# Heritage, natural capital and ecosystem services - Boundaries and Linear Landscape Features in the Lower Severn Vale

John Powell, Jeremy Lake, Rob Berry, Peter Gaskell,

Paul Courtney

Discovery, Innovation and Science in the Historic Environment

Research Report Series no. 8/2019

# Heritage, natural capital and ecosystem services - Boundaries and Linear Landscape Features in the Lower Severn Vale

John Powell, Jeremy Lake, Rob Berry, Peter Gaskell, Paul Courtney



ISSN 2059-4453 (Online)

*The Research Report Series incorporates reports commissioned by Heritage Protection Commissions and by expert teams within Historic England.*

*The Research Report Series is not usually subject to external refereeing, and their conclusions may sometimes have to be modified in the light of information not available at the time of the investigation. Readers must consult the author before citing these reports in any publication. Opinions expressed in Research Reports are those of the author(s) and are not necessarily those of Historic England.*

*For more information write to Res.reports@HistoricEngland.org.uk or mail: Historic England, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth, PO4 9LD*

Summary

This project is one of a series of pilot projects that seek to address the need for the heritage sector to better engage with the ecosystem services approach to assess the benefits that cultural heritage can provide to people's health, wellbeing and prosperity. Understanding and capturing variability in the landscape context of historic linear features is the focus of this project. The key objectives for the project are:

- Develop a research methodology for recording the public and environmental benefits (goods and services) arising from the historic environment, and specifically flowing from linear features in the Lower Severn Vale.
- Identify those benefits in a way that is compatible with 'ecosystem services' and 'natural capital' approaches.
- Attribute value (economic and non-economic) to those benefits (services).
- Identify other values that fall outside the ecosystem services framework that can be ascribed to heritage assets.
- Provide the heritage and natural environment sectors with case study examples, tested at different scales of application, of how this might work for different environmental contexts.

The project builds on existing techniques for valuing the benefits of market and non-market goods and services and has tested the scope for integrating a range of digital and GIS mapping data into the accounting methodology.

The project was carried out in the Lower Severn Vale (LSV), which is situated within the Severn and Avon Vales National Character Area (NCA) and flanked by the Cotswolds and the Forest of Dean NCAs, offering a range of settings to explore the variability of historic linear features and the benefits they offer. Linear features comprise field boundaries, routeways, and other forms of physical structure such as flood protection barriers and drainage features around the River Severn (dykes, embankments, ditches, channels, etc.). The three case studies, which were chosen in consultation with Historic England, were selected in order to explore variations within areas marked by similar characteristics bordering both sides of the Severn.

The project has developed an ecosystem services accounting model for linear features in the landscape. The model was developed and tested in three case study areas of the LSV in Gloucestershire.

The ecosystem services were assessed using indicators tailored to each specific benefit stream identified as emanating from the level of services generated. Indicator scores for cultural heritage benefits were derived from an integration of 'legibility', 'time-depth', and 'inter-relationships' factors for each specific category of linear features. The factors take into account the age, visibility and contribution of specific features to the landscape. Integrated scores for linear features were derived at the 250mx250m cell scale and then aggregated across each of three case study areas. Scores were then entered into a 'return-on-investment' accounting model along with assessment of current condition of linear features (assessed through field

visits) which was utilised to modify indicator scores, and estimates of beneficiary numbers. Benefit streams arising from each type of linear feature were assigned an approximate value (a proxy) using market and non-market values.

The accounting model is based on a 'return on investment' approach, which compares values of a range of benefit flows to expenditure on maintenance over a specific period of time (in this case 50 years). The model takes the current stock of linear features as a given and does not try to compute a value of the stock; it only values the benefits (in terms of ecosystem services) that flow from the current level of stock, and the costs of maintaining that flow of benefits over the time period of interest.

The model produced outputs in terms of monetised benefit flows from ecosystem services, the maintenance costs, and the benefit-to-costs ratios for the different categories of ecosystem service (Supporting, Regulating, Provisioning, Cultural) arising from selected categories of linear feature (Boundary features, Drainage and flood control, Communications). Results for the three case study areas over the 50-year time horizon, are as follows:

| Location | Total present value of ecosystem services | Benefit-Cost Ratio |
|---|---|---|
| Awre Peninsula | £13.25 million | 5.32 : 1 |
| Arlingham Peninsula | £16.65 million | 7.38 : 1 |
| Elmore Area | £16.02 million | 6.65 : 1 |

Each of the three case study areas follows a similar pattern in terms of the value of benefit flows, with 'boundary features' proving the largest proportion of benefits (almost half the total value in the Arlingham case study area), with 'drainage and flood control features' providing the lowest level of benefits. This is mainly due to the relatively smaller length of flood control and drainage features in comparison to boundary features, and low levels of population benefitting. It is also worth noting that in Arlingham almost one third (32.5%) of the benefits arise from Cultural ecosystem services, a higher proportion than for the other two case study areas. This is not surprising given the historical significance of settlement in the case study area, the existence of several ancient routeways traversing across the area, and high legibility, time-depth, and inter-relationships of the linear features in the wider landscape.

The methodological approach also incorporates GIS data which provides a range of information within defined areas, including: population, agricultural land, forest cover, field boundaries, public rights of ways and other linear features. Utilisation of GIS data enables more rapid assessment of larger land areas, and eliminates the need to undertake sampling approaches in order to determine length of certain linear features. It also enables a desk-based approach for large area studies, supported by limited levels of field work for assessing condition and function of linear features, and ground-truthing and updating of GIS data. Incorporating a GIS approach provides a great deal more flexibility in size and location of areas selected for analysis. It also makes the process of scaling up results to larger areas easier through provision of information at different scales.

CONTRIBUTORS
Dr. John Powell, Senior Research Fellow, CCRI, University of Gloucestershire.
Dr. Rob Berry, Research Fellow, CCRI, University of Gloucestershire.
Dr. Peter Gaskell, Senior Research Fellow, CCRI, University of Gloucestershire.
Prof. Paul Courtney, Professor, CCRI, University of Gloucestershire.
Jeremy Lake, Historic Environment Specialist.

ACKNOWLEDGEMENTS
We would like to thank Jenni Butterworth, David McOmish and Hannah Fluck (Historic England) for their support and assistance through all stages of the report.

15/02/2019

CONTACT DETAILS
Countryside and Community Research Institute
University of Gloucestershire
Francis Close Hall
Swindon Road
Cheltenham
GL50 4AZ

Dr. John Powell, Senior Research Fellow, Direct line (01242 714 4129), jpowell@glos.ac.uk

Contents

# 1 INTRODUCTION

## 1.1 Background to the project

This project is one of a series of pilot projects that seek to address the need for the heritage sector to better engage with the ecosystem services approach to assess the benefits that cultural heritage can provide to people's health, wellbeing and prosperity. Understanding and capturing variability in the landscape context of historic linear features is the focus of this project, as it is critical in understanding the value and extent of natural capital and ecosystem services. The project builds on existing techniques for valuing the benefits of market and non-market goods and services, following the completion of a project focused on dry stone walls in the Peak District National Park (Powell *et al*. 2018), and has tested the methodology and a wide range of digital and GIS mapping data.

The Lower Severn Vale (LSV) (Figure 1), situated within the Severn and Avon Vales National Character Area (NCA) and flanked by the Cotswolds and the Forest of Dean NCAs, offers a range of settings to explore the variability of historic linear features and the benefits they offer. These linear features comprise field boundaries, routeways, and other forms of physical structure such as flood protection barriers and drainage features around the River Severn (dykes, embankments, ditches, channels, etc.). Landscapes range from the flat grazing land along the edge of the Severn estuary, with historical drainage and flood protection features, to the higher land of the Forest of Dean on the western side of the estuary, and the edge of the upland scarp of the Cotswolds with its stone walls and hedgerows on the eastern side.

Ecosystem services first emerged in the 1980s but its current iteration stems from the Millennium Ecosystem Assessment that was commissioned by the United Nations in 2001 and published in 2005[1]. Subsequently the UK Government commissioned its own National Ecosystem Assessment (NEA), the first reports from which were published in 2011[2], and reports from the most recent phase of work were published in 2014. While these approaches are becoming increasingly influential in environmental policy and land management decisions, the issue of heritage valuation is insufficiently conceptualised and there is a dearth of empirical research. Historic England recognises that the historic environment is currently poorly represented in ecosystem services and natural capital accounting methods[3].

[1] Board, Millennium Assessment. "Millennium ecosystem assessment." Washington, DC: New Island 13 (2005).
[2] Watson *et al*. "UK National Ecosystem Assessment: understanding nature's value to society. Synthesis of key findings." (2011).
[3] Fluck and Holyoak (2017) *Ecosystem Services, Natural Capital and the Historic Environment*. Historic England Research Report Series 19/2017

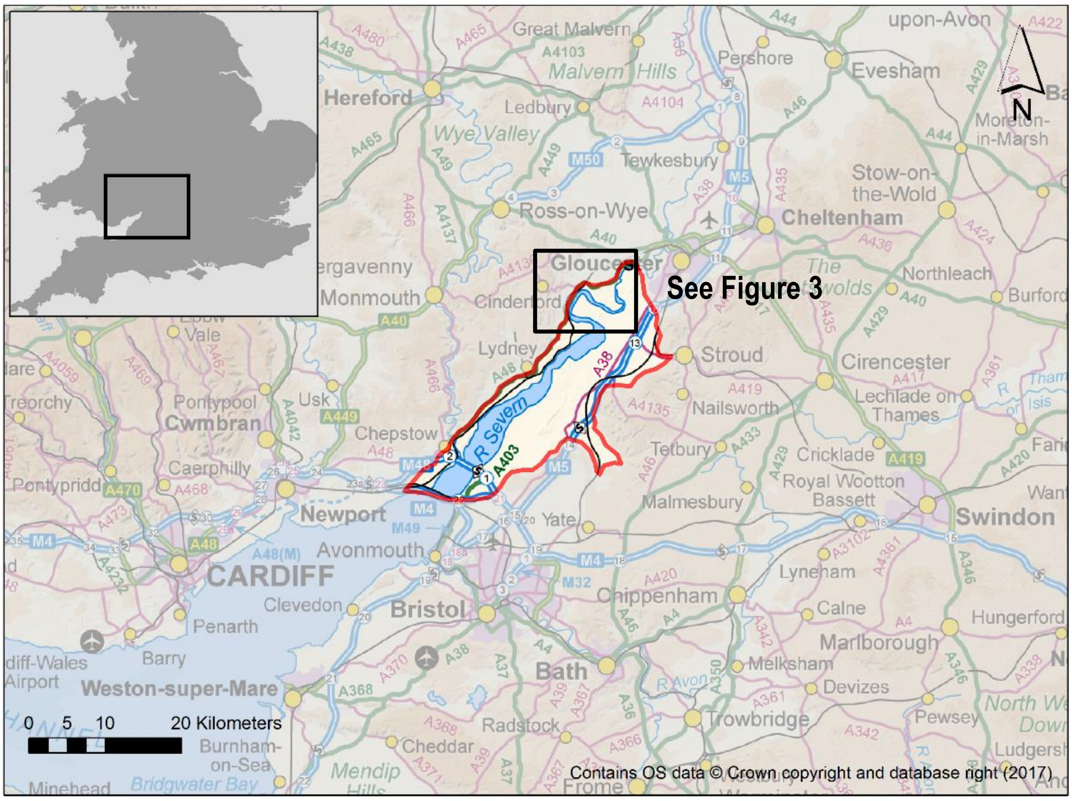



*Figure 1: Lower Severn Vale study area*

There are clear challenges and opportunities here. The breadth and language of ecosystem services is challenging for professionals working in the natural and historic environment, particularly for those working in heritage who have developed expertise in protecting, assessing and providing advice on specific buildings, monuments and areas. Those who work on the natural environment would benefit from a better understanding of the interaction of human and natural factors in shaping landscapes. On the other hand, the integration of historic environment functions and processes into an ecosystem services framework will offer increased opportunities to:

- Consider the benefits offered by historic landscapes, places and assets for inclusion in future land management strategies, including incentives to farmers in agri-environment schemes and regulation for some types of land management and development activities.
- Deliver national and local planning policy including its emphasis on weighing environmental, social and economic factors.

- Understand 'local distinctiveness' and the character of the whole historic environment, defined in The National Planning Policy Framework (NPPF) as resulting from 'the interaction between people and places through time'[4].
- Apply understanding of the inter-relationship between culture and nature to the delivery of integrated approaches to land management, including through the European Landscape Convention (ELC)[5].

## 1.2 Aims and objectives of the project

### 1.2.1 Project aims

The overarching aim of this project is to improve understanding of how the historic environment can be incorporated into ecosystem services and natural capital approaches, in terms of:

- Conceptualisation and practical implementation.
- The monetary and non-monetary benefits they can provide to society.

## 1.3 Project objectives

The key objectives for this project are to:

- Develop a research methodology for recording the public and environmental benefits (goods and services) arising from the historic environment, and specifically flowing from linear features in the LSV.
- Identify those benefits in a way that is compatible with 'ecosystem services' and 'natural capital' approaches.
- Attribute value (economic and non-economic) to those benefits (services).
- Identify other values that fall outside the ecosystem services framework that can be ascribed to heritage assets.
- Provide the heritage and natural environment sectors with case study examples, tested at different scales of application, of how this might work for different environmental contexts.

## 1.4 Principles of assessment

At the heart of this project is the need to inform a fresh perception of the benefits, or ecosystem service flows, that arise from the capital stock of the following linear features:

- Embankments and water channels to prevent and manage flooding, reclaim land and enable its management.

---

[4] And as also stressed in the Farrell Review of Architecture and the Built Environment (www.farrellreview.co.uk)
[5] As adopted by the Committee of Ministers of the Council of Europe on 19 July 2000, with Natural England and Historic England playing a key part in its implementation - https://historicengland.org.uk/advice/caring-for-heritage/rural-heritage/landscape-and-areas

- Boundaries – in the form of hedges, banks, water channels and more rarely stone walls – to enclose new or reordered fields, and to define woodland, parkland, parishes and estates.
- Routeways of different types – trackways, paths and roads – which are often defined by historic field boundaries.
- Canals and railways.

This historic stock developed over centuries to serve a range of functions, most significant being the protection and management of woodland, orchards and of crops and livestock in farmland, to mark out estate, parish and other boundaries, and to enable movement into and through this landscape. The present-day functions or 'services' provided by this stock of linear features are grouped under the key service flows of the ecosystem services model, namely supporting, provisioning, regulating, and cultural services. Service flows can then be explored in terms of 'benefit streams' which allow the project team to identify who or what benefits, enabling the attribution of monetary and non-monetary values to each benefit stream. The service 'flows' depend on the current stock of the asset (in this case the pattern and extent of linear features within a defined area), its condition and the extent to which it continues to support relevant desired functions. The method therefore needs to assess:

- The current functions and condition of the 'stock' of linear features.
- The ecosystem service 'flows' arising from the stock, and how those flows are translated into valued benefits by different stakeholders.

When it comes to understanding the value and extent of ecosystem services provided by linear historic features it is not sufficient to assess specific features in isolation. Linear features need to be assessed within the wider landscape context in which they occur. A hedgerow, or other field boundary, for example, may provide a very different set of benefits in a sparsely populated and low-lying estuarine setting, than one found on higher ground, or around a densely settled area. Understanding and capturing that variability is the focus of this project.

## 1.5 Project stages

There are four main elements or stages to the method developed to meet the aims and objectives of this project, and the fundamental need to better integrate the historic environment into Natural Capital and Ecosystem Approaches. (See Figure 2 and the description of project stages below).

### *Stages 1 and 2:*

- Summarise the historic character and function of linear features in the LSV, based on current understanding and assessment of geo-spatial data.
- Assess how the capital stock contributes 'services' to the socio-ecological and economic systems within the LSV. Services were categorised using the key service flows of linear features using the ecosystem services model (supporting, provisioning, regulating, and cultural), acknowledging that

variations in the extent, condition and use of linear features will contribute different and variable amounts of ecosystem service flows in any given area.

- Consider other values generated by boundaries and their features.

*Stage 3:*

- Assess the value of the benefit streams generated by the 'capital stock' of different categories of boundary and linear feature.
- Apply monetary values to the identified ecosystem service 'benefit streams'. The size, extent, variability, and duration of benefit streams will be taken into account, along with estimates of beneficiary numbers, across the target area.

***Stage 4*** brings together the different strands of the approach to develop a methodology for integrating values of historic assets (in relation to boundaries and linear features) in land management and planning decision-making processes. Finally, ***Stage 5*** considered the reliability and validity of the data utilised.

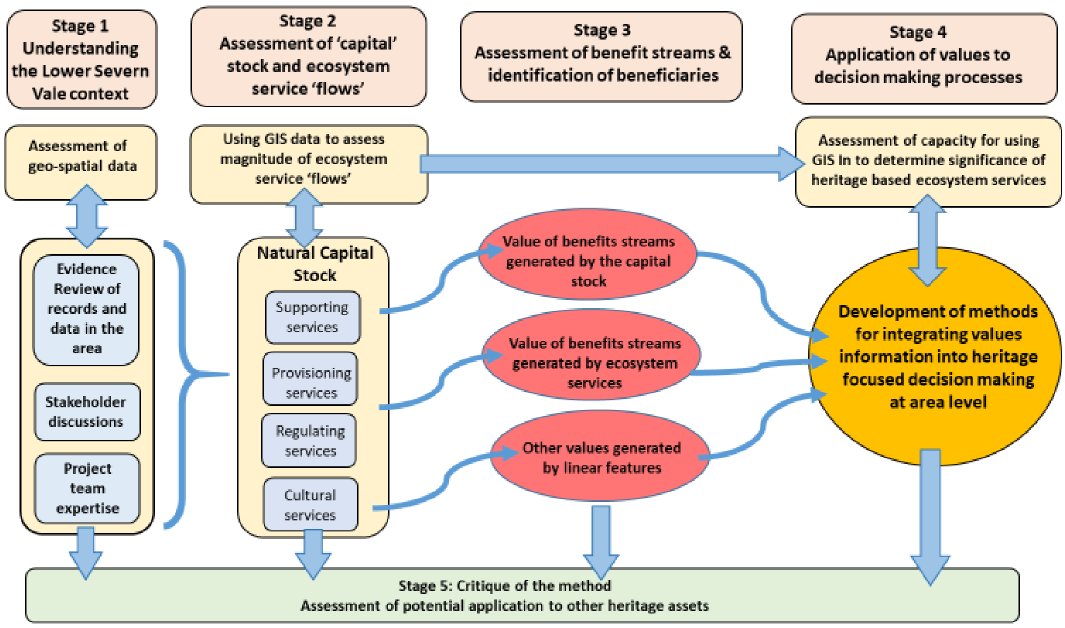



*Figure 2: Overview of the methodological approach*

## 1.6 Report structure

The report has been structured to enable the reader to understand how the assessment process builds upon understanding of the historic stock of linear features in their landscape context. Section 2 introduces the LSV and its linear features. Section 3 provides details of the research methodology and key principles that have guided the approach. In Section 4 the methodology is applied to the case study areas. The empirical results are analysed and discussed. The final section (5) presents the conclusions of the research.

# 2 INTRODUCING LINEAR FEATURES IN THE LOWER SEVERN VALE

## 2.1 Introduction

This section describes the context, the main forms of linear feature incorporated into the analysis, and the broad cultural heritage characteristics of the LSV.

The project area is located within the Severn and Avon Vale NCA, which is one of the largest NCAs in England[6]. It is divided by the Severn itself, and shares the following broad characteristics of the Vale:

- West of the Severn the Mercia Mudstones predominate, producing poorer silty clay soils. Lias Clays in the Avon Valley and east of the Severn create heavy but productive soils. River terrace gravels flank the edges of watercourses.
- The sparse distribution of woodland, but boundaries marked by frequent hedgerow trees, parkland and surviving traditional orchards.
- Small pasture fields and commons are prevalent in the west with a regular pattern of piecemeal and parliamentary enclosure in the east. Fields on the floodplains are divided by ditches fringed by willow pollards and alders.
- Strong survival in a national context of ridge and furrow.
- Evidence for development of farmsteads from medieval period, with threshing barns, cider houses and cheese rooms testifying to the diversity of the rural economy.
- Highly varied use of traditional buildings materials, with timber frame intermixed with deep-red brick buildings, grey lias and Cotswolds stone.

## 2.2 Types of linear features

The types of linear features in the LSV developed over centuries to:

- Create new farmland and prevent flooding along the River Severn.
- Protect arable crops from wind, soil erosion and animals.
- Enclose meadows and pastures.
- Manage different types and ages of livestock.
- Protect and enable the growth and management of woodland.
- Mark out estate and other territorial boundaries - parishes, manors and parkland.

[6] Natural England 2012 *NCA Profile: 106 Severn and Avon Vales*, at http://publications.naturalengland.org.uk/publication/1831421?category=587130

- Enable the movement by land and water of people, goods, vessels, wheeled vehicles and animals, whether as an integral part of how fields have developed or in cutting across earlier alignments of boundaries.

### 2.2.1 Field, routeway and property boundaries

Hedgerows are the dominant form of linear boundary, dry stone walls being concentrated on the Cotswold scarp and confined to churchyards, estate boundaries, and some houses. Hedgerows are associated in some areas with drainage ditches, water channels and earth banks which provided additional barriers and kept roots free from waterlogging. Boundaries have the following characteristics:

- Irregular boundaries mostly result from early 14thcentury and earlier enclosure, all within this area comprising the assarting (clearance under license from the lord) of medieval woodland.
- Irregular riverside enclosures on alluvial land which served as seasonally-flooded grassland and as hay meadows, and may contain linear boundaries for subdividing or 'doling out' strips of land.
- The sinuous or curved forms of boundaries resulting from piecemeal enclosure respond to the forms of medieval ploughland strips, and in places this pattern of enclosures from bundles of strips with their headlands for turning the plough is well-retained.
- Many individual fields or blocks of fields might have one or more straight boundaries and have been enlarged as a result of later (usually post-1750) reorganisation, often accompanying the enlargement of farms.
- Some areas have been enclosed by grid-like patterns of regular enclosure which either completely ignore earlier field patterns or result from the taking-in of open unenclosed land for agriculture.
- There are some areas affected by the extensive loss of field boundaries after the 1950s, most of these being in farmland already subject to reorganisation or new enclosure for new forms of productive agriculture in the 18th and (mostly) 19th centuries.

### 2.2.2 Drainage and flood control linear features

These are concentrated around the River Severn, and comprise:

- *Earthen embankments* which mostly date from the 12th century; they can date from the Romano-British period and include those protecting the 'New Grounds' (such as south of Frampton-on-Severn) taken in during the 19th century.
- *Drainage ditches* and *water channels*, often associated with pollarded willow and other trees and also with hedgerows, which mostly date from the medieval period.

Embankments along the Severn developed from the Roman period and even earlier to act as flood defences and enable land reclamation, the enrichment of soils and the boosting of grass and other crop yields through seasonal flooding. With rare exceptions, such as the probable Roman defences at Elmore, earthen embankments mostly appear to date from around the 12th century and include those protecting the 'New Grounds' (such as south of Frampton-on-Severn) taken in during the 19th century. As elsewhere in the Severn estuary, parallel banks can represent different phases of flood defence. Channels and sometimes post-medieval ridged fields (rather than medieval ridge and furrow) typically ran into larger drainage ditches, known as rhynes (Crowther and Dickson 2008, 157-163). These are drainage ditches which also enable controlled flooding through using sluices and pumps.

### 2.2.3 Communication linear features

This project has focused on *routeways* for the movement of animals (often specifically referred to as droveways), people, and also wheeled vehicles over long or short distances. These are generally an integral part of the layout of fields, often responding to medieval headlands and strip fields that predate enclosure, and are thus bounded by hedgerows, ditches and water channels. Some of the oldest include hollow ways. As a general rule, winding and sinuous routeways are concentrated in those areas of pre-1750 enclosure which typify this area. Straight routeways, Roman roads and turnpikes aside, are typically post-1750 and part of late 18th and 19th century regular enclosure and the reorganisation of earlier farmland. Many have been narrowed and engineered for motor vehicles, in many cases leaving verges, embankments and drainage ditches to either side. Canals, railways and major engineered roads typically cut across the pattern of pre-existing field boundaries and routeways.

Routeways have played a critical role in connecting settlements and the resources of this area to the Cotswolds and the Forest of Dean from the prehistoric period. Some of the oldest routeways enabled access to the Severn's natural resources as well as enabling the bringing and processing of goods such as iron and timber from the Forest of Dean along its shores (Small and Stoertz et al 2006, 26-28; Allen 2008). There is as yet no solid proof of present-day linear boundaries being aligned to pre-Roman routeways and field boundaries, although the alignment of some routeways to the river and of Roman roads does suggest an earlier origin for some. Examples include the crossing point at Arlingham, which is of great significance to the post-medieval droving trade and is of possible pre-Roman date, and the manner in which the Chepstow to Gloucester Roman road cuts across the alignment of routeways extending from the Forest of Dean towards the Severn.

## 2.3 Historic background

Flowing through the LSV is the River Severn, which after the last glaciation and re-shaping of the funnel-shaped estuary developed the world's second largest tidal range. The river valley and access to varied resources extending from it into the surrounding landscapes offered a rich variety of resources for Mesolithic communities (Bell and Neumann 1997; Brown *et al*. 2005). Soils have been affected by slope-wash from the higher ground to the east and west of the river, and the peats and silts of the Severn result from successive deposits and interactions from the Mesolithic period onwards. The fertility of the soils around the Severn derive from the regular deposition of silts, the soft clay soils on the Lias limestones being heavier but also productive arable land.

The river itself – although dangerous in parts to navigate – had ritual and symbolic value as well as offering a significant means of communication, exchange and trade (Moore 2002, 208-210). Prominent monuments along the river include the late Neolithic/Early Bronze Age standing stone at Broad Stone, Stroat, the Roman temple complex close to the port of Lydney and the 2nd-4th century AD lighthouse, harbour and ironworks at Woolaston villa. Evidence for prehistoric settlement includes the positioning of Bronze Age barrows above the floodplain and, from the late 2nd millennium BC, scattered farmsteads with their fields which increase in density from the fourth century BC into the Romano-British period (Moore 2002, 138-141 and 88-90). By the late Iron Age settlement had taken different forms either side of the Severn (Moore 2002, 152-155). The first known embankments for flood protection and taking in new farmland – some of the earliest recorded in Europe - date from the Romano-British period (Allen and Fulford 1990a and b; Allen 2001), which also saw the development of villa-farms such as Frocester, and of riverside ports (Green 1996) including Gloucester, firstly as a forward legionary base near to the Fosse Way, and from AD 97 as one of a scatter across the Empire of high-status *colonia* for retired legionaries.

Linear features in the area overwhelmingly date from the medieval and post-medieval period and bear a close relationship to villages and farmsteads. The historic pattern of settlement, formed by the 11th century, included settlements involved in riverine and overseas trade and fishing along the Severn (Green 1995, 1996; Putley 1999). Boundaries to parishes, deer parks, meadows and the fields of medieval farmsteads sited away from villages are most likely to predate the 14th century; open fields subdivided into furlongs and strips for arable farming dominated most of the area. Decline in the communal regulation of arable and pasture, and a shift from arable to mixed and pastoral husbandry combined with orcharding from the 17th century (Newman 1983), was accompanied by the subdivision or enclosure of land by farmers wishing to take in manage farmland on an individual bases, thus creating new field boundaries that often respected earlier routeways, headlands for turning ploughs and strip fields (Allen 1992).

The waterlogged clays on the older Triassic and Devonian sandstones in the Vales of Gloucester and Berkeley provided particularly rich pastures for cattle, cheese production being a major industry in the 18th and 19th centuries, and for over-wintering sheep brought down from the Cotswolds. Water meadows were also developed across this area from the late 17th century, in order to enable early spring bites of grass and higher yields of hay (Crowther and Dickson 2008, 150-155). This process of piecemeal enclosure was largely complete by the 18th century (Allen 1992) and was driven from farmsteads, some of them newly-sited in their own fields, whose occupants also rebuilt houses, barns and other working buildings on a gradual basis.

The gradual process of enclosure worked with the pre-existing pattern of routeways, connecting farmsteads, houses and settlements to each other and also extending to pastures, fishing grounds and a small number of crossing points along the River Severn. It was not until the 18th and 19th centuries that new routeways cut across the landscape, commencing with the straightening and rerouting of roads by turnpike trusts, and followed by the opening of the Sharpness Canal in 1827, of railways and then the major road-building programmes including the M5 of the post-war period. Another activity was the straightening and removal of boundaries that accompanied the enlargement of farms and changes in land management from at least the 18th century, giving rise to areas of large fields in striking contrast to areas of small fields where stock farming and smallholdings were most dominant. Over the last century, there has also been a decline in the labour-intensive practices of traditional hedge laying and pollarding trees as the costs of labour have increased and cheaper materials have become available. The post-war period was marked by a continuing increase in the size of farms and the return of arable cropping across much of the area, leading to the fragmentation and removal of field boundaries in some areas and the ploughing-out of ridge and furrow. The 2010 Agricultural Census recorded a 30% decline over the previous ten years in numbers of mixed farms in the NCA, accompanied by a 25% increase in land used for 'other arable crops'[7].

## 2.4 Area variations

At its simplest, the area is subdivided into three zones – the Severn with its estuarine margins, and the areas to the east and west. These areas are marked by contrasts in settlement and fields, smaller pasture fields and commons being more common to the west than the east where fields tend to be larger and reflect the piecemeal and planned enclosure of medieval open fields. In fact, the Severn divides two of England's major settlement provinces, as identified in the *Atlas of Historic Settlement* (Roberts and Wrathmell 2000 and 2002), namely a Central Province of nucleated settlement and a Western Province of dispersed settlement. These strong distinctions derive from how land was settled and were evident by the 11th century - either from village farms working large open fields subdivided into blocks of ploughed strips around them or from smaller settlements and scattered farmsteads which worked a more complex mosaic of open fields, enclosed fields which may again be subdivided by ploughed strips and scatters of common land[8]. These factors have shaped the distribution of historic buildings and other heritage assets.

### 2.4.1 The Severn

The Severn has national and international significance for its rich human and environmental history, the movement of sands and silt concealing and revealing an area of exceptionally high archaeological significance and potential. Submerged forests and footprints dating from the Mesolithic period have been identified and are sealed in the lower formations (Crowther and Dickson 2008, 91). Medieval

[7] NCA 106: Severn and Avon Vales, Key Facts and Data, 6.1-4
[8] Poor's Allotment, in Tidenham parish, retains an appearance similar to the original medieval commons (VCH Glos X, 50–57)

settlement was typically on higher ground away from the risk of inundation (Crowther and Dickson 2008, 129). The river relates to:

- The exploitation of its resources over millennia. Weirs and fish traps (Pannett 1987), timber trackways (Price and Spry 2004), piers and quays, as at Aust (Crowther and Dickson 2008, 45-54, 67) - fishing rights being regulated by estates from the late Saxon period (Crowther and Dickson 2008, 92)
- Medieval watermills and windmills, positioned in close relationship to drainage channels and flood defences (Crowther and Dickson 2008, 180-182)
- The movement of peoples over millennia for exchange and trade, including access to safe harbours ('Pills') and via ports to areas and markets for the export and import of goods. Wrecks and memorials (such as at Awre churchyard) attest to the hazardous nature of the river, the stretch north of Sharpness being particularly difficult to navigate (Green 1995; Crowther and Dickson 2008, 86-88).
- Industrial sites dating from the Romano-British period, including for the processing of iron from the Forest of Dean (Allen 2008; Putley 1999).

### 2.4.2 East of the Severn

The area to the east is dominated by village-based farming settlements with isolated farmsteads (mostly post-medieval in date) sited within the planned and piecemeal enclosure of formerly extensive open fields. There is little woodland or common land compared to the west of the Severn. Much of this enclosure had been completed by the 18th century. There are some areas of earlier (pre-14th century) enclosures relating to medieval moated sites, and farmsteads and hamlets standing on shrunken medieval settlements.

### 2.4.3 West of the Severn

In contrast to the dominance of agriculture to the east, linear features along the west bank of the Severn relate to:

- Industrial sites for charcoal burning near the shoreline, the export and processing of iron, coal, other minerals and timber (Crowther and Dickson 2008, 134).
- A higher density of isolated farmsteads dating from the medieval period, associated with a more complex mosaic of medieval strip fields, common land and fields enclosed from woodland (Small and Stoertz *et al*. 2006, 57-58), the communities here having access to unenclosed woods and commons on the sloping ground to the west and meadows along the river.
- Squatter settlements with irregular fields for those working in the woodland industry (Small and Stoertz *et al*. 2006, 46-48).

### 2.4.4 Introducing the case study areas

It was determined in consultation with Historic England to select case study areas that were located close to the river and enabled examination of how the methodology might work at different scales. The case study areas selected for detailed study are Elmore, Arlingham and Awre. Each is approximately 7.5 km$^2$ and broadly representative of the key characteristics of the Severn and Avon Vale NCA, with strong similarities but also subtle contrasts in the time-depth of enclosure landscapes and the distribution of heritage assets (see Figure 3) and fuller analysis in Section 4).

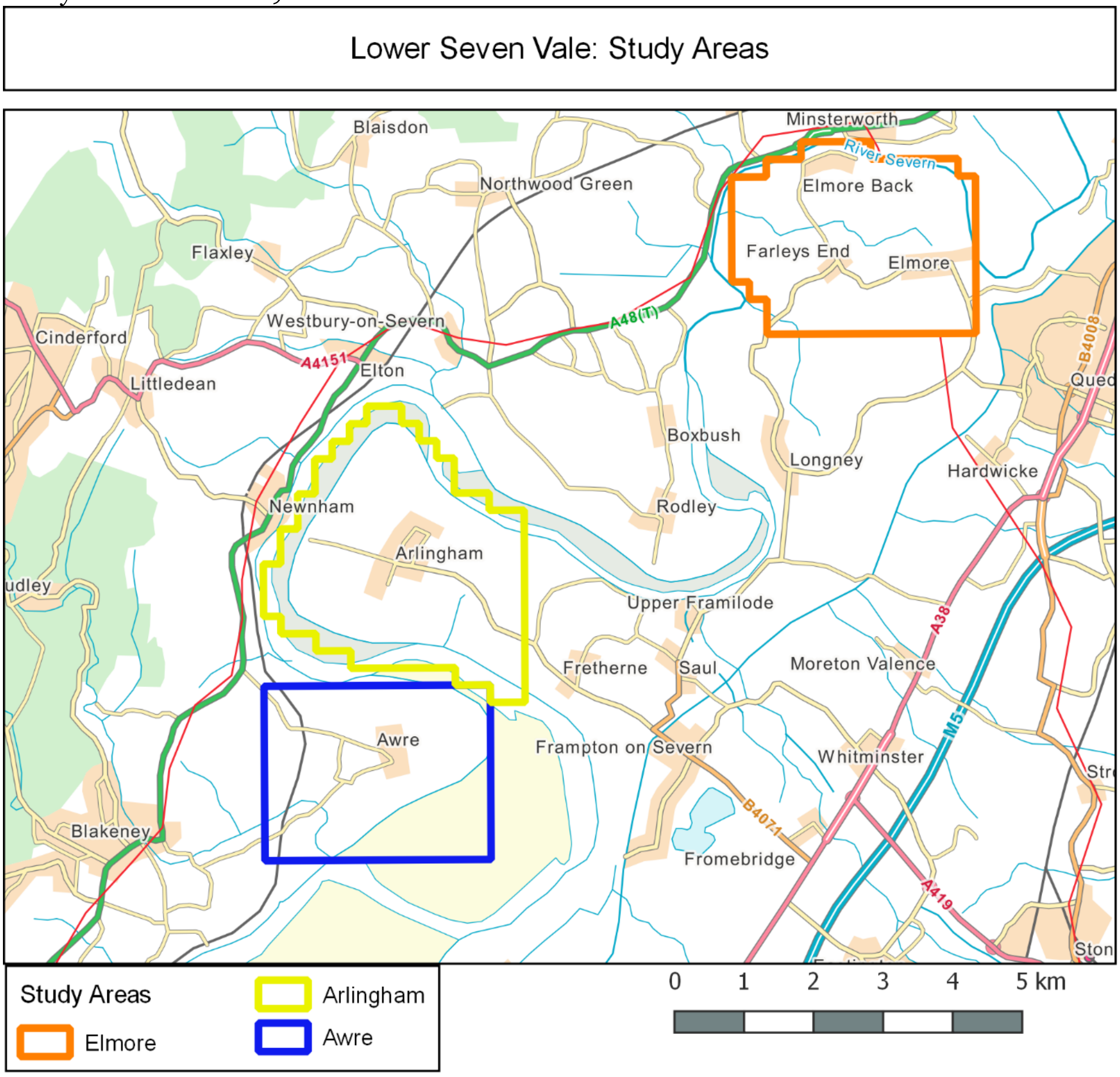



*Figure 3: The case study areas*

# 3 METHODOLOGY

This section sets out the methodology for identifying the 'services' provided by boundaries and linear landscape features in the LSV in a way that is compatible with the language associated with ecosystem services and natural capital. The methodology builds on existing techniques for valuing the benefits of market and non-market goods and services and a recently completed project on dry stone walls in the Peak District National Park (Powell *et al*. 2018). The method essentially brings together valuation approaches with ecosystem services to provide monetary values for 'benefit streams' generated over time by the 'capital stock' made up of the existing systems of boundaries and linear features in the LSV.

## 3.1 Services provided

The linear features introduced in Section 2 provide a range of ecosystem services to various sectors of society and the extent to which they are valued reflect changing perceptions of the constraints and opportunities offered by the landscape of the LSV to communities, property owners, visitors and other individuals. Linear features provide the following services:

- *Supporting*. Linear features are an integral part of landscape character, defining areas of primary production and, as a consequence of their interaction with their local historic and natural environment, support species habitats and wildlife corridors.
- *Provisioning*. Linear features have developed as a critical means of maintaining and enhancing agricultural produce. They protect and define new farmland, shelter, separate and manage crops and farm animals, usually subdividing the land of individual farmers but also separating areas of common land, woodland and other vulnerable resources from farmland. Woody (tree-lined) boundaries to fields and routeways also offered a diversity of other uses such as extracting fuel, building materials etc. They also, in the form of routeways, enable access to and exploitation of the land's resources.
- *Regulating*. The creation, adaptation and maintenance of linear features was also sustained and managed by communities and individuals, obvious contrasts being 1) the communal -management of medieval open fields and the more individual (albeit often co-operative) systems of management that accompanied their enclosure by hedges and other boundaries and 2) the way in which strategic communications (canals, railways and roads) can cut across pre-existing patterns of field boundaries and the routeways that are an integral part of how they have developed. In this area, the regulation of water management developed as a critical means of protecting farmland and enhancing yields for pastoral husbandry in particular.
- *Cultural*. Linear features are an integral part of locally distinctive landscapes, imparting a strong sense of place to residents and visitors, and provide evidence of historic land use and settlement – both in their own right and as

the setting to a wide range of heritage assets, interacting also with local topography, geology, habitats and other natural features.

## 3.2 An integrative approach

These linear features are a dynamic and integral part of landscape, which is defined by the ELC as *'An area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors'* (Council of Europe 2000). This definition also calls for an integrative approach to assessment, complementing existing definitions of the historic environment[9] and methods for heritage assessment but requiring a fully-integrated and seamless approach that takes account of changing functions, perceptions and the whole character of landscapes[10]:

- Place:
  - Linear features are an integral part of how landscapes have functioned and been adapted to support people and habitats over millennia.
  - They are also associated, functionally and/or visibly, with other historic and natural features that help to tell the story of how places have developed into their present form.
  - The 'stock' of boundaries and linear landscape features in the LSV reflect and in turn have influenced historic patterns of land use and movement through and across this landscape.
  - They result from the interaction of human and natural factors - including for example the adaptation of soils and drainage, and the range of land cover associated with them.
- Past change and perception of functions and benefits:
  - The density, date and pattern of linear features reflects historic change and changing perceptions of the constraints and opportunities offered by the landscape of the LSV to communities, landlords and individuals.
  - They reflect past approaches and changing perceptions towards the regulation and provisioning of food and a wide range of other benefits,

---

[9] And defined as 'All aspects of the environment resulting from the interaction between people and places through time, including all surviving physical remains of past human activity, whether visible, buried or submerged, and landscaped and planted or managed flora.' *National Planning Policy Framework*, July 2018

[10] Significance for heritage policy is defined in the glossary of the NPPF as 'The value of a heritage asset to this and future generations because of its heritage interest. That interest may be archaeological, architectural, artistic or historic. Significance derives not only from a heritage asset's physical presence, but also from its setting.' Historic England's *Conservation Principles* states that 'significant places should be managed to sustain their values'. Its four values broadly align with the NPPF's 'heritage interests', although communal value - one of the benefits that flows from the historic character and significance of any place - is not included in the NPPF. The consultation draft of *Conservation Principles*, Historic England's advice for guiding decision-making affecting the conservation of England's heritage, proposes retention of three of the four Values (Evidential, Historic and Aesthetic) in order to better align with the policy and guidance in the NPPF, but contains a proposal to remove Communal Value which clearly aligns with some of the approaches within Natural Capital and ecosystem services (https://historicengland.org.uk/images-books/publications/conservation-principles-sustainable-management-historic-environment/)

  - for example in how piecemeal and planned enclosure reflects the shift from communal to more individual systems of land management.
  - They have provided the framework for shifting cultural perceptions - their sense of place, similarity and difference, their spiritual and reflective qualities, their cultural and historic associations.
- Present perceptions of functions and benefits:
  - A range of factors have led to a shift in the perception of the value of linear features, evident for example in the decline of centuries-old practices such as the pollarding of riverside willows for osiers and of hedgerow timber for fencing, implements, construction and fuel.
- How to integrate valuation of 'heritage' and the historic environment into Natural Capital and the provision of ecosystem services:
  - Valuation focuses on understanding how the historic environment is integral to the stock of Natural Capital and embodied within the 'service flows' or benefits that arise from landscape and the particularities and perceptions of different places.
  - Recognition of the fundamental role of human agency, and realisation of changing perceptions of the benefits afforded by linear features to people, is key to the integration of the historic and natural environment.

## 3.3 Factors in measuring heritage value for ecosystem services

The conceptual framework for assessing the heritage value of linear landscape features is based on an integrated approach, first developed in the Peak District National Park (Powell *et al.* 2018), that combines three facets of the historic environment into a single scoring system, illustrated in Figure 4 and using the following criteria:

- *Legibility* – the scoring relates to the extent to which linear features are present and can be read in the landscape, according the highest scores to the Severn and its riverside flood defences, areas with robust surviving field and routeway boundaries and the lowest to areas with few and/or fragmented boundaries resulting from the development of larger farms and later landscape change.
- *Time Depth* – this relates to the estimated length of time that these linear features have been present in the landscape, again according the highest score to the Severn on account of its use for exchange and resource exploitation since the Mesolithic period and also to medieval field and other boundaries. Rail and canal building add more recent communications features to the landscape.
- *Inter-relationships* – this seeks to identify the relationship of heritage features (archaeological sites such as settlement earthworks and medieval ridge and furrow, historic buildings and their settlements and historic sites such as parks and greens) to the linear features in the landscape. The highest scores relate to those features that best help to 'tell the story' of places, such as the features that result from medieval or Roman flood reclamation and

farmsteads with historic houses and buildings whose owners or tenants made choices that affected the alignment and character of field and other boundaries.

Each aspect in the diagram (Figure 4) contributes to the overall value of cultural heritage of an area. First, legibility relates to the density or 'dominance' of a particular type of linear feature (e.g. drainage ditch) in a landscape, and the level of 'visibility' to residents and visitors. Second, time-depth is based on the estimated age of the capital stock of linear features in an area, and the extent to which their age can be validated or proved by their historic type (different forms of enclosed land, woodland etc), which might vary widely across an area. Thirdly, the concept of inter-relationships focuses on the extent to which a particular type of linear feature relates to other cultural heritage assets within a defined area and helps 'tell the story' of land settlement and use over time. Where all three elements overlap extensively, the value of cultural heritage is likely to be higher than areas where one or more elements are missing or not clear.

Two other closely related aspects of linear features affect the valuation in this study: function and condition. Where linear features continue to fulfil their original function(s) they are likely to be well-maintained and kept in good condition, reflecting an economic and utilisation value in addition to the heritage value. Where features are fulfilling different functions from their original intention, or their functions have been superseded or are no longer required their current utility value is likely to be low, condition is also likely to be low and ecosystem service values will consequently be diminished.

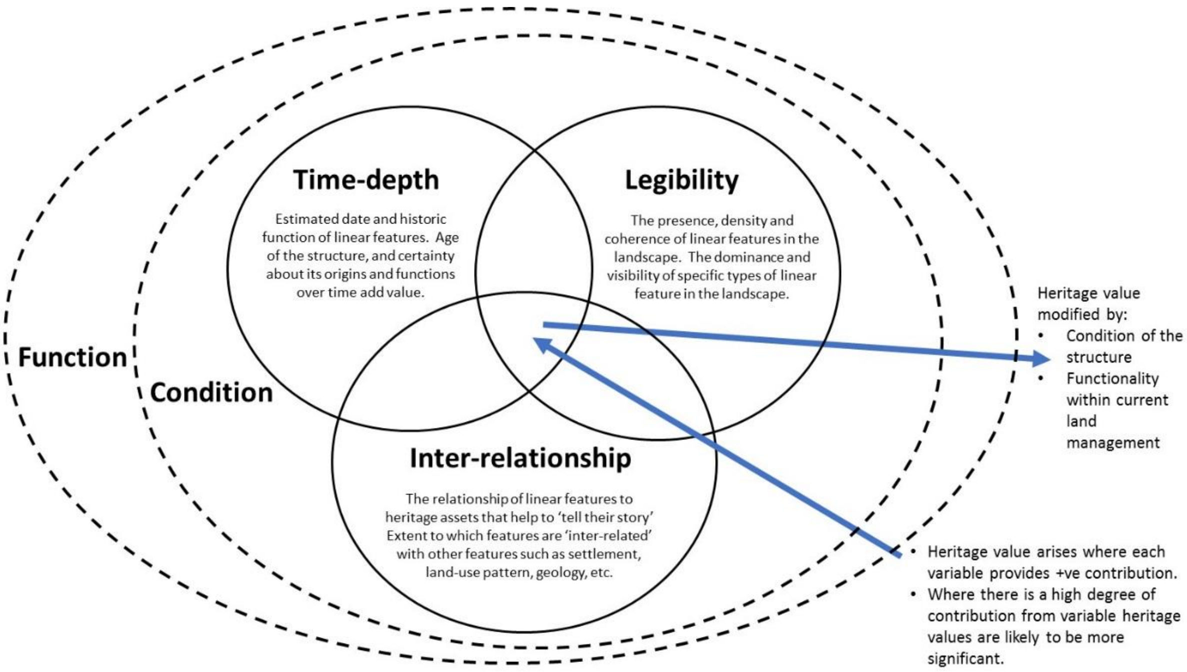



*Figure 4: Factors contributing to the heritage value of linear features*

### 3.3.1 Scoring the elements of cultural heritage

*Legibility:* Scoring reflects the extent to which linear features are present in an area, and thus their potential to serve a broad range of ecosystem services:

- Very high: The Severn corridor and/or areas with very high densities of linear features.
- High: High density of linear features.
- Medium: Average density of linear features.
- Low: Low density of linear features.
- Very low: Linear features make a barely discernible contribution to landscape.

*Time depth:* The scoring has placed value on the estimated date of linear features, according primacy to the River Severn and using analysis of the historic form and type of field and other boundaries.

- Very high: Linear features in areas with high potential for pre-1550 boundaries, which:
  - Bound the Severn corridor, notable in a national and international context for the survival and burial (and often exposure and reburial) of features dating from the prehistoric period.
  - Are sited within areas of pre-1550 enclosure with high potential for an early date.
  - Are boundaries to deer parks and ancient woodland, usually embanked and/or ditched.
- High: Linear features within areas of 16th-19th century enclosure that have retained coherent or fragmented patterns of medieval land use:
  - The piecemeal enclosure of medieval strip fields and also pastures in occasional use for arable, which may have one or more sinuous or curved boundaries responding to the outlines of medieval plough strips.
  - Irregular enclosures around riverine pastures and meadows which have high potential for early origins.
  - Enclosures which have subdivided earlier pastures, which were typically long and thin in shape.
  - Enclosures of uncertain origin which are probably 18th century or earlier date.
  - Boundaries to orchards, which mostly date from the 17th-19th centuries.
- Medium: Linear features within areas dominated by post-1750 landscaping, due to:
  - The reorganisation of earlier farmland or taking in unenclosed land for farmland, leaving no evident trace of earlier cultivation patterns.
  - Enclosure within areas marked as unenclosed on 19th century maps.

- The creation of ornamental landscapes and new plantations (from the late 17th century).
- The taking in of open wastes, pastures and commons including heathland.

- Low: Area with few or no pre-1950 boundaries, mostly resulting from:
  - Removal of earlier boundaries to create large fields.
  - Creation of horticultural land or other functions.
  - Creation of large plantations.
- Very low: Area redeveloped with few or no internal pre-1900 field and other boundaries except to housing and other forms of development

*Inter-relationships:* Scoring considers how historic features and buildings help to 'tell the story' of how places have developed, complementing and adding depth to the identification of what linear features are present in the landscape (their 'legibility') and for how long (their 'time-depth'). The scoring criteria outlined below follow experimentation with different thematic and chronological methods of mapping and analysing the data, which presents a range of challenges with regard to the way that it has been collected and the nature of the historic environment (see section 3.4.2).

- Very high: Area with a mix of features of different dates but with a strong presence of:
  - Heritage features that are recorded as resulting from Romano-British and even earlier land use and reclamation.
  - Probable and recorded routeways of medieval and earlier date.
  - Medieval features - farmsteads, buildings, cultivation earthworks and other forms of land use including unenclosed and common land, parks and woodland.
- High:
  - Area dominated by post-medieval features (c. 1540-1900) and including pre-1750 heritage features that contribute to our understanding of how linear features have developed from the medieval period.
- Medium:
  - Area dominated by modern (post-1750) buildings and other features, which may relate for example to post-1750 enclosure landscapes.
- Low:
  - Inter-relationships of linear features to heritage assets are difficult to appreciate due to sparsity of identified examples.
- Very low:
  - Inter-relationships of linear features to heritage assets very difficult or impossible to appreciate due to lack of identified examples or extent of post-1900 development.

## 3.4 GIS data and methods

Understanding different types of linear feature (Boundaries, drainage and flood control, communications) utilises existing data from a range of sources summarised in 3.5.1. This section of the report describes the range of data that has been used to enable the scoring of cultural heritage value across specific case study areas, in particular:

- Boundary data from Open Source and other data for Legibility (3.5.2)
- Historic Landscape Characterisation for Time Depth (3.5.3)
- The Gloucestershire Historic Environment Record (HER) with Historic England data (mostly derived from the National Mapping Programme (NMP)) for Inter-Relationships (3.5.4)

The criteria for scoring heritage value is based on the ability to identify and assess linear features in the landscape. Of fundamental importance in this respect was the use of Open Source data including the National Historic Landscape Characterisation (NHLC). This project followed completion of a national programme of Historic Landscape Characterisation (HLC), commencing in Cornwall in the late 1990s, which developed over time to incorporate evolving forms of GIS-based analysis of the historic character of the present-day landscape and – through map regression and analysis of a wide range of sources – continuity and change in patterns of land use from the prehistoric period. HLC has also developed to have a wide range of applications, most relevant to this project being its use for agri-environment schemes, landscape management plans and the updating of Landscape Character Assessment at a local level. HLC maps different types of historic character (enclosed land, woodland, unenclosed land etc) *as polygons* using a broad-to-narrow approach, cross-referred to a thesaurus of terms. National HLC is intended for a similarly wide range of applications (Locus Consultants and Exegesis, 2017) but it differs from the Gloucestershire HLC and other HLCs in that it used the thesaurus of terms to bring the results of nearly 20 years of polygonised mapping into a structure using 250x250m and 500x500m cells, based upon the identification of the dominant Thesaurus Types and their associated periods.

The fundamental advantage of using HLC is that it offers a seamless framework for trans- and inter-disciplinary analysis for multiple purposes. As this project progressed it was found that the heritage scoring method adopted has synergies with that of a recently published paper by Stanik *et al.* (2018), which applied a GIS-based approach to generating spatial indicators of cultural heritage in Scotland. In Stanik's approach, the value of cultural heritage is based on the aggregation of data into two 'main-indicators' – Time Depth and Historic Richness. The overall score for Time Depth, which accords progressively higher value from recent to prehistoric periods, is based on the analysis of Historic Land Use Assessment for Scotland, which was developed consequent to the first-generation refinement of HLC in England. The overall score for Historic Richness incorporates data on designated heritage assets (Scheduled Monuments, Listed Buildings, Gardens and Designated Landscapes, Battlefields and World Heritage Sites). The approach adapted for the LSV project thus differs in that:

- It undertakes initial assessment of the density and coherence of asset types, in this case linear features.
- It has used national and local datasets for the assessment of Time Depth.
- It has – under the heading of Inter-Relationships - experimented with different ways of using Historic Environment Record data, in addition to designated heritage assets identified on the National Heritage List for England, in order to add context to the assessment process.

### 3.4.1 Geospatial evidence base

A key aspect of the LSV project was to explore the scope for utilising geospatial data for identifying features and enabling the application of the scoring system to larger areas. A rich database of geospatial data layers (GIS data) was collected for the area, which has enabled the project team to apply the methods developed by Powell *et al*. (2018) in the Peak District National Park to a wider range of linear features occurring within different landscape settings, and explore the factors which influence service provision and how those services are valued. The main GIS datasets used in the project are summarised in Table 1.

*Table 1: GIS data used in the project*

| Theme | Dataset name | Data provider | Description | Format |
|---|---|---|---|---|
| Linear features | Landscape Features | Ordnance Survey (not open data) | Woody farmland boundaries classified by type (hedges, tree canopy, woody | Vector – polyline (.shp) |
| Time-Depth and recorded heritage features and assets | HLC for Gloucestershire | Archaeology Data Service (ADS) | Data characterising the present landscape in terms of the visible evidence of human processes which have formed it through time. | Vector – point, polyline, and polygon (.shp) |
| | NHLC | Archaeology Data Service (ADS)<br>MAGIC<br>(Defra) | Single, consistent, baseline HLC dataset for England, derived from existing sub-regional HLCs. | Vector – polygon (.shp) |
| | Historic Environment Record (HER) for Gloucestershire | Gloucestershire County Council (not open data) | Non-designated heritage assets recorded on the Gloucestershire HER data, including results of the NMP (Crowther and Dickson 2006), the Severn Estuary Rapid Coastal Zone Assessment Survey (Dickson and Crowther 2008), detailed | Vector – point, polyline, and polygon (.shp) |

| Theme | Dataset name | Data provider | Description | Format |
|---|---|---|---|---|
| | | | work around Frampton on Severn (Dickson 2006), Historic England's NMP in the Severn Vale and the adjacent survey areas of the Cotswolds (Janik et al 2011) and the Forest of Dean (Small et al 2006). | |
| | Designated Heritage Assets | Historic England | Listing data from the National Heritage List for England (NHLE) – includes: listed buildings, scheduled monuments, parks and gardens, and protected wreck sites | Vector – point and polygon (.shp) |
| Base mapping | Strategi, VectorMap District, OpenMap Local | Ordnance Survey | Reference mapping from the Ordnance Survey's OpenData portal. Also used for extraction of linear features (e.g. ditches, canals, railways). | Vector – point, polyline, and polygon (.shp) |
| Imagery | Google Imagery | Google | Aerial photography and satellite imagery used for reference and mapping | Raster (WMS) |
| Population | OpenPopGrid | University of Southampton | 1 x 1km open data population grid dataset for England and Wales | Raster (ESRI Grid) |
| Land cover | Land Cover Map 2015 | Centre for Ecology and Hydrology (not open data) | Land cover map (23 land cover classes) of the UK – used for computing agricultural land area. | Vector – polygon (.shp) |
| Access | Public rights of way (PROW) | Gloucestershire County Council (not open data) | Data for footpaths, bridleways etc | Vector – polyline (.shp) |

### 3.4.2 GIS data processing and analysis to quantify linear features

The management, analysis and visualisation of spatial data was conducted using the open source software package QGIS (https://www.qgis.org) and the open source programming language R (https://www.r-project.org/). Reproducibility of the research was an important factor; thus the use of open source software and open data were favoured. All data was referenced to the British National Grid coordinate system (OSGB 1936 / EPSG:27700) and clipped to the geographic extent of the

LSV study area boundary. GIS data were explored for their capacity to support the identification and valuation of the ecosystem services flowing from the cultural heritage of the area. The sections below describe how GIS information were utilised to support the heritage scoring method.

*Quantifying Legibility*

Legibility of woody linear features was calculated across the LSV study area using the NHLC 250 x 250m grid cells as the basic unit of measurement, which provided a spatial framework for estimating the density of linear features. A legibility score was computed by calculating the total length of selected linear landscape features within each NHLC grid cell, and then classifying the range of results into quintiles (alternative classification systems need to be investigated).

Data on woody linear features was provided by the Ordnance Survey Landscape Features (OSLF) data layer. This is a non-open data layer produced by the Ordnance Survey (OS) as part of a project commissioned by the Rural Payments Agency (RPA - see https://tinyurl.com/yblw95ur). Woody linear features are classified into three main feature types:

- Hedges (farmland hedgerows).
- Tree canopy (narrow lines of trees used as field boundaries).
- Wooded strip (trees that mark the outer edge of blocks of woodland).

An alternative spatial dataset on woody linear features produced by the Centre for Ecology and Hydrology (https://www.ceh.ac.uk/services/woody-linear-features-framework) was also assessed, but the poor quality of this data meant that it was not considered for use on the project.

The results of the analysis are shown in Figure 5. When visually compared to the base mapping and aerial imagery for the area, this method was found to be effective at quantifying the density of linear landscape features across the area, though there are data quality issues that need to be taken into consideration. As might be expected with an ambitious data analysis project that aims to map every farmland boundary in England and Wales, the OSLF data layer does have accuracy issues, and significant data gaps. For example, in the Elmore study area, it was noticed that many hedges that should have been included in the OSLF data layer were missing (Figure 6).

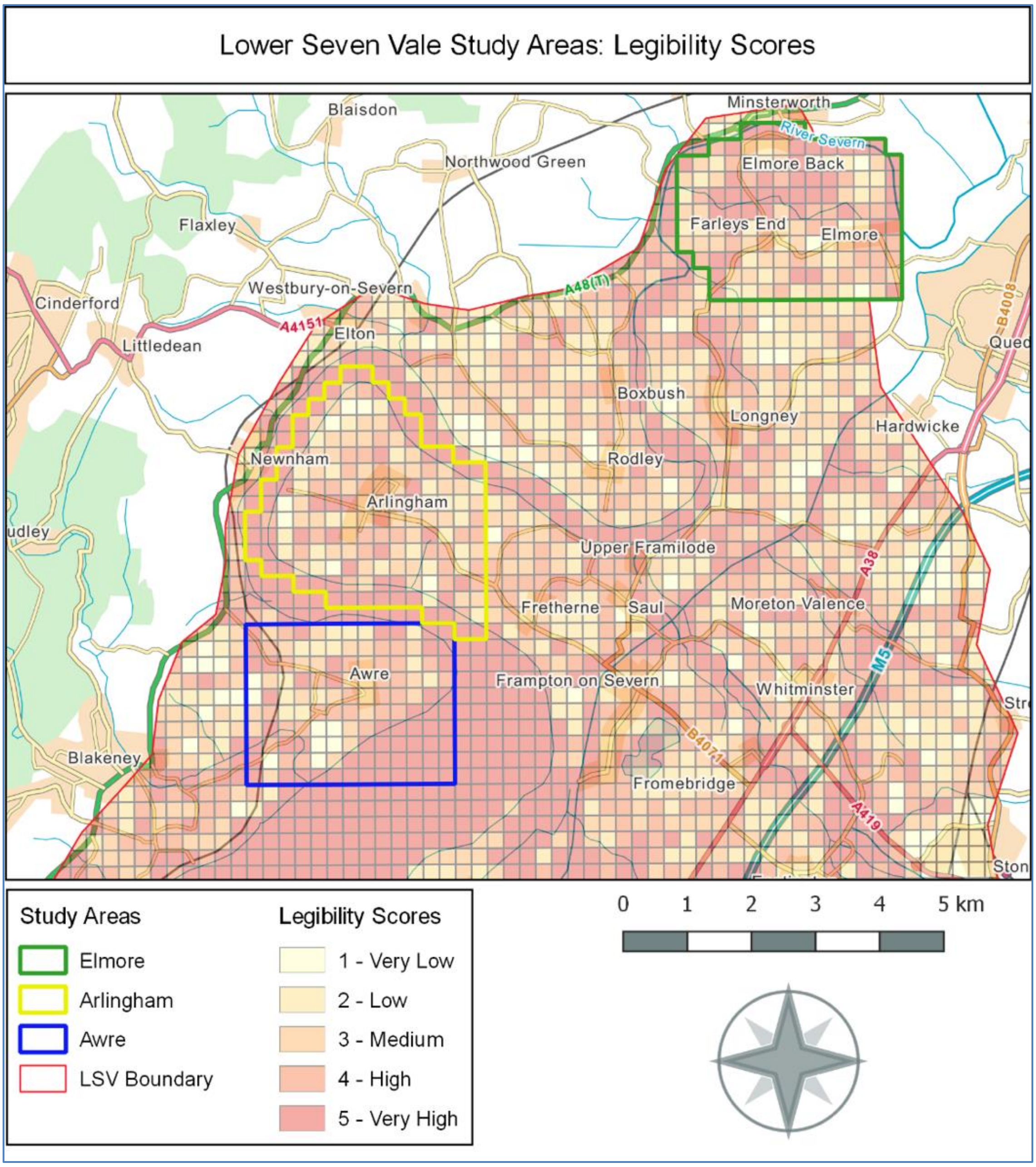



*Figure 5: Lower Severn Vale: legibility scores within and around the case study areas*. Note the primacy accorded to the River Severn and areas with the highest densities of field boundaries.


*Figure 6: Missing hedge data on the OS landscape features data layer at Elmore, within an area of historic meadow*

The missing hedge date in Figure 6 appears to be caused during the OSLF production process, where the algorithm used to extract woody linear features detects a conflict with spatial data representing other linear features which shares the same geographic space. In this case, the problem seems to be caused by the presence of data on linear surface water features. In the Elmore example, the large data gap was found to be due to the presence of drainage ditches in an area of water meadows. Figure 7 illustrates the situation; here surface water data (in this example take from the OS VectorMap District data layer) is overlaid onto the OSLF data. As all the ditches in the Elmore study area are bounded by hedges, it is therefore possible to use this surface water data as a proxy for hedges, though care must be taken, and manual editing is required to remove surface water features that are not a suitable proxy for woody linear landscape features. Reference to the Gloucestershire HLC, and fieldwork, shows that this is indeed the case, and that the boundaries relate to an area of enclosed meadow (see Appendix C).

The density of linear features also results from the presence of routeways and of garden and yard boundaries, as well as field boundaries and embankments. Existing data for routeways, which enabling identification of roads for vehicles and other routeways for 'public highways', does not enable identification of historic routeway types and would even require further analysis outside the scope of the project to distinguish between routeways that are metalled and unmetalled, are bounded on one or more sides, and have wide verges or passing places. However, although routeways are omitted from the data set they are commonly bounded on both sides by boundaries to fields – a factor which runs the risk of 'double counting'. For this reason, they are included as an 'asset type' within the Inter-Relationships section.

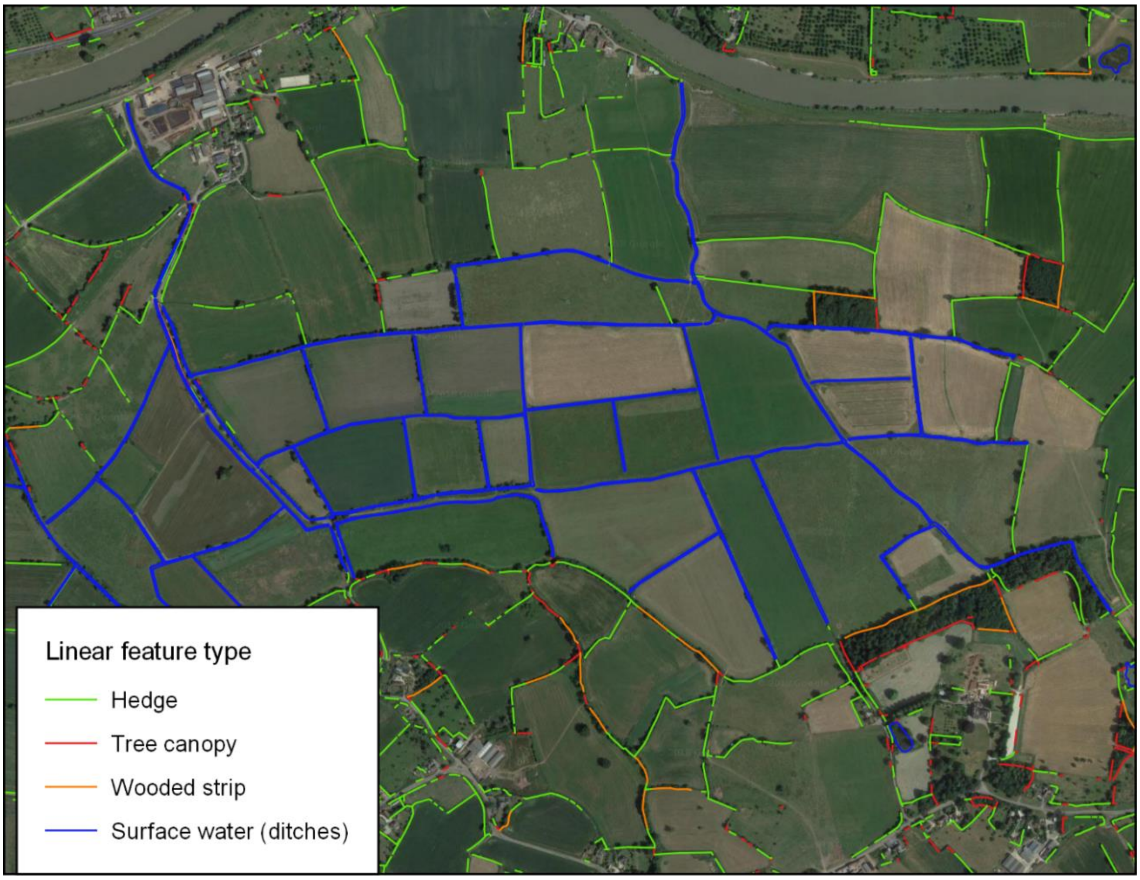



*Figure 7: Using surface water data as a proxy for field boundaries within historic meadow, Elmore*

*Quantifying Time Depth*

Time depth of linear features was calculated using the NLHC dataset (see Figure 8 for an example). The reproducibility of the methodology was an important consideration, hence the decision to test the effectiveness of the grid squares used in the NHLC and examine its relationship and reliability in relationship to the polygonised Gloucestershire HLC data (see Appendices A-C for this and detailed analysis of case study areas). Attached to each NHLC grid square is a rich set of attribute data that can be used to help understand the time-depth and spatial patterning of enclosed land and other land use types in the present landscape. The data fields *DominantBroadType* and *DominantType* were used to assign a time-depth value, based on the scoring system described in Section 3.4. The NLHC is available in two different grid resolutions: 250 x 250m, and 500 x 500m. For this project, the higher resolution 250 x 250m version was used to maximise the granularity of detail when working at a local (large) scale.

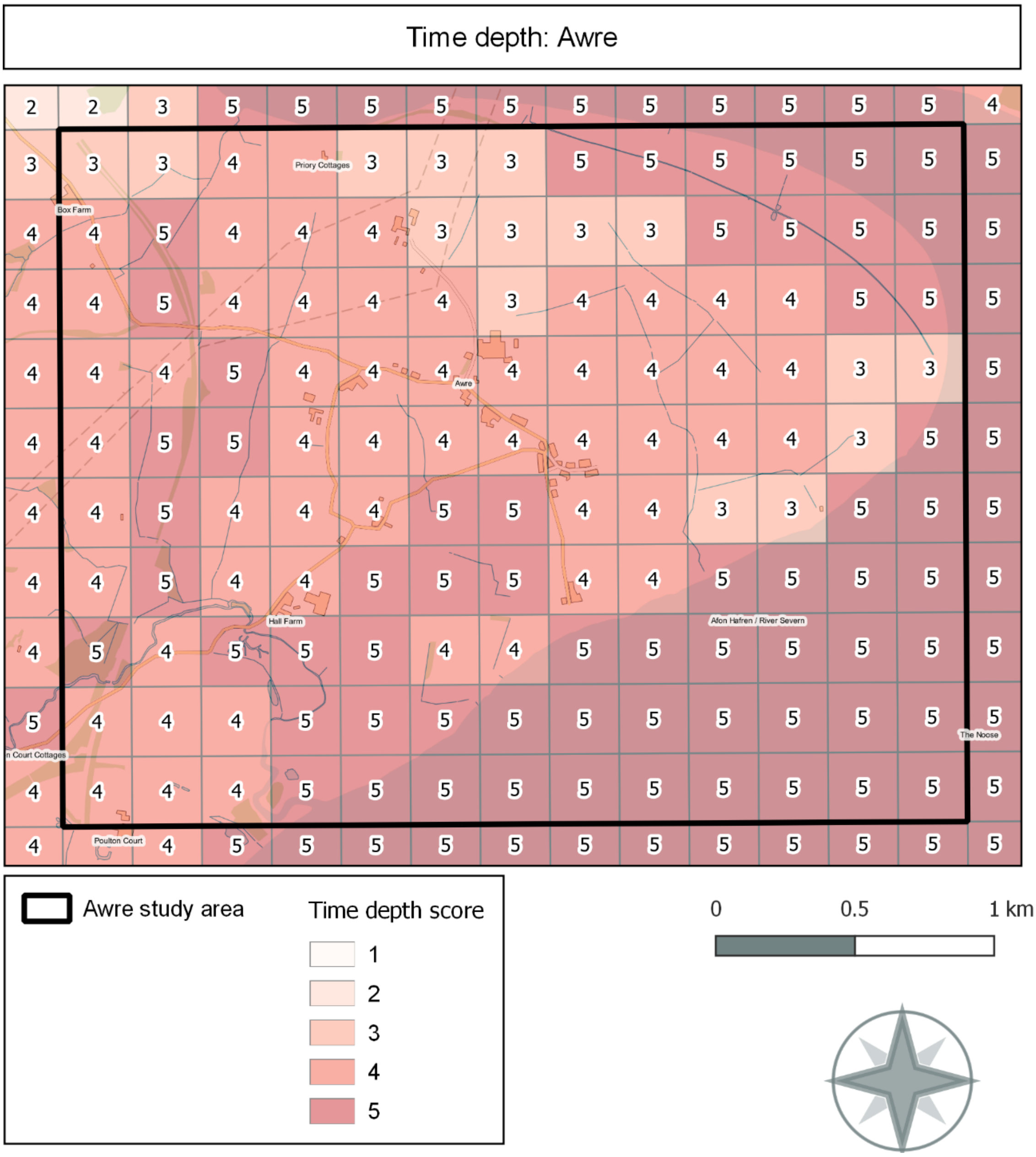



*Figure 8: Time depth scores for the Awre study area, 5 being the highest.*

### *Quantifying Inter-relationships*

A wide range of data was incorporated into the scoring system for assigning value to inter-relationships within a landscape (see Figure 9. Data used to analyse interrelationships included:

- Listed buildings and other designated heritage assets from the National Heritage List for England (see www.HistoricEngland.org.uk/listing/the-list).
- Non-designated heritage assets from the Gloucestershire Historic Environment Record, which includes data from Historic England's NMP

(Crowther and Dickson 2008 and 2016 for the Severn Vale and Estuary, Dickson 2006 for Frampton-on-Severn and Small and Stoertz 2006 for the Forest of Dean), which recorded archaeological remains visible on aerial photographs and lidar remote sensing images.

- Historic routeways (newly digitised from base maps and aerial imagery).

Use of this data (see Appendix B which includes detailed analysis of case study areas) is subject to a number of caveats, the most significant being:

- The criteria for statutory designations exclude the majority of traditional farm buildings and vernacular buildings which have been altered or are hidden behind later re-frontings. Conservation areas tend to be concentrated in nucleated settlements rather than in areas of dispersed settlement that can be equally old. The descriptions including dates and building types for listed buildings do, however, bear a strong relationship to the date and character of settlement and enclosed land.
- Factors, such as historic patterns of settlement and the extent of research and survey, which help to explain the date and distribution of heritage assets including historic buildings, traditional farmsteads and archaeological features (see Appendix B).
- The majority of routeways are excluded from the data sources utilised, unless they have been identified as being Roman, comprise hollow-ways of evident significance, or have been recorded as turnpike roads. Some Roman roads have been identified from cropmarks (as at Over, Crowther and Dickson 2008, 109) or have been found underneath modern roads (Small and Stoertz 2006, 17).
- Soils, geology and land use, and other factors such as visibility on the day affect the survival and visibility of archaeological sites including the medieval ridge and furrow which extended across large parts of the project area (Crowther and Dickson 2016, 24-26).
- Another factor in this respect is the historic character of settlement (ridge and furrow is more fragmented in areas of dispersed medieval settlement than around villages such as Frampton-on-Severn). Ridge and furrow, and associated headlands, were also absent from land use areas as revealed by HLC – meadows and common land in particular.
- The depth of alluvium and other factors in the interpretation and assessment of Lidar imagery (https://www.historicengland.org.uk/research/methods/airborne-remote-sensing/lidar/).

Considerable time and thought was given during this project to the identification and analysis of the Gloucestershire Historic Environment Record data, both on a thematic basis (working from the Class Types such as Agriculture and Subsistence) and the Broad-to-Narrow Terms within them and using multipliers to score those features that made a positive contribution to the setting of linear features. After much deliberation, focusing on ease of use and applicability to other parts of

England, these were rejected in favour of the much simpler system outlined in 3.3.1. This is based on:

- Interpretation of the available data for buildings and above-ground archaeological features, which can be viewed on-line along with data from seven other HERs at the Know Your Place website (http://www.kypwest.org.uk).
- Comparison of modern and historic maps and rapid extensive fieldwork.

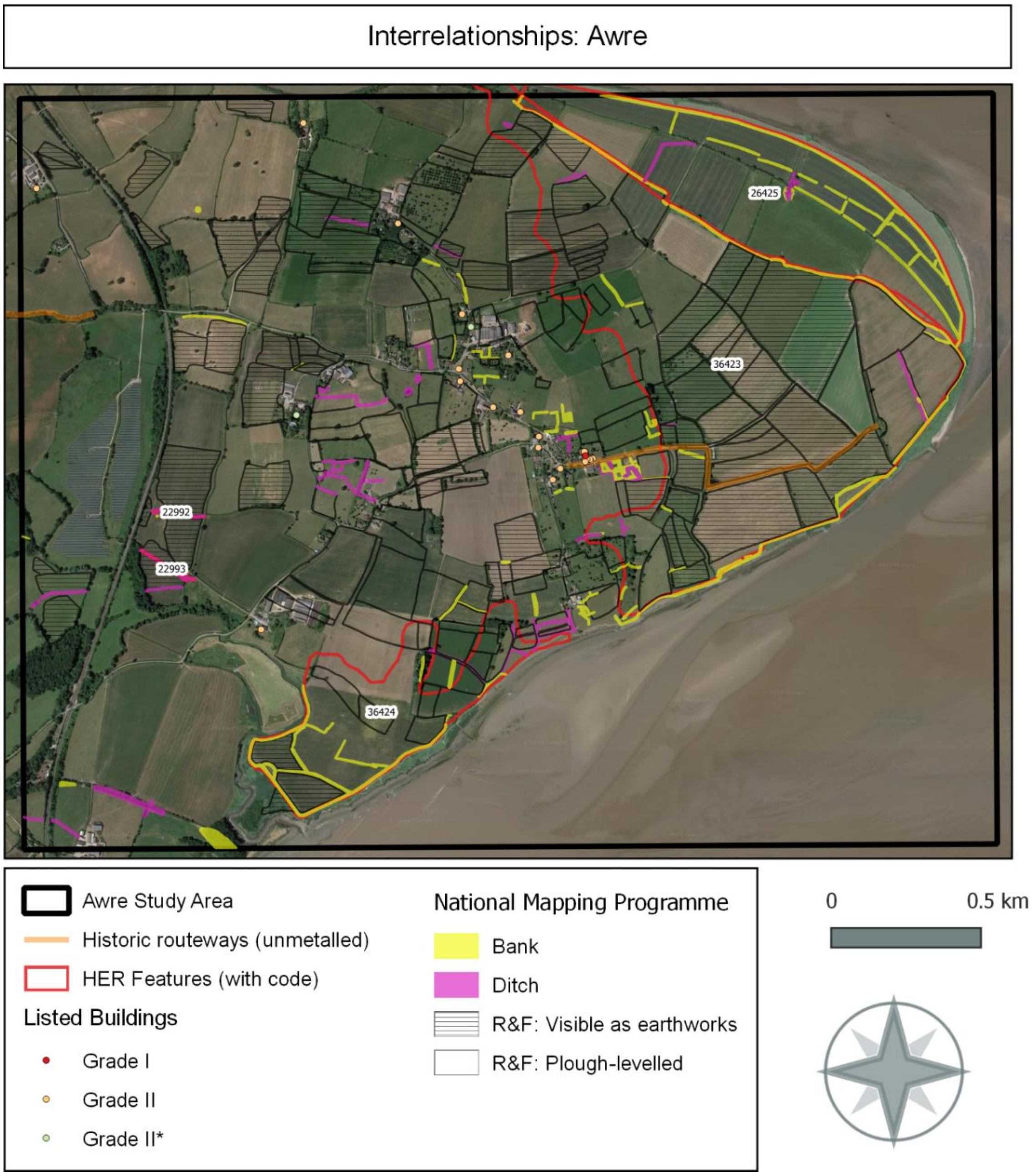



*Figure 9: Inter-relationships of linear features with heritage features and assets in Awre*

Figure 9 shows the clustering of listed buildings within and (relating to medieval farmstead sites) to the west of the historic settlement, medieval hollow ways (2292-3) to the west recorded on the HER, and banks, ditches and medieval ridge and furrow recorded as a result of the NMP. Not included on the HER for this and other case study areas are traditional farmsteads, most non-designated 19th century and earlier historic buildings, and unmetalled historic routeways that are not marked as highways or rights of way: the latter include an early trackway extending from the medieval church into the eastern part of the peninsula.

*Quantifying other model inputs*

GIS analysis provided further inputs for the valuation model, including:

- Data on the total resident population within each study area. This was computed using the OpenPopGrid gridded population data from the University of Southampton. The 10 x 10m population raster was converted to vector points, and the total population calculated using a spatial join the study area polygons.
- The total area of agricultural land in each study area, computed using Land Cover Map 2015 data from the Centre for Ecology and Hydrology. Agricultural land was extracted by selecting *Arable and horticulture* and *Improved grassland* land cover types from the main dataset.
- Farms were digitised using base maps and aerial imagery to help determine the number of farm buildings in each study area.
- The total length of linear features (in addition to farmland boundaries):
    - Canals (using OS OpenMap Local data).
    - Railway (using OS OpenMap Local data).
    - Derelict railway (digitised from Google imagery).
    - Public rights of way (using PROW data supplied by Gloucestershire County Council).
    - Ancient routeways (digitised from OS map data and Google imagery).

## 3.5 Lower Severn Vale linear heritage assets: valuation methodology

The valuation methodology rests upon understanding the extent to which linear features in the landscape provide a range of functions, ranging from supporting livestock management to providing wildlife habitat, recreational spaces, and a sense of place to residents of the area and to visitors. These functions can then be identified, along with those who benefit, and categorised according to the concepts of 'ecosystem services', i.e. the notion that aspects of the environment provide a range of supporting services that benefit society and the environment on which it depends. Assessment of 'value' then involves a careful and detailed analysis of the functions of different types or categories of linear features in terms of how they contribute 'services' to the socio-ecological and economic system of interest. Services can be considered under the key service flows of the ecosystem services model as supporting, provisioning, regulating, and cultural. Service flows can then be explored in terms of 'benefit streams' which allows the project team to identify who or what benefits, and to assess the value of each benefit stream. The service 'flows' depend on the current stock of the asset (in this case the pattern and extent of linear features within a defined area), and not just the stock but also its condition (e.g. good, poor, derelict), and the extent to which it continues to support relevant desired functions. Thus, there are two forms of 'value':

- Value of the 'stock' of the asset (the different categories of linear feature and the 'amount' or linear extent).
- Values of the service flows.
- This project focuses on the latter value – that of the service flows – identified in this study as benefit streams flowing to defined beneficiaries.

All linear features fall into three broad categories: boundary features, drainage and flood control features, and communications, and all functions can be incorporated within one of the four major types of ecosystem service. The tables in Appendix D of this report describe in more detail the major benefit flows which were identified for this study.

The approach taken is a modified cost-benefit analysis based on a 'return-on-investment' model using proxy measures to estimate values of market and non-market benefit flows. Resource and time constraints mean a full-scale cost-benefit approach based on empirical data cannot be developed, and lack of relevant data from secondary sources precludes a standard approach.

Costs and benefits from the different linear features (see Appendix D) are modelled over a 50-year time horizon. A 50-year period will capture the full range of costs that incorporates an annualised maintenance value and captures the benefit flows. Given the durability of linear features it might be necessary to expand the time frame across 100 - 200 years or even longer to fully explore the balance of costs and benefits. However, discounting techniques start to break down and future uncertainties require some heroic assumptions about future conditions when such long time-frames are considered.

## 3.6 Model structure

Figure 10 illustrates the overall structure of the accounting framework, based upon understanding the range of linear features in the LSV (introduced in Section 2) and the services provided (introduced in Section 3.1). Linear features are assigned to one of three categories and for each category the ecosystem services provided are identified and analysed in terms of the level of the flow and the number and type of beneficiaries. Each identified 'flow' of services is represented on a separate line, which enables service flows to be valued individually and in categories (i.e. provisioning, supporting, regulation, cultural). The model has been designed to account for variable size of the selected 'character area' (i.e. the area of interest for analysis). The model operates as follows:

- Each service flow is assessed through an indicator which measures the quantity or 'level' of service delivered. Indicators vary with each identified service flow depending on the type of service and the nature of the beneficiaries. The majority of indicators are measured on 1 – 5 scales which are then scored by stakeholders with specific expertise. For example, the level of livestock management services delivered by the character and condition of field boundaries in a landscape might be assessed by livestock farmers, while the contribution to ecological biodiversity in an area might be assessed by local ecologists.

- The 'level' of each service flow is then modified by assessment of its function and condition. Condition assessment requires ground surveys in order to observe the current state of linear features. For the purposes of this project, in relatively small areas, ground assessments were made by project team members based on driving around the case study sites to obtain a general indication of condition.
- Condition is also related to current functions of linear features; those that are functional (in the sense that they continue to perform the function for which they were originally created) are likely to have more resources invested in maintenance and restoration and are likely to be more robust, than those that no longer perform an economic function.
- A financial approximation (a 'proxy') is assigned to each service flow. Wherever possible proxies are based on market prices of similar goods and services to those delivered through the ecosystem service being valued. Where no market prices exist for specific ecosystem services provided (e.g. the value of biodiversity, or the aesthetic value of landscape) then non-market valuation studies are used as a guide to determine the value of the benefits flows. Values of benefits over the 50-year time horizon are depreciated (where appropriate) and discounted to provide present value figures which can be compared to the present value of maintenance and restoration costs over the period.

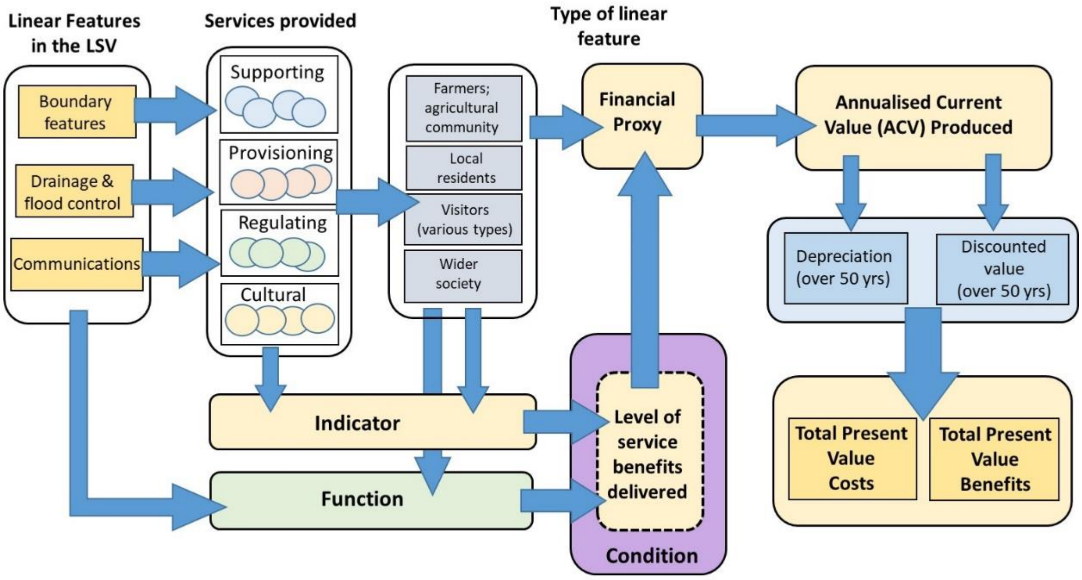



*Figure 10: Diagrammatic overview of the Lower Severn Vale linear features valuation model*

# 4 APPLYING THE METHODOLOGY TO THE CASE STUDY AREAS

## 4.1 Case study areas

It was determined in consultation with Historic England to select case study areas that were located close to the river and enabled examination of how the methodology might work at different scales. The case study areas selected for detailed study are Elmore, Arlingham and Awre (see Table 2). Each is approximately 7.5 $km^2$ and broadly representative of the key characteristics of the Severn and Avon Vale NCA, with strong similarities but also subtle contrasts in the time-depth of enclosure landscapes and the distribution of heritage assets:

- Elmore displays strong contrasts between meadow and farmland within an area of Roman reclamation and a landscape of post-medieval enclosures within a framework of medieval and earlier routeways and mixed settlement comprising farming hamlets and farmsteads.
- Arlingham is a medieval village landscape to the east bank of the Severn, which developed within six phases of late Roman reclamation and is traversed by routeways of Roman or earlier origin across fording and crossing points.
- Awre is a medieval village landscape to the west bank of the Severn, with farmsteads working strip fields and meadows enclosed in the $16^{th}$-$19^{th}$ centuries, with more anciently-enclosed fields and medieval dispersed settlement along its western margins.

The next sections summarise the allocation of scores to the case study areas.

*Table 2: Basic data on the case study areas*

| Case Study area | Length Hedges (metres) | Length Wooded Strips (metres) | Length Tree Canopy (metres) | Length Total Landscape Features (metres) | Population Count (number) |
|---|---|---|---|---|---|
| Arlingham | 75015.9 | 14498.5 | 4992.9 | 94507.4 | 389 |
| Awre | 67848.6 | 15077.5 | 3694.7 | 86620.8 | 128 |
| Elmore | 75499.4 | 10139.5 | 8382.8 | 94021.7 | 214 |

### 4.1.1 Elmore

This area (see Figure 11) displays strong contrasts between meadow and farmland within an area of Roman reclamation and a landscape of post-medieval enclosures within a framework of medieval and earlier routeways and mixed settlement:

- Legibility
    - There is a varied range in terms of density of linear features across this area, the most concentrated area with very high scores of 5 being in the area of historic meadow to the north, at the intersection of routeways and in the area of dispersed medieval settlement including the church in the south-west.
- Time Depth
    - Using HLC grid squares: Most of the area is dominated by a high score (4) using the NHLC reflecting the dominance of post-medieval piecemeal enclosure, with the exception of very high scoring areas (5) comprising medieval meadow land to the north with a high density of water channels and blocks of ancient woodland (Hockley Wood, Shatford Grove). This reflects the dominance of 16th century and later piecemeal enclosure.
    - Using Gloucestershire HLC: There is a close match to the NHLC, the key distinction in the area of meadow land being between larger enclosures to the east and those retaining the outlines of doled-out apportionments of meadow to the west.
- Inter-Relationships
    - The very high score (5) for the whole area reflects the significant contribution made by features dating from the Roman period, as recorded on the HER. These include earth and stone-revetted banks which mark areas of late Roman land reclamation, a species-rich boundary with veteran trees marking the division between the landscape of Roman reclamation and recorded features within the medieval farmed landscape to the south - ridge and furrow. medieval greens, routeways, a church, buildings and parkland. This boundary matches a significant Time Depth. There is also a rare survival of a cider house in a historic orchard and a salmon fishing house close to the river.

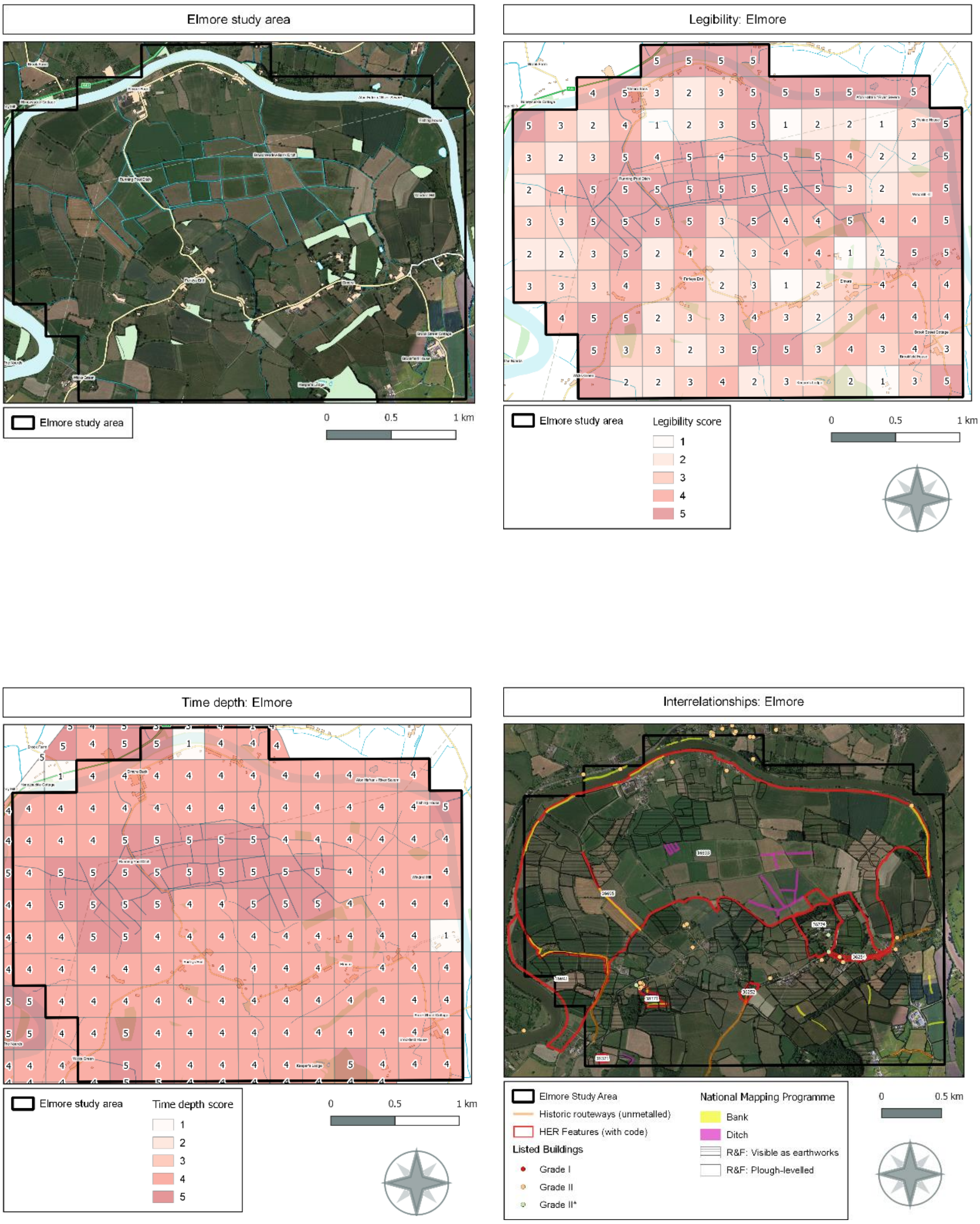



*Figure 11: Sample illustration of the scoring system for legibility, time-depth, and inter-relationships for the Elmore case study area.*

See Appendix A for comparison of the local and national HLCs and Appendix B for further details on Inter-Relationships.

### 4.1.2 Arlingham

A medieval village landscape to the east bank of the Severn, which developed within six phases of late Roman reclamation and is traversed by routeways of Roman or earlier origin across fording and crossing points (see Figure 12):

- Legibility.
    - Mixed pattern of densities, the squares scoring 5 (excepting the Severn) being concentrated around early routeways, rhynes and associated water channels.
- Time Depth.
    - Using NHLC grid squares: The variety of densities of field boundaries relate to the dominance of post-medieval enclosure across this area. The area with the highest score (5) is the block of enclosed meadow (including the areas scoring 5 for Legibility) north of Passage Road, the predominant pattern across the area being piecemeal 16th-19th century enclosure of medieval strip fields (4). The areas scoring 3 relate to the Gloucestershire HLC A3 type for regular enclosure that ignores medieval strip fields.
    - Using Gloucestershire HLC: A more subtle picture emerges within the piecemeal enclosure that highlights the meadowland to the NE and NW of the peninsula, and areas of enclosure that have retained more coherent patterns of strip fields (A1) to the NE of Milton End and in eastern quadrants extending towards Overton where east of the case study area medieval farmsteads related to more irregular enclosures demonstrates the relationship between the piecemeal enclosure around the village (A2) and more species-rich boundaries with hedgerow trees, in contrast to hedgerows associated with water channels in the areas of historic meadow (D1), excepting the strip of woodland extending towards Awre Mill.
- Inter-Relationships.
    - The very high score (5) for the whole area reflects the evidence from the NMP and research recorded in the HER for the formation of this landscape from the Roman period and earlier. Ditched and banked boundaries, and routeways, mark six phases of late Roman land reclamation. Routeways are of medieval or earlier date: they include a Roman or earlier routeway clearly extending across the peninsula to an ancient crossing point at Newnham Passage and unrecorded unmetalled tracks (not present on the HER) which mostly extend towards riverside meadows and include a back lane between the Roman reclamation boundary and Arlingham.
    - There is extensive evidence across the area for ridge and furrow cultivation. Recorded rhynes and water channels extend inland from the Severn.
    - Observation reveals a rich variety of historic building types within and around Arlingham, complementing the evidence offered by designated

heritage assets and the HER for the development in particular of the farming community. To the east is a landscape of dispersed settlement, medieval in origin, with buildings for cider and cheese production set amongst more irregular species-rich boundaries.

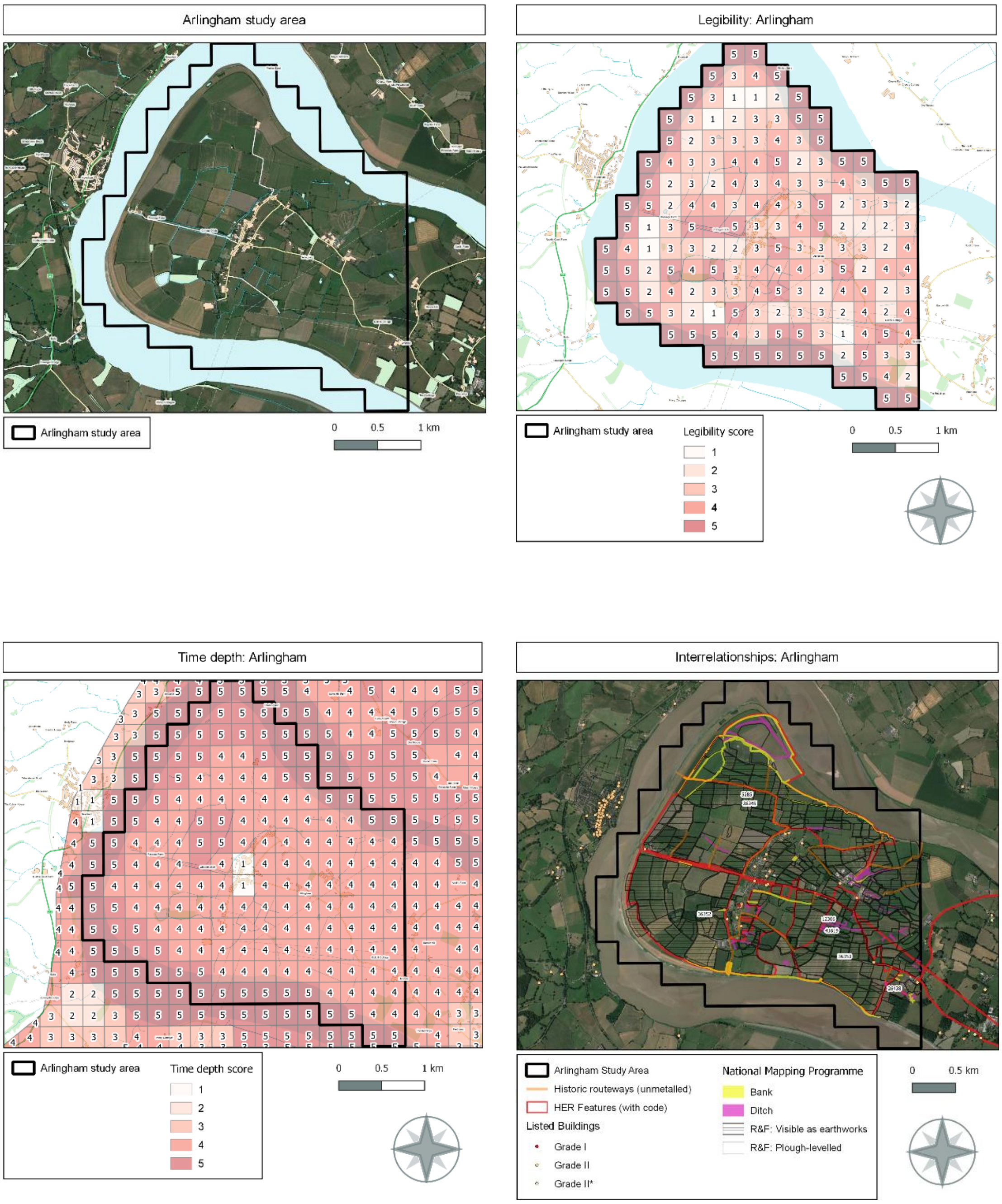



*Figure 12: Sample illustration of the scoring system for legibility, time-depth, and inter-relationships for the Arlingham case study area*

See Appendix A for comparison of the local and national HLCs and Appendix B for further details on Inter-Relationships.

### 4.1.3 Awre

A medieval village landscape to the west bank of the Severn, with farmsteads working strip fields and meadows enclosed in the 16th-19th centuries, with more anciently-enclosed fields and medieval houses along its western margins (see Figure 13):

- Legibility.
  - There is a lower density of linear features than in the other sample areas, the main zone scoring 5 (excepting the Severn) being to the west where there is a denser concentration of fields deriving from the medieval period (part of a pattern extending in the Forest of Dean), the site of Awre mill, Brims Pill and associated rhines and the building of the railway with its tree-lined embankments.
- Time Depth.
  - Using NHLC grid squares: The areas with the highest scores (5) are enclosed meadow (including the areas scoring 5 for Legibility), the predominant pattern across the whole of the remainder being piecemeal 16th-19th century enclosure of medieval strip fields (4). The areas scoring 3 relate to the Gloucestershire HLC A3 type for regular enclosure that ignores medieval strip fields.
  - Using Gloucestershire HLC: A subtler picture emerges that demonstrates the relationship between the piecemeal enclosure around the village (A2) and more species-rich boundaries with hedgerow trees, in contrast to hedgerows associated with water channels in the areas of historic meadow (D1) excepting the strip of woodland extending towards Awre Mill.
- Inter-Relationships.
  - The high score (4) reflects the dominant post-medieval character of this area, which has worked within an inherited framework of earlier routeways and boundaries that relate to medieval and Roman reclamation; much of the latter has been lost due to erosion. The loss of ridge and furrow in the older A2 enclosure landscape around the village offers evidence of arable farming working out of the courtyard farmsteads which grew in size within Awre.
  - Medieval farmsteads and buildings to the west suggest an earlier origin for some of the field boundaries in this area bordering the ancient enclosures of the Forest of Dean.
  - Medieval routeways provided access to the medieval nucleated settlement of Awre and include an unmetalled trackway extending from the 13th century church towards the meadows and the Severn. The HER records two isolated hollow-ways north-west of Hall Farm (22992-3).

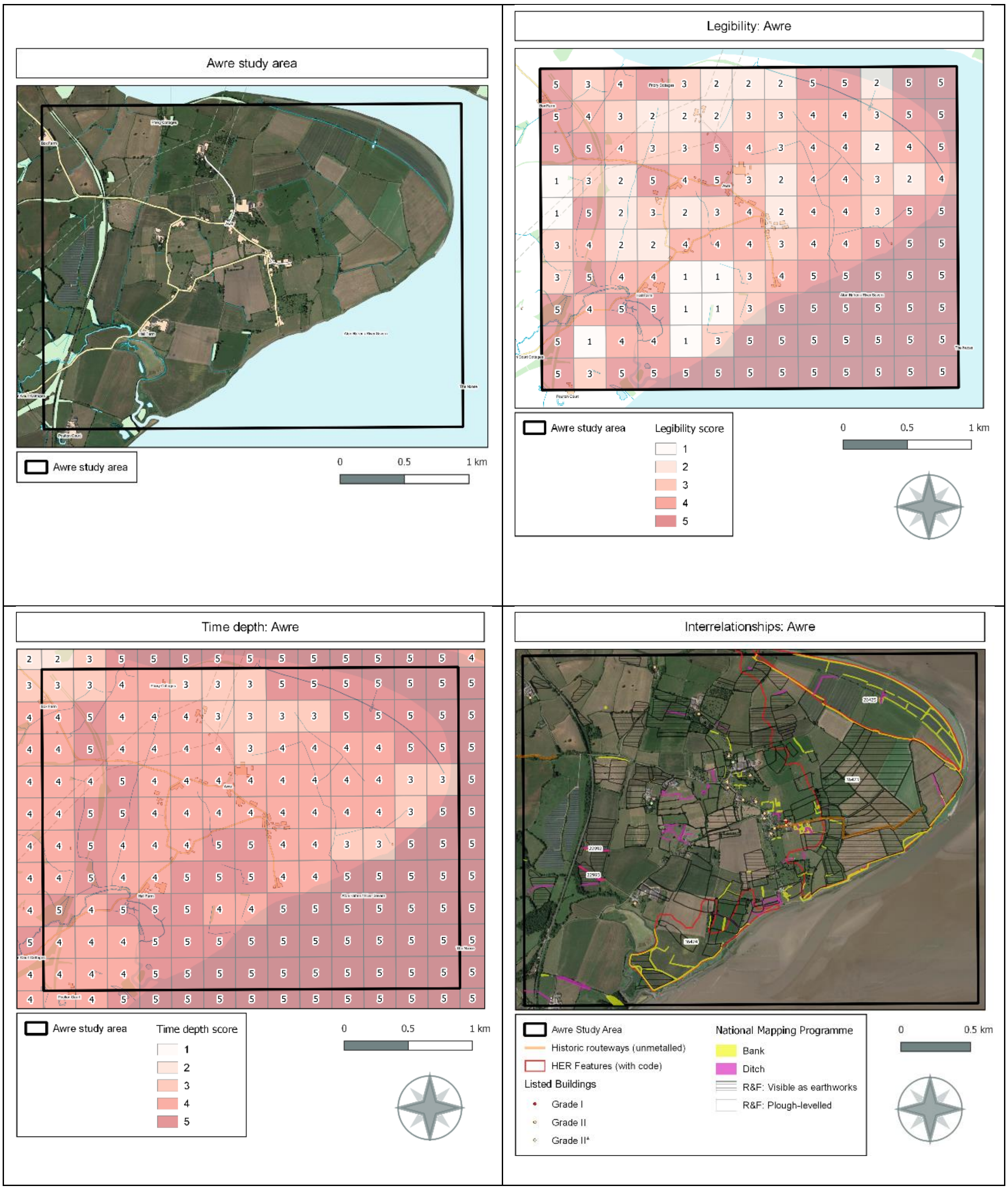



*Figure 13: Sample illustration of the scoring system for legibility, time-depth, and inter-relationships for the Awre case study area*

See Appendix A for comparison of the local and national HLCs and Appendix B for further details on Inter-Relationships.

Table 3 below summarises the range of scores for the three case study areas and the aggregate score assigned to each area. With the exception of legibility, which is subject to a high degree of variation according to the dominance or otherwise of linear features in each cell, scores were relatively high for each of the three case study areas, reflecting the selection of areas with relatively high cultural value and abundant examples of linear features that help to explain the settlement and land-use pattern of the area over time. The case study areas selected do not display strong contrasts, subtle variations in scores may reflect significant differences as noted in the assessment process. The aims of the pilot study included examination of the issue of scale and potential application of GIS to the methodology, as well as assessing values of linear features across the Lower Severn Vale area.

***Table 3: Summary scores for legibility, time-depth, and inter-relationships (case study areas)***

| Case study area | Legibility | Time-depth | Inter-relationships | Summary score for each case study area |
|---|---|---|---|---|
| Elmore | 1-5 | 4-5 | 5 | 4.0 |
| Arlingham | 1-5 | 4-5 | 5 | 4.3 |
| Awre | 1-5 | 3-5 | 4 | 3.7 |
| Mean score across the case study areas | 3.0 | 4.0 | 4.7 | |

## 4.2 The heritage accounting framework

A return on investment model was utilised, based on the accounting model developed to assess the value of ecosystem services for dry stone walls in the Peak District (Powell *et al.* 2018). The three case studies areas were each modelled separately and within each model the ecosystem services associated with linear features were assessed in three categories:

- Boundary features (walls, hedgerows).
- Aquatic and drainage (drainage ditches, flood control channels, streams, canals, flood embankments).
- Communications (footpaths and public rights of way, ancient routeways, railways).

The case study areas of approximately 7.5 km$^2$ were selected to explore ecosystem service values. Key data on linear features were obtained where possible from remotely sensed data. However, the linear features captured by GIS data were limited:

- Field boundaries (hedgerows, it was not possible to utilise GIS data to determine the limited extent of walls in the case study areas).

- Drainage and Flood Control (drainage ditches, flood channels, embankments) were identified on OS maps and the linear length within the case study areas measured. It was not possible to correctly identify the total length of drainage ditches directly from GIS sources.
- Communications links (rail, footpaths, canals, ancient routeways). Some of these are included on the HER but coverage is not systematic. Large scale features such as canal and rail links could be readily identified using remotely sensed sources, and data regarding length of public rights of way could be accessed for the case study areas. Ancient routeways, other than hollow ways which where identified have been included on HERs, had to be identified on OS maps and measured by hand as this information is not available from GIS sources.

Indicators and scoring approaches were designed for each of the three categories of linear feature. Table 4 is one example and describes the indicators for boundary features (i.e. walls and hedgerows). Similar tables were drawn up for Drainage and Flood Control, and for the Communications categories of linear features.

*Table 4: Ecosystem service and indicators used to assess benefits flowing from boundary features*

| Ecosystem Service type | Ecosystem Service delivered | Indicator description |
|---|---|---|
| Supporting | Primary Production (e.g. lichens; nutrient cycling) | Hedgerow: Variety of plant species |
| | Primary Production (e.g. lichens; nutrient cycling) | Wall: proportion of walls in the area with high levels of lichens/mosses (i.e. greater than 50% coverage). |
| | Species habitat | proportion of hedgerows/walls in the area with suitable micro-climate and exposure. |
| | Wildlife Corridors | Indicator score based on enhanced species resilience as a result of the boundary feature |
| | Local Economy | Annual number of person-days in hedge-laying/wall building generated per km of hedge/wall |
| Provisioning<br><br>Regulating | Arable and livestock management | Farmer estimate of efficiency savings through reduction in crop damage as a result of the boundaries. |
| | Livestock management | Farmer functional utility of boundary for livestock management. |
| | Shelter | Indicator scores based on farmer's functional utility of the following:<br>- boundary utilised for livestock shelter. |

| Ecosystem Service type | Ecosystem Service delivered | Indicator description |
|---|---|---|
| | | - efficiency savings from provision of field boundaries<br><br>supports high nature value farmland. |
| | Food source | Index based on quantity of fruit produced; range and number of food /medicinal plants available per km of hedgerow |
| | Land ownership boundary marker | Landowner/land agent/surveyor estimate of functional value of wall and hedgerows in marking property boundaries. |
| | Soil erosion (location specific) | Farmer estimate of functional utility of walls and hedgerows for decreasing soil erosion and soil creep |
| | Soil quality | Indicator score based on farmer estimate of functional utility of walls and hedgerows for enhancing crop production or supporting livestock production through lower feed costs |
| | Water flow (location specific) | Farmer estimate of functional utility of walls for reducing overland water flow. |
| Cultural | Landscape and aesthetic; sense of place | Mean score from expert assessment of Time depth (scored on a 1 - 5 scale) |
| | | Mean score from expert assessment of Connectivity (scored on a 1 - 5 scale) |
| | | Mean score from expert assessment of Legibility (scored on a 1 - 5 scale) |
| | Tourism | 1 - 5 scale assessing contribution of boundary features to landscape/aesthetic value |
| | Traditional skills | 1 - 5 scale assessing significance of boundary features in maintaining traditional skills |

## 4.3 Model operation

The model is based on a simple return on investment framework where benefit flows arising from ecosystem services and maintenance costs required to maintain the current level of flow, are valued over a 50-year time period and discounted back to present value (using the standard Treasury recommended discount rate of 3.5%). The model does not incorporate the value of the natural capital, or the costs of creating/constructing features in the landscape from which benefits flow (e.g. flood control embankments, hedgerows, drainage channels, etc.). The model does include, however, some costs of replacement over time based on assumptions, for example, about the length of time a wall might stand before falling down, or how long a hedgerow might last before it needs to be replaced.

GIS data provided a range of inputs which were fed into the model, including:

- Agricultural area.
- Population.
- Length of linear features.

In addition, the cultural heritage scores derived from the scoring system were used in the model as the indicator values for cultural ecosystem services where appropriate.

Benefit flows arising from each of the four categories of ecosystem services are identified (see Figure 14 below for an overview). For each 'flow' or stream of benefits a beneficiary or set of beneficiaries is identified (e.g. farmers, local residents, visitors, wider public). An indicator is selected to measure the 'value' of each flow to the beneficiary using a 1 to 5 scale (e.g. a hedgerow might have value to a farmer for livestock management and score high but the same hedgerow might also be single species and have limited value in providing source of food or habitat for wildlife, receiving a lower score on a scale designed to measure the value of habitat). The benefits of each service flow are measured in terms of the quantity of the benefit provided per kilometre of linear feature, which are then modified by measures of functional utility (where appropriate) and condition (e.g. 'gaps' within a hedgerow or wall, whether or not the feature is well-maintained).

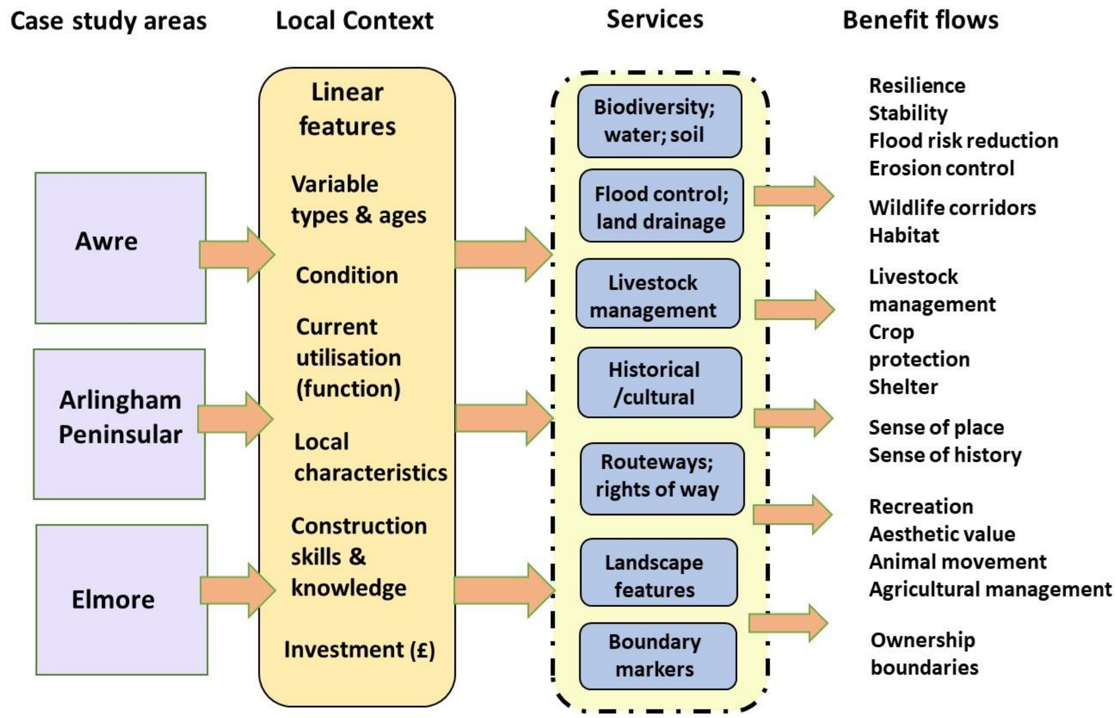



*Figure 14: Lower Severn Vale case study areas and benefit flows*

The modified indicator scores are then monetised through application of a financial approximation, which assigns a market value to each benefit flow. Financial approximations (proxies) are selected based on previous experience and accepted practice. Where possible a market value is ascribed as a proxy (e.g. the cost of flood damage avoided can be utilised to value the annualised benefits flowing from a flood control embankment). Where suitable market values cannot be found, non-market values are assigned to the stream of benefits (selected from the academic literature). A depreciation calculation is included in the accounting, and a discount factor applied over a 50-year time horizon to provide total present value for each benefit stream. On the costs side, maintenance costs are obtained from a range of sources (including farmers, rural contractors, and published costs of operations such as drainage ditch clearance). Costs for each type of linear feature (e.g. hedgerow, wall, drainage ditch) are also discounted over the 50-year time horizon to provide a total present value estimate.

### 4.3.1 Detail of the model: calculations for attributing values

The model is a basic form of Cost-Benefit Analysis (CBA) which examines streams of costs (in the form of restoration, maintenance and repair costs) and benefits over a multi-year period (currently the time frame utilised in the model is 50 years, but this can be altered if desired). Figure 14 illustrates the overall model structure.

The operational steps are as follows:

*Step 1:* Identify ecosystem services originating from linear features under each of the four categories of ecosystem service.

Ecosystem services generated by linear features

*Step 2:* For each service identified determine the nature of benefits flowing, and who benefits:

- The form of the benefits flowing from each service
- The magnitude of each flow of benefits
- The number and type of beneficiary (e.g. farmers, visitors, community residents, etc.)

Flows of benefits arising from each service

Number and type of beneficiaries

*Step 3:* Determine how each benefit flow will be measured (e.g. a benefit such as livestock management might be measured in terms of sheep protected per kilometre of wall; sense of place might be measured by kilometre of linear features in a defined area and an indicator reflecting strength of the association between walls, the landscape, and well-being of community residents). Indicators are identified for each ecosystem service which produces a flow of benefits. Additional indicators can be used to modify the flow of benefits from a particular service depending on its quality, magnitude, or strength. Thus, an indicator can assess the condition of linear features and modify the benefit flows generated from services by decreasing or increasing the size of the indicator. A feature (such as a hedgerow) in poor condition would be given a low indicator score, thus reducing the level of benefits flowing from a particular service. Different indicators can be allocated to the same area/section of linear features for each service provided, if necessary, to account for variability of benefit flows resulting from a particular condition. Linear features in poor condition, for example, may have a low condition indicator score in relation to benefit flows relating to livestock management, a medium level score in relation to ecological services (as the feature may still provide habitat for certain species), yet maintain a high score for cultural heritage due to its historical significance in the area.

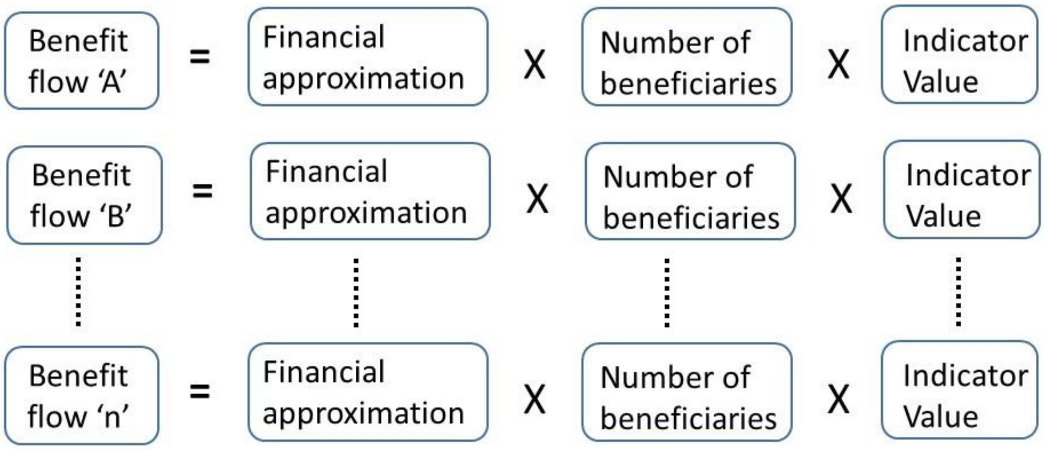
Indicators for each flow of benefits

*Step 4: Valuation of benefits.* The services that produce benefit flows for identified sectors of society are valued using surrogates, or 'financial approximations', which match the magnitude of a benefit received with a market-based estimation of its worth. Since benefits such as 'sense of place' do not have market values, some form of approximation is required. Financial approximations are intended to 'reflect the value' of a benefit acquired, rather than be regarded as a fixed measure of monetary worth. The aim is to identify the price that is actually paid in market transactions for similar categories of benefits (i.e. what people actually pay to acquire a similar benefit). The CBA accounting framework recognises this may not reflect the actual worth of a flow of benefits to an individual, it is only an approximation based on ability to pay a market price (which not everyone may be able to afford). The advantage is that it allows us to represent flows of unpriced social and environmental benefits in terms of monetary value, which can then be compared to each other, and to construction, restoration, maintenance, and repair costs.

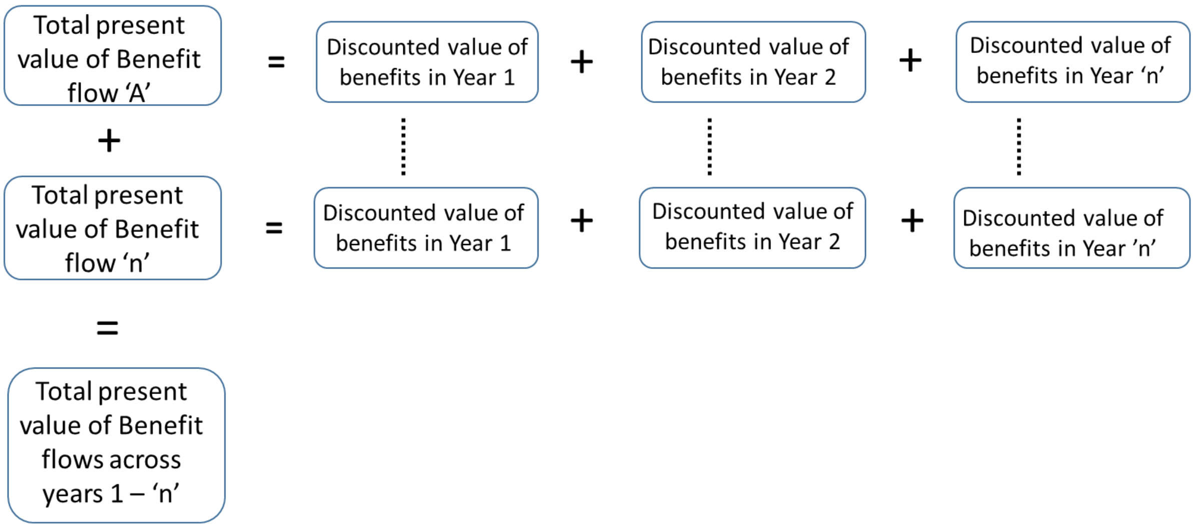
The model outcomes are clearly sensitive to the choice of financial approximations, so discussion is required, and agreement on the values selected. One clear benefit of the model is that different financial approximations can be applied to explore the sensitivity of the model outcomes to changes in the size of approximations used.

Financial approximations for each benefit flow & category of beneficiary

*Step 5:* Financial approximations are multiplied by both the number of beneficiaries (there may be several categories of beneficiary for each benefit flow), and by the indicator selected for the benefits flowing from each different service provided.




*Step 6: Discounting over time.* Standard discounting approaches (HM Treasury, 2018) are then applied over the relevant time frame for both costs and benefits. The model currently uses the Green Book Treasury Guidance to select 3.5% as the discount rate. For each year of the time period the benefits are assessed and then discounted back to present value. Discounted values for each year across the time period (currently 50 years) are summed to provide results in terms of total present value of future flows of costs and benefits, which can then be compared.




The final output from the model is therefore not a measure of the value of linear features at a single point in time, but a present value measure of the benefits flowing to society from the services provided over a 50-year time period, along with a measure of the present value costs of maintaining a constant flow of those benefits over that period.

Tables 5 and 6 below are a simplified illustration for the key elements of the model (only cultural services are shown, although the same approach is taken for all service categories). Each identified 'flow' of services is represented on a separate line, which enables service flows to be valued individually and in categories (i.e. provisioning, supporting, regulation, cultural). The model has been designed to account for variable sizes of the selected 'character area' (i.e. the area of interest for analysis). The Tables summarise how the model operates.

In Table 5 each service flow is assessed through some form of indicator which measures the quantity or 'level' of service delivered. Indicators vary with each identified service flow depending on the type of service and the nature of the beneficiaries. In the Lower Severn Vale linear features model, the majority of indicators are measured on 1 – 5 scales which are then scored by stakeholders with specific expertise. For example, the level of livestock management services delivered by a particular set of linear features in a landscape might be assessed by livestock farmers, while the contribution to ecological biodiversity in an area might be assessed by local ecologists.[11]

The 'level' of each service flow is then modified by assessment of its condition. Condition is a key variable and assessed on a 1 – 5 scale (where 1 = very poor condition such as a hedgerow with significant gaps; 5 = very high condition with well-maintained features). Condition assessment requires ground surveys in order to observe the current state of linear features. For the purposes of this study, in relatively small areas, ground assessments were made by project team members based on driving around the case study sites to obtain a general indication of state of the linear features. In practice a condition survey would be required (perhaps based on geographic information system (GIS)-supported sampling) in order to arrive at an average condition score for a defined area. It would not be possible to undertake a condition survey without some form of 'ground-truthing' since care must be taken to differentiate between a more permanent deterioration in the condition of a feature, and temporary aberrations (such as a collapsed wall, which can occur, for example, from a period of bad weather).

Condition is also related to current functions of linear features; features that are functional (in the sense that they continue to perform the function for which they were originally created) are likely to have more resources invested in maintenance and restoration and are likely to be more robust, than those that no longer perform an economic function.

Table 6 is a continuation of the model structure assigning monetary value to each ecosystem service flow. A financial approximation (a 'proxy') is assigned to each service flow. Wherever possible, proxies are based on market prices of similar goods and services to those delivered through the ecosystem service being valued. Thus, for example, in order to assess the value of livestock shelter provided by linear features the price of purchasing animal shelters is utilised. The match is not perfect as a purchased livestock shelter would have to be in a fixed position and owing to construction would have a limited lifetime (compared to a wall or hedgerow). These factors are also taken into consideration in the determination of expenditure required to provide an alternative to the shelter function, and hence value, provided by linear features.

[11] Note: as the project is a small-scale pilot to develop a valuation model the results presented in this paper arise from assessments made by the project team following documentary analysis and multiple field visits. In practice a certain amount of empirical data would be collected from a range of stakeholders.

Where no market prices exist for specific ecosystem services provided (e.g. the value of biodiversity, or the aesthetic value of landscape) then published non-market valuation studies are used as a guide to determine the value of the benefits flows.

Financial proxies are multiplied by the level of services provided for the total length of linear features in the defined area of interest to derive an annual monetary value for the flow of each defined benefit in the model.

The remainder of the model accounts for depreciation in the condition of linear features over a 50-year time horizon and discounts the stream of annual benefits back to present value (using a 3.5% discount rate).

*Table 5: Part 1 of the structure of the accounting model for linear features*

| Service category | Linear feature length (Separate entry for each type of feature within area of interest, and for each applicable ecosystem service) | No. & type beneficiaries | Service(s) & Function(s) delivered | Indicator | Condition |
|---|---|---|---|---|---|
| Cultural | Km of the feature in the selected area | Variable by area | Variable with case study areas | Tailored to specific service delivered | Variable by linear feature type – requires field survey |
| Supporting | | | | | |
| Provisioning | | | | | |
| Regulating | | | | | |

*Table 6: Part 2 of the structure of the accounting model for linear features*

| Service category | Financial proxy | Current value generated (per year) | Depreciation over 50 yrs | Value generated per yr | Total value | Present value of benefit stream |
|---|---|---|---|---|---|---|
| Cultural | Closely linked to service characteristics of each feature in relation to ecosystem service provided | Based on linear extent of each type of feature & number of beneficiaries | Variable 0.03 – 0.4 | 1 – 50 yrs | Over 50 yr cycle | Discounted to present |
| Supporting | | | | | | |
| Provisioning | | | | | | |
| Regulating | | | | | | |
| Total discounted benefits (over 50 yrs)<br>Total discounted maintenance costs<br>Benefit – Cost ratio | | | | | | £ Benefits<br>£ Costs<br>B-C Ratio |

### 4.3.2 Scale and aggregation issues

The model converts ecosystem services to benefit 'flows' per kilometre (km) of linear feature, thus it is capable of operating over a wide range of geographic scales. The issue with scale of operation relates to the most suitable level at which to assess the individual streams of benefits. Some benefit streams can be assessed at a very detailed level (e.g. habitat per km of hedgerow; number of species utilising a given linear feature) while others require placing a particular location into a larger context. Measures of historic value (based on the potential time-depth and legibility of linear features and their inter-relationships with recorded and observed features and heritage assets such as ancient trackways and historic buildings), and some of the ecological processes such as drainage and wildlife movements all require understanding of a specific locality within a larger landscape.

Utilising a high-resolution approach, whereby areas of approximately $1km^2$ form the basis for accounting, provides capacity for managing variability while retaining the ability to identify the inter-relationships of linear features with recorded and observed features and heritage assets. At this level indicator scores can be aggregated across an area without losing variability (except in cases where there is a large amount of small-scale variability in the features), although for the ecological, cultural and historic benefit streams assigning the indicator values requires expert input. The pattern of individual $km^2$ grid square scores can then be explored across larger landscape areas. Aggregation of scores across larger areas based on case study examples (such as the three areas explored here) presents difficulties unless there is a uniform landscape pattern. Where the landscape is more variable expert input is likely to be required to assign indicator scores to each grid square. Where expertise is limited the model is likely to be more useful (and accurate) if representative case study areas are selected, the benefit streams valued, and then scaled up to larger defined landscape areas. The three case study areas utilised in the present study provide broadly similar values and could be utilised to assess the wider landscape adjacent to the river down through the LSV, but should not be applied to areas further away from the river (edging onto the Cotswold escarpment for example).

## 4.4 Model outputs

Ecosystem service values were calculated in two ways: first, by developing a model based on values assigned to the LSV as a whole; and secondly, through aggregating values based on case studies which were selected to reflect the variability in density, function, and condition of linear features across the project area. Case study areas were relatively small (around $7.5Km^2$) and selected to represent specific characteristics as set out in Section 3. Even within these areas there was some variability in condition, function, and utilisation of linear features. Dominant characteristics of case study areas were therefore utilised to assess level of service flows and condition. The accounting model is currently based on a 50-year time horizon and present values (PV) of ecosystem service flows are discounted using a

3.5% discount rate[12]. Sensitivity testing on the discount rate and time horizon have not been carried out.

### 4.4.1 Assessing values of ecosystem services across the project area

*Model outputs*

Tables 7 to 9 describe the model outputs in terms of values of the benefit flows from ecosystem services, the maintenance costs, and the benefits to costs ratios for the different categories of ecosystem service (Supporting, Regulating, Provisioning, Cultural) and the groups of linear features (Boundary features, Drainage and flood control, Communications). The results for the Awre Peninsula (Table 7) indicate that total present value of the benefit flows from ecosystem services are equivalent to £13.254 million, while maintenance costs over the period amount to £2.489 million giving a benefit to cost ratio over the 50-year time period of 5.32. Note that Section 4.3.1 of this report describes how the values are calculated for each linear feature and ecosystem service delivered. The benefit flows are fairly evenly split between the three categories of linear feature, although boundaries (walls and hedgerows) account for a larger proportion of benefits (38.8%) than either of the other two categories. In terms of value of benefit flows, the largest proportion (48.2%) arises from supporting services (largely the ecological values from hedgerows), while cultural services contribute 21% of the total value.

Each of the three case study areas follows a similar pattern in terms of the value of benefit flows, with Boundary features proving the largest proportion of benefits (almost half the total value in the Arlingham case study area), with drainage and flood control features providing the lowest level of benefits. This is mainly due to the relatively smaller length of flood control and drainage features in comparison to boundary features. It is also worth noting that in Arlingham almost one third (32.5%) of the benefits arise from Cultural ecosystem services, a higher proportion than for the other two case study areas. This is not surprising given the historical significance of settlement in the case study area, the existence of several ancient routeways traversing across the area, and high legibility, time-depth, and inter-relationships of the linear features in the wider landscape. The Arlingham Peninsula also has the highest overall level of benefits of the three areas examined at £16.65 million, and the largest benefits to costs ratio (7.38).

[12] HM Treasury (2018) The Green book: Central Government Guidance on Appraisal and Evaluation.

*Table 7: Total Present Value of Ecosystem Services: Awre Peninsula*

| Service type | Field Boundaries | Drainage and Flood Control | Communications | Total Present Value (PV) for all linear features (£) | % Contribition to PV of service types |
|---|---|---|---|---|---|
| **Supporting** | 1,979,386 | 2,015,862 | 2,398,080 | **6,393,328** | 48.2% |
| **Provisioning** | 1,755,525 | 376,952 | 321,931 | **2,454,409** | 18.5% |
| **Regulating** | 187,487 | 1,416,629 | 21,500 | **1,625,616** | 12.3% |
| **Cultural** | 1,223,972 | 322,806 | 1,233,962 | **2,780,740** | 21.0% |
| **Total PV (£)** | **5,146,371** | **4,132,249** | **3,975,474** | **13,254,094** | 100.00% |
| % Contribution to PV of linear feature categories | 38.83% | 31.18% | 29.99% | 100.00% | |
| **Maintenance costs (£)** | **£846,103** | **£368,253** | **£1,275,336** | **£2,489,692** | |
| Benefit-Cost Ratios | 6.08 | 11.22 | 3.12 | 5.32 | |

*Table 8: Total Present Value of Ecosystem Services: Arlingham Peninsula*

| Service type | Field Boundaries | Drainage and Flood Control | Communications | Total Present Value (PV) for all linear features (£) | % Contribition to PV of service types |
|---|---|---|---|---|---|
| **Supporting** | 2,376,262 | 2,525,133 | 2,282,972 | **7,184,366** | 43.1% |
| **Provisioning** | 1,866,199 | 296,625 | 514,196 | **2,677,020** | 16.1% |
| **Regulating** | 195,662 | 1,152,901 | 34,341 | **1,382,904** | 8.3% |
| **Cultural** | 3,487,920 | 66,608 | 1,859,846 | **5,414,373** | 32.5% |
| **Total PV (£)** | **7,926,043** | **4,041,266** | **4,691,354** | **16,658,663** | 100.00% |
| % Contribution to PV of linear feature categories | 47.58% | 24.26% | 28.16% | 100.00% | |
| **Maintenance costs (£)** | **£899,267** | **£284,089** | **£1,073,149** | **£2,256,505** | |
| Benefit-Cost Ratios | 8.81 | 14.23 | 4.37 | 7.38 | |

*Table 9: Total Present Value of Ecosystem Services: Elmore Area*

| Service type | Field Boundaries | Drainage and Flood Control | Communications | Total Present Value (PV) for all linear features (£) | % Contribition to PV of service types |
|---|---|---|---|---|---|
| **Supporting** | 2,649,767 | 2,705,499 | 2,446,041 | **7,801,308** | 48.7% |
| **Provisioning** | 1,880,860 | 382,924 | 514,196 | **2,777,980** | 17.3% |
| **Regulating** | 195,904 | 1,400,770 | 34,341 | **1,631,014** | 10.2% |
| **Cultural** | 1,867,724 | 37,656 | 1,906,635 | **3,812,014** | 23.8% |
| **Total PV (£)** | **6,594,255** | **4,526,849** | **4,901,212** | **16,022,316** | 100.00% |
| % Contribution to PV of linear feature categories | 41.16% | 28.25% | 30.59% | 100.00% | |
| **Maintenance costs (£)** | **£899,267** | **£435,201** | **£1,073,149** | **£2,407,617** | |
| Benefit-Cost Ratios | 7.33 | 10.40 | 4.57 | 6.65 | |

## 4.5 Discussion points

The accounting model is a pilot to test the feasibility of taking an ecosystems services approach to valuing the cultural heritage value of linear features. Three categories of linear features were examined: boundary features; drainage and flood control features, and communications, across three case study areas.

### 4.5.1 Scale

The cultural heritage scoring system comprising individual scores for legibility, time-depth and inter-relationships was applied at the 250mx250m cell level using the National HLC. This approach worked well for scoring legibility but required more detailed examination of a wider area to assess time-depth and inter-relationships. The cell areas were too small to identify time-depth without some understanding of the wider context (settlement and linear feature pattern) in which they lay. For example, it is not possible to identify the age of a hedge, or flood embankment, without being able to access more information about the landscape and utilisation of the wider area. In order to accomplish this at least four (of the 250mx250m) cells were utilised (i.e. an area 500mx500m, or ¼ $km^2$).

The scale at which boundary features deliver ecosystem services, and the scale at which benefit flows are measured is significant. Ecosystems operate at different and overlapping scales, and while valuing the benefits of ecosystem services at operational scales is attractive, it is too difficult incorporate into a simple valuation model. The aim of the model is to value the benefits flowing from specific categories of linear features, and not from ecosystems as a whole, and thus the extent and condition of each category of linear feature in a defined area takes precedence in the model. In addition, age of linear features (which might incorporate more complex or richer ecosystems is partially accounted for through assessment of time-depth and condition. One aim of the study was to explore the size of area most suited to assessing benefit flows as this would enable more effective scaling up from a selected size of grid square to larger landscape scale areas. Work on dry stone walls in the Pennines had indicated the problems associated with assessment of ecosystem services and benefit flows from both case study areas (covering approximately 7.5km$^2$) and large areas (e.g. National Park scale). At the large scale the variability in benefit flows (and consequent value of features) could not be accounted for, resulting in broad average scores awarded to large landscape scale areas, and 'loss' of smaller areas of extremely high or low benefit flows. At the smaller case-study scale it became easier to capture the variability across an area and ensure relatively small areas of high/low benefit flows were taken into account, although there were still issues in aggregating the results to larger areas.

The initial focus of the current study was not only to expand the assessment of benefit flows to a wider set of linear features, but also to explore the potential for utilising remotely sensed and GIS data at smaller scales that might then enable a more efficient means of aggregating the value of benefit flows from ecosystem services across large areas. The project started with an examination of ecosystem services at the 250x250m cell level, but it soon became apparent that many of the benefit flows (supporting, regulating and cultural) required assessment at a larger scale in order to understand condition, functionality, ecological processes, and cultural value. For example, a hedgerow can be measured at the 250x250m level and to a certain extent its condition can be assessed, but what is not apparent is its role in the larger landscape, its cultural value in the locality, how it connects to other linear and non-linear features (inter-relationships), its role in providing a wider habitat or wildlife corridor, or its functionality (i.e. current utilisation). In order to identify and capture the full value of benefit flows a scale of somewhere between 0.5 and 1km$^2$ provides more scope. Table 10 below offers an overview of issues surrounding the scale at which ecosystem services and benefit flows are assessed.

*Table 10: Overview of issues surrounding the scale at which ecosystem services and benefit flows are assessed*

| Scale | Advantages | Disadvantages | Issues |
|---|---|---|---|
| 250 x 250m (0.0625Km$^2$) | Measurement of linear features relatively easy<br><br>Condition can be assessed<br><br>Time-depth scores can be assigned (in particular to point | Loss of connectivity; particularly in relation to ecological processes and cultural connectivity<br><br>Difficult to score cultural value as linear features isolated<br><br>Ecosystem service benefit flows need to be assessed | Functionality not apparent (e.g. agricultural utilisation)<br><br>Condition requires ground checking |

| Scale | Advantages | Disadvantages | Issues |
|---|---|---|---|
| | information such as individual buildings). | in terms of features in surrounding grid squares | |
| 1,000 x 1,000m<br><br>(1Km²) | Cultural ecosystem services easier to assess: time depth and legibility are apparent<br><br>Supporting services can be identified and assessed<br><br>Ecological processes more apparent across larger areas. | Surrounding areas need to be examined to fully understand benefit flows from cultural services, e.g. Inter-relationships<br><br>Surrounding areas need to be examined to understand benefit flows from regulating services (e.g. flood control); some ecological processes not apparent without looking at wider surrounding area.<br><br>Provisioning services difficult to assess, although land utilisation can be identified | Functionality not apparent<br><br>Condition requires ground checking<br><br>Land utilisation requires ground checking<br><br>Some loss of detail, particularly where many small-scale features occur, or high variability in cultural value (e.g. where a square cuts across a village or significant time or ecological boundary |
| 2,500 x 3,000m<br><br>(7.5 Km²) | Improved capacity to 'read' the landscape and identify relationships<br><br>Cultural services easier to ascertain (e.g. inter-relationships, legibility, time-depth more apparent).<br><br>Larger scale ecological processes and benefit flows easier to understand and assess.<br><br>Agricultural (Provisioning), settlement, and communications patterns become more apparent. | Variability can be lost<br><br>Cultural, regulating, provisioning and supporting services: Significant variability can occur across the area which can be difficult to capture in a single score.<br><br>Tendency to average out assessment scores across areas of extreme value. | Functionality not apparent<br><br>Condition requires ground checking<br><br>Land utilisation requires ground checking<br><br>Aggregating scores across larger areas (e.g. landscape scale) becomes more difficult due to loss of variability in the scoring.<br><br>Average scores do not adequately reflect the level of variability; high value services can be subsumed into a lower average score. |

| Scale | Advantages | Disadvantages | Issues |
|---|---|---|---|
| >20Km$^2$ | Good for looking at large areas – including at a national and NCA scale - to get overall sense of significance of an area<br><br>Provides indications of where significant areas of cultural heritage value might occur<br><br>Data is readily available and digitised – can easily be converted to heritage value score | No information on utilisation or condition<br><br>No information on the inter-relationships of the features with the wider landscape, in particular other linear features such as routeways, farmsteads and other forms of communication<br><br>No information on the reasons for the pattern of field boundaries (e.g. whether removed, or more recent farming area);<br><br>historical connections / inter-relationships not made apparent. | Use density of field boundaries and time depth at grid square level (250m x 250 m) as a proxy for scoring cultural heritage value of the area.<br><br>Where density of linear features in combination with time depth is high it suggests high cultural heritage value.<br><br>assume that where field boundary density and time depth is lower the ecological value is lower |

### 4.5.2 Aggregation of values

The accounting model operates through identification of the number and type of person benefitting from a particular ecosystem service. By definition, if there are no beneficiaries then there is no value to a particular outcome or process. The level of benefits measured is clearly linked to the issue of scale of model application. Small areas will have smaller numbers of direct beneficiaries (e.g. number of farms in the case study areas), and the consequent value of benefit flows might be relatively low. When the model is applied to larger areas, in a rural setting, centres of population are more likely to be included and certain benefit streams (though not all) will be proportionally larger, a direct result of having larger numbers of residents who benefit.

The study has not considered the value of benefit flows, such as improved biodiversity or cultural heritage value of hedgerows, to wider society. An argument can be made that the entire population of England benefits indirectly through provision of wildlife habitat and heritage as improvements in these services lead to a general increase in social welfare, especially where unique, rare, or vital ecosystem services are provided. However, unless a national scale approach is being taken, it does not make sense to allocate benefits to large sectors of the population (even though they may benefit in some minor way from existence and option values) as this could result in large benefit levels for relatively small land areas. The approach taken here has been to focus on those directly benefitting from the services identified and to restrict benefit streams to two groups:

- Residents and local businesses located in the area that benefit directly from the ecosystem service.
- Visitors who benefit directly from their temporary stay.

The accounting model allows for greater populations of beneficiaries to be included when case study estimates are scaled up to include larger areas. The advantage of the approach is that is enables stakeholders to explore how marginal changes in the extent and/or condition of the stock of the asset alters the value of the service flows over time. This project has not concerned itself with measuring the inherent value of the current stock of linear features (i.e. the 'natural capital'), which requires a different valuation approach. Neither has the approach attempted to value ecosystem services such as carbon sequestration, which might have wider societal values. Although features such as hedgerows and soils (on embankments) might lock up carbon, that is not the primary function of the features explored in the study, and lack of resources prevented adequate consideration of such issues. The current accounting model thus provides a conservative assessment of the value of identified ecosystem services.

# 5 CONCLUSIONS

## 5.1 Introduction

The project has developed an ecosystem services accounting model for linear features in the landscape. The model was developed and tested in three case study areas of the LSV. Linear features were identified through utilisation of geospatial data, HLC and Ordnance Survey's Landscape Features being particularly valuable for the purposes of the project.

The ecosystem services were assessed using indicators tailored to each specific benefit stream identified as emanating from the range of services generated. Indicator scores for cultural heritage benefits were derived from an integration of legibility, time-depth, and inter-relationships factors for each specific category of linear features. Integrated scores were assigned across case study areas at the 250mx250m cell scale and then aggregated across each case study areas for inclusion in the accounting model. Function and current condition of linear features were taken into account through field visits and utilised to modify indicator scores. Each benefit stream was then assigned an approximate value (a proxy) using market values, and non-market values from the academic literature where that was not possible. Present values totals for each benefit stream were derived for each case study area across a 50-year time horizon, enabling comparison across case study areas and ecosystem service categories.

## 5.2 Lessons learned: Strengths and weaknesses of the approach

### 5.2.1 Weaknesses

*Gaps in the data:*
As with any modelling approach, a number of assumptions have been made regarding variables where data was not available (or available at the correct scale). These include:

- Length of field boundaries within case study areas were derived from GIS data and allocated to hedgerow or wall categories based on field surveys. The total length of field boundaries within case study areas may be underestimated as some boundaries are formed from forest edge and some from single lines of trees, which were calculated separately in the data.
- One drawback of utilising GIS data on density of linear features as a means for scoring legibility is the limited range of linear features included in the data set: routeways, for example, are not included and relatively very few linear features other than hollow ways and land use reclamation boundaries have been entered as individual entries on Gloucestershire Historic Environment Record (HER). On the other hand this could be provided as an additional layer, and the approach could also be modified to utilise a specific linear feature such as hedgerows in the determination of legibility.

- Drainage ditches and flood control barriers were calculated from OS map-based measurements within case-study areas. Field surveys identified a higher density of drainage ditches than those appearing on maps or in GIS data, in some cases drainage ditches and hedgerows together formed field boundaries. The length of drainage ditches and thus the value of ecosystem services provided is likely to be an underestimate. This could be improved with spatial data provided by an internal drainage board (data requested from the Lower Severn Internal Drainage Board arrived too late to be used in this study).
- Condition of linear features within case study areas was assessed through expert judgement during field visits. Condition is based on small localised situations that are aggregated up across the larger case study area. Ideally some form of sample surveying would be required utilising a template for data collection, and ensuring adequate coverage of variability across boundaries, aquatic, and communications features.
- Estimates have been made of the following:
    - Number of farm holdings/farmers in the case study areas based on OS maps and local business directories
    - Number of visitors in the case study areas. The assumption was made that 90% of visitors are day trippers, with only 10% staying overnight within the case study areas.
    - Proportion of walls contributing to biodiversity through provision of shelter/habitat.
    - Functionality of linear features for livestock management, shelter, crop protection, drainage, flood control and local level communications. Assumptions were made on the basis of condition and maintenance of linear features.

*Current functionality and condition*

Condition of linear features is closely related to functionality. Where features (e.g. walls, hedgerows, ancient routeways, drainage ditches) no longer perform the function for which they were constructed their condition tends to deteriorate. It can be difficult to differentiate between long-term deterioration of a feature, such as a hedgerow, where the functions are no longer valued, and temporary reductions in condition due to severe weather. Determination of condition thus requires some knowledge of agricultural activity in an area and expert judgement. That judgement must then feed into a process of understanding the impact of condition and function of linear features and their inter-relationships across a landscape.

*Local and inter-disciplinary engagement*

This project has considered how both data and narrative can be used as a framework for fieldwork by ecologists and other disciplines, and also by local communities. Whilst data collected on the ground can be collated into national datasets that can be read in relationship to the National HLC, ground survey needs to work below the grid-cell level of NHLC and with the more detailed grain of local

HLCs as explored in Appendix C. Historic characterisation can thus inform and in turn be informed by the results of ground survey, as it has in many parts of England. Of particular relevance to linear features is the development of methods for the assessment of field boundaries and of survey packs and tutoring for community groups, as developed for example in the High Weald AONB.[13] We consider that – whilst this project has focused on analysis and assessment of available data - it is critical not to lose sight of the importance of 'telling stories of landscape' as a tool for community engagement. Available data simply cannot be used on its own, it needs to be considered within the context of its own constraints and opportunities. It also requires time and expertise for analysis, with an ability to understand places in context and identify features such as the character of historic buildings, farmsteads and routeways that are often not recorded in HERs.

### 5.2.2 Strengths of the model

The accounting model is based on a 'return on investment' approach, which compares values of a range of benefit flows to expenditure on maintenance over a specific period of time (in this case 50 years). The model takes the current stock of linear features as a given and does not try to compute a value of the stock; it only values the benefits (in terms of ecosystem services) that flow from the current level of stock, and the costs of maintaining that flow of benefits over the time period of interest.

*Utilisation of GIS data*

The methodological approach incorporates GIS data which provides a range of information within defined areas, including: population, agricultural land, forest cover, field boundaries, public rights of ways and other linear features. In addition, historical information can be mapped and added to the GIS data. Utilisation of GIS data enables more rapid assessment of larger land areas, an eliminates the need undertake sampling approaches in order to determine length of certain linear features. It also enables a desk-based approach for large area studies, supported by limited levels of field work for assessing condition and function of linear features, and ground-truthing and updating of GIS data.

*Flexibility*

Incorporating a GIS approach provides a great deal more flexibility in size and location of areas selected for analysis. It also makes the process of scaling up results to larger areas easier through provision of information at different scales.

The model allows for flexibility in the following:

- Application across variable time scales (the current model is set at 50 years) although longer time-scale run into problems associated with discounting monetary value over time.

[13] High Weald AONB website (http://www.highweald.org ) for Routeway Survey Pack and the Field Systems in the High Weald Project supported by Historic England.

- Application across variable spatial scales (though once scale gets below 5km$^2$ benefits are likely to be low due to the small number of beneficiaries available).
- Changes in function/condition of linear features.

*Transparency*
The model is transparent. The data incorporated into the model is clearly visible, along with the selection of financial proxies and the calculations used to derive value.

*Enables comparisons*
The models can be varied in a number of ways to enable comparisons and exploration of marginal changes due to alterations in the level of key variables. The model enables:
Comparison across time scales.

*Comparison between areas*
Exploration of the impact of changes in key variables (e.g. length of feature, condition, functionality).

*Exploration of ecosystem service values by beneficiary type*
Values of ecosystem services can be explored for each individual service identified, for categories of ecosystem service (i.e. cultural, provisioning, supporting, regulating), for different categories of linear feature (e.g. drainage and flood control, boundaries), and for different types of beneficiary.

## 5.3 Applicability of the method at a national scale

### 5.3.1 Scale

Scale of application and aggregation of values across large areas remains problematic. The utilisation of GIS data has illustrated the benefits of this technology, particularly in relation to the ability to examine large areas relatively quickly. A grid overlay (perhaps at 0.5km$^2$ scale) enables relatively rapid scoring of cultural heritage values. Using case studies of around 7 or 8 km$^2$ enables adequate interpretation of the wider context in which linear features are situated and the ability to capture variability across a larger area. Challenges remain, however, as a result of the nature of the data. Particular issues include:

- Completeness: GIS information does not provide information on age or current utilisation of features.
- Quality and age of the data: GIS information can be out of date and no longer accurately reflect the situation on the ground (e.g. removal or creation of hedgerows, clearing/planting woodland).

- Function and condition: current utilisation and value of functions performed by linear features can only be obtained from (sample) surveys that extract such information from relevant stakeholders (e.g. farmers). Current condition (linked to function and utilisation) can only be ascertained from ground surveys and site visits.
- Interpretation: historical values of linear features need interpretation by experts (or trained individuals) who can identify time-depth and interpret inter-relationships in the wider context.

Larger-scale ecological processes might not be captured through a GIS approach, particularly any changes or trends in the function of those processes, which might affect current or future value. The same issues apply in terms of data quality and the extent to which it reflects the current situation and relevant to the wider area.

In terms of aggregating from case study areas to larger landscapes it is possible to do this with some validity over relatively small areas. Average case study values can be applied across larger areas, as long as they are representative of the larger area (e.g. in this case the whole of the LSV project area and the Severn and Avon Vale NCA). NHLC has considerable potential as a framework for aggregating the land area occupied by different types of enclosed land (which occupy over 70% of England's land area), woodland and other HLC types. It is doubtful, however, whether values could be aggregated up to national level with any validity at this point as we have only explored a very small and particular landscape area.

### 5.3.2 Geospatial data: limitations and opportunities

*Geographic extent*
Key datasets used this analysis are restricted to England; namely the NHLC and OS Landscape Features data layers. It is not clear whether the coverage of these data sets will be extended to Scotland, Wales and Northern Ireland in future.

*Data openness*
The use of freely-available and open data is critical to producing a reproducible, low-cost methodology that can be successfully applied to other study areas in England. Currently, the main dataset for modelling woody linear features – OS Landscape Features - is non-open data that can only be accessed for specific projects under licence from the OS. There were no issues acquiring this data however, and there is no reason to suggest that this will be problematic in future. In fact, the situation is likely to improve as the OS continues its programme of liberating licensed data products as open data. HER data is another important source of data that may not be open, depending on the policy of the local authority holding the data. In this case, Gloucestershire County Council charged a fee (£292.80) for accessing and distributing their HER data under a commercial-use licence. Other non-open datasets used in the project included the Land Cover Map Vector 2015 data from the CEH (used to calculate agricultural land area), and public rights of way data (PROW) from Gloucestershire County Council. Agricultural land area can be calculated with lower-resolution, freely-available

raster land cover data from the CEH however, while local authorities are usually forthcoming with PROW data when asked.

*Data quality*
Data quality has already been discussed in some detail in relation to the OS Landscape Features data. Though there are significant gaps in the data and accuracy issues, it's an extremely useful resource and the only useable dataset for farmland boundaries that has national (albeit England-only) coverage. All spatial data are subject to quality issues and an assessment needs to be made by the user/research team as their usability. For example, the NHLC gridded data is necessarily an abstraction of local, more refined HLC polygon data, but allows nation-wide reproducibly – a judgement therefore needs to be made on the fitness for purpose of this dataset based on an assessment of the robustness of the methodology and the original data used to produce it.

*Addressing data gaps*
There are many ways in which the data gaps revealed in this project might be addressed with further work. Perhaps the most important of these is developing an automated (or at least semi-automated) technique for helping to assess the condition of woody linear features. An obvious starting point for doing this would be to investigate the use of high-resolution digital surface models (i.e. lidar) for determining the density and condition of hedgerows. Manual editing of the OS Landscape Features data in conjunction with aerial imagery may also help to improve the data, though this will only likely be feasible for smaller study areas. Time constraints meant that other datasets that could potentially provide useful input data into the scoring and modelling were not investigated. These include data on habitat and ecology, soils, land use, and drainage.

*GIS skills requirement*
As this project required management and analysis of a fairly complex geospatial database, similar work would require the input of a GIS specialist with intermediate to advanced level skills in GIS. If subsequent researchers wished to run the analysis using the code developed in this project, then skills in the R programming language would be required.

*Code*
R programming code has been developed for the legibility and time depth indicators. In time, it is hoped that code for the interrelationships indicator will be developed, and also the heritage accounting model, meaning the analysis for the entire project will be documented in code and can be fully reproduced. The code will be made available under an open licence via Github.

### 5.3.3 Model improvement

The accounting model is flexible enough to handle the increase/decrease in the number of benefit streams identified, variations in population, and changes in the duration of the accounting period. Current utilisation is based on a 50-year time horizon. Given that many of the ecosystem services operate over much longer time horizons, and in some cases the value of services can increase rather than decrease over time (e.g. the ecological value of hedgerows can be much higher for ancient hedgerows), one potential area for improvement is enabling a more flexible discounting procedure over longer time periods. This would enable sensitivity testing on the effects of different discount factors and exploration of how values of different ecosystem services alter over long time periods (e.g. 100 years).

A second key area for improvement requires increasing the flexibility of the model to enable variability across areas to be accounted for more accurately. In the current accounting system uniform indicator scores are assigned across each case study area, which to a certain extent masks local variation and differences. This is a particular issue where case study areas incorporate significant historical boundaries that result in a wider range of scores assigned to the grid overlay of 250mx250m cells. This would be relatively straightforward to undertake for cultural heritage values, but would significantly increase model complexity and utility if it were to be applied to all benefit streams included in the model.

# 6 REFERENCES

Allen, J. (1992) A Reconnaissance Map of Medieval Ploughlands in the Vale of Berkeley, Gloucestershire and Avon. Transactions of the Bristol and Gloucestershire Archaeological Society 110, 87–97.

Allen, J. (2001) Land-claim and sea defence: labour costs of historic earth banks in Holocene coastal lowlands, NW Europe. Archaeology in the Severn Estuary 12, 127-134.

Allen, J. (2008) Romano-British iron making in the Severn Estuary Levels: towards a metallurgical landscape. Archaeology in the Severn Estuary 19, 71-119.

Allen, J. and Fulford, M (1987) Romano-British Settlement and Industry on the Wetlands of the Severn Estuary. Antiquaries Journal, 67, 237-289.

Allen, J. and Fulford, M (1990a) Romano-British and later reclamations on the Severn salt marshes in the Elmore area, Gloucestershire. In, Transactions of the Bristol and Gloucestershire Archaeological Society, 108, 17-32.

Allen, J. and Fulford, M. (1990b). Romano-British wetland reclamations at Longney, Gloucestershire, and evidence for the early settlement of the inner Severn Estuary. Antiquaries Journal, 70 (2), 288-326.

Bell, M. and Neumann, H (1997) Prehistoric intertidal archaeology and environments in the Severn Estuary, Wales. In World Archaeology 29(1), 95-113.

Brown, A., Bell, M., Timpany, S., and Nayling, N. (2005) Mesolithic to Neolithic and Medieval coastal environmental change: intertidal survey at Woolaston, Gloucestershire. Archaeology in the Severn Estuary, 16, 67-83.

Council of Europe (2000) European landscape convention. US/ICOMOS Scientific Journal, 2, 88-92.

Crowther, S. and Dickson, A. (2008) Severn Estuary Rapid Coastal Zone Assessment Survey: National Mapping Programme Report. Gloucestershire County Council Archaeological Service for Historic England. At https://historicengland.org.uk/research/research-results/recent-research-results/south-west/severn-estuary-rczas-nmp/

Crowther, S. and Dickson, A. (2016) An Archaeological Survey in the Severn Vale, Gloucestershire: A Highlight Report for the National Mapping Programme. Report by Gloucestershire County Council for Historic England. https://research.historicengland.org.uk/Report.aspx?i=15715

Dickson, A. (2006) Frampton on Severn: Aggregate Levy Sustainability Fund: Archaeological Aerial Survey National Mapping Programme Report. Gloucestershire County Council Archaeological Service.

Exegesis and Locus Consulting (2017) National HLC Stage 5: Final Report. Report for Natural England and Defra.

Green, C. (1995) Trows and the Severn Coastal Trade. Archaeology in the Severn Estuary 6, 97–113

Green, C. (1996) The Forest Ports of the Severn. Archaeology in the Severn Estuary 7, 107–113

Hoyle, J. (2006 revised 2013) Historic Landscape Characterisation. Gloucestershire, Cotswolds Area of Outstanding Natural Beauty and Wye Valley Area of Outstanding Natural Beauty. Report by Gloucestershire County Council for English Heritage. http://archaeologydataservice.ac.uk/archives/view/gloucs_hlc_2013 /

Janik, J., Dickson, A. and Priest, R. (2011) An Archaeological Aerial Survey in the Cotswold Hills: A Report for the National Mapping Programme. Typescript. Gloucestershire County Council Archaeological Service and English Heritage.

Margary, I. (1973) Roman Roads in Britain. London: John Baker

Moore, T. (2006a) The Iron Age. In N. Holbrook, & J. Juřica (eds.) Twenty-five years of Archaeology in Gloucestershire: a review of the new discoveries and new thinking in Gloucestershire, South Gloucestershire and Bristol. 1979-2004. Bristol and Gloucestershire Archaeological Report No.3. Kemble: Cotswold Archaeology

Moore, T. (2006b) Iron Age societies in the Severn-Cotswolds: developing narratives of social and landscape change. BAR British Series 421. Oxford: Archaeopress.

Newman, R. (1983) The effect of orcharding and the cider industry on the landscape of West Gloucestershire c.1600-1800. Transactions of the Woolhope Naturalists Field Club 44 (2), 202-214.

Pannett, D. (1987). Fish weirs of the River Severn. Folk Life, 26, 54-64.

Price, E., and Spry, N. (2004) Notes on a Timber Trackway Close to the River Severn at Hinton. Glevensis 37, 42.

Powell, J., Lake, J., Gaskell, P., Courtney, P. and Smith, K. (2018) Developing an Ecosystem Approach – dry stone walls in the Peak District National Park. Report for Historic England. Research Report Series 43-2018.

Putley, J. (1999) The Riverine Dean: The Maritime and Waterfront Archaeology of the Forest of Dean. Dean Archaeological Group Occasional Publication 5. Lydney.

Roberts, B. and Wrathmell, S. (2000) An atlas of rural settlement in England. London: English Heritage.

Roberts, B. and Wrathmell, S. (2002) Region and place: a study of English rural settlement. English Heritage.

Rowbotham, F. (1978) The River Severn at Gloucester with Particular Reference to its Roman and Medieval Channels. Glevensis Gloucestershire and District Archaeological Research Group 12, 4-9.

Small, F. and Stoertz, C. (2006) Gloucestershire: Forest of Dean NMP, National Mapping Programme Report. English Heritage. https://content.historicengland.org.uk/images-books/publications/forest-of-dean-mapping-project-nmp/FoD_Final_Doc_web.pdf

Stanik, N., Aalders, I. and Miller, D. (2018) Towards and indicator-based assessment of cultural heritage as a cultural ecosystem service – A case study of Scottish landscapes. Ecological Indicators 95, 288-297.

Sylvester, A. (2004) Settlement and structures of the Severn Estuary region as evidence of wetland-dryland interaction in the Iron Age. Archaeology in the Severn Estuary 15, 9-30

# 7 APPENDIX A: DATA ANALYSIS FOR TIME DEPTH

## 7.1 Introduction

Historic patterns of enclosure, if the results of intensive fieldwork (as carried out over decades at Frocester) are not available, provide the most rapid initial framework for considering the age of linear features in an area. These have been mapped in the project area through Historic Landscape Characterisation (HLC). Analysis of HLC data used the National and Gloucestershire datasets. The HLC of Gloucestershire, undertaken between 2000 and 2002, was one of the first to be completed (Hoyle 2006).

## 7.2 Using National HLC

The Broad Enclosure Types established for the National HLC project[14] fall into three broad categories of enclosures that allow the identification of areas dominated by, typically:

- Ancient fields (broadly pre-1750) – Very High to High Significance.
- Pre-modern fields (broadly 1750-1939) – High to Medium Significance.
- Modern fields resulting from new enclosures or reorganisation in the post-1940 period). These would score 'Low'.

The datasets were examined so that five rather than three categories of Time Depth could be selected, using the following Broad (BT) and Narrow (NT) Types.

- Very high: Linear features in areas which have high potential for pre-1550 boundaries and survival:
    - NHLC BT Enclosed Land/ NT - Ancient Fields, Assart, Open Fields, Barton Demesne Fields, Grange Fields, Floodplain and Meadow, Croft, Unplanned Fields.
    - NHLC BT Unimproved Land (all NT in this BT e.g. Coastal and Intertidal Rough Ground).
    - NHLC Ancient Woodland and Wood Pasture.
- High: Linear features within areas of 16th-19th century enclosure that have retained coherent or fragmented patterns of medieval land use – these would align with Typically Ancient (Broadly pre-1750):
    - NHLC BT Enclosed Land/ NT - Piecemeal Enclosure.
    - NHLC BT Enclosed Land/ NT - Re-organised Field System, Unspecified.
    - NHLC BT Enclosed Land/ NT - Unplanned Fields.
    - NHLC BT Communications/ NT – Routeway.
- Medium: Linear features within areas dominated by post-1750 enclosure of common land, reorganisation of farmland and creation of ornamental

[14] National HLC, archived at http://archaeologydataservice.ac.uk

landscapes - Typically pre-modern (broadly 1750-1939), and resulting from post-1750 construction:
    - NHLC BT Enclosed Land/ NT - Planned Fields, Reclaimed Land, Smallholding.
    - NHLC BT Plantation/ NT – all.
    - NHLC BT Communications/ NT Canal, Road Transport, Railway Transport.
    - NHLC BT Woodland, all other narrow types.
- Low: Fields with few or no internal pre-1950 boundaries but often earlier outer boundaries:
    - NHLC BT Enclosed Land/ NT - Amalgamated Fields, Post-War Enclosed Land, Restored Fields.
- Very low: Area redeveloped with few or no internal pre-1900 field and other boundaries except to housing and other forms of development:
    - NHLC BT Residential Extension / NT – all.
    - All other NHLC Types – Industrial, Commercial, Housing, Military etc.

## 7.3 Using Gloucestershire HLC

The same approach was used for Gloucestershire. We considered but rejected a scoring within a decimal point or 1-25 range – from recent to oldest historic landscape and boundary types - which would take account of the finer grain at which the data was captured. The provisional scorings are bracketed to the left of each entry in the list below. Very High is 21-25, High is 16-20, Medium is 11-15, Low is 6-10 and Very Low is 1-5. The key reason for this is marginal differences between some of the scores, in particular some of the Piecemeal Enclosure Types of 16th-19th century date. A solution would be to consider this issue in a national context and include a greater temporal range, from the recent past (early 21st century) to progressively earlier epochs in prehistory (which here would include for example, some of the Wentlooge Peats along the banks of the Severn, and at a national level would include unenclosed land resulting from prehistoric land clearance and settlement change).

- Very high: Linear features in areas which have high potential for pre-1550 boundaries and survival, because they:
    - are water bodies including the Severn corridor, notable in a national and international context for the survival and burial (and often exposure and reburial) of features dating from the prehistoric period:
        - 25) Water bodies (Category K) including the tidal rivers and estuaries of the Severn and Wye (K2). Also unenclosed estuarine waste (W2) which may contain evidence of estuarine activities such as fishing or trade.
        - 24) C4 is assarting (clearance under licence) of early woodland

- are dominated by enclosures of pre-1550 date:
    - 23) Surviving Early Woodland of probable medieval or earlier origin (C1).
    - 22) probable woodland boundaries of probable medieval or earlier origin (C3).
    - 21) cleared woodland of documented or probable medieval or earlier origin which may have retained earlier boundaries (C2).

- High: Linear features within areas of 16th-19th century enclosure that have retained coherent or fragmented patterns of medieval land use, resulting from:
    - 20) the piecemeal enclosure of medieval strip fields and also pastures in occasional use for arable, which may have one or more sinuous or curved boundaries responding to the outlines of medieval plough strips Smaller-scale inter-related enclosures which reflect medieval strip fields (A1).
    - 19) and larger-scale enclosures with more straight boundaries (A2).
    - 18) enclosures around riverine pastures and meadows which have high potential for early origins Riverine pastures (Category D) relating to alluvial soils, which historically served as wet grassland or as hay meadows and may also include linear ditches or boundaries which follow how strips of land were doled out. These may be riverine pastures doled out as meadows (D1), including many next to the Severn, non-riverine pastures fed for example from springs (D2), floated water meadows in river valleys developed between the 17th and 19th centuries (D3, NB NHLC places this in post-1750 period which does not correctly respect their date of origin), and valley-side meadows (D4).
    - 18 also) enclosures around medieval deer parks (E).
    - 17) piecemeal enclosure and reorganisation of earlier farmland or common land with fragmentary survival of outlines of medieval plough strips in boundaries. Enclosures which partly reflect medieval strip fields – A4 and the larger-scale A5 - may be a modified variant of A1 resulting from removal of field boundaries.
    - 16) enclosures around and sometimes subdividing unenclosed pastures – (B), not in LSV and enclosures which retain outlines of earlier pastures. Long thin boundaries subdivided into a 'laddered' pattern, probably from pastures (A6).
    - 16) enclosures of uncertain origin which are probably 18th century or earlier Enclosures where the former land use has not been identified (Category L) which may be irregular (L1) or regular (L2-3).
- Medium: Linear features within areas dominated by post-1750 enclosure, mostly regular in their form, planting and landscaping, due to:

- 15) reorganisation of earlier farmland or taking in unenclosed land for farmland, leaving no evident trace of earlier cultivation patterns Regular organised enclosure ignoring earlier cultivation patterns (A3).
- 14) enclosure within areas marked as unenclosed on 19th century maps (Category W) with regular boundaries (W1), irregular boundaries (W3) or be which are typically separated from adjacent farmland by boundaries (often similar to L3).
- 13) establishment of 17th to 19th century ornamental landscapes which have retained their outer boundaries (F1) or lost them (F2, being 33% of parkland in the county as recorded from c. 1900).
- 12) establishment of Crown plantations dating from the late 17th century (C6).
- 11) the taking in of open wastes, pastures and commons including heathland:
    - Areas with 'heath' place names (Category R) - Berkeley Heath and Heathfield represent 18th-19th century regular enclosures of heaths (R3) and may retain parish boundaries and boundaries following medieval furlongs, where heath was separated from former open fields.
    - enclosure of open commons and pastures (Category B), which are rare in this area.
- Linear features within historic settlements (G).

- Low: Area with few or no pre-1950 internal boundaries, mostly resulting from:
    - 8) removal of earlier boundaries to create large fields Large modern fields (Category N), may be derived from regular enclosures of 18th-19th century date (N1, typically of 18ha or over), piecemeal enclosures of former unenclosed land (N2).
    - 7) creation of large plantations Boundaries to Modern plantations over 30 ha in size (C5).
    - 6) creation of horticultural land or other functions Modern horticulture (Category S).
- Very low: Area redeveloped with few or no internal pre-1900 field and other boundaries except to housing and other forms of development:
    - 4) NHLC BT Residential Extension / NT – all.
    - 2) All other NHLC Types – Industrial, Commercial, Housing, Military etc.

# 8 APPENDIX B: DATA ANALYSIS FOR INTER-RELATIONSHIPS

## 8.1 Data issues

Available data comprises:

- ***Designated heritage assets*** from the National Heritage List for England (see www.HistoricEngland.org.uk/listing/the-list).
- ***Non-designated heritage assets*** from the Gloucestershire Historic Environment Record, which includes data from Historic England's NMP (Crowther and Dickson 2008 and 2016 for the Severn Vale and Estuary, Dickson for Frampton-on-Severn and Small et al for the Forest of Dean), which recorded archaeological remains visible on aerial photographs and lidar remote sensing images.

Use of this data has to be subject to a number of caveats, the most significant in relationship to this project being:

- The criteria for designation exclude the majority of traditional farm buildings and vernacular buildings which have been altered or are hidden behind later refrontings. Conservation areas tend to be concentrated in nucleated settlements rather than in areas of dispersed settlement that can be equally old. The descriptions including dates and building types for listed buildings do, however, bear a strong relationship to the date and character of settlement and enclosed land.
- Historic patterns of settlement are of fundamental importance in helping to explain the date and distribution of recorded buildings and archaeological features. Outside the scope of this project, but perhaps to explore, would be the development of a model to help interpret the pattern of linear features in an area that builds on the settlement provinces developed for the *Atlas of Rural Settlement in England* (Roberts and Wrathmell 2000 and 2002).
- The majority of routeways are excluded from the data, unless they have been identified as being Roman, comprise holloways of evident significance and have been recorded as turnpike roads; some Roman roads have been identified from cropmarks (as at Over, Crowther and Dickson 2008, 109) or have been found underneath modern roads (Small and Stoertz et al 2006, 17). Present-day legal definitions for routeways do not easily align with historic routeway types, which have typically changed function over time (Table 11).
- Soils, geology and land use, and other factors such as visibility on the day affect the survival and visibility of archeological sites including the medieval ridge and furrow which extended across large parts of the project area (Crowther and Dickson 2016, 24-26).
- Another factor in this respect is the historic character of settlement, ridge and furrow being more fragmented in areas of dispersed medieval settlement than around villages such as Frampton-on-Severn where it covered most of the landscape around the settlement. Ridge and furrow, and associated

headlands, was also of course absent from land use areas as revealed by HLC – meadows and common land in particular.

- NMP has made increasing use of Lidar imagery as supplied by the Environment Agency, although its use has to be again guided by some caveats of which the depth of alluvium is one (https://historicengland.org.uk/research/methods/airborne-remote-sensing/lidar/).

*Table 11: Routeways: present and historic function*

| PRESENT FUNCTION | HISTORIC ROUTEWAY TYPE |
|---|---|
| If a public highway:<br>• **Road** (A-C class, unclassified, access, dual carriageway or motorway).<br>• **Green Lanes and Byways Open to All Traffic (BOATS)** over which the public have to right to take vehicular and other types of traffic.<br>• **Footpath** for pedestrians only.<br>• **Bridleway** where there is the additional right to ride a horse or bicycle.<br>• **Carriageway** for vehicles, horses and livestock.<br>• **Driftway** over which there exists a right to drive cattle. | • Paved or metalled **roads** which enabled the most rapid means of transport, including of heavy loads, to and through areas.<br>• **Trackways** for the movement of animals (often specifically referred to as droveways), people and also wheeled vehicles over long or short distances. These include ridgeways traversing high ground and droveways for moving livestock and which often cut across contours in the land.<br>• **Access routes** which terminate at farmsteads, houses and other sites and which also include **drives** to country houses, villas and their estates.<br>• **Footpaths** for the movement of people within and between fields, farms and settlements, usually only marked on historic OS maps with a dotted line. |

## 8.2 Inter-relationships in the study areas

### 8.2.1 Elmore

This area landscape displays strong contrasts between meadow and farmland within an area of Roman reclamation and a landscape of post-medieval enclosures within a framework of medieval and earlier routeways and mixed settlement.

- Legibility
    - There is a varied range in terms of density of linear features across this area, the most concentrated area with very high scores of 5 being in the area of historic meadow to the north, at the intersection of routeways and in the area of dispersed medieval settlement including the church in the south-west.
- Time Depth
    - Using HLC grid squares: Most of the area is dominated by a high score (4) using the NHLC, with the exception of very high scoring areas (5)

comprising medieval meadow land to the north with a high density of water channels and blocks of ancient woodland (Hockley Wood, Shatford Grove). This reflects the dominance of 16th century and later piecemeal enclosure.

  - Using Gloucestershire HLC: There is a close match to the NHLC, the key distinction in the area of meadow land being between larger enclosures to the east and those retaining the outlines of doled-out apportionments of meadow to the west.

- Inter-Relationships (Figure 15)
  - The very high score (5) for the whole area reflects the dispersal across the area of historic linear and other features dating from the Roman period:
    - Earth and partly stone-revetted banks including Great Wall mark an area of late Roman land reclamation to the north (HER 16693, 45676 and 16695). Lake Street runs on the same alignment as Great Wall to the west (visible as a bank north-west of Bridgemacote Farm) and Broadmeadow Ditch to the east.
    - Lake Street Farm dominated this area by the 19th century, adjacent to an area of smallholdings including a late 18th century cider house which developed within orchards enclosed and separated from the meadows to the south.
    - A species-rich embanked boundary with veteran trees marks the division between the landscape of Roman reclamation and the medieval farmed landscape to the south.
  - Medieval features are dispersed across the landscape to the south – greens (Step Green HER 36254, Kenton Green HER 36252), an isolated 13th century church with earthworks to the south-east (HER 38371), cruck-framed buildings dating from the 14th-15th centuries, ancient woodland and the park to Elmore Court which dates from at least the 13th century (HER 36274). All of these suggest a mixed settlement pattern the presence of medieval enclosed as well as open strip fields, and thus boundaries that may on examination be shown to be of medieval or even earlier date.
  - Extensive evidence for ridge and furrow, more than 50% of which is legible as earthworks, except in the area of meadow to the north where the NMP has identified historic water channels.
  - Very rare surviving salmon fishing house (listed grade II) to east north of Weir Green.

The form and alignment of many field boundaries, when read in relationship to these features and the meeting-points of Gloucestershire HLC areas, probably reflects a long process of enclosing a mosaic of enclosed fields, commons and strip fields sited amongst scatters of farmsteads, an isolated 13th century church and settlements strung along the routeway on the higher land.

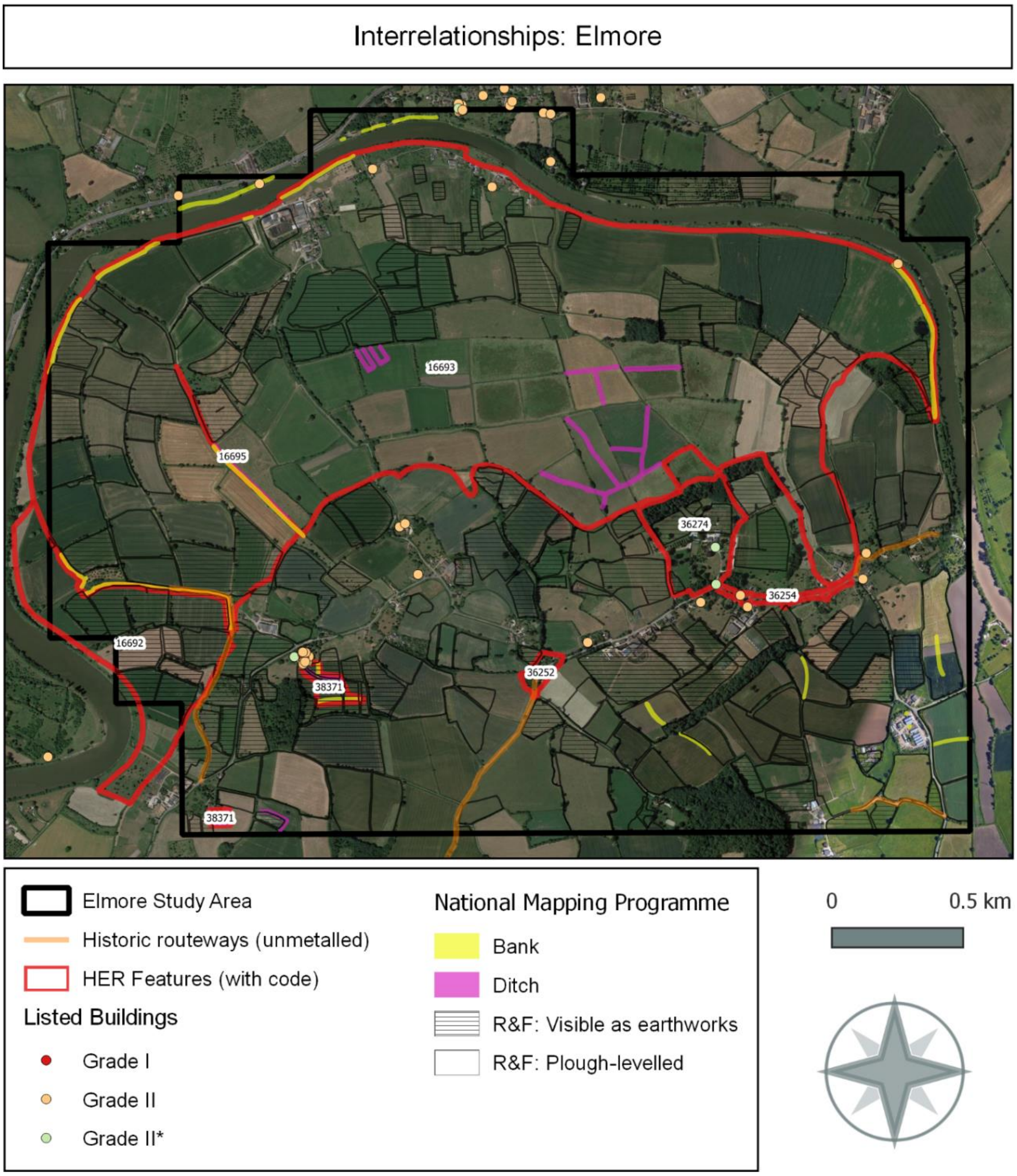



*Figure 15: Elmore case study area*

### 8.2.2 Arlingham

A medieval village landscape to the east bank of the Severn, which developed within six phases of late Roman reclamation and is traversed by routeways of Roman or earlier origin across fording and crossing points.

- Legibility.
  - Mixed pattern of densities, the squares scoring 5 (excepting the Severn) being concentrated around early routeways, rhynes and associated water channels.
- Time Depth.
  - Using NHLC grid squares: The variety of densities of field boundaries relate to the dominance of post-medieval enclosure across this area. The area with the highest score (5) is the block of enclosed meadow (including the areas scoring 5 for Legibility) north of Passage Road, the predominant pattern across the area being piecemeal 16$^{th}$-19$^{th}$ century enclosure of medieval strip fields (4). The areas scoring 3 relate to the Gloucestershire HLC A3 type for regular enclosure that ignores medieval strip fields.
  - Using Gloucestershire HLC: A subtler picture emerges within the piecemeal enclosure that highlights the meadowland to the NE and NW of the peninsula, and areas of enclosure that have retained more coherent patterns of strip fields (a1) to the NE of Milton End and in eastern quadrants extending towards Overton where east of the case study area medieval farmsteads related to more irregular enclosures demonstrates the relationship between the piecemeal enclosure around the village (A2) and more species-rich boundaries with hedgerow trees, in contrast to hedgerows associated with water channels in the areas of historic meadow (D1), excepting the strip of woodland extending towards Awre Mill.
- Inter-Relationships (Figure 16).
  - The very high score (5) for the whole area reflects the evidence from the NMP and research recorded in the HER for the formation of this landscape from the Roman period and earlier and also from observation of features not recorded on the HER.
  - Ditched and banked boundaries, and routeways, mark six phases of late Roman land reclamation (HER 36352 to south and 36345 to north of Passage Road, HER 36353 to south east). Extensive evidence for medieval and later drainage ditches (NMP).
  - Routeways including unrecorded unmetalled tracks (mostly extending towards riverside meadows and including a back lane between the Roman reclamation boundary and Arlingham) are of medieval or earlier date. These include the medieval or earlier routeway running from Milton End to the fording point across the river (HER 5285), a hollow-way (HER 26438) and the course of the Roman or even earlier road which runs along the centre of the peninsula (HER 12306) to Newnham

    Passage (HER 5172) and onward along the Roman road to Cardiff and drovers' routes to Wales. Its straightness at Passage Road can probably be attributed to the siting of the 18th-19th century rope walks, but there are also numerous flint finds on the HER which suggest movement and exchange through this landscape in the Neolithic or earlier. The routeways from the Severn developed as significant droving routes from at the least the late medieval period. Passage Road and Overton Road were turnpiked in 1779 (HER 41619), the evidence for this being confined to some narrowing and straightening leaving wide verges and passing places.

    - There is extensive evidence across the area for ridge and furrow cultivation, with the exception of historic meadow (D1) including around Longmarsh Rhyne.

- The medieval village of Arlingham, its 14th century church (grade I), the site of Arlingham Court, farmsteads and a cluster of 16th-19th century buildings also lying to its south. Most buildings are listed at grade II, but observation reveals rich evidence for threshing barns, cider houses and cheese rooms dating from the 1§7th-19th centuries that complement the evidence for arable farming and the evidence from historic maps for orchards (now very fragmentary, concentrated around Milton End and south of the church). There is 19th century housing, including for farmworkers – both 19th century new-build and adapted from earlier buildings. The higher landscape to the south-east has a long history of arable farming (large 18th century barn at Overton Farm).
- Rhynes and water channels extend inland from the Severn. Field boundaries respond to medieval ridge and furrow which is well-retained across most of this area, except in areas of former meadow and to the east of the medieval secondary settlement of Milton End with 16th century and later buildings for cider and cheese production in its farmsteads. To the east is a landscape of dispersed settlement, medieval in origin, with more irregular species-rich boundaries.

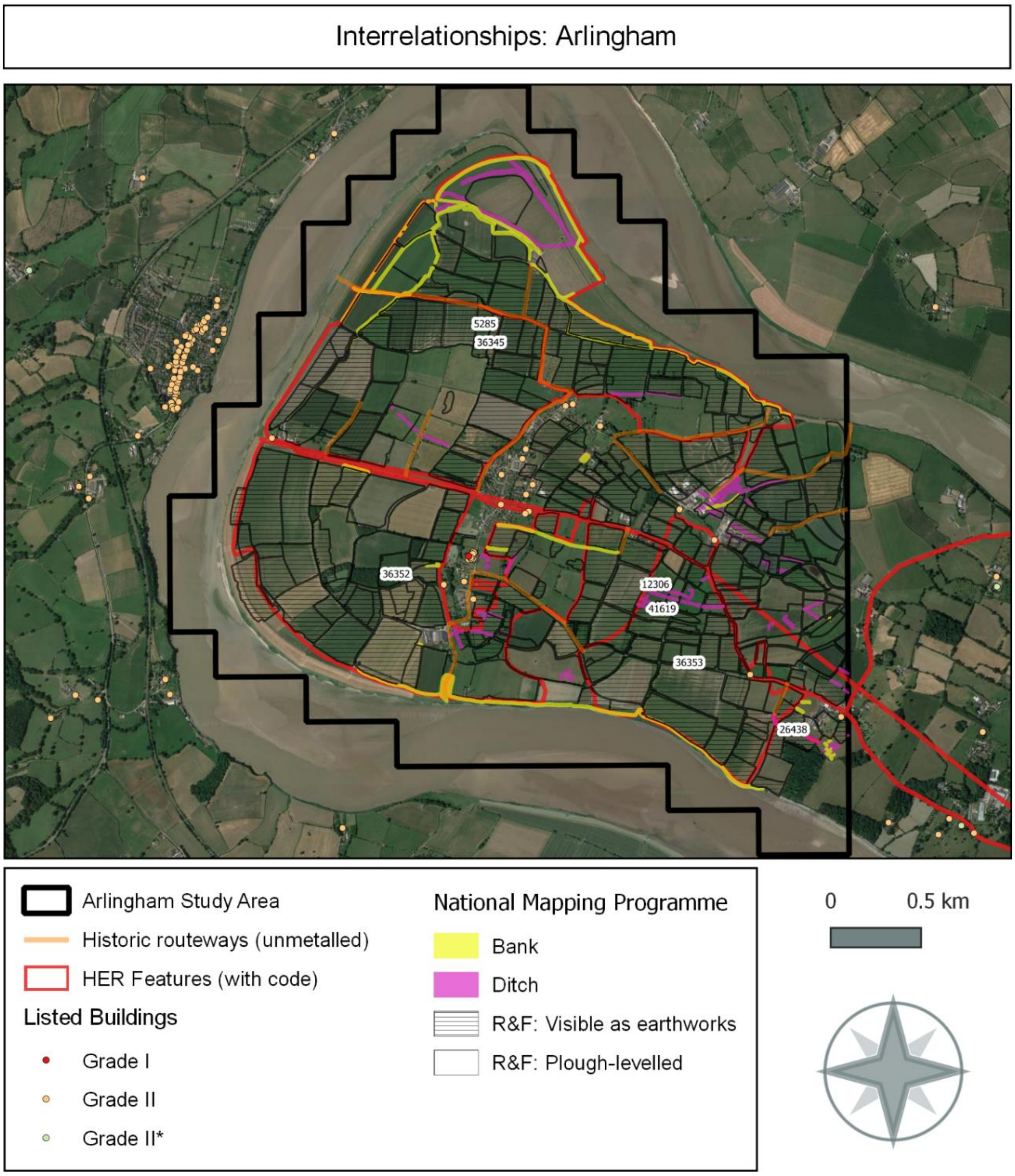



*Figure 16: Arlingham case study area*

### 8.2.3 Awre

A medieval village landscape to the west bank of the Severn, with farmsteads working strip fields and meadows enclosed in the 16th-19th centuries, with more anciently-enclosed fields and medieval houses along its western margins.

- Legibility.
  - There is a lower density of linear features than in the other sample areas, the main zone scoring 5 (excepting the Severn) being to the west where there is a denser concentration of fields deriving from the medieval period (part of a pattern extending in the Forest of Dean), the site of Awre mill, Brims Pill and associated rhines and the building of the railway with its tree-lined embankments.
- Time Depth.
  - Using NHLC grid squares: The areas with the highest scores (5) are enclosed meadow (including the areas scoring 5 for Legibility), the predominant pattern across the whole of the remainder being piecemeal 16th-19th century enclosure of medieval strip fields (4). The areas scoring 3 relate to the Gloucestershire HLC A3 type for regular enclosure that ignores medieval strip fields.
  - Using Gloucestershire HLC: A subtler picture emerges that demonstrates the relationship between the piecemeal enclosure around the village (A2) and more species-rich boundaries with hedgerow trees, in contrast to hedgerows associated with water channels in the areas of historic meadow (D1) excepting the strip of woodland extending towards Awre Mill.
- Inter-Relationships (Figure 17).
  - The high score (4) reflects the dominant post-medieval character of this area, which has worked within an inherited framework of earlier routeways and boundaries that relate to medieval and Roman reclamation; much of the latter has been lost due to erosion.
  - The present form of the peninsula results from reclamation in the Roman and medieval periods, these being in part marked by field boundaries with water channels. Strong relationship of banks and water channels to the area of historic meadow on reclaimed land bordering the Severn and around Awre Mill (NMP; HER 26425, 36423-4)).
  - Medieval routeways provided access to the medieval nucleated settlement of Awre and include an unmetalled trackway extending from the 13th century church towards the meadows and the Severn. The HER records two isolated hollow-ways north-west of Hall Farm (22992-3).
  - Extensive evidence for ridge and furrow from NMP. The loss of ridge and furrow in the older A2 enclosure landscape around the village offers evidence of arable farming working out of the courtyard farmsteads which grew in size within Awre, its loose form with evidence for settlement shrinkage (NMP, Small and Stoertz 2006, 56-59) matching

the evidence for threshing barns and 18th century and earlier houses (some listed grade II) in its farmsteads.

- The 14th century house at Box (listed grade II) and the cruck-framed house at Fieldhouse (listed grade II*) testify to the development of dispersed medieval settlement away from the village core, and together with 'Reddings' field names suggest an earlier origin for some of the field boundaries in this area bordering the ancient enclosures of the Forest of Dean.
- Historic orchards developed in 17th-19th centuries around village and farmsteads, now fragmentary survival except Whitecourt and Northington farms.

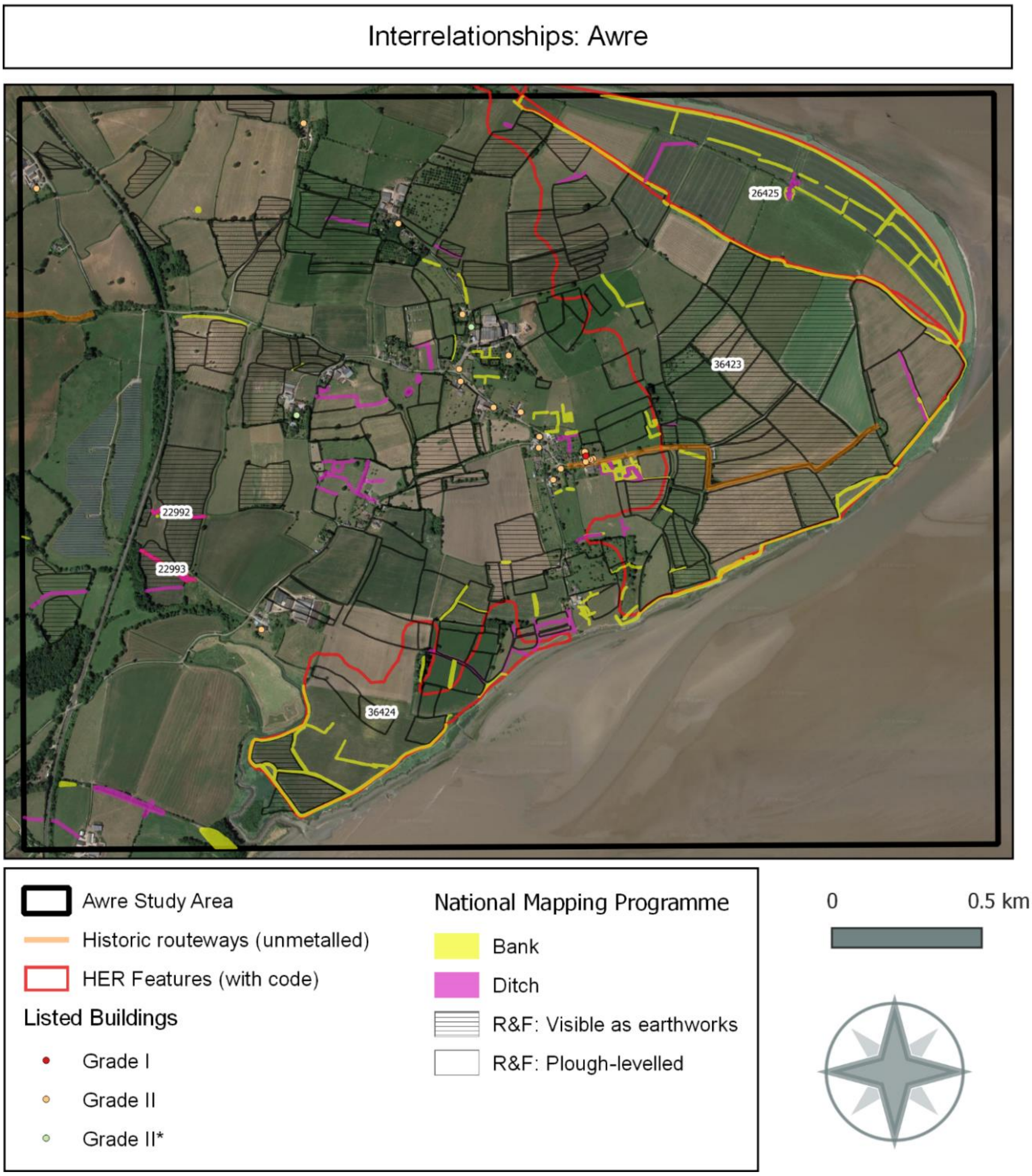



*Figure 17: Awre case study area*

# 9 APPENDIX C: ANALYSIS BELOW GRID CELL LEVEL

## 9.1 Introduction

The project has concluded that the National HLC dataset offers an interpretative framework down to the 500mx500m level. Detailed examination of four cells at this scale, centred within each of the maps from the case study areas, concluded that:

- *Legibility*. The scoring for the cells offers a generally reflection of the density of linear features of different types. Boundary types – and combinations for example of water channels and hedgerows – can be readily identified and corrected where necessary. This would not demand specialist expertise.
- *Time Depth*. The spatial patterning of the Gloucestershire HLC, if amalgamated so that the scoring aligns with the National HLC (this being subject to any recommendations for improving the clarity of the method made in this project), enables the user to identify significant or dominant boundaries at the interfaces of Historic Landscape Character Types. These boundaries may be earlier than the boundaries within HLC Types but may have been internally reorganised, which would demand more specialist expertise and a non-technical 'toolkit' for users that can be used at a national (including NCA) level.
- *Inter-Relationships*. Identification of locally characteristic and significant features is a vital corrective, adding context to interpretation of an area through identification for example of early routeways, reclamation boundaries and farmsteads that influenced the form and scale of linear features. This would also demand more specialist expertise and a non-technical 'toolkit' for users that can be used at a national (including Agricultural Landscape Types) and NCA level.

The maps that accompany the summaries of each area show (top) the Legibility scores in relationship to satellite mapping, and (below) Time Depth scores derived from the National HLC (bottom left) in relationship to the Gloucestershire HLC.

## 9.2 Detailed analysis

### 9.2.1 Elmore – north-west of Farley's End

Legibility (top row of Figure 18): The strong species-rich with veteran trees marks division between the medieval and 16$^{th}$-19$^{th}$ century enclosed farmlands to the south (2-4) and the enclosed meadows with willows and water channels to the north (5).

Time Depth (bottom row of Figure 18): The high score in the northern area reflects 17$^{th}$-19$^{th}$ century enclosure of meadows, retaining the pattern of doled-out allotments to the west (D1g) and later more regular enclosures to the east. The NHLC grid does not adequately reflect the ancient boundary and division between the northern and southern halves of this area, as seen in the Gloucestershire HLC map to bottom right.

Inter-relationships: Medieval settlement at Farleys End (G5), of particular importance being Farleys End Farm with 14th-15th century buildings, the medieval routeway which has later been narrowed and heightened with a raised causeway and is lined with pollarded willow, the strong boundary marking the pre-Roman bank of the Severn (Great Wall, marking the edge of the Roman reclaimed area, lies in the adjacent western cell.


*Figure 18: Cell analysis in Elmore*

### 9.2.2 Arlingham – to south-west of village

Legibility (top row of Figure 19): Accurate reflection of density of field boundaries and historic routeway (Passage Road) to south and routeway along ditched Roman reclamation boundary to east.

Time Depth (bottom row of Figure 19): National HLC grid squares accurately reflect dominance of village to south east (1: G3 in Gloucestershire HLC), of enclosed meadow (5), D1 with regular boundaries) and 16th-19th century piecemeal enclosure (A2 with straight boundaries). Gloucestershire HLC: enables interfaces with potential for early boundaries to be identified.

Inter-relationships: Strong relationship to medieval village with 16th-19th century farmsteads and houses, to ditched Roman reclamation boundary with trackway along its western edge and to probable Roman road to south. Extant ridge and furrow except in D1 meadow.

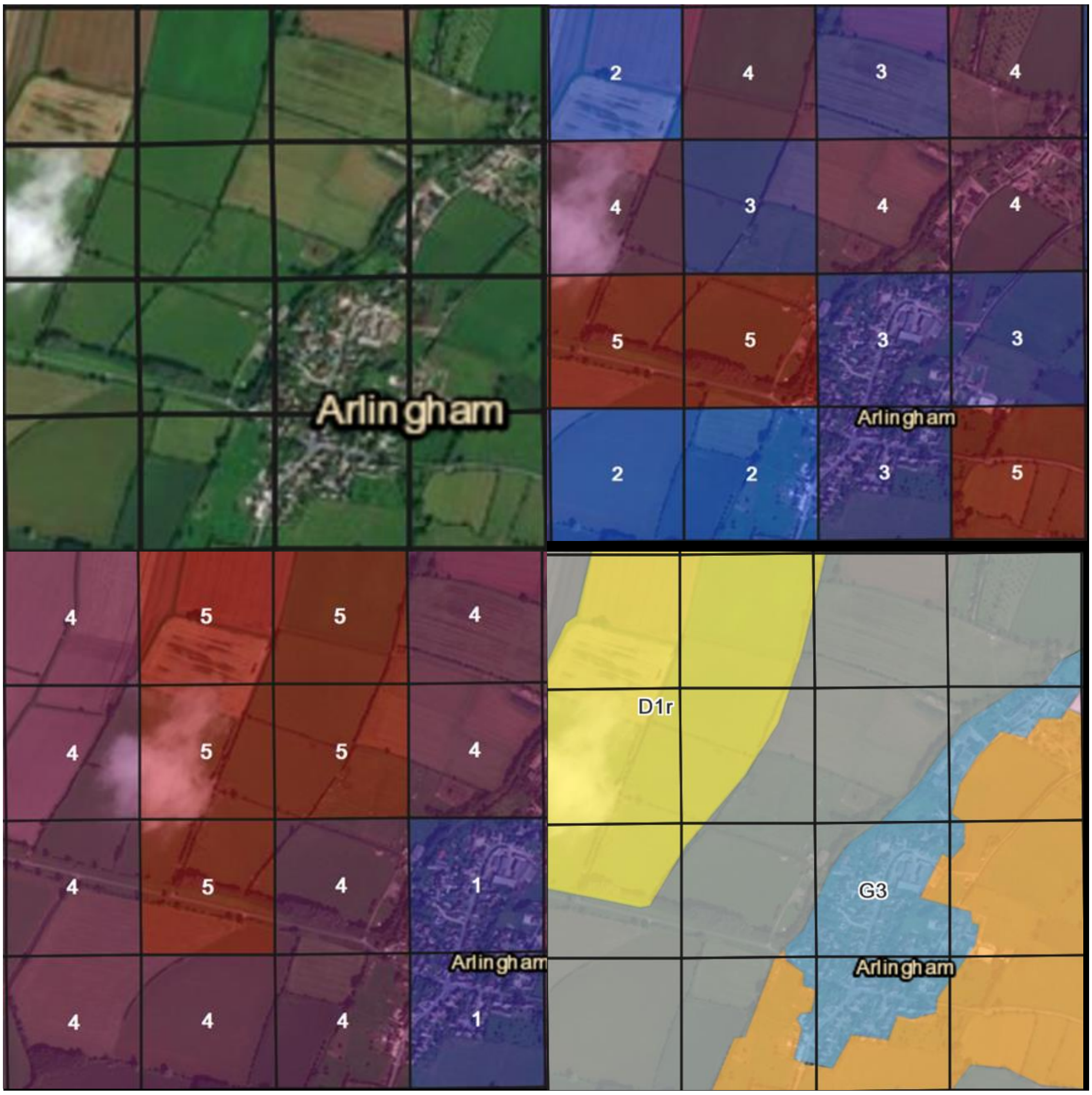



Figure 19: Cell analysis in Arlingham

### 9.2.3 Awre - east of Hall Farm in south east of study area (top left)

Legibility (top row of Figure 20): Low score of 4 central cells reflects relative absence of linear features.

Time Depth (bottom row of Figure 20): the National HLC cells scored at 5 relate to enclosed meadow D1 (from Gloucestershire HLC, bottom right); one cell to SE scored at 4 is located in a field with a wooded strip and boundary trees typical of the older piecemeal enclosures around Awre village.

Inter-relationships: Recorded ridge and furrow, not present; traditional farmstead in adjacent cell (Hall Farm) in farming use with early 18th century farmhouse (listed grade II) and courtyard steading replaced by modern sheds. Cells traversed by post-1950 farm access road.


*Figure 20: Cell analysis in Awre*

# 10 APPENDIX D: HERITAGE ACCOUNTING FRAMEWORK: LINEAR FEATURES MODEL

## 10.1 Introduction

This Appendix consists of a set of tables identifying the service flows from linear features. Tables are organised to identify the services generated according the four main categories of ecosystem services:

- Supporting
- Provisioning
- Regulating
- Cultural

Tables are colour coded and presented in the following order:

- Green - Hedgerows
- Grey - Walls
- Blue – Drainage and flood control features
- Brown - Communications linear features (ancient trackways; footpaths; drove roads, lanes)
- Red - Costs: restoration and maintenance

## 10.2 Accounting framework

*Table 12: Value of service of service flows model: Hedgerows*

*Supporting*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Supporting | Primary production (e.g. lichens; nutrient cycling); | Nutrient cycling;<br>Provision of habitat for lichens, mosses, and other plants | • Society overall<br>• Landowners; farmers;<br>• local community<br>• higher level species | Variety of plant species; age and density of hedgerow | Km of hedgerow in area of interest |
| | Formation of species habitat | Flora - long-term habitat creation (e.g. plant habitats; enhanced biodiversity); important habitats for pollinator species | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Number of species present; Protected species present | Km of hedgerow in area of interest |
| | Formation of species habitat | Fauna - long-term habitat creation (e.g. for insects, reptiles, small mammals, birds, other species); enhanced biodiversity;<br>Food source for insects and wildlife | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Number of species present; Protected species present | Km of hedgerow in area of interest |
| | Wildlife corridors | Potential to support wildlife movements;<br>Enables or inhibits movement (possible migration of species along sheltered linear corridors)<br>Greater resilience to climate change | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Number of species with potential to spread through provision of 'transition' corridors.<br>Enhanced species resilience | Km of hedgerow in area of interest; Resilience capacity factor |

*Provisioning*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Provisioning | Livestock management; | Separation of arable crops from livestock; | • Number of arable farmers (farmers with crops needing protection)<br>• Mixed farms | Reduction in crop damage. | Estimated efficiency savings from provision of hedgerows |
| | Livestock management | Separation of animal types and by gender | • Livestock farmers | Efficiency of livestock production through ability to separate animals | Estimated efficiency savings from provision of hedgerows |
| | Shelter | Provision of shelter in poor weather for livestock; | • Livestock farmers<br>• Sheep<br>• Cattle<br>• Other | In situ shelter – enables livestock to be left outside in poor weather (lowland) | Estimated efficiency savings from provision of hedgerows |
| | Shelter | Shelter for crops against wind: | • Arable farmers<br>• Farmers producing fodder crops | Enables enhance productivity of otherwise marginal land, or production of higher value crops | Estimated productivity gains |
| | Shelter | Provision of shelter for seeds, plants, fauna. Creation of micro-climate | • Biodiversity (flora/fauna) | Supports high nature value farmland | Estimated areal extent ($km^2$) of sheltered field margins |
| | Food source | Provision of berries, fruits, plants for food/medicine | • Local residents (usually); possibly some visitors from nearby area | Quantity of fruit produced; range of food/medicinal plants available | Market value of similar fruit/food/medicinal plants obtained |

*Regulating*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Regulating | Boundary marker | Identification of land ownership boundaries. Provision of certainty over land ownership.<br>Reduction in need for land surveys at point of sale of property.<br>Fencing against the common<br>Markers for historical ownership and landscape management | • Land owners<br>• Local community (to a lesser extent) | Proportion of total hedgerow forming property boundary between land ownership units. | Average Km of hedgerow per property |
| | Soil erosion (location specific) | Provision of shelter for soil against wind erosion; | • Arable farmers<br>• Farmers producing fodder crops | Estimated decrease in soil erosion and soil creep<br>Estimated proportion of wall preventing soil erosion in the landscape/type of farm | Estimated area protected (Ha) per farm |
| | Soil quality | Enclosure by hedgerow has played a role in retaining long-term pasture alternating with arable use and hay production. | • Farmers producing fodder crops | Enhanced crop production<br>Support for livestock production (lowers feed costs) | Estimated area protected (Ha) per farm |
| | Water flow (location specific) | Slows down overland flow during high intensity rainfall periods.<br>Limited in extent – depends on orientation of hedgerow in relation to slope and bare soil. | • Arable farmers<br>• Mixed farms where bare soil exposed for cropping. | Estimated proportion of wall with potential for preventing water erosion in the landscape/type of farm | Average Km of hedgerow per farm providing the service |

*Cultural*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Cultural | Landscape and aesthetic | Sense of place<br>Wellbeing<br>Sense of history<br>Utilisation of native species | • Local residents<br>• visitors | Improved sense of well-being from living in or visiting an 'Iconic landscape' | Wellbeing improvement measure |
| | Landscape and aesthetic | Utilisation of native species | • Land owners<br>• Local residents<br>• visitors | Reduced environmental impacts from alternative forms of fencing | Cost of fencing avoided |
| | Tourism | Valued landscape attracts visitors<br>(hedgerows are an attractive feature that contribute to visitor attraction – but cannot quantify directly) | • Visitors | 'Improved sense of well-being from living in or visiting an 'Iconic landscape' | Wellbeing improvement measure |
| | Traditional skills | Traditional skills for construction, repair, maintenance; skills are in short supply; creates local jobs | • Skilled hedge layers<br>• Casual labour<br>• Local communities | Maintenance of traditional skills in hedge laying & maintenance | Average income from hedge work/person/year |

*Table 13: Value of service of service flows model: Walls*

*Supporting*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Supporting | Primary production (e.g. lichens; nutrient cycling); | Breakdown of stone to release nutrients; food source for higher plants;<br><br>Provision of habitat for lichens, mosses, and other plants | • Society overall<br>• Landowners; farmers;<br>• local community<br>• higher level species | Rate of weathering by geological type. Proportion of walls with extensive growth of moss and lichen (depends on age of wall, exposure, aspect) | Average Km of wall per farm type |
| | Formation of species habitat | Flora - long-term habitat creation (e.g. plant habitats; enhanced biodiversity); Walls can be important habitats for pollinator species | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Provision of shelter and habitat for range of local species | Km of wall |
| | Formation of species habitat | Fauna - long-term habitat creation (e.g. for insects, reptiles, small mammals, birds, other species); enhanced biodiversity; | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Provision of shelter and habitat for range of local species | Km of wall |
| | Wildlife corridors | potential to support/ inhibit animal movements;<br>Enables or inhibits movement (possible migration of species along sheltered linear corridors)<br>Greater resilience to climate change | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Number of species with potential to spread through provision of 'transition' corridors | Km of wall provided with spaces that allow ease of movement. |

*Provisioning*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Provisioning | Livestock management; | Separation of arable crops from livestock; | • Number of arable farmers (farmers with crops needing protection)<br>• Mixed arable and livestock farms | Reduction in crop damage. | Estimated efficiency savings from provision of walls |
| | Livestock management | Separation of animal types and by gender | • Livestock farmers | Improved efficiency of livestock production through ability to separate animals | Estimated efficiency savings from provision of walls |
| | Shelter | Provision of shelter in poor weather for livestock; | • Livestock farmers<br>• Sheep<br>• Cattle<br>• Other | In situ shelter – enables livestock to be left outside in poor weather;<br>Reduces mortality (e.g. lambing; winter)<br><br>NOTE: need to calculate how many animals a single shelter will support. | Estimated efficiency savings from provision of walls |
| | Shelter | Shelter for crops against wind: | • Arable farmers<br>• Farmers producing fodder crops | Enables enhanced productivity of otherwise marginal land, or production of higher value crops | Estimated productivity gains |
| | Shelter | Provision of shelter for seeds, plants, fauna against wind.<br>Creation of micro-climate | • Biodiversity (flora/fauna) | Supports high nature value farmland | Estimated areal extent ($km^2$) of sheltered field margins |

*Regulating*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Regulating | Boundary marker | Identification of land ownership boundaries. Provision of certainty over land ownership.<br>Reduction in need for land surveys at point of sale of property.<br>Fencing against the common<br>Markers for historical ownership and landscape management | • Land owners<br>•<br>• Local community (to a lesser extent) | Proportion of total wall used as property boundary.<br><br>Proportion of total wall forming boundary between commons and improved land. | Average Km of wall per property |
| | Soil erosion (location specific) | Provision of shelter for soil against wind erosion; | • Arable farmers<br>• Farmers producing fodder crops | Estimated decrease in soil erosion and soil creep<br>Estimated proportion of wall preventing soil erosion in the landscape/type of farm | Estimated area protected (Ha) per farm type |
| | Soil quality | Enclosure by walls has played a role in retaining long-term pasture alternating with arable use and hay production.<br>Enables manuring, of the in-bye land | • Farmers producing fodder crops | Enhanced crop production<br>Support for livestock production (lowers feed costs) | Estimated area protected (Ha) per farm type |
| | Water flow (location specific) | Slows down overland flow during high intensity rainfall periods.<br>Limited in extent – depends on orientation of wall in relation to slope and bare soil. | • Arable farmers<br>• Mixed farms where bare soil exposed for cropping. | Estimated proportion of wall with potential for preventing water erosion in the landscape/type of farm | Average Km of wall per farm type providing the service |

*Cultural*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Cultural | Landscape and aesthetic | Sense of place<br>Wellbeing<br>Sense of history<br>Utilisation of existing stone | • Local residents<br>• visitors | Improved sense of well-being from living in or visiting an 'Iconic landscape' | Wellbeing improvement measure |
| | Landscape and aesthetic | Utilisation of existing stone | • Land owners<br>• Local residents<br>• visitors | Reduced environmental impacts from alternative forms of fencing | Cost of quarried stone avoided |
| | Tourism | Valued landscape attracts visitors<br><br>(Need to make point that walls are an attractive feature that contribute to certain proportion of visitor spending – but cannot quantify directly) | • Visitors | 'Improved sense of well-being from living in or visiting an 'Iconic landscape' | Wellbeing improvement measure |
| | Traditional skills | Traditional skills for construction, repair, maintenance; skills are in short supply; creates local jobs | • Skilled dry stone wallers<br>• Casual labour<br>• Local communities | Maintenance of traditional skills in building with local stone | Average income from walling work/person/year |

*Table 14: Value of service of service flows model: Drainage and flood control linear features*

*Servicing*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Supporting | Primary production (e.g. aquatic vegetation; nutrient cycling); | Nutrient cycling;<br>Provision of habitat for lichens, mosses, and other plants | • Society overall<br>• Landowners; farmers;<br>• local community<br>• higher level species | Variety of plant species; age and density of hedgerow | Km of drainage ditches in area of interest |
| | Formation of species habitat | Long-term habitat creation (e.g. plants; insects, reptiles, small mammals, birds, enhanced biodiversity); pollinator species; Food source for insects and wildlife | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Number of species present; Protected species present | Km of **drainage ditches** in area of interest |
| | Formation of species habitat | Long-term habitat creation (e.g. plants; insects, reptiles, small mammals, birds, enhanced biodiversity); pollinator species; Food source for insects and wildlife | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Number of species present; Protected species present | Km of **flood control embankment** in area of interest |
| | Wildlife corridors | Potential to support wildlife movements; Enables or inhibits movement (possible migration of species along sheltered linear corridors); Greater resilience to climate change | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Number of species with potential to spread through provision of 'transition' corridors. | Km drainage ditch & embankment in area of interest; Resilience capacity factor |

*Provisioning*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Provisioning | Livestock management; | Separation of arable crops from livestock; | • Number of arable farmers (farmers with crops needing protection)<br>• Mixed arable and livestock farms | Reduction in crop damage. | Estimated efficiency savings from provision of drainage ditches /embankments |
| | Livestock management | Separation of animal types and by gender | • Livestock farmers | Efficiency of livestock production through ability to separate animals | Estimated efficiency savings from provision of drainage ditches /embankments |
| | Shelter | Shelter for crops against wind: | • Arable farmers<br>• Farmers producing fodder crops | Enables enhance productivity of otherwise marginal land, or production of higher value crops | Estimated productivity gains from embankments |
| | Shelter | Provision of shelter for seeds, plants, fauna against wind.<br>Creation of micro-climate | • Biodiversity (flora/fauna) | Supports high nature value farmland | Estimated areal extent ($km^2$) of sheltered field margins |
| | Water supply | Provision of water in dry periods | • Arable & livestock farmers | Easier access to water | Cost of alternative provision of water (e.g. pipeline, pumping, tanker) |
| | Pollarded willows | Associated feature with drainage ditches | • Landowner/farmer | Quantity of fuel wood produced; small scale construction; crafts (e.g. basket making) | Cost of alternative supply of fuel wood |

*Regulating*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Regulating | Boundary marker | Identification of land ownership boundaries. Provision of certainty over land ownership. Reduction in need for land surveys at point of sale of property. Fencing against the common. Markers for historical ownership and landscape management | • Land owners<br>• Local community (to a lesser extent) | Proportion of total drainage ditches/embankments used as property boundary. | Average Km of drainage ditches /embankments per property |
| | Soil erosion (location specific) | Provision of shelter for soil against wind erosion; | • Arable farmers<br>• Farmers producing fodder crops | Estimated decrease in soil erosion and soil creep<br>Estimated proportion of drainage ditches/ embankments preventing soil erosion in the landscape/type of farm | Estimated area protected (Ha) per farm |
| | Flood control | Prevents flooding of land in periods of high rainfall/high water river flows; reduces land erosion at margins; reduces property damage | • Arable & livestock farmers<br>• Land / property owners | Estimated proportion of wall with potential for preventing water erosion in the landscape/type of farm | Estimated area protected (Ha); enhanced land value |
| | Flood safety | Flood prevention increases feelings of safety and well-being. | • Property owners<br>• Residents | Improved sense of wellbeing based on existence of flood control measures | Enhanced property value; Number of households (or residents) in the area |

*Cultural*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Cultural | Landscape and aesthetic | Sense of place<br>Wellbeing<br>Sense of history<br>Utilisation of native species | • Local residents<br>• visitors | Improved sense of well-being from living in or visiting an 'Iconic landscape' | Wellbeing improvement measure |
| | Landscape and aesthetic | Utilisation of native species | • Land owners<br>• Local residents | Reduced environmental impacts from alternative forms of fencing | Cost of fencing avoided |
| | Tourism | Valued landscape attracts visitors<br>(ditches and flood control measures may be considered attractive features that contribute to visitor attraction – but cannot quantify directly) | • Visitors | 'Improved sense of well-being from living in or visiting an 'Iconic landscape' | Wellbeing improvement measure |
| | Traditional skills | Traditional skills for construction, repair, maintenance; skills are in short supply; creates local jobs | • Skilled ditch maintenance<br>• Casual labour<br>• Local communities | Maintenance of traditional skills in water management | Average income from ditch/embankment work/person/year |

*Table 15 Value of service of service flows model: Communications linear features (ancient trackways; footpaths; drove roads, lanes)*

*Servicing*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Supporting | Primary production (e.g. lichens; nutrient cycling); | Nutrient cycling;<br>Provision of habitat for lichens, mosses, and other plants | • Society overall<br>• Landowners; farmers;<br>• local community<br>• higher level species | Variety of plant species; age and density of hedgerow | Km of communication feature in area of interest (e.g. trackways) |
| | Formation of species habitat | Flora - long-term habitat creation (e.g. plant habitats; enhanced biodiversity); important habitats for pollinator species | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Number of species present; Protected species present | Km of communication feature in area of interest |
| | Formation of species habitat | Fauna - long-term habitat creation (e.g. for insects, reptiles, small mammals, birds, other species); enhanced biodiversity;<br>Food source for insects and wildlife | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Number of species present; Protected species present | Km of communication feature in area of interest |
| | Wildlife corridors | Potential to support wildlife movements;<br>Enables or inhibits movement (possible migration of species along sheltered linear corridors)<br>Greater resilience to climate change | • Society overall<br>• Landowners; farmers;<br>• local community<br>• local ecological system | Number of species with potential to spread through provision of ‘transition’ corridors. | Km of communication feature in area of interest;<br>Resilience capacity factor |

*Provisioning*

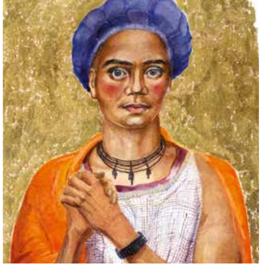
| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Provisioning | Livestock management; | Facilitates movement of livestock | • Livestock farmers | Number of animal movements using linear communications features | Estimated efficiency savings from provision of communication feature |
| | Machinery movement | Facilitates movement of machinery between farm units | • Arable & livestock farmers | Number of machinery movements using linear communications features | Estimated efficiency savings from provision of communication feature |

*Regulating*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Regulating | Boundary marker | Identification of land ownership boundaries. Provision of certainty over land ownership.<br>Reduction in need for land surveys at point of sale of property.<br>Fencing against the common<br>Markers for historical ownership and landscape management | • Land owners<br>• Local community (to a lesser extent) | Proportion of communications feature forming boundary between land units. | Average Km communications feature per property |
| | | | • | | |
| | | | • | | |
| | | | • | | |

*Cultural*

| Service category | Asset/service | Function | Stakeholder type | Indicator | Measure |
|---|---|---|---|---|---|
| Cultural | Landscape and aesthetic | Sense of place<br>Wellbeing<br>Sense of history<br>Utilisation of native species | • Local residents<br>• visitors | Improved sense of well-being from living in or visiting an 'Iconic landscape' | Wellbeing improvement measure |
| | Recreational value | Health benefits from walking on trackways, etc.<br>Wellbeing<br>Sense of history | • Local residents<br>• visitors | Health and well-being from ability to utilise communications features (e.g. trackways; paths) | Wellbeing improvement measure |
| | Tourism | Communications features attract visitors (e.g. ancient trackways; railways) | • Visitors | 'Improved sense of well-being from living in or visiting an 'Iconic landscape' | Wellbeing improvement measure |
| | Traditional skills | Traditional skills for construction, repair, maintenance; (e.g. railways; bridges, aqueducts, roads) skills are in short supply; creates local jobs | • Skilled workers<br>• Casual labour<br>• Local communities | Maintenance of traditional skills | Average income from communications feature related work per person/year |



# Historic England Research and the Historic Environment

## We are the public body that helps people care for, enjoy and celebrate England's spectacular historic environment.

A good understanding of the historic environment is fundamental to ensuring people appreciate and enjoy their heritage and provides the essential first step towards its effective protection.

Historic England works to improve care, understanding and public enjoyment of the historic environment. We undertake and sponsor authoritative research. We develop new approaches to interpreting and protecting heritage and provide high quality expert advice and training.

We make the results of our work available through the Historic England Research Report Series, and through journal publications and monographs. Our online magazine Historic England Research which appears twice a year, aims to keep our partners within and outside Historic England up-to-date with our projects and activities.

A full list of Research Reports, with abstracts and information on how to obtain copies, may be found on www.HistoricEngland.org.uk/researchreports

Some of these reports are interim reports, making the results of specialist investigations available in advance of full publication. They are not usually subject to external refereeing, and their conclusions may sometimes have to be modified in the light of information not available at the time of the investigation.

Where no final project report is available, you should consult the author before citing these reports in any publication. Opinions expressed in these reports are those of the author(s) and are not necessarily those of Historic England.

The Research Report Series incorporates reports by the expert teams within Historic England. It replaces the former Centre for Archaeology Reports Series, the Archaeological Investigation Report Series, the Architectural Investigation Report Series, and the Research Department Report Series.

ISSN 2398-3841 (Print)
ISSN 2059-4453 (Online)