardens Registered Historic Battlefields	 n=2 n=31 13,382 1,617	 *3 in the fluvial floodplain* *52 (of 119) sites intersect the fluvial floodplain* *5 sites intersect the fluvial floodplain*
Sites of Antiquity Scheduled Ancient Monuments Linear antiquity	 10,316 317	
Camping and caravan sites Golf courses	n=247 n=203	*17 in the fluvial floodplain* *13 in the fluvial floodplain*
MOD land	12,287	
Moorland	223,777	14.4%
Common land	80,690	6,701 ha of non-moorland are subject to commoners rights.
Land over 450m AOD	55,695	All of this high ground is on the

		moors
Urban	143,806 *17,362*	9.3% *13.4%*
Roads	60,795 *4,612*	3.9% *3.5%*
Rail	6,018	
Landfill Sites	n=313	*30 in the fluvial floodplain*
Existing woodland	94,828 *4,027*	6.1% *3.1%*
Prime agricultural land – Grade 1	18,979 *3,976*	1.2% *3.1%*

Table 4 Constraints to woodland planting in the region

Of the 10,061 km^2 of the region mapped as free from constraints, 1,538 km^2 (16% of area) is classed as high priority for woodland planting on the basis of soil propensity to generate rapid runoff, soil sensitivity to structural degradation and/or high risk of sediment delivery to watercourses (Table 5, Map 23).

Priority for new woodland planting	Total area (km^2) and % of region	Area (km^2) and % of region free from constraints	Area (km^2) and % of ECSFDI land free from constraints
Low priority	6769 [44 %]	4511 [45 %]	2290 [48%]
Medium priority	5549 [37 %]	3834 [38 %]	1603 [34%]
High priority	2878 [19 %]	1538 [16 %]	865 [18%]

Table 5 Assessment of priority areas for woodland creation in the region on the basis of the propensity of soils to generate rapid runoff, sensitivity to structural degradation and/or risk of sediment delivery to watercourses.

This is a slightly lower percentage than that in the region as a whole, reflecting the exclusion of the majority of the more vulnerable moorland soils from woodland planting. The high priority land is spread across the region but tends to dominate within upland areas, with the exception of coastal parts of Holderness and the Lincolnshire Wolds. Interestingly, the proportion of the ECSFDI priority catchments classed as high priority (18%) is only slightly higher than that in the wider region, indicating a widespread distribution of sensitive soils. High priority land is most extensive within the catchment of the River Ure (excluding fragmented catchments), followed by the Swale, Derwent and Nidd catchments (Table 6). Only 4.8% of the high priority land is currently wooded. A greater part of the region (3,834 km^2) is classed as medium priority while the majority of land (45%) lies within the low priority class.

Catchment	Area (km^2) of region available for tree planting	Area (km^2) of region classed as high priority for woodland planting	% of region classed as high priority for woodland planting
Esk	195	33	7%
Don and Rother	909	72	5%
Grimsby and Ancholme	453	60	10%
Hull and Coastal Tributaries	1,724	267	13%
Catchments of the Yorkshire Ouse:			
Wharfe	490	69	7%
Ure	507	234	24%
Nidd	330	68	13%
Swale	844	203	15%
[Ouse]*	2001	386	13%
Derwent	1435	288	14%
Aire	608	44	4%
Calder	473	81	9%
Fragments:			
Trent	524	37	5%
Louth Coastal	46	13	26%

*Values for River Ouse include those for the Swale and Nidd sub-catchments.

Table 6 Extent and distribution of land classed as high priority for planting within the river catchments of the region. Classification based on propensity of soils to generate rapid runoff, sensitivity to structural degradation and/or risk of sediment delivery to watercourses.

6. Conclusions

A wide range of data sets have been accessed from partners to generate suitability maps identifying potential areas within the Yorkshire and the Humber Region where woodland could aid flood risk management. The restoration of floodplain woodland is considered to offer the greatest ability to reduce flood flows and significant opportunities exist within the region to realise this benefit. A total of 35,328 ha of the fluvial floodplain is potentially available for woodland planting, including 168 major sites with an individual area of >50 ha. The majority of these lie within the catchments of the River Derwent, River Swale, River Ure and central section of the River Ouse, where there is potential to help reduce the flooding of small towns and villages, as well as major towns such as York. Constraints mean that there is limited scope for planting sizeable areas of floodplain woodland in the catchments of the River Aire, River Calder, and River Don and Rother to reduce flood risk in the major urban conurbations along the Southern Pennine Fringe. Mapping was extended to highlight those sites where the restoration of floodplain woodland would confer a number of other environmental benefits, especially nature conservation and water quality.

There are also significant opportunities across the region for using riparian woodland to help reduce flood flows. A total of 18,730 ha are available for planting in the upper reaches of most rivers, including those catchments in the Southern Pennine Fringe at high flood risk but with limited potential for planting floodplain woodland. Around 2,562 ha is adjoined by land at high risk of sediment delivery, where woodland creation could potentially benefit both flood risk management and diffuse pollution control. Some 997 ha lie within ECSFDI priority catchments, although most of this is located in the catchment of the River Derwent.

Finally, 65% of the land in the wider region is potentially available for woodland creation for multiple benefits, including flood reduction. Some 1,538 km^2 or 16% of the region is mapped as high priority for woodland planting on the basis of soil propensity to generate rapid runoff, soil sensitivity to structural degradation, and/or high risk of sediment delivery to watercourses. This land tends to be concentrated in the upper parts of river catchments and is most extensive within the River Ure, Swale, Derwent and Nidd catchments. Around 52% of the region’s soils are classed as at high or extreme risk of poaching by livestock.

It is recommended that regional stakeholders use these maps to help target future woodland creation to aid flood risk and diffuse pollution management. Map 24 combines the high priority areas for floodplain, riparian and wider woodland planting to reduce downstream flooding in the region. However, if the opportunities identified in this study are to be realised, there will also be a need to increase the value of and improve 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 and success of a more integrated whole catchment based approach to water management.

7. Acknowledgements

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Appendix 1: GIS data sources used in the project

Data set	Source Agency
River catchments and sub catchments	EA
Sediment Delivery to Watercourses from Land	EA
Flood Zone Map	EA
Main Rivers 10k	EA
Washlands – flood storage areas	EA
Existing raised flood defences	EA
Landfill sites	EA
Urban areas	EA
Rivers, lakes and reservoirs	FCSDR [OS 50k].
Roads	FCSDR [OS 50k].
Rail	FCSDR [OS 50k].
England Catchment Sensitive Farming Delivery Initiative Priority Catchments	NE: Downloaded from the magic website
National soil map Standard percentage runoff HOST soil classification POACH risk classification	National Soil Resources Institute
Geology	FCSDR [BGS]
Land Use – Countryside Survey 2000	CS2000 Downloaded from NERC CIS website
Scheduled Ancient Monuments	EH: Downloaded from the EH website
Registered Historic Battlefields	EH: Downloaded from the EH website
Registered Historic Parks and Gardens	EH: Downloaded from the EH website
World Heritage Site (Fountains Abbey and Studley Royal)	EH: Downloaded from the EH website
Airports	FCSDR [OS Strategi - Indicative only intended to be used at >250k].FCSDR
MOD	FCSDR [OS Strategi]]
Golf courses	FCSDR [OS Strategi].
Race courses	FCSDR [OS Strategi]
Country parks	FCSDR [OS Strategi]
Gardens	FCSDR [OS Strategi]
Castles	FCSDR [OS Strategi]
Zoos	FCSDR [OS Strategi]
Camp and caravan sites	FCSDR [OS Strategi]
Hill forts	FCSDR [OS Strategi]
Linear antiquity	FCSDR [OS Strategi]
SSSI	FCSDR [NE]

National Nature Reserves	FCSDR [NE]
Local Nature Reserves	FCSDR [NE]
Special Areas of Conservation	FCSDR [NE]
Special Protection Areas	FCSDR [NE]
Ramsar sites	FCSDR [NE]
Ancient Woodland	FCSDR [NE]
Natural Areas	FCSDR [NE]
Landscape Character Areas	FCSDR [NE]
Habitat Networks Grassland Heathland Mire/fen/bog Woodland	FCSDR [NE]
National Parks	FCSDR [DEFRA]
AONB	FCSDR [DEFRA]
Environmentally Sensitive Areas	FCSDR [DEFRA]
Agricultural Land Classification	FCSDR [DEFRA]
RSPB Reserves	FCSDR [RSPB]
Important Bird areas	FCSDR [RSPB]
NIWT - Existing Woodland	FCSDR [FR]
Agricultural Land Classification	FCSDR
Digital elevation model - used to derive: Sub-catchments boundaries Drainage network Slope Contours	OS Profile

FR: data set created by Forest Research
FC: data set created by Forestry Commission
FCSPR: obtained from the Forestry Commissions' spatial data repository, original data source indicated within square brackets
EA: Environment Agency (supplied direct)
NE: Natural England
EH: English Heritage

Appendix 2: Pre processing required to generate spatial data for the constraints to 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 1,612 settlements that intersected the floodplain.

Roads

The roads were available as OS 50k 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 road network.
The road network +300 m buffer: As with the urban areas, a wider buffer was created along all roads and floodplain fragments within these excluded if they occurred adjacent or downstream of a road.

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. The North Yorkshire Moors railway between Pickering and Grosmont was added to the main lines by creating an additional feature in the rail network, based on OS 1:25,000 raster data.

Airports

Military and civilian airports were identified using the OS 250k Stategi airport data set. Aerial photographs were then used to select the appropriate polygons from OS Master Map to create a shapefile for the boundary of each airport. The airports were then excluded from the floodplain. Each airport was buffered to form a bird strike exclusion zone of 13 km radius.

SSSIs, Special Areas of Conservation and Special Protection Areas

These comprised 381 sites in the region. Where they occurred outside the floodplain they were considered to present a constraint to woodland planting. However the 150 sites situated in the floodplain were assessed more carefully. 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 72 sites classed as solely open habitats where woodland was unlikely to be appropriate, but 65 sites with predominantly woodland or geological features where woodland expansion may be acceptable.

Local Nature Reserves

There were 97 local nature reserves within the region, 40 of which occurred in the floodplain. Brief information on the nature of the habitat at each site is available on line www.english-nature.org.uk/special/inv/pdf/lnr.project.xls. This table was used to identify which sites were unsuitable (28 of 40) for woodland expansion and these classed as a constraint.

Scheduled Ancient Monuments

Scheduled Ancient Monuments including linear antiquity and World Heritage Sites (Fountains Abbey and Studley Royal) were all buffered by 30 m, in accordance with the Forest and Archaeology Guidelines

Registered Historic Battlefields

Registered battlefields spatial data set was obtained from the English Heritage website. Each site was buffered by 30 m in accordance with the Forest and Archaeology Guidelines and excluded from the floodplain. See:
http://www.english-heritage.org.uk/upload/img/Boroughbridge-Map.gif
http://www.english-heritage.org.uk/upload/img/Myton-Map.gif
http://www.english-heritage.org.uk/upload/img/Stamford-Bridge-Map.gif
http://www.english-heritage.org.uk/upload/img/Northallerton-Map.gif
http://www.english-heritage.org.uk/upload/img/Marston-Moor-Map.gif
http://www.english-heritage.org.uk/server/show/conBattleField.41 for map of Towton battlefield

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. The extent of the land included in the register is extensive and many landscapes include elements of trees and woodland. It was decided that rather than treat them as an absolute constraint they would be considered a potential constraint. Therefore the areas of Potential New Floodplain Woodland that intersect a registered historic park have been identified as requiring further consideration. This affects 57 of the 1,902 sites identified.

Landfill sites

Data was supplied to the project by staff from the regional office of the EA. The point source data was buffered by 100 m and excluded from the floodplain. All active and inactive landfill sites were considered to be unsuitable for the creation of new woodland. Until the introduction of legislation in 2004 halting the co-disposal of hazardous waste it had been possible to send toxic/hazardous waste to landfill and consequently there is no way of knowing the nature of the waste which has been dumped at a site. Tree planting is often an important landscape element in the restoration of a land fill site once it becomes inactive, however special measures, such as additional soil depth, are frequently required to protect the underlying material from the actions of trees roots. It was therefore deemed inappropriate to include such sites in any potential scheme to create or restore floodplain woodland.

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.

Appendix 3: List of Maps

Map 1: The Yorkshire and the Humber Region

Map 2: Landscape character areas and elevation across the region

Map 3: Geology in the region

Map 4: Soils of the region

Map 5: Land use in the region

Map 6: Existing woodland in the region

Map 7: Urban infrastructure of the region

Map 8: EA flood zones and river catchments within the region

Map 9: Constraints to woodland planting across the region

Map 10: Illustration of the de-selection procedure to define, identify and remove areas of the fluvial floodplain where urban infrastructure is at risk from the backing-up of floodwaters

Map 11: Fluvial floodplain of the region free from constraints to woodland planting

Map 12: Areas suitable for potential new floodplain woodland (PNFW) and their location with respect to existing raised flood defences

Map 13: Potential new floodplain woodland offering additional biodiversity gain by extending woodland habitat network

Map 14: Location of airfield bird strike zones and ECSFDI priority catchments within the region

Map 15: Estimated rates of sediment delivery to watercourses for a 1-in-10 year erosion event (from EA project P2-209)

Map 16: Priority areas for potential new riparian woodland (PNRW) to reduce flood flows and sediment delivery to watercourses

Map 17: Land free from constraints to woodland planting within the region

Map 18: Hydrology of soil types (HOST) classification of the soils of the region

Map 19: Propensity of soils to generate surface runoff within the region

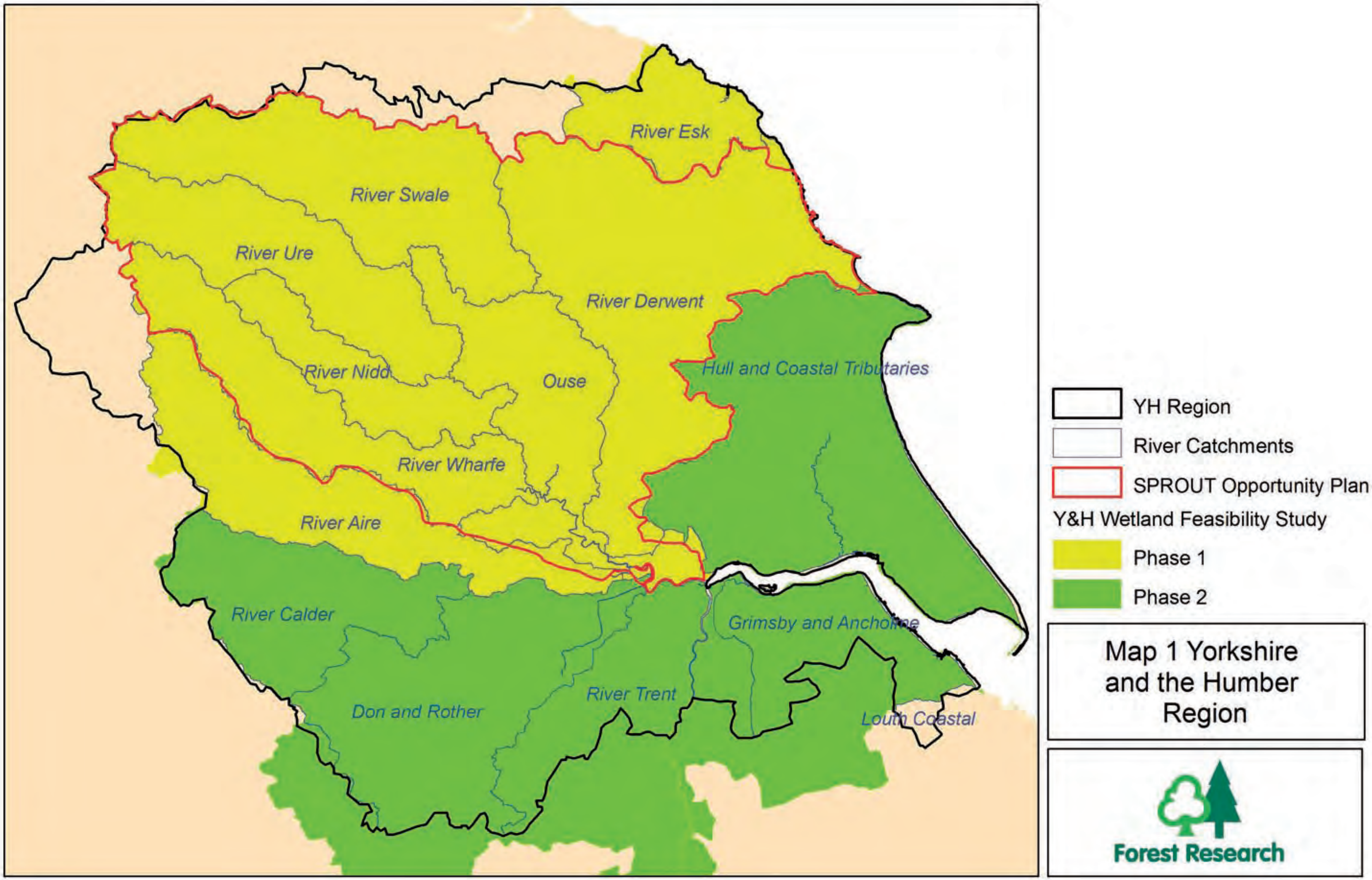
Map 20: Vulnerability of seasonally waterlogged soils to damage by livestock poaching within the region

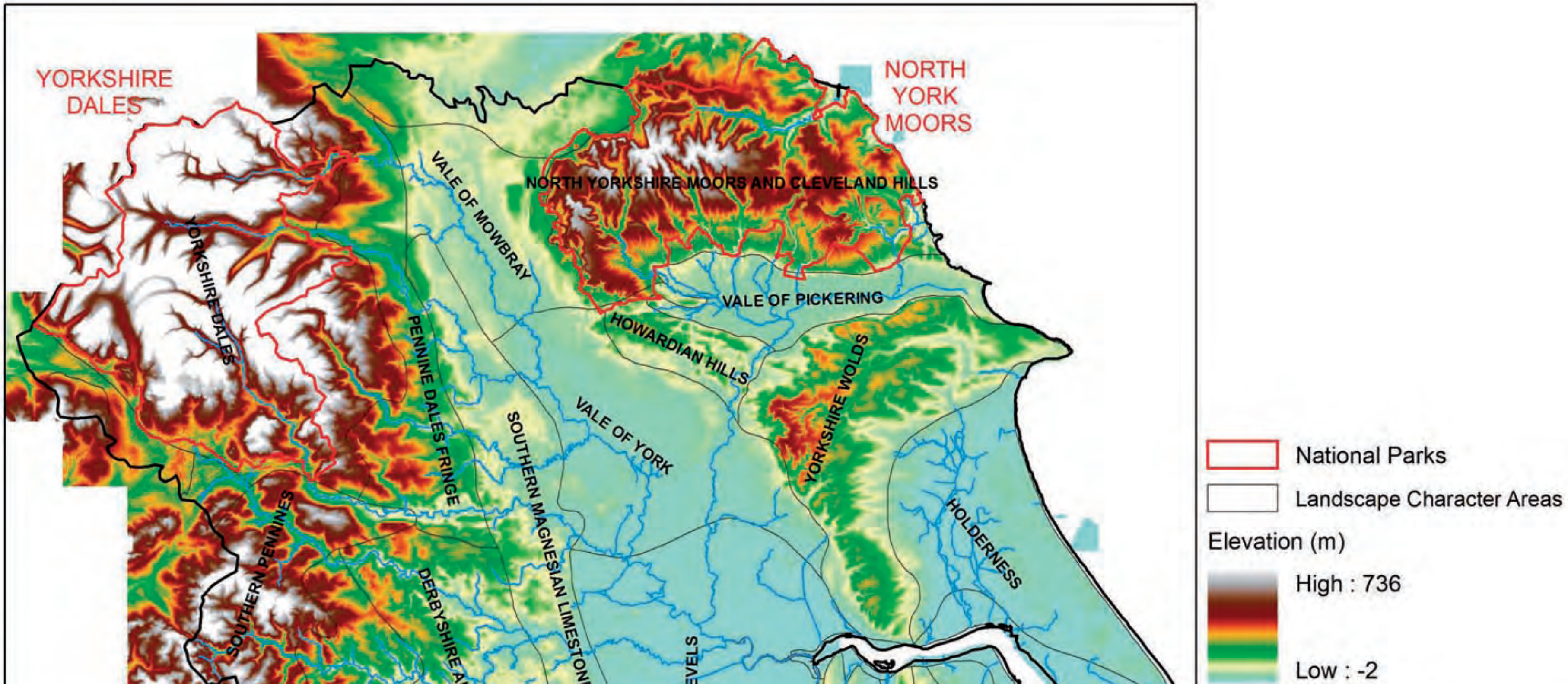
Map 21: Sensitivity of soil types to degradation by agricultural practices within the region (from EA Report NA788)

Map 22: Classification of slope across the region according to land sensitivity to damage by land use practices

Map 23: Priority areas for new woodland planting to reduce rapid surface runoff, soil structural degradation and/or sediment delivery to watercourses within the region

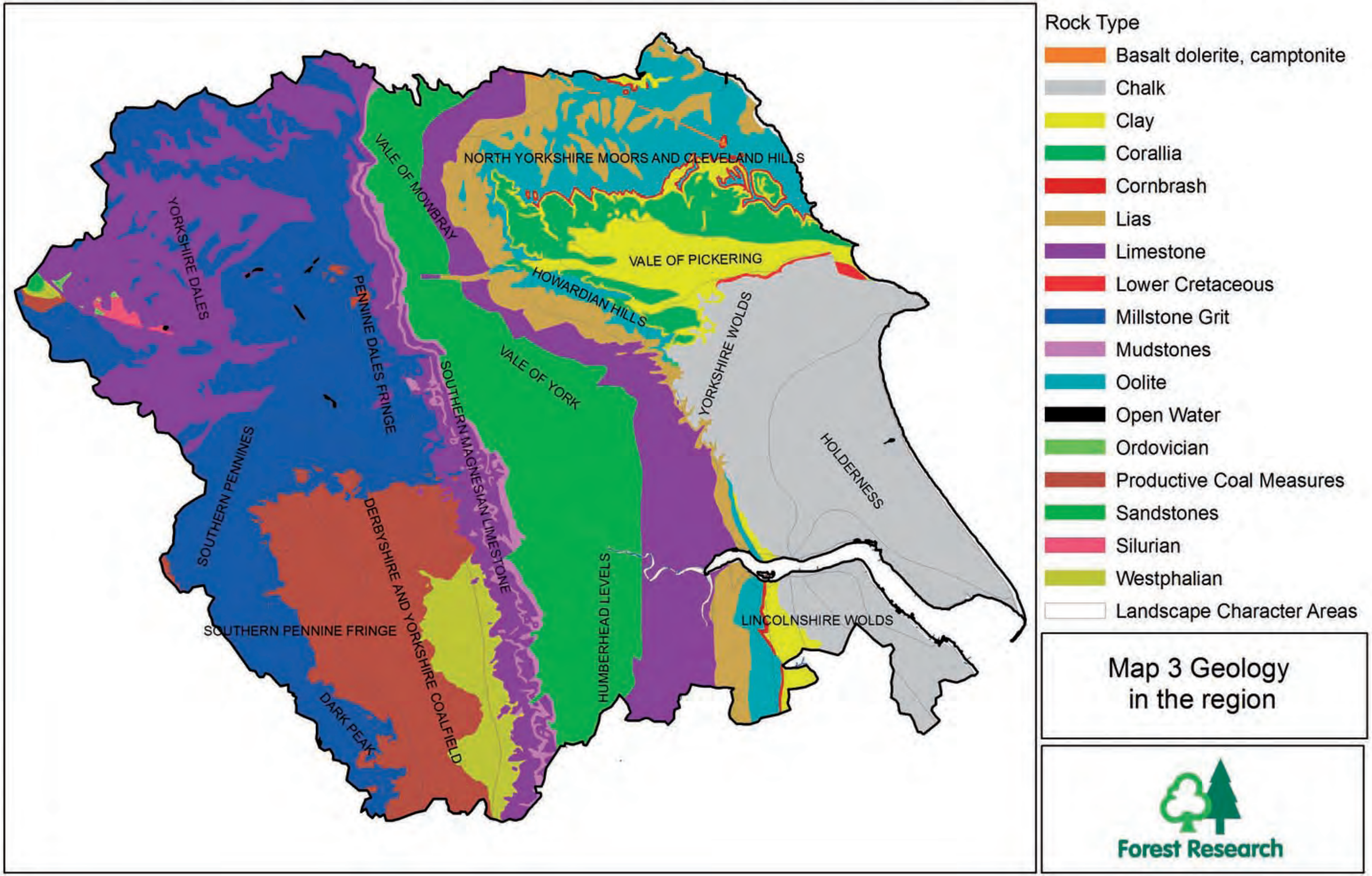
Map 24: Combined map showing high priority areas for floodplain, riparian and wider woodland planting to reduce downstream flooding in the region.


River Esk
River Swale
River Ure
River Derwent
River Nidd
Ouse
Hull and Coastal Tributaries
River Wharfe
River Aire
River Calder
Grimsby and Ancholme
River Trent
Don and Rother
Louth Coastal
YH Region
River Catchments
SPROUT Opportunity Plan
Y&H Wetland Feasibility Study
Phase 1
Phase 2
Map 1 Yorkshire and the Humber Region
Forest Research

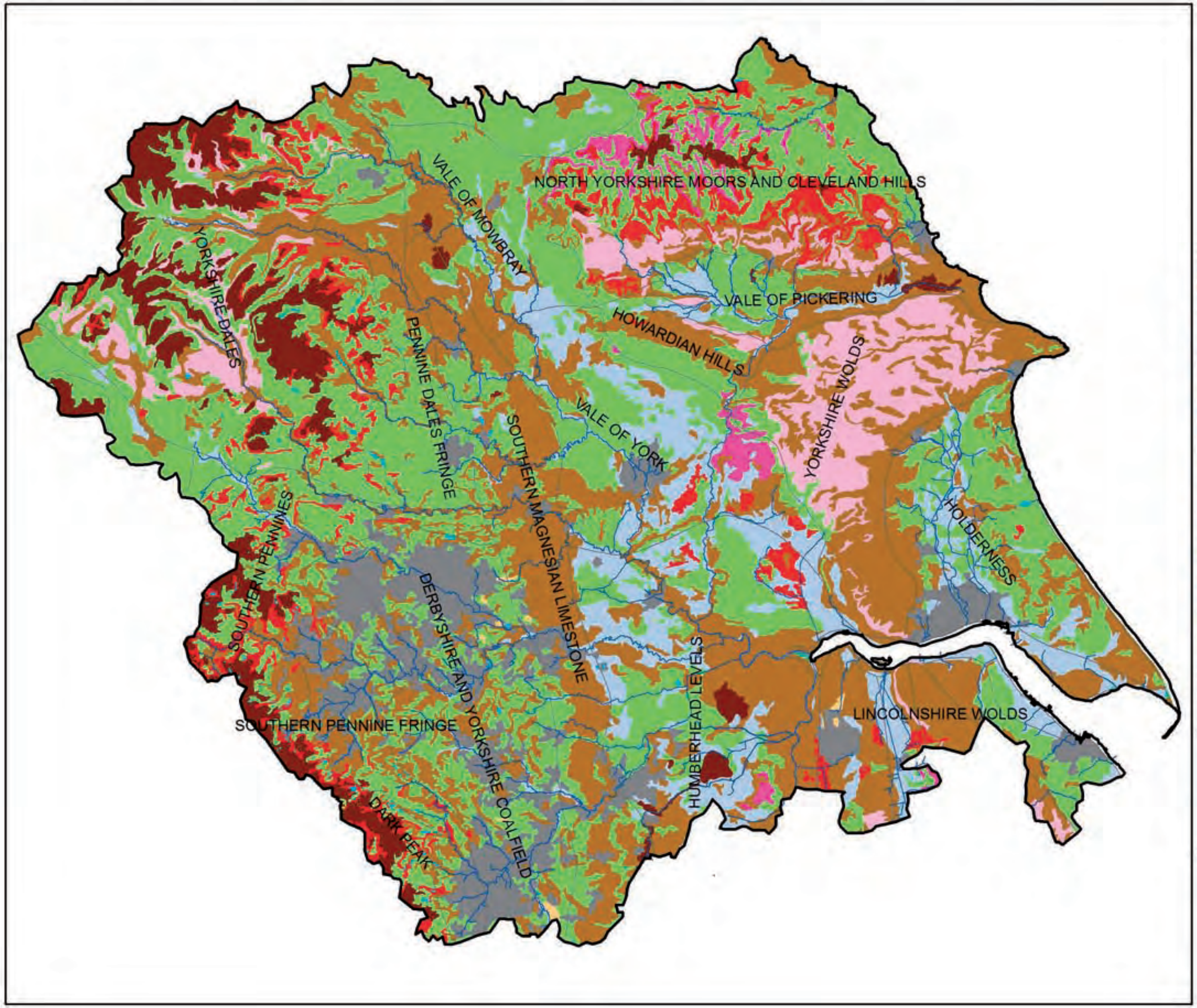


Map 2 Landscape character areas and elevation across the region

Forest Research

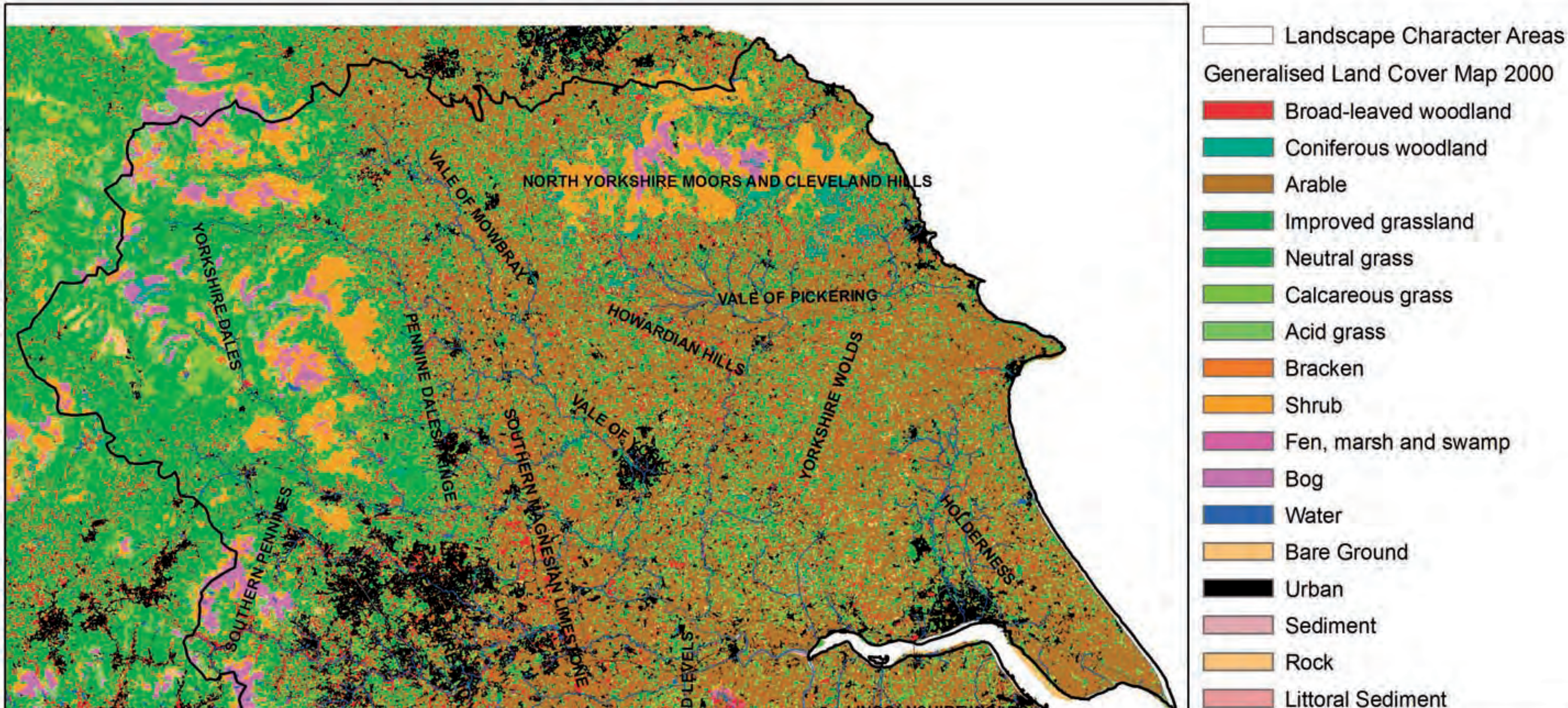


Map 3 Geology in the region



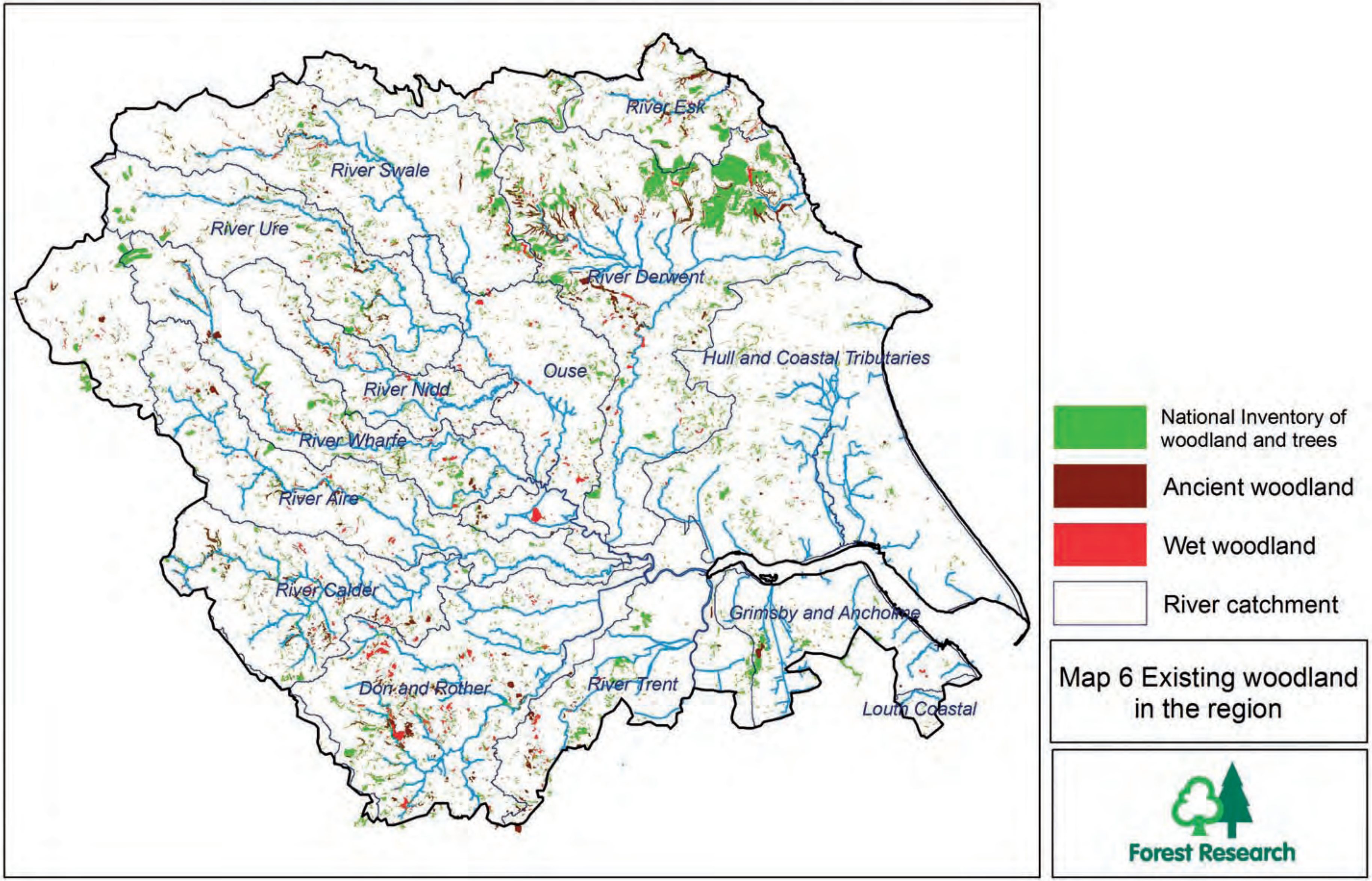
Map 4 Soils of the region

Forest Research

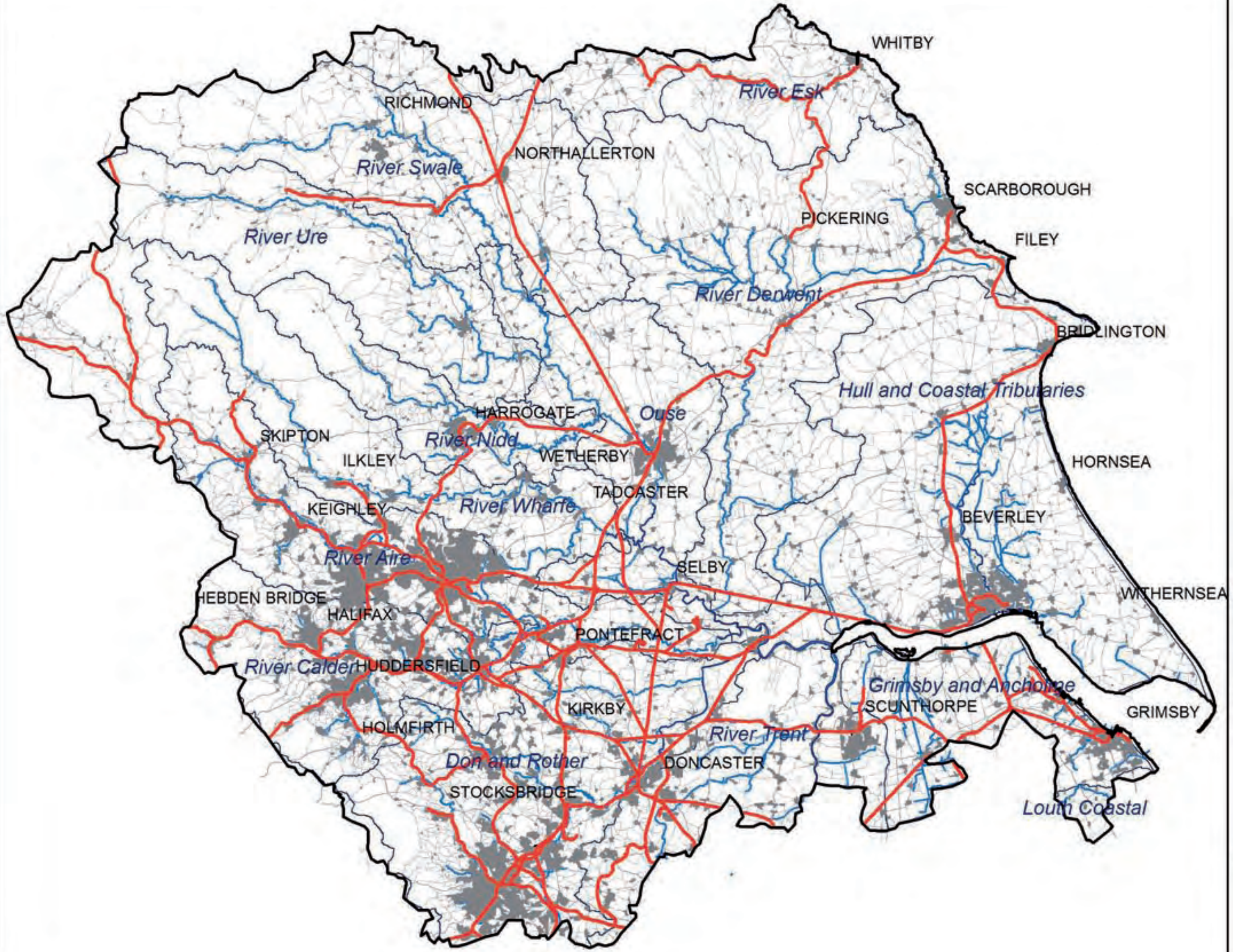


Map 5 Land use in the region

Forest Research

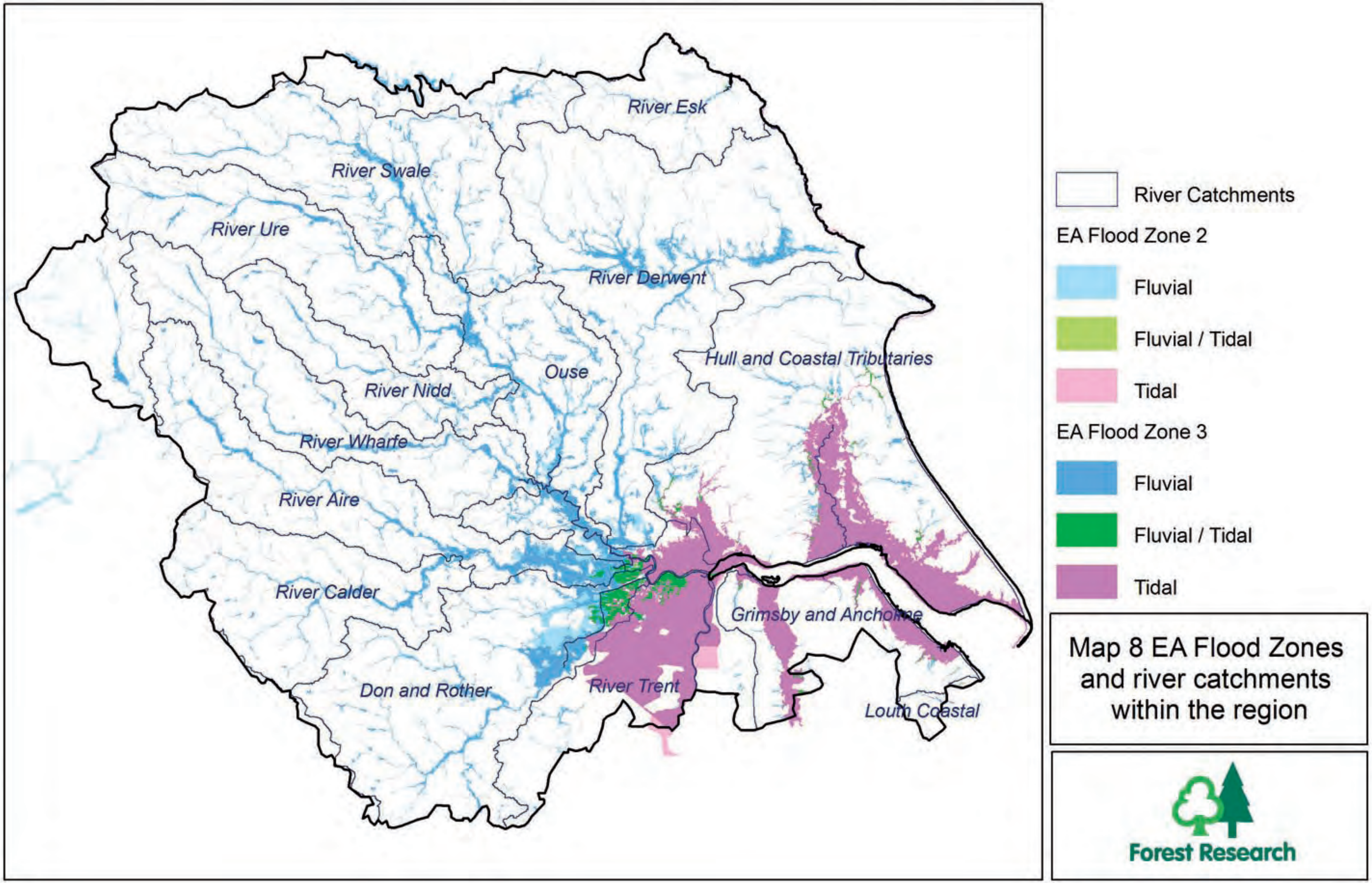


Map 6 Existing woodland in the region

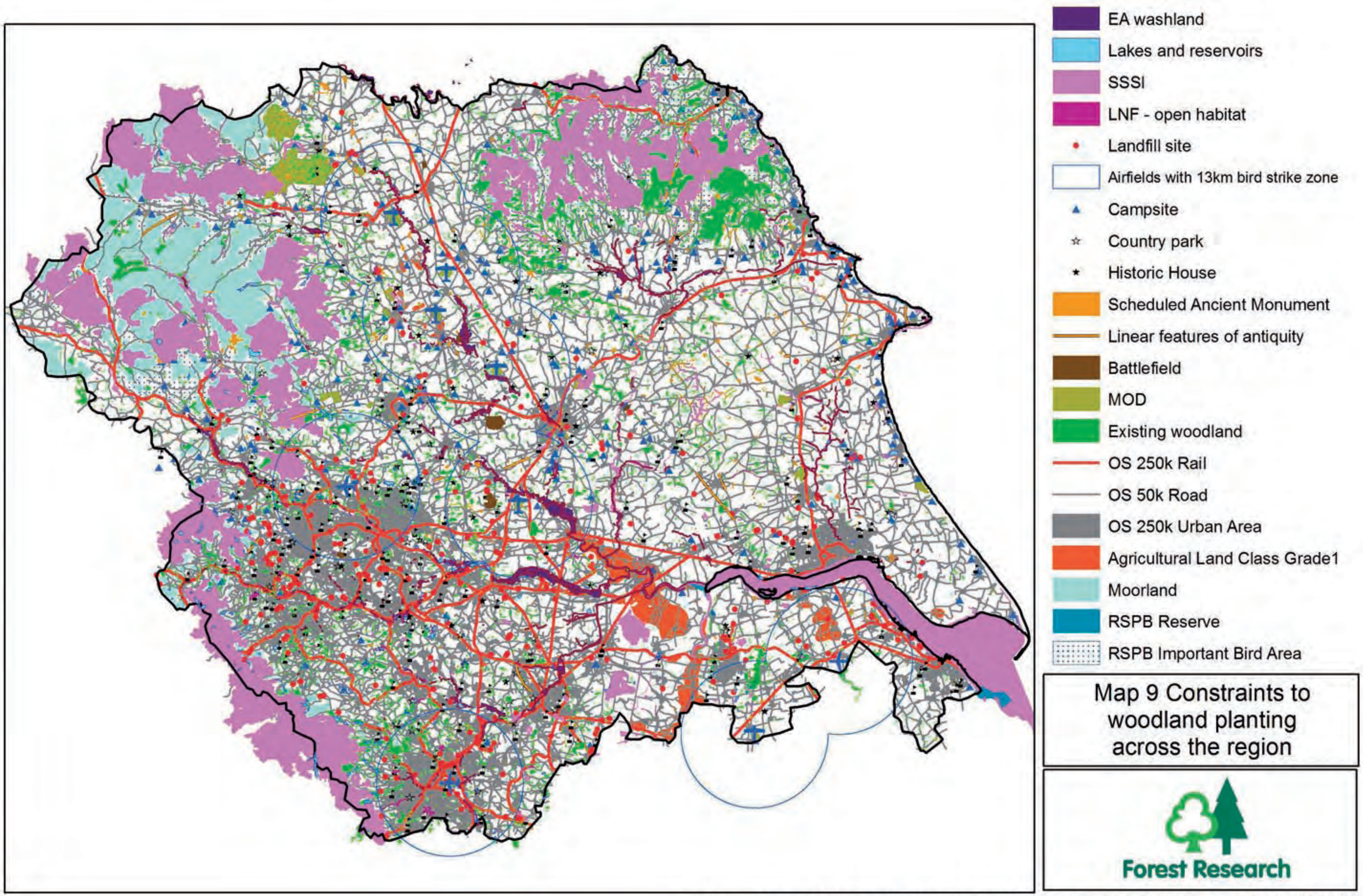


Map 7 Urban infrastructure of the region

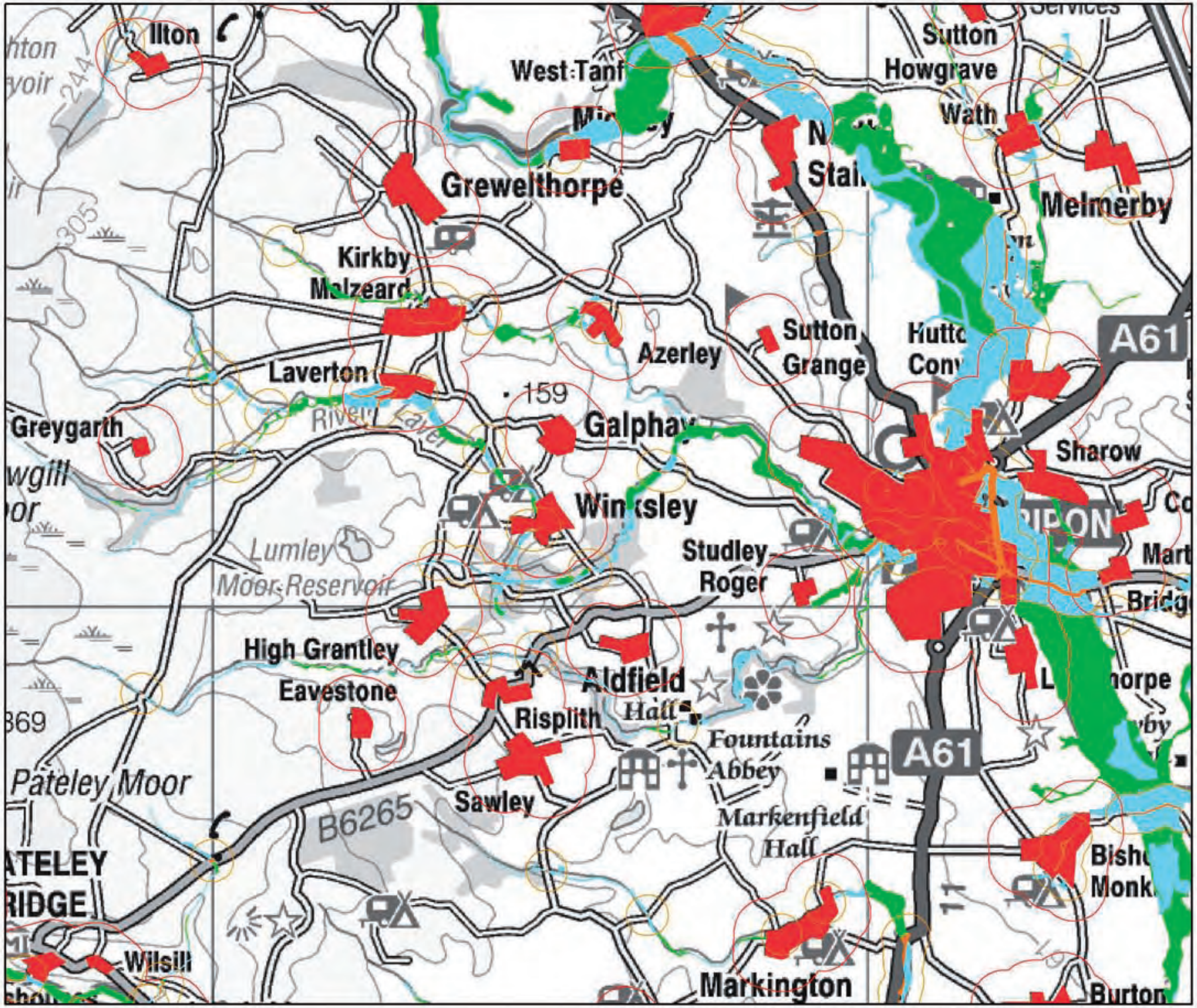
Forest Research



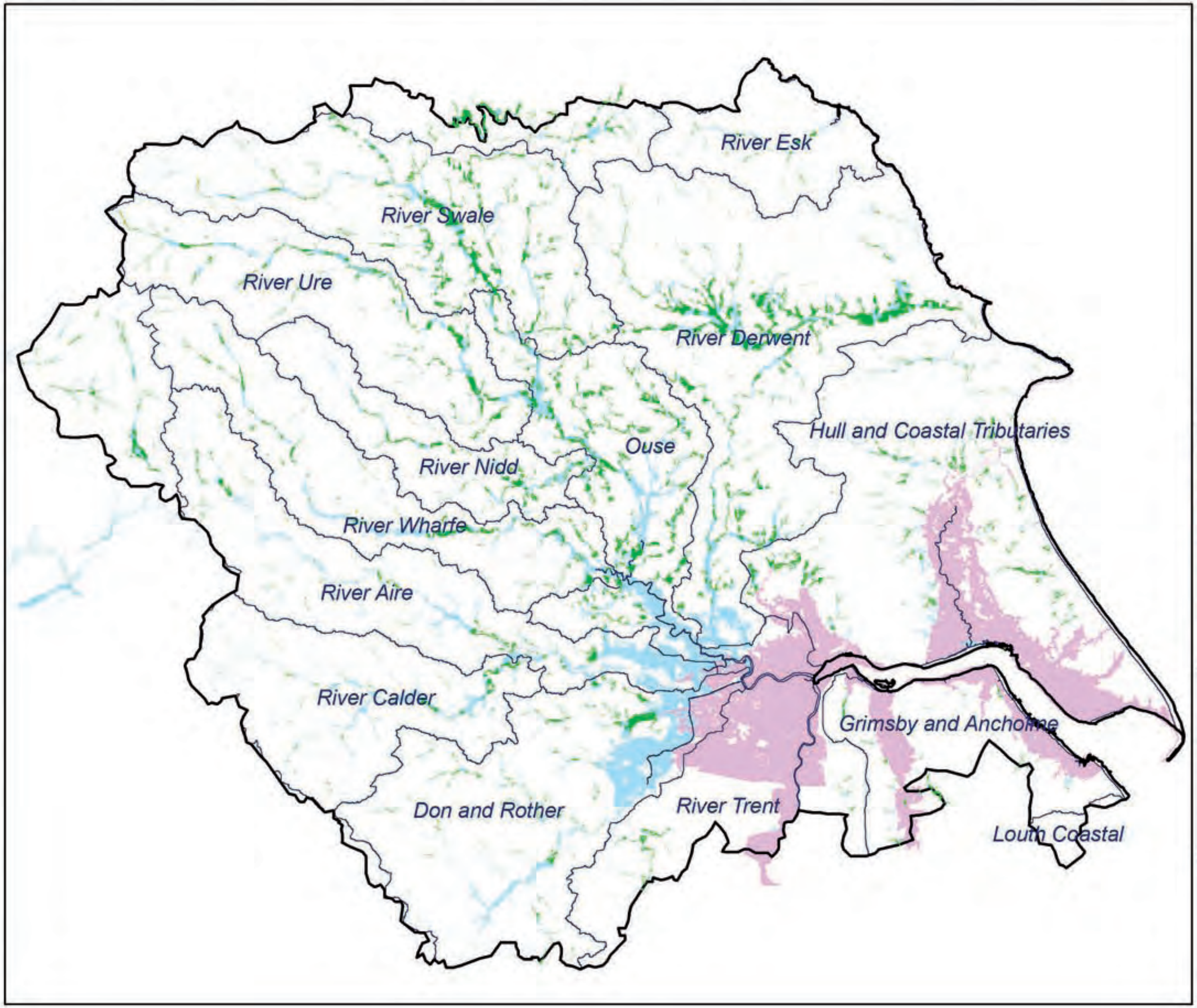
Map 8 EA Flood Zones and river catchments within the region



Map 9 Constraints to woodland planting across the region

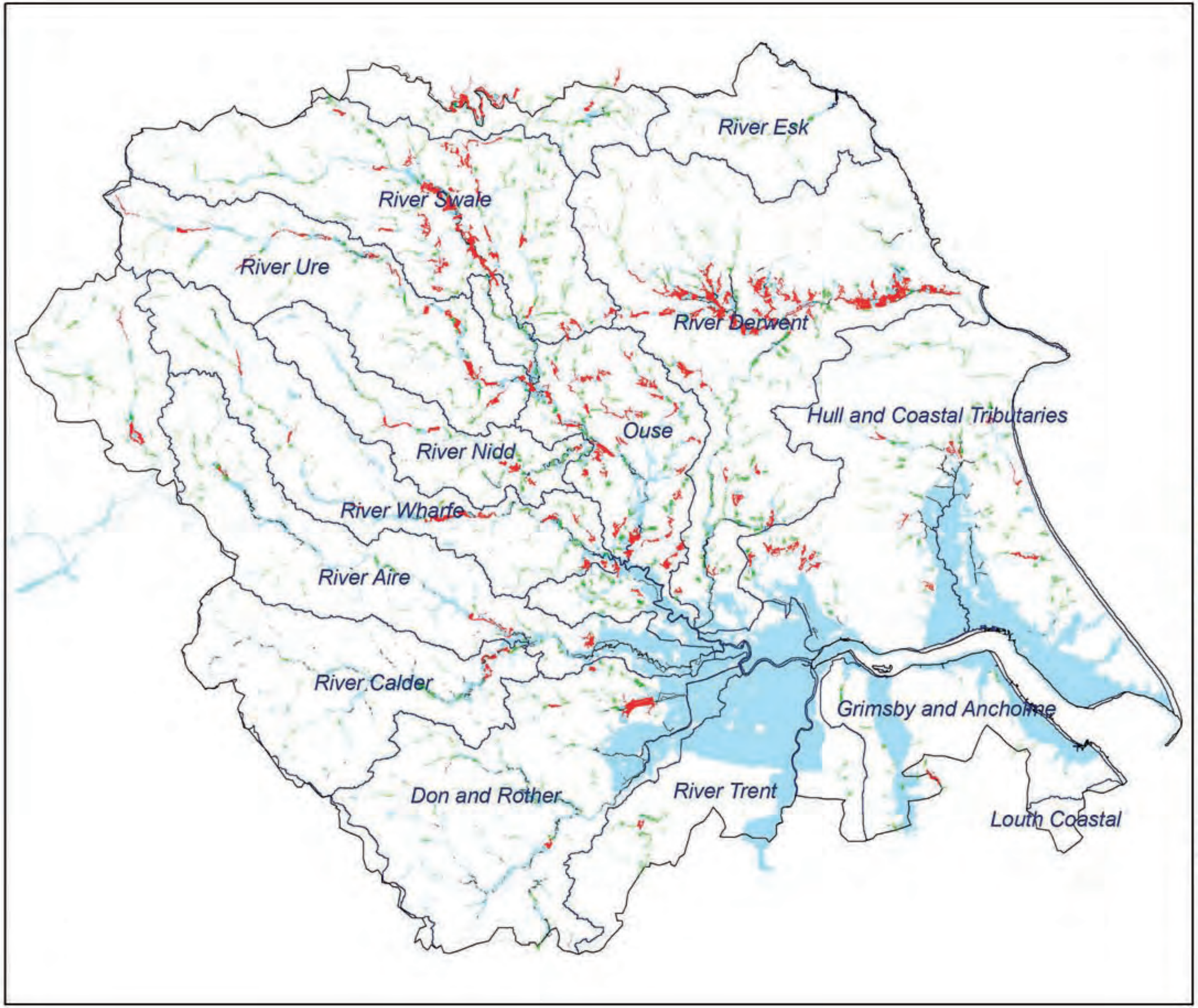


Map 10 Illustration of the deselection procedure to define, identify and remove areas of the fluvial floodplain where urban infrastruture is at risk from the backing-up of floodwaters.



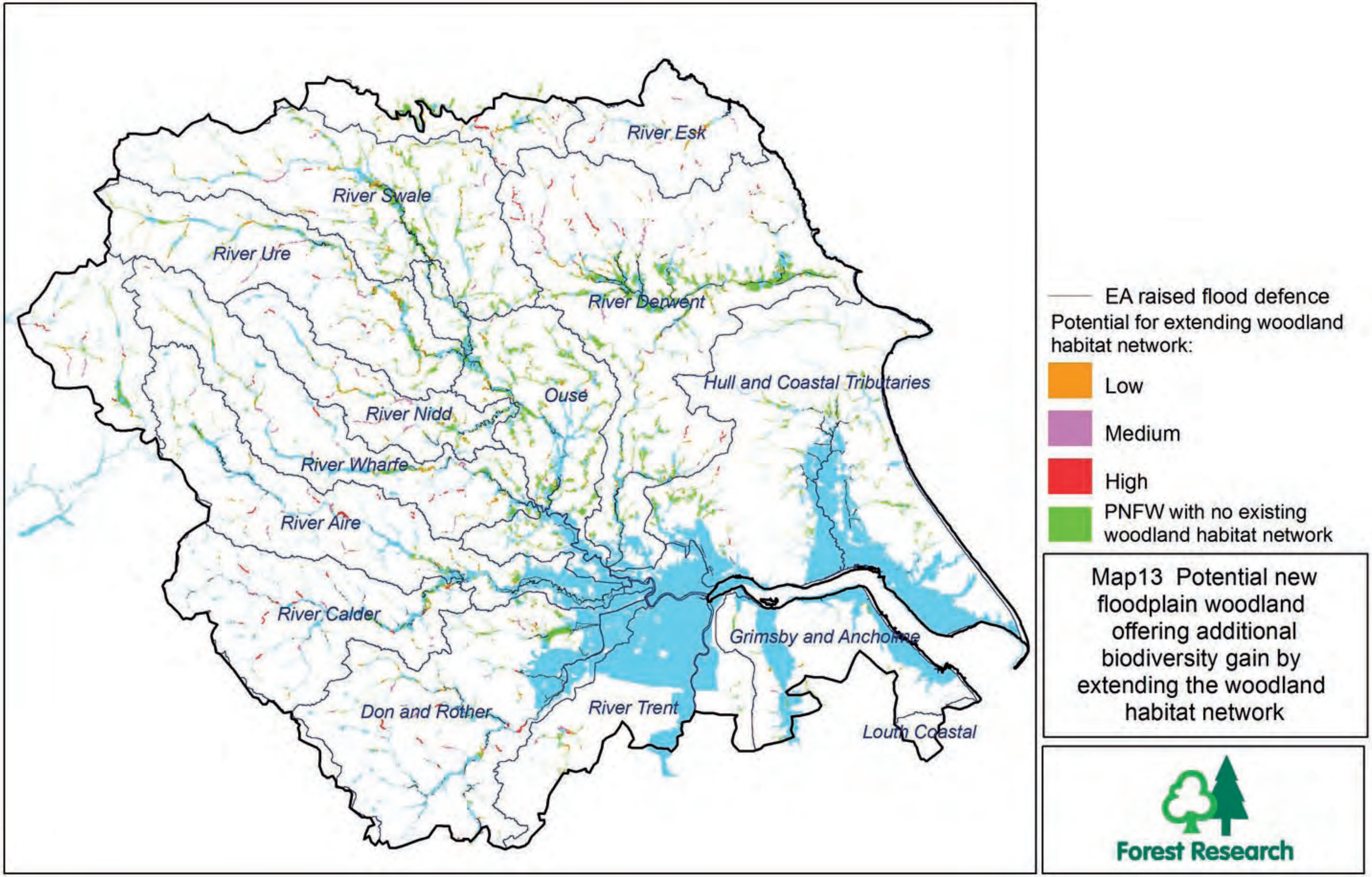
Map 11 Fluvial floodplain of the region free from constraints to woodland planting

Forest Research

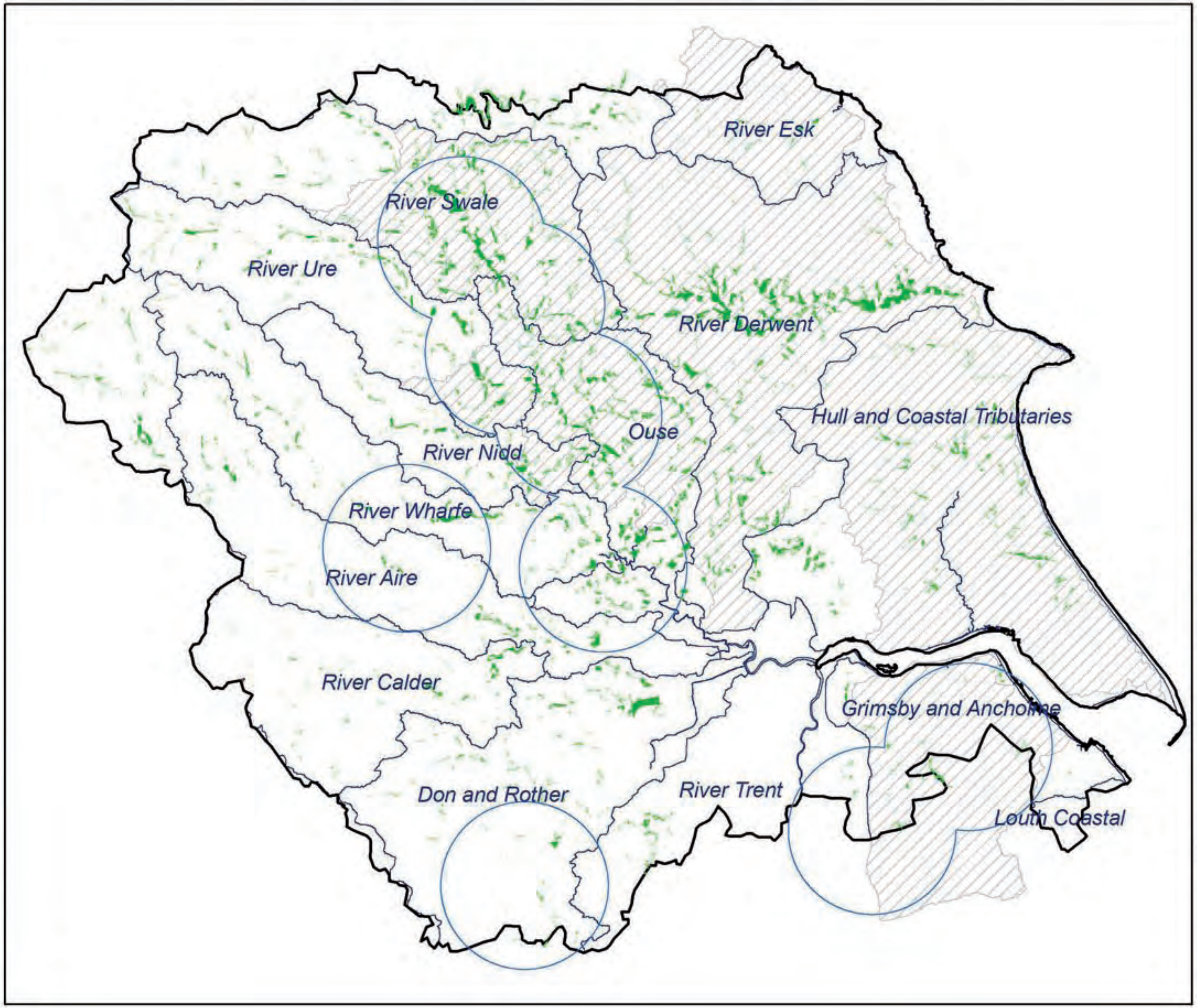


Map 12 Areas suitable for potential new floodplain woodland (PNFW) and their location with respect to existing raised flood defences

Forest Research

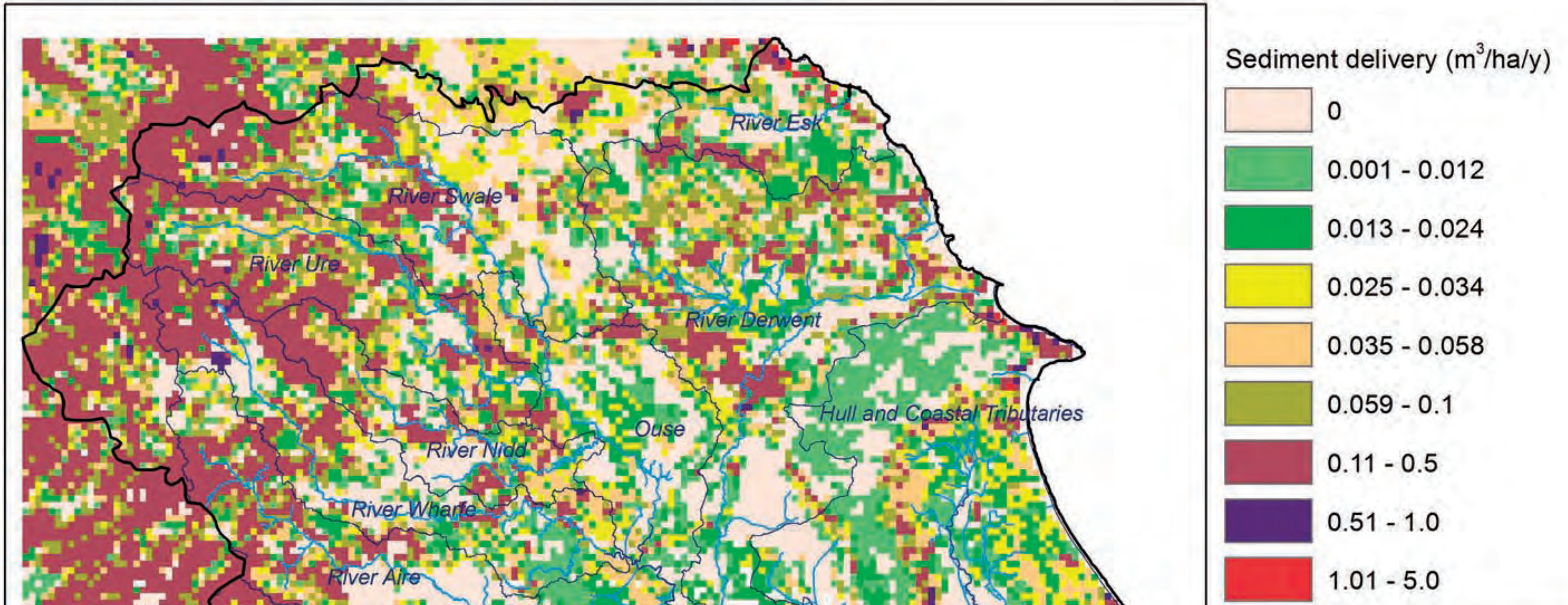


Map13 Potential new floodplain woodland offering additional biodiversity gain by extending the woodland habitat network



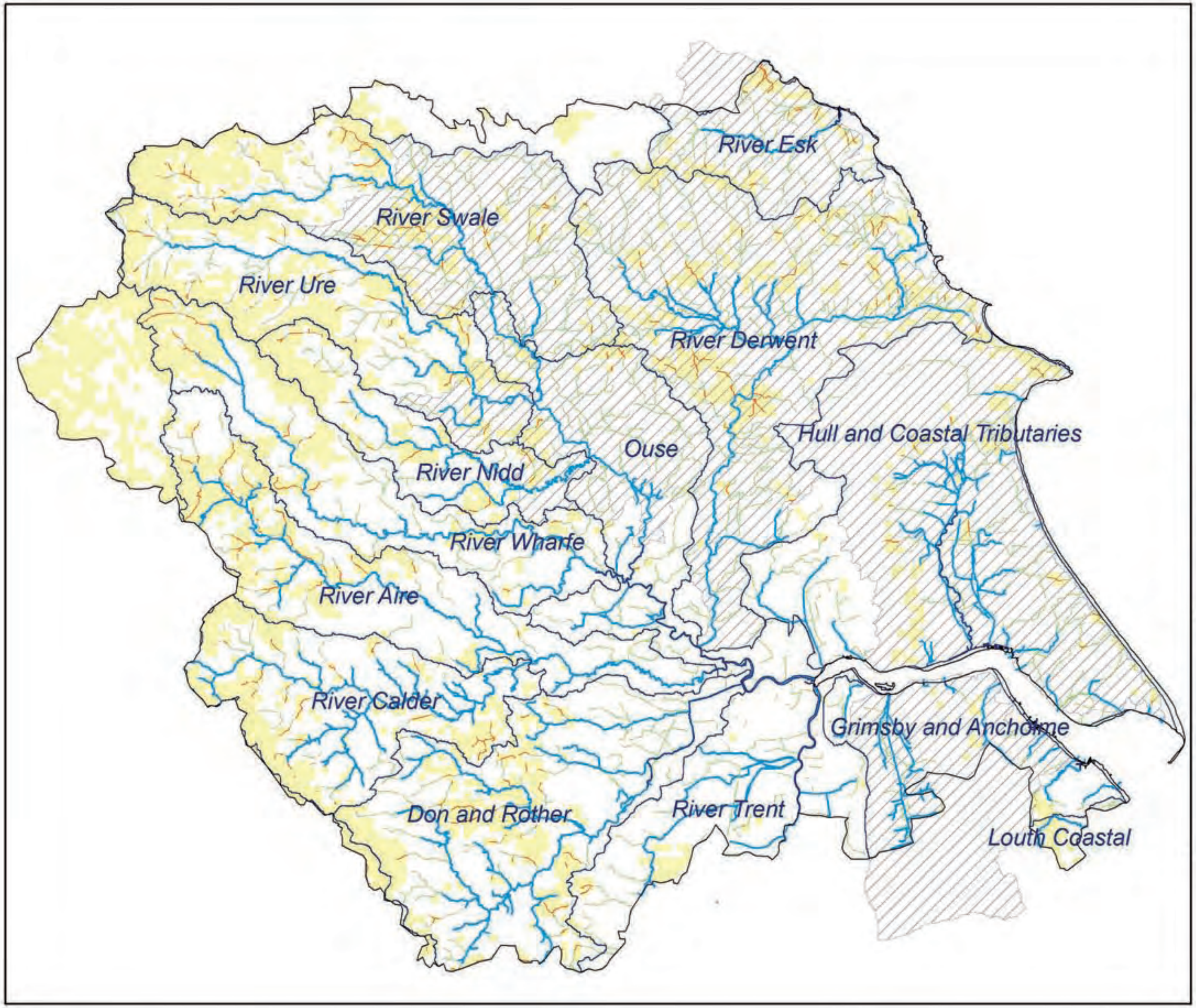
Map 14 Location of airfield bird strike zones and ECSFDI priority catchments within the region

Forest Research



Map 15 Estimated rates of sediment delivery to watercourses for a 1-in-10 year erosion event (from EA project P2-209)

Forest Research



Priority areas for PNRW

PNRW

ECSFDI Priority Catchments

Sediment delivery >0.1 m^3/ha/y

Map 16 Priority areas for potential new riparian woodland (PNRW) to reduce flood flows and sediment delivery to watercourses

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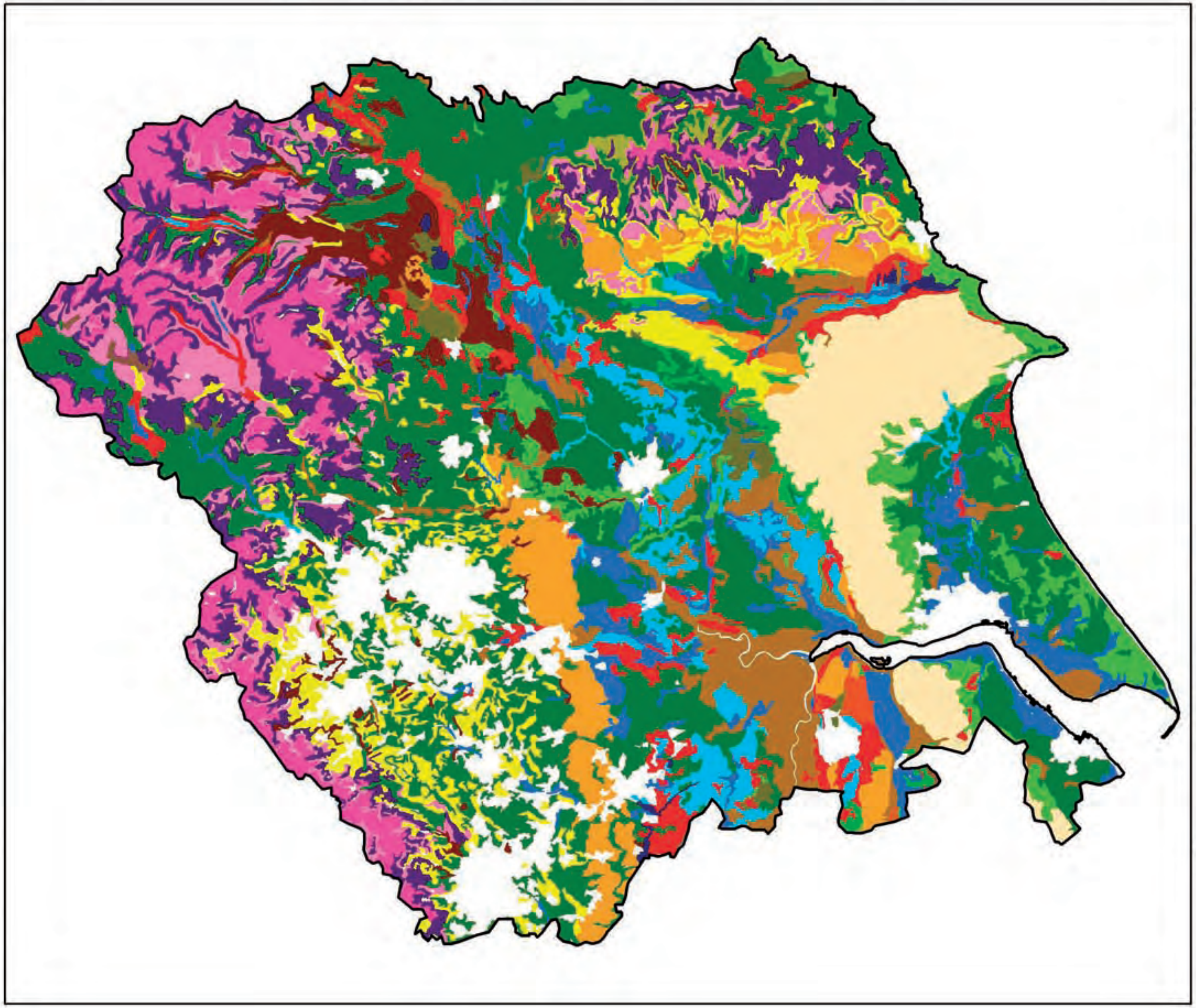
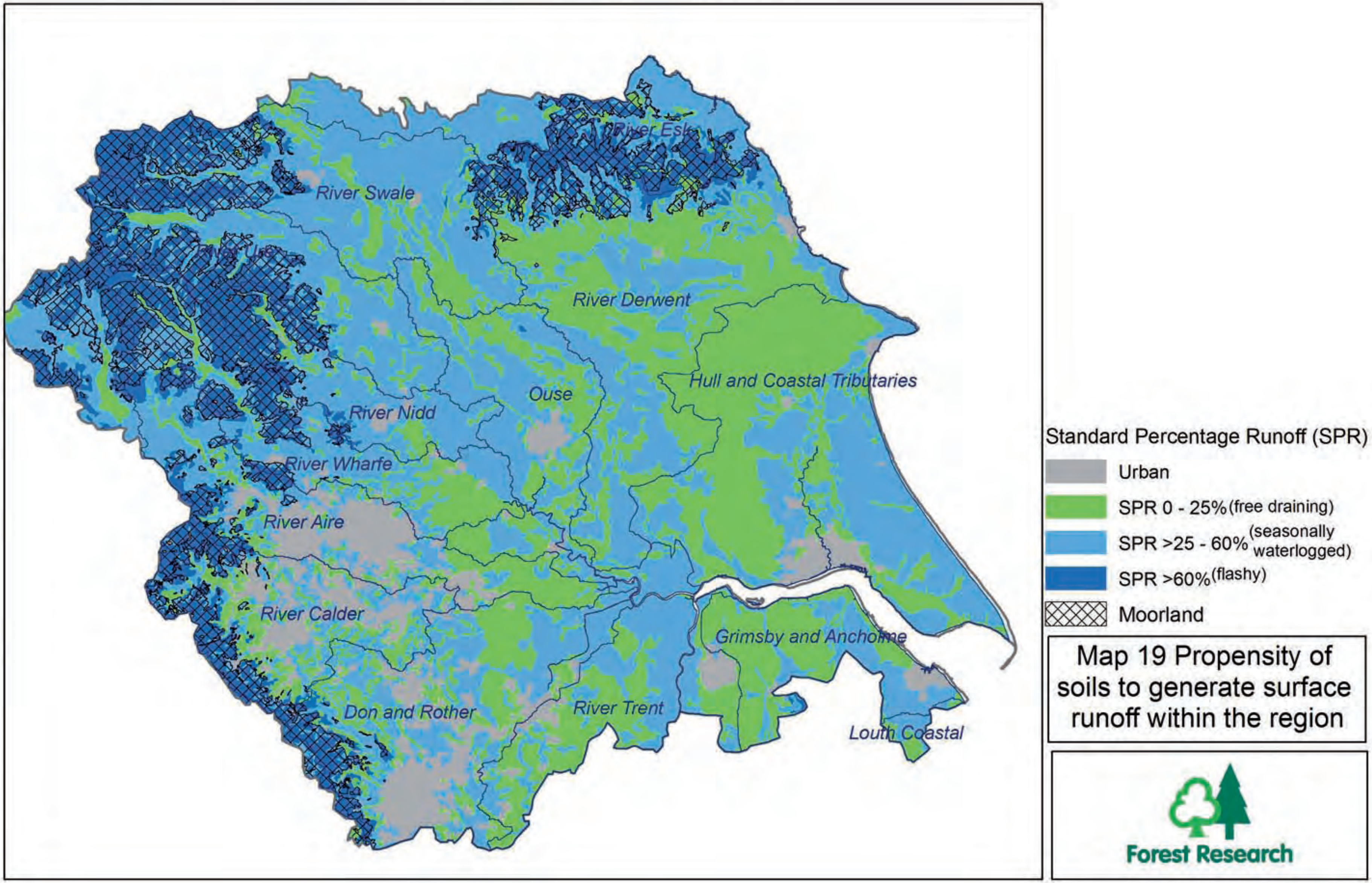
Map 17 Land free from constraints to woodland planting within the region

Forest Research

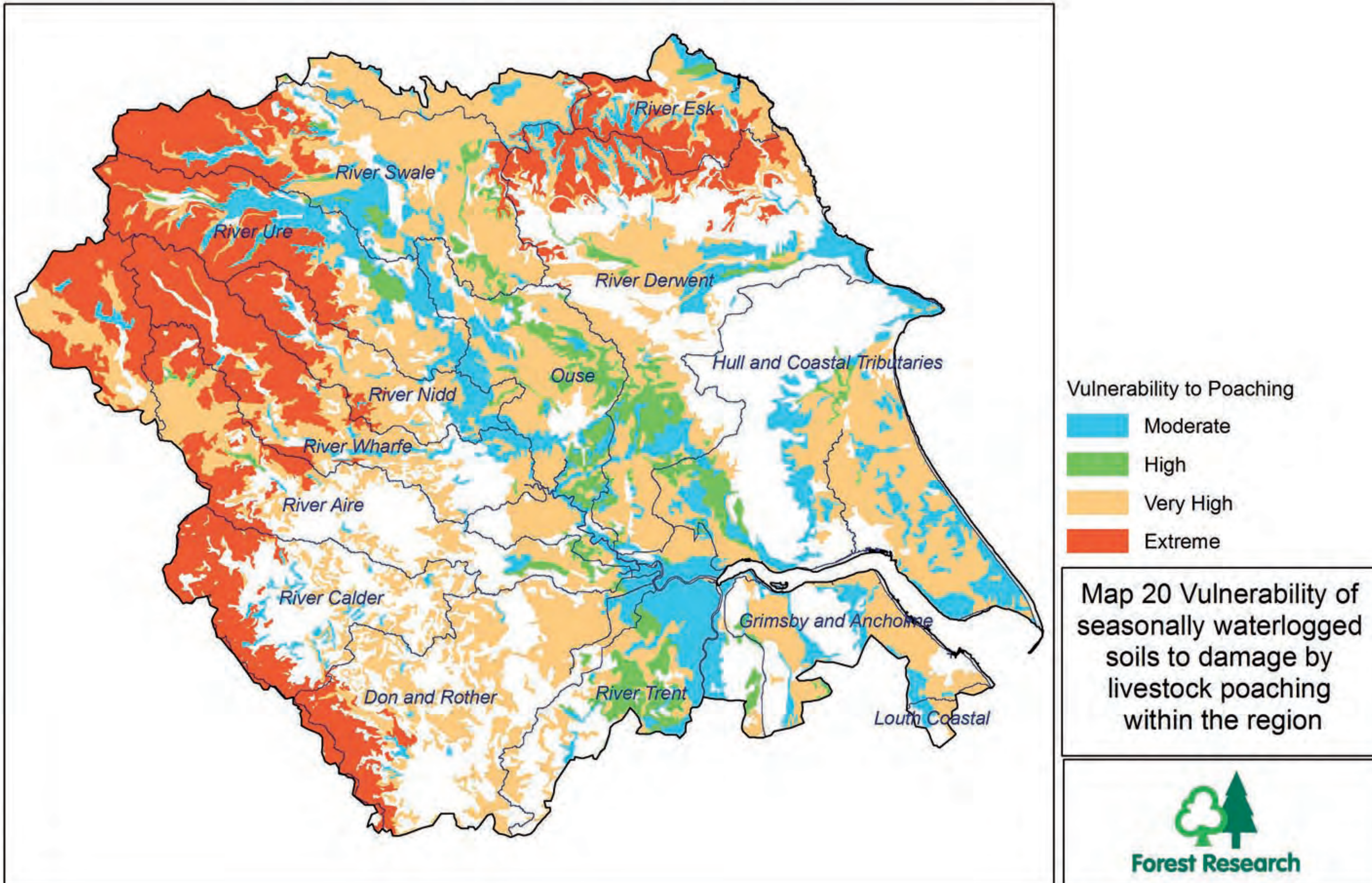


Map 18 Hydrology of soil types (HOST) classification of the soils of the region

Forest Research

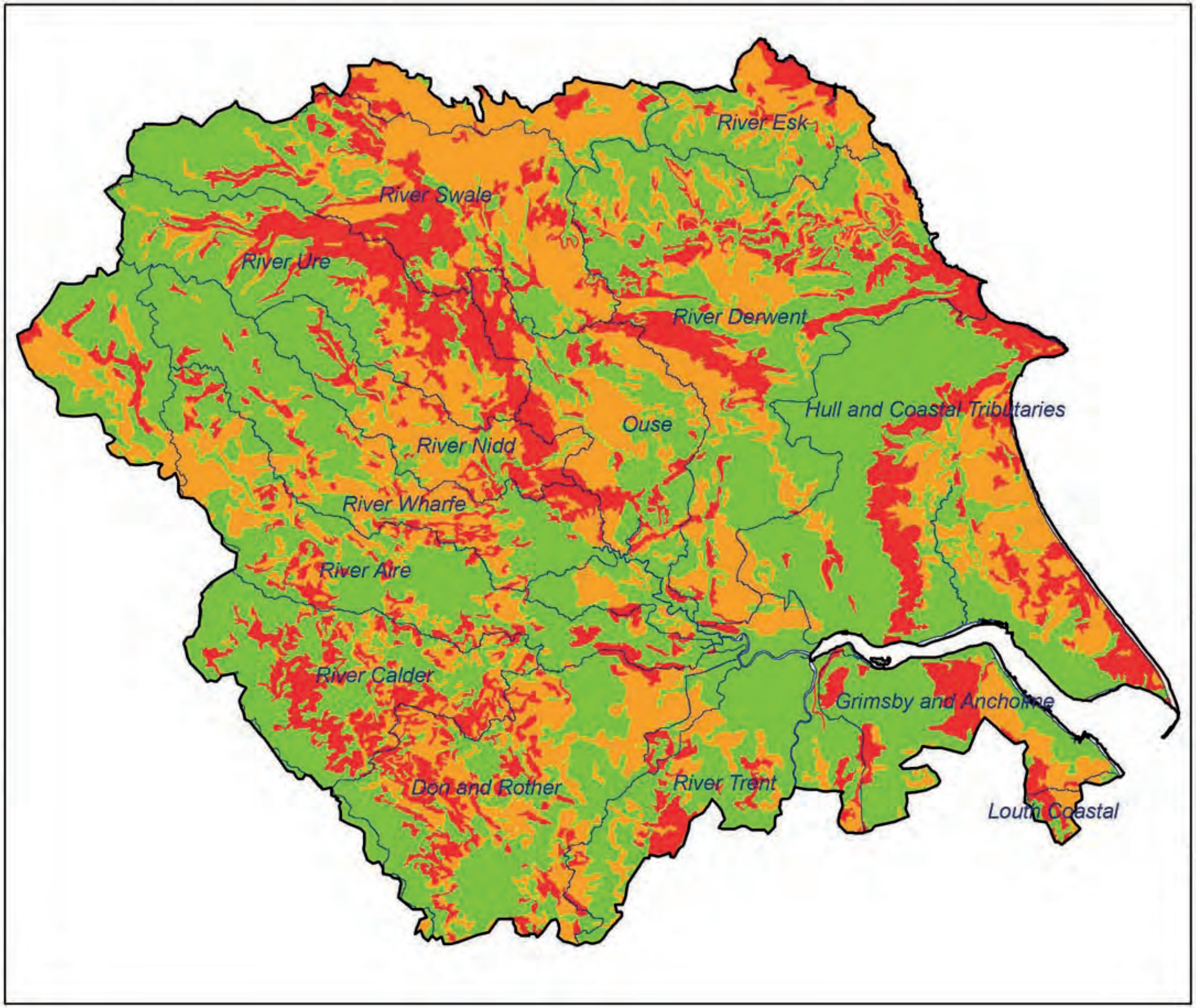


Map 19 Propensity of soils to generate surface runoff within the region



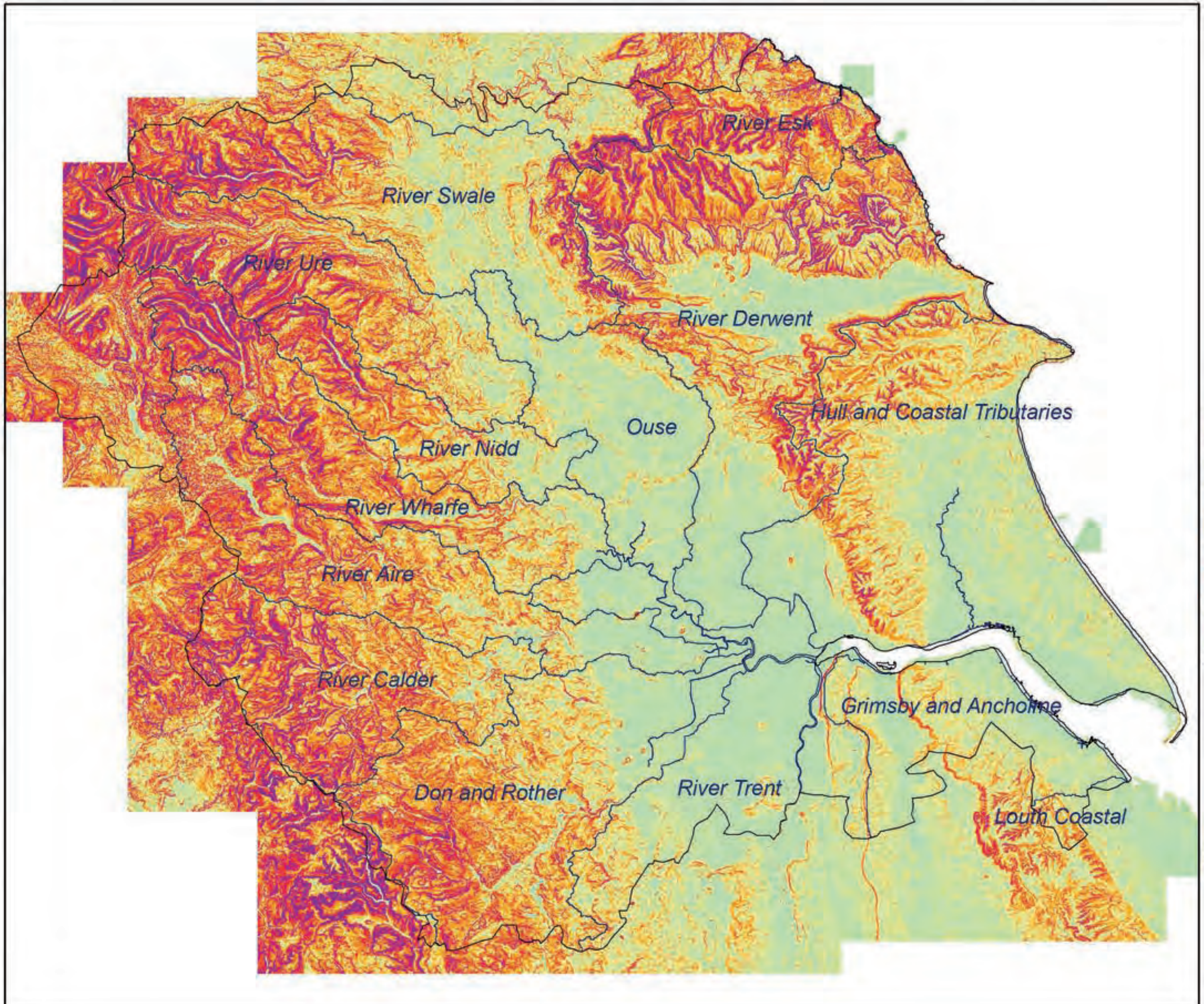
Map 20 Vulnerability of seasonally waterlogged soils to damage by livestock poaching within the region

Forest Research



Map 21 Sensitivity of soil types to degradation by agricultural practices within the region (from EA report NA788)

Forest Research



very low sensitivity
low sensitivity
moderate sensitivity
high sensitivity
very high sensitivity

Map 22 Classification of slope across the region according to land sensitivity to damage by land use practices

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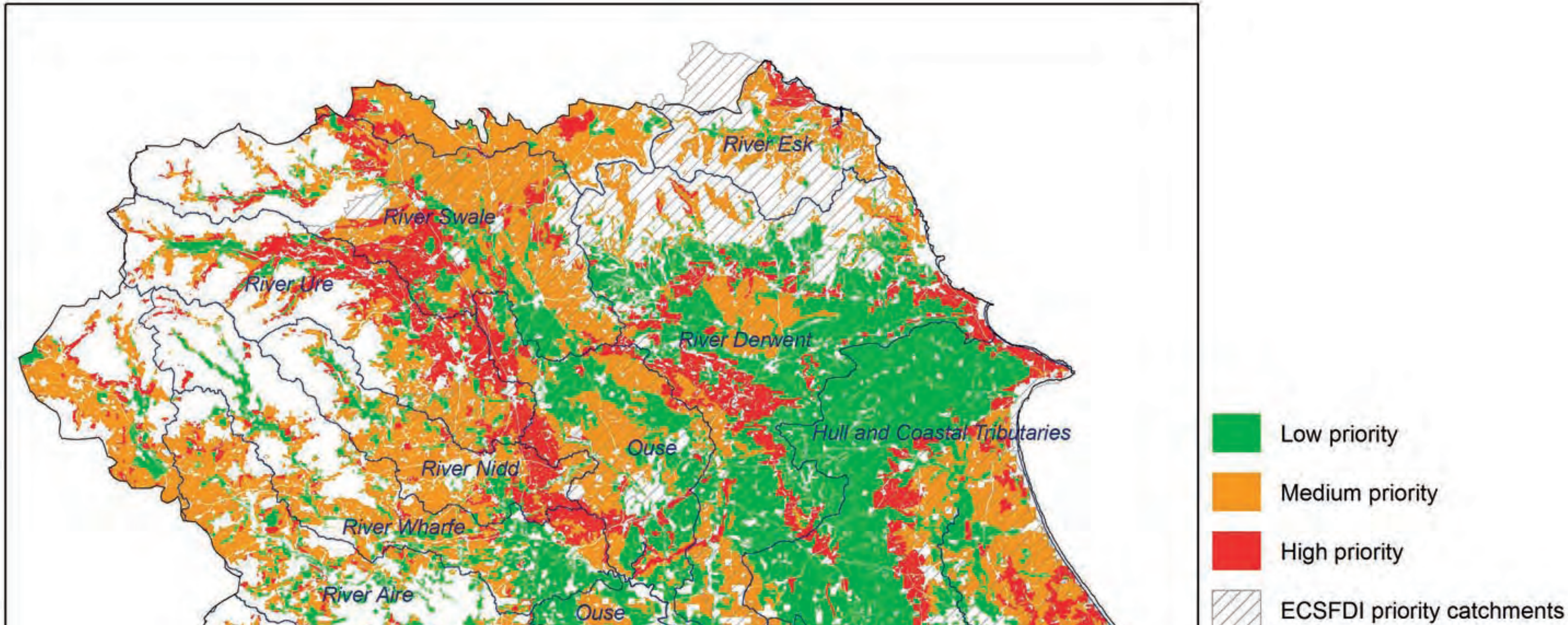
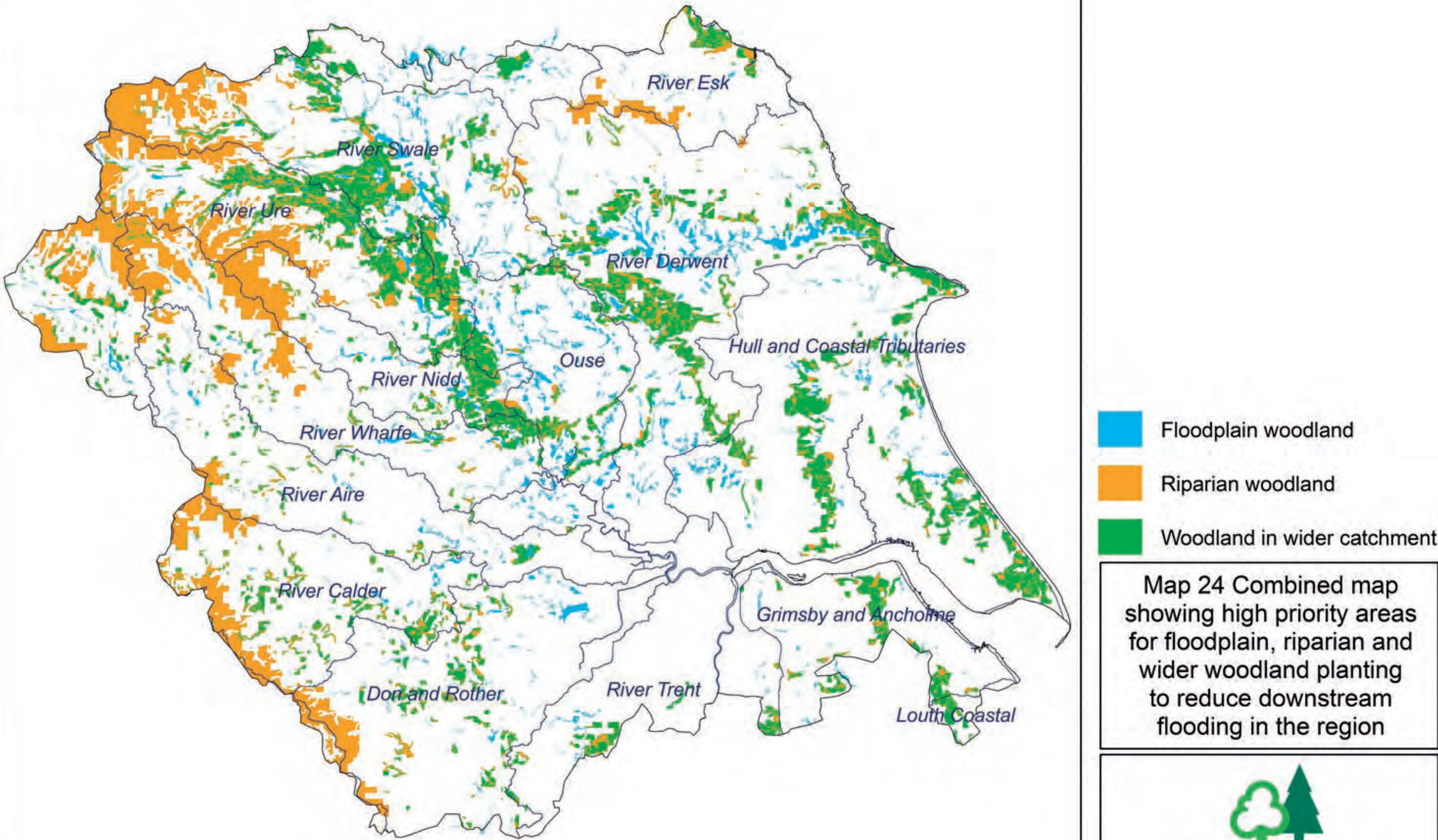


Map 23 Priority areas for new woodland planting to reduce rapid surface runoff, soil structural degradation and/or sediment delivery to watercourses within the region

Forest Research



Map 24 Combined map showing high priority areas for floodplain, riparian and wider woodland planting to reduce downstream flooding in the region

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