INVESTIGATING THE POTENTIAL OF 3D VISUALISATION TO ENHANCE STAKEHOLDER ENGAGEMENT IN NATURAL FLOOD MANAGEMENT

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Abstract

There have been several recent high-profile flood events in the UK, such as the July 2007 events where significant flooding occurred across much of the UK following a prolonged period of rainfall. One approach to reducing flood risk that has received considerable recent interest is Natural Flood Management (NFM), which aims to work with nature alongside other measures. Incorporating multiple NFM interventions over a wide area, this is also thought to offer additional benefits for water quality and biodiversity. Using the River Isbourne catchment in Gloucestershire as a case study, this thesis examines the potential of 3D landscape visualisation for enhancing the communication of complex spatial information to educate people about, and generate interest in, a proposed NFM project that is being implemented in the area. Early stakeholder engagement is key to the success of a catchment scale project such as the Isbourne, with a variety of interests and stakeholders to consider. A Google Earth virtual globe tour approach is investigated, based on the findings of previous research that have identified the benefits of the technology for enhancing the communication of digital spatial data. This thesis describes the design process and the techniques of Keyhole MarkUp Language (KML) scripting used to build an effective 3D landscape visualisation for online distribution to a public audience. Collaborating with a local catchment group to identify key information requirements, an animated, interactive Google Earth tour was created utilising open geospatial data. End user evaluation, undertaken in both a workshop and an online setting, provided feedback on the developed visualisation in terms of its usability and how effective it was for communicating complex spatial data to generate an interest in this NFM project. The results indicate that the virtual globe tour was easy to use and, although some information is more difficult to convey and there are limitations to the data, it was a helpful tool for educating and engaging users in the NFM approach.

Declaration

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Gloucestershire and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other education institution in the United Kingdom or overseas.

Any views expressed in the thesis are those of the author and in no way represent those of the University.

Signed Date December 2017

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Abbreviations

AONB	Area of Outstanding Natural Beauty
BGS	British Geological Survey
BOS	Bristol Online Survey
CaBA	The Catchment Based Approach
CAD	Computer Aided Design
CCRI	Countryside and Community Research Institute
CEH	Centre for Ecology and Hydrology
CORINE	EU land cover data, ‘coordination of information on the environment’
DEFRA	Department for Environment, Food and Rural Affairs
EA	Environment Agency
FD	Floods Directive
FWAG	Farming and Wildlife Advisory Group
GIS	Geographical Information Systems
ICG	Isbourne Catchment Group
KML	Keyhole Markup Language
KMZ	Zipped package archive containing KML file and resources
NFF	National Flood Forum
NFM	Natural Flood Management
NRFA	National Rivers Flow Archive
OGL	Open Government Licence
OGS	Open Geospatial Consortium
PGIS	Participatory Geographical Information Systems
RBMP	River Basin Management Plan
SEPA	Scottish Environmental Protection Agency
SSSI	Site of Special Scientific Interest
UoG	University of Gloucestershire
WFD	Water Framework Directive
XML	eXtensible Markup Language

Chapter 1 Introduction

1.1. Background

Changes in agricultural practices, such as ploughing and cultivation techniques, increased field size and loss of hedgerows, have caused significant landscape changes since the Second World War that reduce infiltration and increase run off (O'Connell *et al.*, 2007). This, along with channel modifications for land drainage and flood protections in urban and rural areas, has had an impact on natural catchment processes (Defra, 2016).

With ongoing debate about the causes and likely future trends, with the impact of climate change, there is also evidence that rainfall and run off have notably increased in the 21st century; UK average annual rainfall was 9% higher between 2000-2015 than the period 1910-1999 (Marsh *et al.*, 2016). Widespread, significant flooding in summer 2007 affected several areas of the UK including Gloucestershire, North Yorkshire, Hull and the Thames region. Across the UK thirteen people died and 55,000 properties were flooded (Pitt, 2008). A key component of the subsequently published 'Pitt Review', (2008), was to reduce the risk of future flooding. This policy review recommended that the Department for Environment Food & Rural Affairs (DEFRA), the Environment Agency (EA) and Natural England work together to improve the understanding of working with natural processes to reduce flood risk and to develop catchment wide flood management plans. In England local level flood risk management is currently led by local authorities, under the Floods and Water Management Act (2010) which includes a requirement to work with natural processes.

Policy developments in the fields of water resource and flood risk management have led to a shift from a technical, structural approach using traditional engineering solutions to control rivers towards a sustainable management approach to reducing flood risk (Cook *et al.*, 2016; Rouillard *et al.*, 2015). The European Union (EU) Water Framework (2000/60/EC) Directive (WFD) and EU Floods (2007/60/EC) Directive (FD) recognise both the potential role of the land in retaining water and the importance of local stakeholder involvement in catchment and flood management. 'Making Way for Water' published in 2005 by DEFRA, also promoted a holistic catchment-wide strategy, particularly for areas where engineered solutions are not considered cost effective. These developments have led to flood management policy and decision making becoming more public-focussed (Hopkins and Warburton, 2015).

Natural Flood Management (NFM), defined by Wentworth (2011, p. 1) as the "'alteration, restoration or use of landscape features to reduce flood risk", is a sustainable approach to catchment management. It seeks to reduce flood risk alongside conventional flood risk measures (Wilkinson *et al.*, 2014), using a suite of nature-based techniques designed to attenuate or slow the flow of water (Figure 1). Unlike engineered solutions, which tend to focus on the use of single sites to protect large areas, it utilises multiple interventions over a wider landscape or catchment scale to achieve a targeted threshold of change (SEPA, 2015). Considerable interest has been generated by recent pioneering schemes in the UK, such as those in Pickering (Forestry Commission, 2017) and Stroud (Stroud District Council, 2017), and this has provided the catalyst for significant government backing of NFM with a £15 million government commitment from Defra to spending on projects (Kaminski, 2016).

The current status of the evidence base for NFM was published in October 2017 (Environment Agency, 2017b) and suggests further monitoring of the impact on flood risk, the performance of techniques and the wider benefits that can be achieved. Published research on NFM has largely focussed on modelling and evidence gathering on the effectiveness of techniques (Metcalfe *et al.*, 2017; Dixon *et al.*, 2016) with limited research that has considered communication and stakeholder engagement for NFM projects such as the barriers to implementation for farmers (Holstead *et al.*, 2017).

Achieving early engagement with stakeholders, and maintaining their support, is a critical component of NFM planning as the implementation of a range of measures across a wide area at a catchment level requires a collaborative partnership approach to be successful (Wentworth, 2011). This could involve a range of stakeholders including wildlife and landscape organisations, local authorities, landowners, farmers and the wider community. One of the research gaps identified by the EA in their review 'Working with natural processes to reduce flood risk' (Environment Agency, 2014) was how to effectively engage stakeholders and communities at an early stage to help identify options and make decisions. This

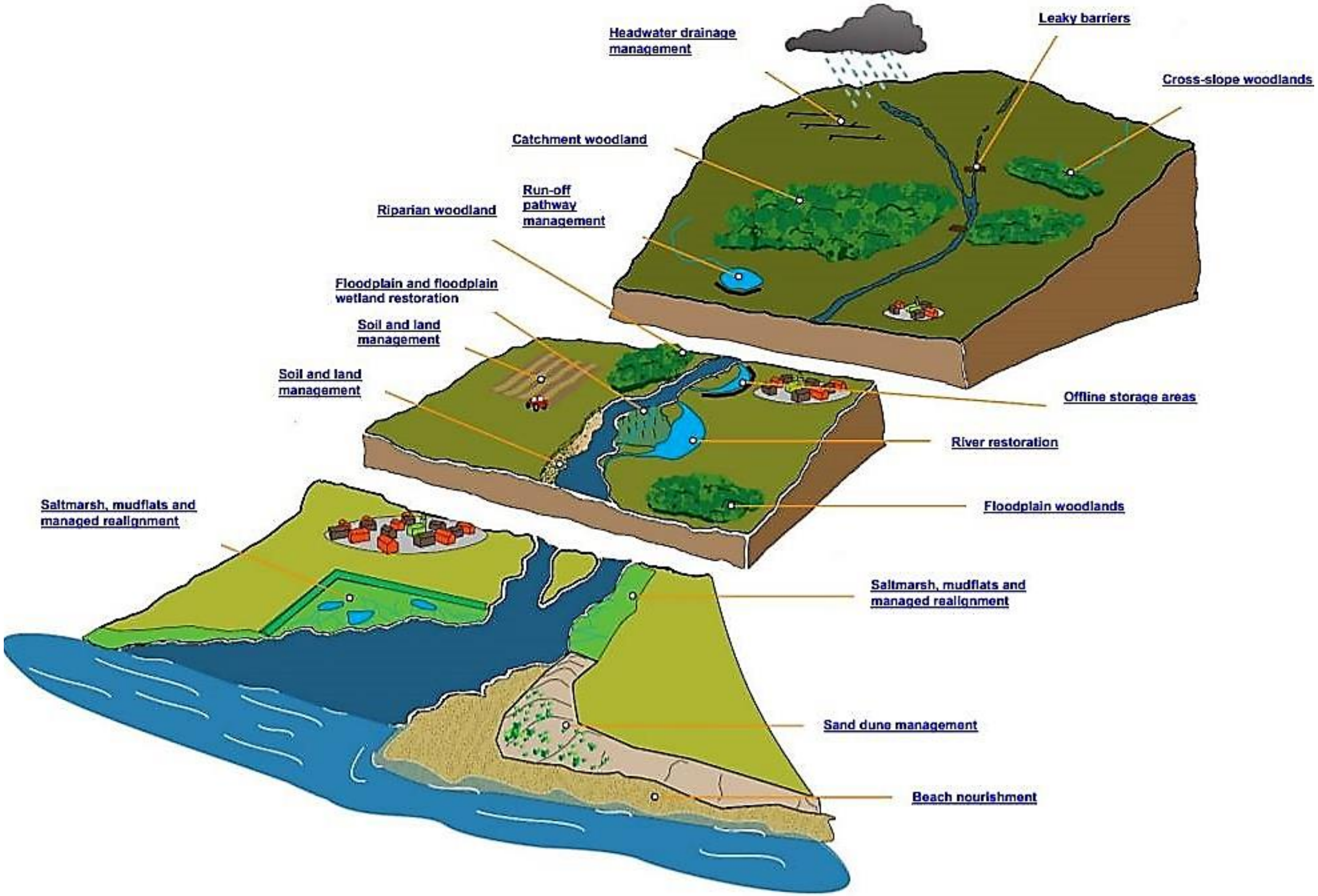


Figure 1. Working with natural process – from source to sea (Environment Agency, 2017b)

included the identification of key messages and methods of communication to demonstrate the multiple benefits of NFM, noting the potential for employing software and visual aids.

Environmental science, once communicated through formats familiar to expert users, must be communicated effectively to non-experts with requirements for more transparency and engagement and an increasing amount of available data (Grainger, Mao and Buytaert, 2016). Spatial information is no longer confined to paper maps but can be represented digitally using Geographical Information Systems (GIS). It is also no longer confined to experts, with Participatory GIS (PGIS) enabling communities to create and use mapping for spatial information, expanding access to data for research and decision-making (Brown and Kyttä, 2014). Recent technological developments mean spatial data can now also be communicated through three-dimensional (3D) landscape visualisations (Lovett *et al.*, 2015), created using GIS and specialist software or through a virtual globe approach, such as Google Earth, where abstract data can be represented on a satellite base map making it more meaningful and accessible (Sheppard and Cizek, 2009). Such visualisations have been recognised to engage stakeholders by connecting them with familiar environments, engaging their sense of place (Newell and Canessa, 2015).

This thesis explores the potential of 3D landscape visualisation for communicating spatial information for early stakeholder engagement in a catchment wide NFM approach. Previous research has investigated the use of virtual globe tours to communicate local impacts climate change (Schroth, Pond, *et al.*, 2011) and ecosystem services (Harwood, Lovett and Turner, 2015). Using a virtual globe tour approach on the Google Earth platform this research considers how practical and accessible the method is for developing a landscape visualisation for a catchment wide NFM project and how effective it is for communicating information to enhance the understanding for a variety of users. A thorough understanding of how to put together a virtual globe tour with techniques for scripting with Keyhole MarkUp Language (KML), was achieved with the aid of online resources (Google Developers, 2016), published literature (Wernecke, 2009) and inspecting other available tours.

Based on a catchment management project for the River Isbourne, a case study approach was considered suitable for the design and construction of a virtual globe tour. An element of collaboration was incorporated through consultation with an active community group, the Isbourne Catchment Group (ICG), at the outset to identify the key information and data requirements. The operation, navigational features and data content of the developed final virtual globe tour is covered in detail in the results.

The tour was also evaluated through end user assessment using a pre- and post-use survey undertaken in a facilitated group setting, where the participants approach to use could also be observed, and through an online survey. This survey was designed to assess users' opinions on the Google Earth virtual globe tour approach for communicating the NFM project by rating both the technical elements and the content. Both quantitative and qualitative data were collected using a mix of Likert type scale and free text questions. This approach was followed to obtain a deeper understanding than through quantitative analysis alone. The survey was also designed to identify if there was any sense of place effect for participants who were familiar with the area and additional feedback was gathered on the participants perceptions of the impact of NFM in the catchment after viewing the tour.

1.2. Aims and scope

The aim of this research was to explore the potential role of a 3D landscape visualisation in the early development of a NFM scheme. Involving collaboration with a local community catchment group, it explores the extent to which such visualisations can enhance the communication of spatial data and identify key messages and information that could engender early stakeholder engagement in such projects.

Research Objectives

Two research objectives were framed to explore the research aim: -

1. To identify the information requirements and messages that can facilitate positive stakeholder engagement in the development of a NFM project.

2. To establish whether 3D landscape visualisation enhances the communication and understanding of spatial information related to NFM for the engagement of stakeholders.

The research was based on the River Isbourne catchment project, being supported by the University of Gloucestershire (UoG) and the Countryside and Community Research Institute (CCRI). This project was considered suitable for the research as it was in the very early stages of development before any decisions had been made to target specific areas or interventions. Funding had been applied for but was yet to be approved. A scoping report had previously identified the potential for NFM to address issues within the catchment (Clarke, Short and Berry, 2016) and an existing and an active community group, the ICG had consented to take part in the process. Stakeholder engagement will be necessary to gain the support of a wide range of local landowners, farmers, businesses and residents to identify and progress opportunities to implement NFM measures in the catchment.

A 3D landscape visualisation tool, the Google Earth virtual globe tour, was selected to develop and to evaluate a final visualisation product through end user testing. The research was undertaken alongside a wider project evaluating a range of 3D landscape visualisation and GIS tools for communicating catchment features. The survey findings of the end user testing could be used at a later stage to make any necessary modifications and improvements to the developed landscape visualisation for use in the wider evaluation or by the catchment group.

The design and development of the landscape visualisations took place from January to June 2017 and end user assessment followed between June and August 2017.

1.3. Study area and context

The River Isbourne catchment is located within the counties of Gloucestershire and Worcestershire (Figure 2). The river rises to the North East of Cheltenham and flows in a northerly direction for 30km, through the towns of Winchcombe, Toddington, Sedgeberrow and Hinton on the Green, before converging with the River Avon at Evesham. Throughout this thesis the National River Flow Authority (NRFA) catchment boundary has been used to outline the extent of the catchment for consistency, having been used in the catchment project scoping report (Clarke, Short and Berry, 2016). There is some minor variation between the extent of the NRFA boundary, covering an area of 93km2, and the WFD catchment which covers an area of 88km^2 (Environment Agency, 2017a) (see section 4.3.2).

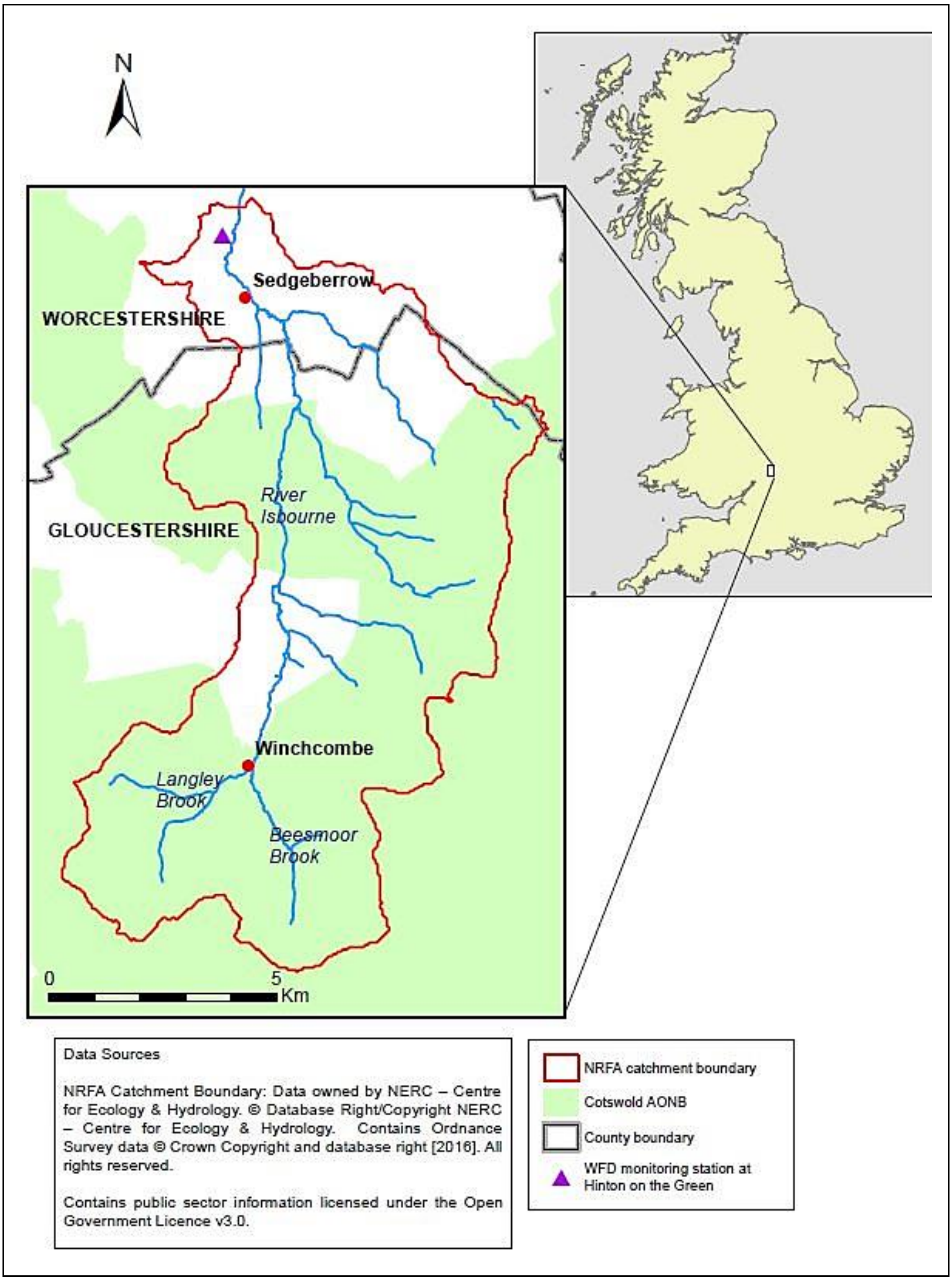


Figure 2. Study Area Location -The River Isbourne Catchment.

Several streams join the main river body along its length, including Beesmoor Brook and Langley Brook which join above Winchcombe (Figure 2). A large part of the catchment sits within the Cotswolds Area of Outstanding Natural Beauty (AONB). The Cotswolds landscape is characterised by stone buildings, drystone walls, rolling grasslands and beech woodland (Figure 3). The Cotswold Conservation Board oversee a management plan that has objectives and policies for future management and Landscape Strategy and Guidelines to support decision making for planning and development (Cotswolds AONB, 2017). In addition, the area contains a number of designated areas including priority habitats, ancient woodlands and Cleeve Common, a Site of Special Scientific Interest (SSSI) covering over 400ha (Cleeve Common Trust, 2017), located at the top of the catchment (Figure 4). The highest point is 330m above ordnance datum (AOD).

Figure 3. A Cotswold landscape view within the River Isbourne catchment (photo by Kate Smith, May 2017.

Figure 4. A man-made pond on Cleeve Common, close to the source of the River Isbourne (photo by Kate Smith, May 2017).

In his book, Lovatt (2013) records the historical use of the river including water mills, swimming pools, livestock and tanning. Some of these features are still in use, others have since been filled in or fallen into disrepair. The river flows through the ancient town of Winchcombe, which is home to many listed buildings, and Sudeley Castle. Figure 5 shows the River Isbourne as it approaches the town.

Figure 5. The River Isbourne as it reaches the town of Winchcombe (Photo © Paul Harrop (cc-by-sa/2.0) geograph.org.uk).

The upper catchment is characterised by springs that appear on the valley sides below the permeable limestone upland geology. These springs are used in places as a source of drinking water for livestock (Figure 6).

Figure 6. A spring below Cleeve Common, now used for livestock drinking (photo by Kate Smith, May 2017).

The River Isbourne catchment is an Avon Warwickshire management catchment within the River Severn Basin District (Environment Agency, 2017a). The water bodies are recorded as not heavily modified or artificial. The latest records for the WFD water body (Table 1) classify the river body as failing, based on ecological standards (specifically for fish, macrophytes and phosphate levels). The failure on phosphates is due to agricultural and rural land management, whereas the biological quality is affected by both physical modifications to the channel and nutrients from sewage and livestock. There are no records for this water body under the earlier Cycle 1 river basin plans to allow direct comparison, however the previous classified waterbodies for the area were also recorded as failing from 2009 (Appendix C). The objective is to achieve a ‘Good’ status by 2021 for phosphates and by 2027 for fish and macrophytes, however there are noted disproportionate burdens of natural conditions and expense involved. The catchment also falls within a Nitrate Vulnerable Zone (NVZ) and is subject to the Nitrates Directive (1991), as part of the WFD, aiming to protect surface and ground waters from agricultural source pollution.

Table 1. WFD status for the River Isbourne, Environment Agency (2017a)

Class	Elements	2016 classification	Reasons for Failure	Objectives
Overall Water Body		**Poor**		To achieve a 'Good' status by 2027
Ecological	Biological quality	**Poor**	Fish	To achieve a 'Good' status by 2027
		Moderate	Macrophytes/ Phytobenthos	
	Physico-chemical quality	**Moderate**	Phosphates **(Poor)**	To achieve a 'Good' status by 2021
Chemical (Priority and hazardous substances)		**Good**		

Flooding in 2007, affected the length of the Isbourne from Winchcombe through to the River Avon at Evesham (Figure 7), inundating farmland, residential and business property and infrastructure. Approximately 90 homes were evacuated in Sedgeberrow, where 4 times the long-term average rainfall fell on July 20th. The river gauge in Hinton on the Green recorded levels rising by 4.6m in one day (Environment Agency, 2010).

The ICG, a community group formed in 2015 to focus on minimising flood events along with the environmental management of the wider catchment area (Isbourne Catchment Group, 2017), has support from the UoG (School of Natural and Social Sciences), CCRI, EA and the Farming and Wildlife Advisory Group (FWAG).

A project scoping report, prepared at the request of the EA (Clarke, Short and Berry, 2016), assessed the feasibility and benefits of using NFM as significant engineering solutions have previously been ruled out as not cost effective. This report concludes that while it is difficult to predict or quantify potential benefits with confidence such measures could improve biodiversity and contribute to improving the WFD status. A community report has also been issued to the catchment group recommending a catchment wide collaborative approach (Clarke and Short, 2016). These reports suggested targeting Langley Brook and Beesmoor Brook in the upper part of the catchment above Winchcombe (Figure 7) as a priority, as the steep slopes cause rainfall to move rapidly down contributing to downstream flooding.

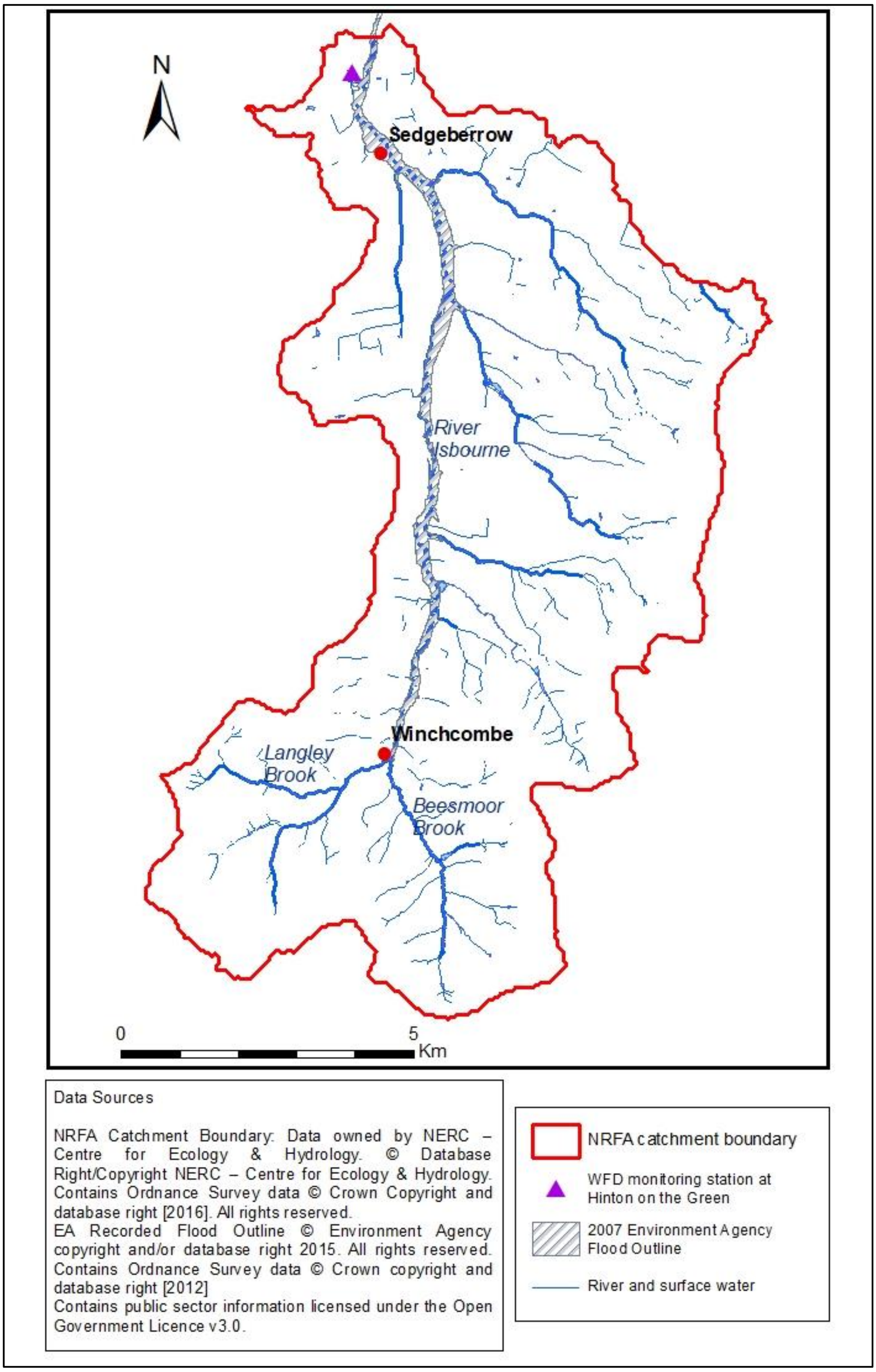


Figure 7. Environment Agency 'Recorded Flood Outline' data for the July 2007 flood event.

Exploring partnership opportunities and funding sources is vital in this catchment wide approach, requiring collaboration with multiple stakeholders, including several county and district authorities, national agencies such as DEFRA and Natural England, and local landowners.

1.4. Chapter review

The remaining chapters of this thesis continue as follows.

Chapter 2 provides a review of literature, exploring existing NFM projects and techniques; stakeholder engagement in environmental management; previous application of GIS for NFM and how 3D landscape visualisation, including Google Earth virtual globe tours, has been utilised for communicating spatial data. It also considers the relevance of sense of place research in the field of landscape visualisation, information systems theories for technology acceptance and end user evaluation.

Chapter 3, the methodology, outlines the research philosophy; the choice of the Google Earth virtual globe tour as a landscape visualisation tool; the design process for development of a prototype tour and final tour and the design of the end user evaluation.

The results have been divided into two chapters. **Chapter 4** details the outcome of the collaborative design process with the ICG and the design and operation of the final developed virtual globe tour. **Chapter 5** contains the results of the end user evaluation surveys, with quantitative analysis supported by qualitative data obtained from free text responses.

Chapter 6, the discussion, reflects on the significance of the results against the initial aims and objectives of this thesis and previous research in the relevant fields. It provides a critical evaluation, identifying the limitations of this research and the visualisation tool.

Chapter 7 summarises the conclusions for the thesis, identifying opportunities for further research.

Chapter 2 Review of Literature

2.1. Natural Flood Management

NFM is a term used to cover a set of interventions and soft engineering approaches working with nature to hold water back in catchments and slow the flow of water by manipulating hydrologic run off pathways and in-channel hydraulic flow regimes (SEPA, 2015). There are a range of materials now available covering the practical application of NFM techniques, providing advice on development of schemes and the suitability of different techniques which include in-channel modifications, floodplain and land-based measures, woodland planting, land and soil management practice (JBA Consulting, 2015; SEPA, 2015; Avery, 2012). Table 2 contains a summary of available NFM interventions that aim to slow the flow of water into and through channels, thereby reducing downstream flood peak and also reduce soil erosion and nutrient loss. Further details of these interventions, along with the benefits and limitations, is provided in Appendix A.

Several NFM schemes have been created in the UK, operating at a variety of scales. These include Defra's' three demonstration projects (Pilkington *et al.*, 2015); 'From Source to Sea' (Holnicote), 'Making Space for Water' (Peak District) and 'Slowing the Flow' (Pickering), along with Stroud RSuDs (rural sustainable drainage systems), Belford and Calderdale 'Slow the Flow'. A summary of the main features of a selection of existing schemes, found in Appendix B, shows that the features of the catchments and the emphasis on techniques varies greatly. Catchment projects range from the relatively small 5.7km^2 Belford Burn to Calderdale, covering 957km^2. All these projects use a range of interventions. Approaches vary from focussing largely on in-channel measures with leaky dams (Stroud) to land management through planting for moorland and peat bog restoration (Calderdale and Edale). No two catchments are alike; each requires a unique approach, utilising a variety of partnerships and funding providers.

As a 'nature-based solution', NFM relates positive outcomes for society with nature (Nesshöver *et al.*, 2017). In addition to reducing flood risk, it offers the potential to deliver multiple benefits to wider beneficiaries; water quality and soil conservation, carbon storage and biodiversity need to be recognised as these could be more valuable (Wentworth, 2011). It is also an opportunity for community benefit (Pilkington *et al.*, 2015) through enhancement of local amenity value. Iacob *et al.* (2014) caution that careful management is required to reduce any potential trade-off in ecosystem services.

Table 2. Available Natural Flood Management (NFM) interventions (source: SEPA (2015) and Avery (2012).

NFM options	Aims	Possible measures or interventions
In-channel measures	Slowing the flow of water through the channel to delay downstream flood peaks Reducing sediment loss	Woody debris Leaky dams Weirs Ditch blocking In-channel planting
Land based structures and modifications	Intercepting overland flow Diversion and storage of run off	Interception ponds and basins Buffer strips Shelterbelts Contour bunds Hedgerows
Woodland planting (using appropriate native species)	Reversing the decline in tree cover, increasing interception, evapotranspiration and infiltration	Woodland restoration and planting (riparian and catchment wide) Shelterbelts Copses
Farmyard measures	Reducing surface water flows and sediment loss and managing water quality	Sediment management Storage structures (silage, manure, yards) Soakaways Rainwater harvesting Swales Cross drains
Land and soil management	To preserve and improve soil structure by controlling erosion and nutrient loss	Buffer strips Contour ploughing Reduced and zero tillage Species rich grassland
Other	Improving and increasing storage of existing channel and catchment structures	Ponds Wetlands Mill structures

Following the recent interest and the noted lack of evidence base to support the use of these techniques (Holstead, Colley and Waylen, 2016; JBA Consulting, 2015), Dadson *et al.* (2017) published a review of the gaps in evidence and priorities for future research. The priorities for NFM were identified as: -

- continued development of a wider evidence base with baseline studies and long-term monitoring;
- assessing the transferability of models developed for small catchments to larger catchments;
- investigating the interaction with groundwater and engineered solutions and with wider implications beyond the catchment level;
- more sharing of information, evidence and experience and development of protocols.

Much of the recently published research around NFM has considered the effectiveness of interventions using modelling; engineered log jams and woody debris (Dixon *et al.*, 2016; Thomas and Nisbet, 2012) forest restoration (Dixon *et al.*, 2016), land management (O'Donnell, Ewen and O'Connell, 2011) and mixed catchment approaches (Metcalfe *et al.*, 2017).

Metcalfe *et al.* (2017) and O'Donnell, Ewen and O'Connell (2011) found that benefits to flood peaks or water quality from interventions and management techniques may be effective only in moderate events. Research has also cautioned the extrapolation of small scale benefits to larger catchments (Metcalfe *et al.*, 2017; Thomas and Nisbet, 2012). Dixon *et al.* (2016) noted there while there was potential for both engineered log jams and forest restoration to reduce flood peaks, at a catchment scale the complex interconnections the effects are variable and require careful analysis. Run off attenuation features also have the capacity to reduce flooding, sediment and nutrient loss but the benefits have been shown to be difficult to assess (Barber and Quinn, 2012).

In addition to this lack of developed evidence base, coordination, communication and access to data are also recognised as barriers to stakeholder engagement and implementation of NFM (Waylen *et al.*, 2017). In a survey exploring the criteria that affect farmers uptake of NFM in Scotland, Holstead *et al.* (2017) found that 60% of respondents had never heard of or had limited knowledge of NFM. Among farmers who had heard of the term there was also doubt about how their actions could have downstream impact. One recommendation was for more effective communication of the science to demonstrate how and where NFM could be used and the benefits that could be achieved both on farmers land and for downstream flood risk.

The communication of river and catchment characteristics, issues of flooding and water quality and the promotion of NFM as an approach to address these issues is important not just for farmers but for all stakeholders, including local government, residents and businesses, as “ultimately stakeholders must agree with the interventions proposed” (Wilkinson *et al.*, 2014, p. 1247). Hopkins and Warburton (2015) found that raising awareness of flood risk is not easy, particularly where there is a lack of direct experience or where perceived blame is directed at poor river management such as a lack of vegetation clearance. Through a co-production of knowledge approach involving local people, Bracken *et al.* (2016) concluded that knowledge of flood risk and measures to reduce it can be improved with the inclusion of a wide range of stakeholders.

The review of literature in the field of NFM indicates that there is a need to communicate the potential mitigation measures and potential wider benefits effectively to a range of stakeholders whose interests and information requirements may vary.

2.2. Stakeholder engagement

Both the WFD and FD encourage public participation. The provisions of the WFD are more specific and far reaching than those of the FD (Albrecht, 2016). Article 14 of the WFD requires the active involvement of interested parties in the consultation procedure for the production and implementation of River Basin Management Plans (RBMP). This includes the discussion of issues and solutions at an early stage in the planning process. Article 10 of the FD includes more general provisions for access to flood risk assessments, plans and maps but has no specific provision for public comment in the early stages of planning.

Whitman, Pain and Milledge (2015, p. 624) recognised interested parties as “any person, group or organisation with an interest or stake in an issue, either because they will be directly affected or because they may have some influence on its outcome”. Research into the involvement of interested parties, or the engagement of stakeholders, in environmental management is not new. From his review of literature, Reed (2008) concluded that integrating scientific and local knowledge enhances decision making through increased transparency and acceptance. A growing body of literature has investigated stakeholder engagement in a range of fields within environmental management, including diffuse agricultural pollution (Blackstock *et al.*, 2010), soil science (Ingram *et al.*, 2016), biodiversity (Sterling *et al.*, 2017), catchment management (Whitman, Pain and Milledge, 2015; Blackstock *et al.*, 2012; Cook *et al.*, 2012) and flood risk management (Evers *et al.*, 2016; Ball, 2008).

It is advisable to engage stakeholders early in the design process and throughout environmental management projects to achieve high quality decisions (Reed *et al.*, 2014; Ball, 2008; Reed, 2008). It is also important to incorporate a wide range of diverse interest groups to incorporate all knowledge and values (Richards *et al.*, 2017; Sterling *et al.*, 2017; Evers *et al.*, 2016; Ball, 2008) and clearly communicate the potential for achieving multiple benefits (Richards *et al.*, 2017; Ball, 2008).

There has been a recent shift in culture from knowledge transfer, promoting education and solutions, to knowledge exchange or co production of knowledge methods, generating solutions using an interactive human development approach (Fazey *et al.*, 2014; Blackstock *et al.*, 2010). Reed *et al.* (2014) suggested that knowledge exchange should be designed into projects to build trust and dialogue for lasting motivation and involvement.

A co-production of knowledge can be achieved with local stakeholders and regulators working together as experts (Lane *et al.*, 2011; Whatmore, 2009). Within the UK there has been a growth in participatory or collaborative approaches to catchment management with an increasingly broad representation (Cook *et al.*, 2012). This includes Rivers Trusts and other voluntary based groups such as the Catchment Based Approach (CaBA, 2017). However, Maynard (2013) also found that there was an inverse relationship of participation of non-experts with the scale of the catchment.

Wilkinson *et al.* (2014) suggested that stakeholder engagement is crucial to greater confidence in catchment management plans designed to reduce flood risk or improve water quality. The proposed catchment systems approach (Figure 8) endorses the incorporation of stakeholder engagement throughout the development and delivery of a run off management scheme, from the identification of the problem through to the implementation and evidence gathering. To achieve a clear understanding of the catchment characteristics local knowledge should be incorporated.

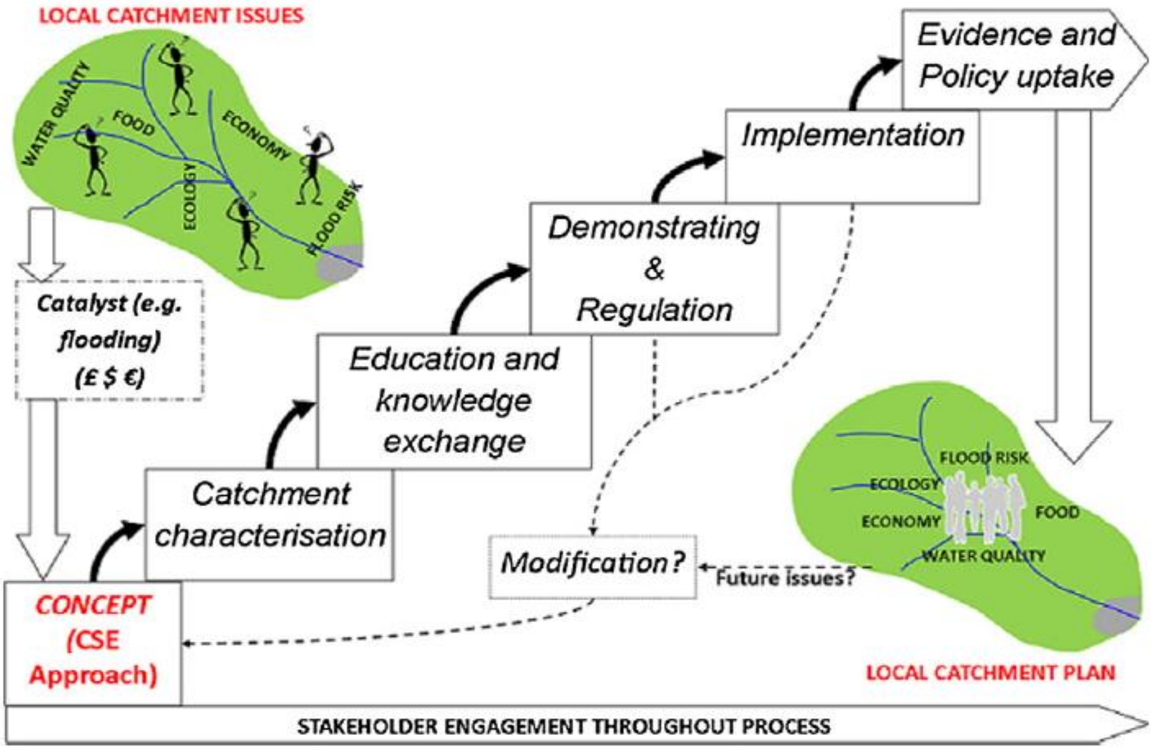


Figure 8. The Catchment Systems Approach (Wilkinson *et al.*, 2014).

Bracken *et al.* (2016) used a co-production of knowledge approach to flood risk management decisions in a project on the River Tweed, where professionals and the community were keen to incorporate NFM measures. Starkey *et al.* (2017) established a community-based monitoring scheme collecting wider catchment data to supplement and enhance official gauged data. This not only provided valuable information; it also encouraged wider engagement within the catchment.

Flood risk management and NFM schemes may require support from a broad range of stakeholders and cross administrative boundaries (Evers *et al.*, 2016; Holstead, Colley and Waylen, 2016). This may include land owners, farmers, businesses, wildlife and heritage organisations, local authorities, river trusts and the local residents.

As noted previously, recent research has explored how farmers can be effectively engaged in environmental management (Holstead *et al.*, 2017; Mills *et al.*, 2017;

Ingram *et al.*, 2016; Blackstock *et al.*, 2010). Reviewing existing literature, Blackstock *et al.* (2010) considered how persuasion theories and knowledge transfer approaches could apply to understanding the influences on farmers beliefs and attitudes to diffuse pollution and water management. They found that farmers need to believe that they are not only part of the problem but can make a difference before they will consider solutions; and that they will want the benefits to outweigh costs. In addition, as farmers are not one distinct group but a diverse range of groups and individuals with different cultures and values, a variety of approaches and tailored advice will be required to engage them (Mills *et al.*, 2017; Blackstock *et al.*, 2010). The importance of involving facilitators to provide farm specific advice for encouraging interest in NFM interventions was a key finding of Holstead *et al.* (2017).

To gain and maintain stakeholder support for a NFM approach, the effective communication of science is vital (Waylen *et al.*, 2017; O'Connell and O'Donnell, 2014). To be effective, any communication of science needs to be salient (relevant to the context), credible (accurate and unbiased) and legitimate (transparent and useable) (Grainger, Mao and Buytaert, 2016; Ingram *et al.*, 2016; Blackstock *et al.*, 2010). Trade-offs may arise in trying to achieve these outcomes. Increasing legitimacy through interaction and an iterative process may decrease the credibility as it can expose uncertainties in the science, raise the expectation of participants and be affected by perceptions of bias (Ingram *et al.*, 2016).

The effective engagement of stakeholders may be limited not only by the credibility, salience and legitimacy of scientific data, but also by the methods of delivery. Cook *et al.* (2012) suggested that closing the gaps in knowledge was limited by the availability of data, use of technology and lack of education effort. Communicating complex spatial and environmental information is challenging and must also consider political and social values (Smith, Wall and Blackstock, 2013).

There are questions regarding stakeholder engagement that remain to be explored in relation to NFM - what information or messages about a river catchment will generate an interest and have the potential to engage a broad range of stakeholders, and what formats can assist with the communication of this spatial information.

2.3. GIS and 3D landscape visualisation

The communication of spatial information and representation of landscapes, historically achieved using paper maps, photographs and models, has progressed to the use of digital technology with the development of GIS and Computer Aided Design (CAD) (Lovett *et al.*, 2015). GIS offers a set of software and hardware tools for acquiring, managing and visualising spatially referenced digital data (Heywood, Cornelius and Carver, 2011).

GIS mapping has been utilised to varying degrees in the development of NFM projects, for desk based scoping studies to identify catchment characteristics and location opportunities (Atkins, 2013; Nicholson *et al.*, 2012; SEPA, 2011) and as a platform for hydrological and hydraulic modelling in options appraisal (Dixon *et al.*, 2016; Iacob, 2015; National Trust, 2015; Nisbet *et al.*, 2015). Such modelling requires large detailed datasets and expert knowledge limiting it to consultant and academic use (SEPA, 2015). The reliability of models is directly related to the available data and the applicability to the scale and nature of the catchment, making them difficult to transfer and apply to other locations (Iacob, 2015).

PGIS balances access to data for research and decision making. For many community or action groups it is used as a tool to support or contest projects (Brown and Kyttä, 2014; Elwood, 2006; Sieber, 2006). Web-based GIS improves accessibility, enabling a large number of users to access and interact with data to facilitate more inclusive, democratic spatial decision making (McCall and Dunn, 2012). Applications of GIS and PGIS to assist with public participation in NFM projects includes the recording of spatial gauge data and enhancement of stakeholder communication (Starkey and Parkin, 2015; Forrester and Cinderby, 2012) and participatory mapping of local knowledge of flood risk and mitigation ideas (Bracken *et al.*, 2016).

Smith, Wall and Blackstock (2013) caution that, although GIS mapping has some value for communication and decision making, there is a risk that it is used for quick access to environmental information at the expense of useful dialogue and that it may unduly influence or create barriers to integration. GIS mapping is also suggested by Starkey and Parkin (2015) as being ineffective alone as a communication tool; additional and supporting methods may be required. 2D maps are not always interpreted correctly, viewers may have problems with orientation or imagining the wider picture (Appleton and Lovett, 2005).

Science has traditionally been presented in formats that are aimed at those familiar with the data or the method of presentation (Grainger, Mao and Buytaert, 2016). More attention is now focussing on the effective communication of science to stakeholders and the public, including the creation and use of data visualisation in the fields of environmental science (Grainger, Mao and Buytaert, 2016) and ecology and biodiversity (McInerny *et al.*, 2014). Visualisations have the potential to improve transparency and build confidence of both scientific process and data for non-scientists and can also challenge the assumptions of scientists (Grainger, Mao and Buytaert, 2016).

Landscape visualisation is created using GIS and 3D CAD software to communicate spatial data. By representing real world places digitally, incorporating recognisable objects, abstract data can become more meaningful, visualisation can make something "seeable to the eye" (Grainger, Mao and Buytaert, 2016, p. 301). 3D visualisations created to communicate flood risk in Exeter and demonstrated at public engagement events and council meetings were found to be helpful and generated interest. Video was also hosted on YouTube and stills used by the media and flood defences were subsequently upgraded (Todd *et al.*, 2014).

A review of published literature indicates that the effectiveness of 3D landscape visualisation has been explored through facilitated workshops, web-based surveys and other settings for a variety of subjects including climate change, planning and land use change and catchment demonstration (Table 3).

A range of tools have been used to create these landscape visualisations including specialist 3D software packages such as 3D Visual Nature Studio[1] and GIS extensions such as Community Viz[2] (for ESRI Arc Scene). These can produce rendered still images, animations that move through landscapes and real-time models that allow navigation and exploration.

[1] https://3dnature.com/
[2] http://communityviz.city-explained.com

Table 3. Applications of 3D landscape visualisation in published research.

Forum	Topic	Location	Visualisation tool	References
Workshop	Climate Change	Canada	Virtual globe (Google Earth) Community Viz, (ArcScene)	Schroth, Pond, *et al.* (2011), Schroth, Pond and Sheppard (2015), Sheppard *et al.* (2011)
		Scandinavia	3D software (not specified) VisAdapt™ project	Glaas *et al.* (2017)
Workshop	Planning/land use	Canada	2D plans and 3D Community Viz (ArcScene)	Salter *et al.* (2009)
		Switzerland	'VisuLands' project 3D Nature Visual Nature Studio, Arc GIS	Wissen *et al.* (2008), Schroth, Hayek, *et al.* (2011)
		Australia	3D software (not specified)	Stock, Bishop and Green (2007)
Workshop and online survey	Climate Change	Australia	Virtual globe tour (Google Earth)	Pettit *et al.* (2011)
Online web-based survey	Planning/wind farm	UK	GIS mapping (2D), photomontage, wire-frame, 3D Nature Visual Nature Studio	Berry and Higgs (2012); Berry *et al.* (2011)

Table 3. cont.

Forum	Topic	Location	Visualisation tool	References
Online survey	Planning/rural landscape	UK	3D Nature Visual Nature Studio	Appleton and Lovett (2003)
IT lab and online survey	Role of sound and realism on perception	UK	Virtual globe (Google Earth)	Lindquist, Lange and Kang (2016)
IT lab online	Planning/land use	Netherlands	Virtual globe (Google Earth)	van Lammeren *et al.* (2010)
Schools use and online file download	Catchment ecosystem services	UK	Virtual globe tour (Google Earth)	Harwood, Lovett and Turner (2015)
Online video and exhibition demonstrations	Flood risk modelling	UK	3D software (not specified)	Todd *et al.* (2014)
Focus groups and public street survey	Biomass crops	UK	3D Nature Visual Nature Studio	Dockerty, Appleton and Lovett (2012)
Targeted interviews	Planning/land use	UK	3D Nature Visual Nature Studio	Appleton and Lovett (2005)

In addition to commercial software products virtual globe applications such as Google Earth offer the ability to view spatial data and objects geolocated onto a satellite base map with guided navigation interactivity (Harwood, Lovett and Turner, 2015; Schroth, Pond*, et al.*, 2011). See section 2.5 for a more detailed review of the application of the virtual globe tour.

Workshop or focus group settings, used in a number of research projects, have been found to encourage discussion regarding land use change (Wissen *et al.*, 2008) and to promote participation and knowledge generation more than still images (Schroth, Hayek*, et al.*, 2011). Schroth, Pond*, et al.* (2011) found that visualisations were best used face to face in planning scenarios, advocating a collaborative and iterative process for development. For Harwood, Lovett and Turner (2015, p. 108) early stakeholder involvement and continued collaboration through iterative workshops "was central to the research design".

Several studies have made recommendations for the use of visualisations in workshops stressing the importance of effective facilitation (Lovett *et al.*, 2015; Schroth, Hayek*, et al.*, 2011; Salter *et al.*, 2009; Stock, Bishop and Green, 2007) and ensuring that content is audience specific (Lovett *et al.*, 2015; Pettit *et al.*, 2011; Salter *et al.*, 2009). Evaluating visualisations in workshop environments limits the results to the participatory audience (Wissen *et al.*, 2008), allowing an insight but limiting the ability to generalise (Schroth, Hayek*, et al.*, 2011) or to use quantitative analysis (Pettit *et al.*, 2011). Wissen *et al.* (2008) noted that visualisations needed to be tested on the pubic to cover a wide range of abilities and learning styles. Salter *et al.* (2009) also found that the room set up and time availability in a workshop can limit the evaluation.

A significant shortcoming of workshops and demonstrations is the potential limit to exploration. According to Glaas *et al.* (2017) visualisations should not just tell a story. This limitation may be overcome by using online, web-based tools and survey evaluation, offering participants the ability to navigate or interact unrestricted by time, and widening the potential audience (Berry *et al.*, 2011). Problems may however be encountered by remote access with lower resolution displays on domestic computer hardware, limited bandwidths for data download and also potential bias in the participant samples (Lovett *et al.*, 2015). Lindquist, Lange and Kang (2016) found no statistical difference in results between IT lab-based use and remote online access (78 lab and 128 online participants) and

Pettit *et al.* (2011) successfully used online evaluation with students with the view that it would be their likely mode of access in the future. In a classroom-based forum Harwood, Lovett and Turner (2015) found primary school children accepted the technology and confidently navigated virtual globe tour visualisations. Although this research did not incorporate end user evaluation the visualisations were also hosted on a website and the number of hits was recorded to track the interest in viewing. Berry and Higgs (2012) found that participants could see the potential for web-based GIS to consider landscape impacts of windfarms in the planning consultation process with 78% of respondents more likely to participate if this was available online.

The evaluation of 3D landscape visualisation can be divided into two main approaches, empirical studies of preference for different formats or tools and case studies of practical applications (Lovett *et al.*, 2015). Schroth, Pond*, et al.* (2011) developed 2D maps, posters and Google Earth presentations and found that preferences varied, those who preferred posters ranked the virtual globes last but those who preferred the virtual globe approach also liked the posters. The sample sizes were too low to determine if this was due to learning styles or technology acceptance. Berry *et al.* (2011) tested a range of formats, including rendered 3D landscape visualisations produced using Visual Nature Studio (Figure 9), for online participation in wind farm planning and found 2D GIS mapping less well understood than 3D images, with photomontages ranking highest for usability and perceived accuracy. A real time 3D model had some usability issues and more research into other formats, including interactive tools, was recommended.

Case study evaluation has been used for landscape visualisation using a participatory, iterative development process for a climate change project (Sheppard *et al.*, 2011) and for demonstrating catchment ecosystem services (Harwood, Lovett and Turner, 2015). The long-term impact of landscape visualisations has also been assessed with follow up research (Schroth, Pond and Sheppard, 2015), finding that they had contributed to awareness and understanding of the local impacts of climate change and had been used to inform policy decisions.

Figure 9. Rendered landscape visualisation model (Berry *et al.*, 2011).

Research undertaken by authors in the field of 3D landscape visualisation has led to the development of frameworks and practical guidelines for their creation and application. Sheppard (2005) considered the risks of using visualisations for future climate change scenarios and developed a methodology for preparation. This was followed by the development of a conceptual framework (Sheppard *et al.*, 2011) for community engagement.

Finding that integrating information as thematic overlays and incorporating diagrams and indicators in landscape visualisation were effective for communicating visual and non-visual information Wissen *et al.* (2008) considered cognitive theory and the functions of 3D visualisation to develop design recommendations (Table 4).

Table 4. Functions of 3D visualisation for information processing (Wissen *et al.*, 2008).

Function	Design recommendations
Directing the viewers' attention, raising awareness and enhancing the chance of perceiving information	Focus attention with dynamic, concise and relevant content. Generate emotion, use interactivity, originality, consider colour and size
Drawing the viewers' attention to the relevant information	Organise complex issues ensure clear transparency of data Simple design instructive presentation
Contextualising the information to help the viewers familiarity	Using an overview of the area and comparative data in realistic situations
Linking the contextual with reality to develop the viewers perception	Provide for mid-levels of reality and complexity, use abstract topographic and spatial information. Use interaction and zooming to develop mental models Provide different layers of access to information

Others have developed practical guidance and frameworks for the development and use of visualisations for the general communication of science and the engagement of stakeholders (Grainger, Mao and Buytaert, 2016; McInerny *et al.*, 2014) that also have application to 3D landscape visualisation. Lovett *et al.* (2015) developed specific guidelines on three key questions regarding development of 3D landscape visualisation; when to use, what to include and how to present them (Figure 10). Table 5 summarises the considerations for effective use and the practical implications for designing visualisations.

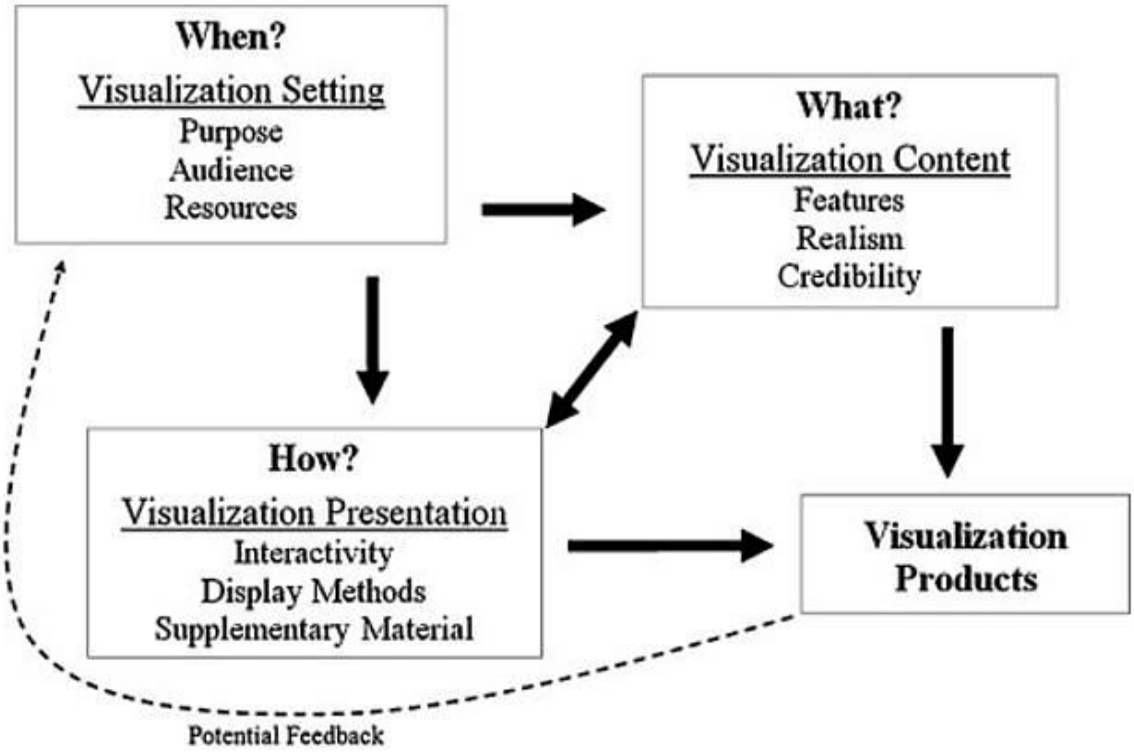


Figure 10. Questions to consider in the development of landscape visualisations Lovett *et al.* (2015).

There is much discussion in published literature on the ability of 3D landscape visualisation to meet the needs for information to be credible, salient and legitimate (Lovett *et al.*, 2015). Credibility can be achieved by not being misleading and using appropriate levels of realism (Schroth, Pond*, et al.*, 2011; Sheppard *et al.*, 2011). Appropriate levels of realism were a key consideration of early research where foreground detail was found to be more important than background and too much realism could be misleading in situations with uncertainty (Appleton and Lovett, 2005, 2003). Visualisations need sufficient realism to hold viewers interest and be engaging (Glaas *et al.*, 2017; Sheppard *et al.*, 2011), should justify the data and processes with clear sources and metadata (Schroth, Pond*, et al.*, 2011) to be legitimate and be relevant to the context and the audience to be salient (Pettit *et al.*, 2011; Salter *et al.*, 2009). Sheppard (2015) argues that to be relevant climate change must be made local, visually compelling and connect across scales. Iterative, collaborative design processes can support credibility by reducing the risk of developer bias where the technician (intentionally or unintentionally) influences content or style (Lovett *et al.*, 2015).

Table 5. Considerations for the effective use and design of 3D landscape visualisations, from Lovett *et al.* (2015).

	Things to consider	**Practical implications for design**
WHEN to use		
Purpose	Stage of planning Level of required detail or realism Scale of the area Involvement of stakeholders Non-visual information requirements	• Overview or navigation with low level of detail and design is more suitable early in planning and for wider areas. • High levels of detail or realism are more suitable at site specific, proposal stages. • Incorporating local knowledge early can enhance legitimacy.
Audience	Variety of interest and understanding Age, background and technical familiarity	• Be audience aware e.g. older participants may prefer photomontages. • Assist viewers with issues such as orientation by incorporating inset maps.
Resources	Available time, experience, data and budget	• Be realistic about what is achievable with the resources available.
WHAT to include		
Features	Choice of content and viewpoints	• Content and presentation may be influenced by the technician, a consultative process can provide salience.
Realism	Level of detail and realism	• High levels of detail can suggest accuracy but can be misleading if there is uncertainty involved. However, realism can also generate familiarity. • Foreground detail can be more influential than distance or background. • Practical issue of rendering large files of complex data, needs processing capability.
Credibility	Transparency	• Technicians can influence, through style or representation, leading to potential bias – disclosure and transparency of data and processes are essential.
HOW to present		
Interactivity	Navigation and control	• Appropriate level of interactivity depends on the nature of the audience and resources available.
Display Methods	Level of immersion or interactivity required Workshop v internet-based distribution	• Target audience and resources available will determine decisions e.g. immersive technology in a workshop will require resources for support. • Consider the geographical location and potential size of the audience.

Balancing the information needs and presentation methods can be difficult (Glaas *et al.*, 2017; Lovett *et al.*, 2015). Glaas *et al.* (2017) found that visualisations made climate change relevant to individuals at a household level by using Google Street view imagery, but not necessarily accurate in content. Relevance can be improved by providing a variety of viewpoints that will be appropriate for different viewers (Appleton and Lovett, 2005) and incorporating interactivity to enable participants to access the level of information that is relevant to them (Harwood, Lovett and Turner, 2015). Lovett *et al.* (2015) considered content and interactivity to be more important than immersive capacity to achieve salience and credibility.

Ultimately visualisations will only be as helpful as the information they contain (Lovett *et al.*, 2015) or the scenario in which they are applied (Schroth, Pond and Sheppard, 2015). They must be followed up with discussion to maintain interest and engagement (Todd *et al.*, 2014). According to Lovett *et al.* (2015, p. 91) "3D visualisation tools will not be relevant for all landscape planning issues and are certainly not a panacea for poorly implemented participatory processes or scenario modelling".

The review of GIS and landscape visualisation literature indicates that for NFM the use has been limited to scoping, modelling and collecting spatial data. Visualisation approaches to communicating spatial data have been used in a variety of other fields and there are supporting resources with frameworks and guidelines to consider for effective design to achieve the requirements for information to be credible, salient and legitimate. The following section will consider the relevance of sense of place and place attachment to visualisation.

2.4. Sense of place, place attachment and visualisation

Within environmental psychology and human geography, sense of place and place attachment theorise the bonds that individuals and groups have with their environment. Masterson *et al.* (2017) describe how place attachment and place meaning together form a sense of place, with attachment being an emotional bond and meaning being the description, symbolism or character of a place. A framework created by Scannell and Gifford (2010a) identified three dimensions of place attachment - 'person' (individual or collective meanings), 'psychological process' (cognitive and behavioural) and 'place' (having civic or social and physical elements at spatial levels). The significance of sense of place and place attachment have been studied in a range of environmental scenarios and locations including a flood protection scheme in Italy (Laborde, Imberger and Toussaint, 2012), river restoration in Bangladesh (Alam, 2011), vegetation management and biodiversity in Australia (Gosling and Williams, 2010) and pro environmental behaviour in UK towns (Scannell and Gifford, 2010b).

The relationship between sense of place and environmental action is not straightforward. Attitudes may vary with regards to proximity, length of residence, depth of experience (Alam, 2011), and the quality or uniqueness of the environment (Scannell and Gifford, 2010b). Kudryavtsev, Stedman and Krasny (2012) found that meaning can be created through experiential or instructional education even if people have no direct experience of being in an environment. Stedman (2003) found that natural or physical attachment, not civil attachment, may predict pro environmental behaviour, however it was not a simple relationship as the basis of attachment or meanings associated with the landscape can change over time. In a study of farmers attitudes to vegetation management and native tree planting in Australia connectedness to nature, not place attachment, were found to be associated, but not causal (Gosling and Williams, 2010). Farmers had multiple goals, including profit, and complex values and interests. They suggested that multiple benefits for wildlife and nature must be included in communication to promote conservation.

Chapin III and Knapp (2015) concluded that sense of place can engage individuals in local sustainability initiatives but as scale increases there are greater challenges in the management of conflicting place meanings where different stakeholders' values within the community should be considered. They assert that cooperation can be fostered among the varied stakeholders through transparency and dialogue to identify shared aims. Gosling and Williams (2010) and Scannell and Gifford (2010b) noted that further research was required to determine how natural place attachment can be developed for more pro-environmental behaviour with Alam (2011) advocating more effort on education and awareness. Masterson *et al.* (2017) argued that sense of place can both determine an outcome or be the outcome.

Reviewing landscape visualisation literature, Newell and Canessa (2015, p. 26) looked at how geovisualisations, as "digital representations of real world places that are geographically-accurate and built with high degrees of realism", could connect people with a sense of place. They assert that it can stimulate thoughts by drawing upon memories and understanding, generating interest and identifying concerns and as such it is a useful tool for a collaborative approach for environmental management where stakeholders have familiarity with places. Collaborative landscape visualisation processes have been found effective for communicating local impacts of future climate change (Schroth, Pond*, et al.*, 2011; Sheppard *et al.*, 2011) as they stimulated thought and emotion. Salter *et al.* (2009) noted the importance of considering what stakeholders find important in their sense of place as their values will determine the emotional response where they can better imagine the impacts or opportunities.

Findings in sense of place and place attachment research indicate that landscape visualisation has the potential to engage stakeholders by connecting them with familiar environments. This has implications for deciding what to include and how to create visualisations to generate familiarity and connect with viewers sense of place, with Newell and Canessa (2015) advocating the use of collaborative approaches. Over a catchment wide scale there may be several potentially conflicting stakeholder values to be considered. It also has implications on how to interpret the results of this landscape visualisation research, considering how opinions may vary with the level of familiarity with NFM, the catchment area or meanings attached to the landscape.

2.5. Google Earth and virtual globe tours

Virtual globes, viewed on flat, 2D screens, provide users with a digital, visually accurate representation of the earths 3D surface (Elvidge and Tuttle, 2008) which can be viewed from different angles and altitudes. Launched in 2005, Google Earth is a freely available online virtual globe platform. It offers "the ability to view seamless, true colour satellite imagery at every location on the surface of Earth" Ballagh *et al.* (2011, p. 57) and allows the exploration of spatial and temporal changes at different scales and perspective (Tooth, 2015; Ballagh *et al.*, 2011). Other online virtual globes include NASA World Wind and Arc Explorer (Butler, 2006). Constructed as a mosaic of satellite and photographic imagery, Google Earth coverage varies in image quality, collection date and the availability of 3D coverage for terrain, buildings and trees however it is recognised as a useful tool for education and research (Tooth, 2015). In addition to a place search function it has a number of other features; it can be annotated with placemarks, paths and photographs, can import GPS data and can be used to create animated virtual globe tours (Google Earth Outreach, 2017). The latest version, Google Earth 9, a web version for Google Chrome, was released in April 2017.

The development and use of virtual globe applications has been explored in research into the communication of ecosystem services (Harwood, Lovett and Turner, 2015), climate change landscape planning (Schroth, Pond*, et al.*, 2011) and landscape futures under different natural resource management scenarios (Pettit *et al.*, 2011). The approach allows the addition of spatial data, georeferenced 3D models and text placemarks to the satellite base imagery (Figure 11). Guided navigation can be incorporated in the approach, with onscreen tour controls offering viewers the ability to stop, rewind and resume the navigation at their own pace and levels of interactivity can be achieved with the addition of hyperlinks and the ability to click to activate placemarks on the map (Harwood, Lovett and Turner, 2015).

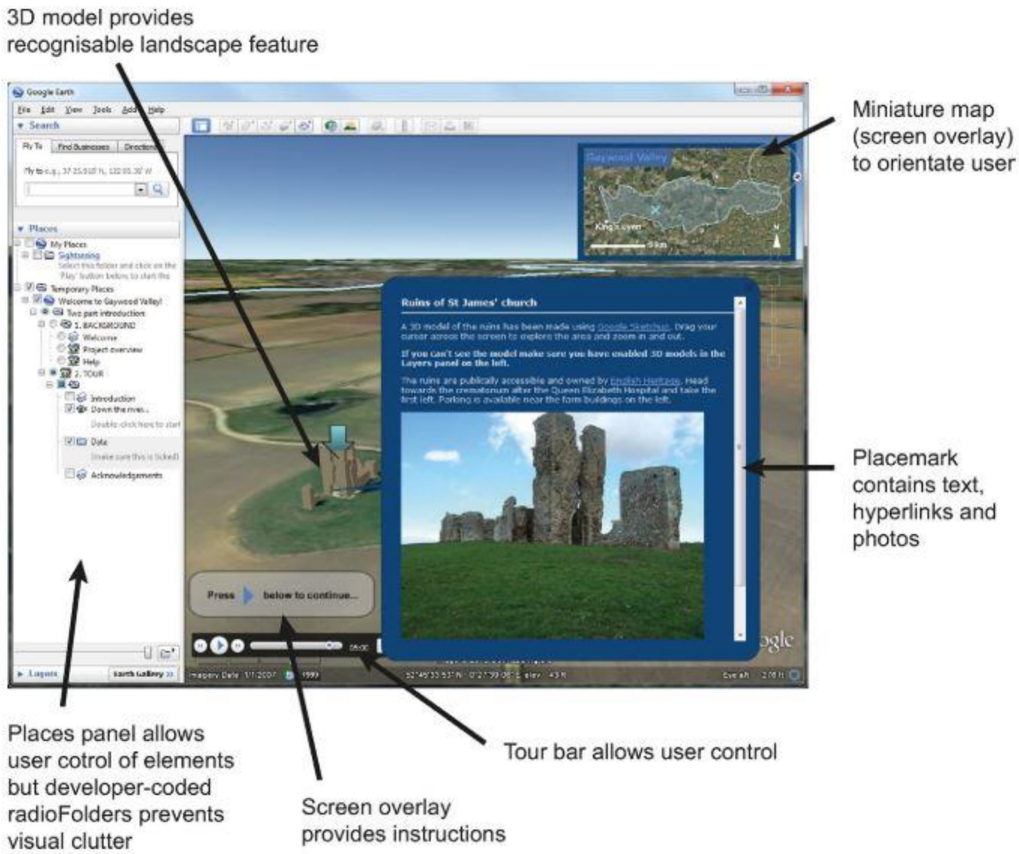


Figure 11 Components of a virtual globe tour used to demonstrate catchment ecosystem services (Harwood, Lovett and Turner, 2015)**.**

A virtual globe approach has also been used to assess the contribution of sound to perception using photorealistic perspective views (Figure 12) (Lindquist, Lange and Kang, 2016) and the cognition of spatial data presented in different formats, using coloured raster cells and icons (van Lammeren *et al.*, 2010).

Figure 12. Photorealistic view from Google Earth used by Lindquist, Lange and Kang (2016) in an online survey.

Web based GIS, including virtual globes such as Google Earth, offer accessibility and inclusivity for participatory approaches with the potential for interaction with large numbers of users and democratic management of information (McCall and Dunn, 2012) although caution has been advised for the use of the tool. According to Sheppard and Cizek (2009) Google Earth virtual globe tours have the benefits of accessibility and the ability to interest and engage through interactivity and representative views. However, they also add caution on the potential for misuse and unintentional bias in preparation. Phadke (2010) contends that while Google

Earth is an accessible tool that enables viewers to explore landscapes outside their locality, it does not necessarily engender trust or credibility as it lacks realism, relies on a snapshot in time and can distort perception. The author also contends that viewers will interpret visual images through their own episteme or value systems and that they may not be persuaded by image alone.

Sheppard and Cizek (2009) developed guidelines for the ethical use of virtual globes for 3D landscape visualisation to address potential issues including accuracy, representation and visual clarity. Table 6 outlines the design criteria and a selection of key recommendations that aim to address these issues. (Phadke, 2010) suggests that to support credibility, transparency of both data and the process of creation are vital and also that Google Earth should not be used to simulate uncertainty or future landscape scenarios that may alienate or shock.

Table 6. Criteria for designing Google Earth virtual globe tour landscape visualisations, from Sheppard and Cizek (2009).

Design criteria	**Recommendations for the design of virtual globe tours**
Accuracy (not distorted)	• Avoid manipulation or distortion of the landscape views with vertical exaggeration. • If exaggeration is used declare it.
Representation (typical and significant)	• Use of typical and important views at different altitudes, scales and views • Involve local people with selections
Visual clarity (appearance)	• Present clearly, using suitable and appropriate colours with consideration of the subject and background imagery
Interest (engaging for the audience)	• Involve the ‘community’ in development – use local knowledge and purpose • Allow the user to interact independently • Use simple non-technical terminology and focus on the key messages
Legitimacy (supported data)	• Avoid emotive or leading information • Provide metadata and supporting references • Use up to date and relevant site photography to support aerial views
Accessibility (ease of use)	• Use free to download platform of Google Earth • Provide easily downloadable files and clear instructions for use
Presentation and framing (labelling and animation)	• Use an iterative review process to achieve a credible presentation • Locate overlaid imagery appropriately (don’t block the view unnecessarily)

Google Earth virtual globe tours have been shown to raise community awareness in facilitated workshops (Pettit *et al.*, 2011; Schroth, Pond*, et al.*, 2011) and online using navigation and interactive features (Harwood, Lovett and Turner, 2015; Pettit *et al.*, 2011) and can be useful tool for strategic planning (Pettit *et al.*, 2011) and for education purposes (Harwood, Lovett and Turner, 2015) (see Table 2). They have the potential to change the traditional relationship of expert and client by being freely available (Lange, 2011) and to be a significant addition to the web-based tools available for PGIS (McCall and Dunn, 2012).

Problems have been identified with the use of the virtual globe approach. Schroth, Pond*, et al.* (2011) found that users can get lost when exploring and navigating independently and that adding in the dimension of time, considering historical or future changes may be difficult to comprehend. To lessen these issues, they recommended the use of guided navigation or adding a facility for reorientation. When observing school children using tours Harwood, Lovett and Turner (2015) found that they had no issue navigating or understanding the format supporting the suggestion of Pettit *et al.* (2011) that online and interactive formats are the likely future mode of access for the younger generation. Some doubt has also been raised regarding the long-term impact of virtual globe tours by Schroth, Pond and Sheppard (2015) who found that, although the format had been initially effective for generating interest and engagement, it was not well remembered and had not been used in decision making processes where still images were favoured.

There are obstacles to the preparation of virtual globe tours with Schroth, Pond*, et al.* (2011) noting that although Google Earth is accessible it takes considerable knowledge and time to prepare and present the data and additional materials such as models or images. Distribution clauses limit the online dissemination of licenced data restricting the use to open licence datasets (Berry *et al.*, 2011). Scale also affects the representativeness of landscape visualisation (Schroth, Pond*, et al.*, 2011). Pettit *et al.* (2012) found multi scale visualisation approaches to the impact of climate change were limited by the availability of suitable and openly available datasets at appropriate resolutions.

Despite the limitations to both the use and the preparation of Google Earth virtual globe tours noted in this review of literature, this approach to 3D landscape visualisation has been explored in previous research and it offers an approach that is technically accessible and can be distributed online. Referring to the guidelines suggested by Sheppard and Cizek (2009), practical recommendations can be followed to meet design criteria along with reference to approaches suggested in other research including the incorporate local knowledge through collaboration.

2.6. Future visioning approaches

In addition to the use of 3D software and virtual globes, which have changed little since their initial use (Schroth, Pond and Sheppard, 2015), recent research has considered the potential of mobile technology with virtual or augmented reality (Bishop, 2015; Gill and Lange, 2015; Lange, 2011) and how it may change the future of landscape visualisation. Bishop (2015) created an iPhone app with augmented sound and visuals for the potential application in the fields of climate change, sea level and landscape change and renewables. There were data and technical issues and the technology was still to be evaluated to determine the functionality, the ability to influence, and levels of enjoyment and trust. A virtual reality simulation Flash Flood! built using a gaming engine and a terrestrial laser scanner to record river valley adjustments after rainfall events, can be viewed with Oculus Rift or through YouTube on a mobile device (SeriousGeoGames, 2017). The in-situ use of smartphones, using GPS and streaming data, reduces the need for expensive hardware and graphics for viewing and allows a multi-sensory experience incorporating sound and smell but is still constrained by network limitations (Gill and Lange, 2015). These approaches are likely to be more suitable for visualising localised, site specific design proposals than wider applications in the early planning stage (Lovett *et al.*, 2015) such as the early stages of a catchment wide NFM project.

2.7. Information systems theories and end user testing

Information systems theory modelling considers how users come to accept and use technology. Davis, Bagozzi and Warshaw (1989) developed the technology acceptance model (TAM), drawing on experience of information systems research. They assert that user acceptance is determined by a combination of two factors, the perceived usefulness being the primary factor and perceived ease of use being secondary; users will tolerate usability issues to access functionality. These factors should be considered when developing a new system with thought required for prototype development and the appropriate level of user input. Systems that are not perceived as being useful should not be rolled out. (Bresciani and Eppler, 2015) developed a framework to evaluate information visualisation. This combines TAM with Rogers' Theory of Innovation Diffusion (TID) (Rogers, 1995), which seeks to explain how the use of technology spreads. This adds a social component, the dimension of perceived authority (Table 7). This framework can be used for evaluation but can also be considered in the development of visualisation techniques.

Table 7. Key Factors for adopting systems for information visualisation determined by TAM and TID **(Bresciani and Eppler, 2015).**

Dimension	Factors determining adoption
Perceived ease of use	
Easy to learn	Easy to start interacting effectively
Controllable	Easy to interact and easy to change parameters
Clear and understandable	No previous knowledge required
Flexible	Easy to manipulate for the purpose
Easy to become skilful	Quick to reach full potential
Easy to use/understand	Limited cognitive effort required
Perceived usefulness	
Work more quickly	Helps focus on relevant aspects
Job performance	Augments reasoning and coordination
Increased productivity	Working faster
Effectiveness	Achieve tasks promptly
Makes job easier	Simplifies main tasks
Useful insight	Leads to new insights
Perceived authority	
Subjective norms	Important people think it should be used
Network effects	Peer use after innovators set trend
Image	Perceived to improve ones' image
Observability	Information visible to others
Branding	Distinctive name, well promoted
Aesthetics	Fun and pleasing to the eye

Evaluation of information visualisation has been categorised by Lam *et al.* (2012) into two scenarios; understanding data analysis and evaluating visualisations, including user preference and experience. User experience evaluation is required to obtain feedback and opinion to inform the process to improve the visualisation. This can be practically achieved through end user testing with observation and questionnaires. Questionnaires have been used to obtain feedback on landscape visualisations presented in facilitated workshops (Glaas *et al.*, 2017; Schroth, Pond*, et al.*, 2011; Salter *et al.*, 2009) and in lab-based and online study (Berry *et al.*, 2011; Pettit *et al.*, 2011; van Lammeren *et al.*, 2010).

When planning a usability study, decisions are required about how the data will be used and what the user will be interested in. According to Tullis and Albert (2013) a usability study may be formative, an iterative process making improvements to the system as it is developed, or summative, reviewing the user experience of the developed system to establish if it meets its objectives. Measuring the user experience will determine if it can be successfully used and how satisfactory the interaction is.

Tullis and Albert (2013) contend that focus groups for iterative development should ideally have around eight participants to reduce the risk of any dominant personalities. A summative usability study should have 50 to 100 participants, with numbers as low as twenty there may be high variance and a difficulty in generalising. However, the majority (80%) of usability issues can be identified with as few as five participants if all potential user groups are represented and the scope of evaluation is limited.

In addition to the ease of use, user experience evaluation can also assess attributes to inform design such as the visual appeal, usefulness of features, credibility of content, and the level of understanding achieved (Lam *et al.*, 2012). These are more often assessed by collecting subjective ratings in questionnaires with Likert type and open-ended questions.

TAM, TID and user experience evaluation have relevance in this research for considering both the usefulness and the usability of the visualisation tool for communicating the catchment features, issues and the potential for using of NFM.

2.8. Summary of literature review

This review of literature indicates that there is a need to develop effective methods to communicate catchment information for NFM projects to generate interest from a wide range of stakeholders, with much of the previously published research focussing on the evidence base (Dadson *et al.*, 2017), data collection (Starkey *et al.*, 2017) and farmers attitudes to uptake (Holstead *et al.*, 2017).

Stakeholder engagement is known to enhance decision making (Reed, 2008) and is recommended at the outset and throughout any environmental management project along with the incorporation of knowledge exchange (Reed *et al.*, 2014). It is important to communicate the multiple benefits (Richards *et al.*, 2017) of NFM to encourage the involvement of a broad range of stakeholder interests.

Investigated in other scenarios, 3D landscape visualisations have the potential to facilitate the understanding of complex spatial information, generating interest and consensus among participants (Lovett *et al.*, 2015). They also have the potential to connect viewers with a sense of place making data more meaningful for familiar places (Newell and Canessa, 2015). Virtual globe tours have the benefit of being accessible for creation and distribution (Sheppard and Cizek, 2009). They can be used in both a workshop forum and online to communicate and engage viewers at a variety of scales incorporating representational views and interactivity (Harwood, Lovett and Turner, 2015; Pettit *et al.*, 2011; Schroth, Pond*, et al.*, 2011).

End user evaluation can be used to assess both the usability of a visualisation and its effectiveness for communication through subjective ratings and open-ended questions. Technology acceptance and innovation diffusion also have relevance for design decisions during development of visualisations.

Chapter 3 Methodology

3.1. Research philosophy and methodology

This research was undertaken using the River Isbourne catchment as a case study to focus on the communication of spatial data in a NFM project. This approach was followed to gain an in-depth understanding of the potential for the application of a landscape visualisation technique in a specific scenario. A case study approach to research seeks a deeper understanding of one instance rather than broader knowledge of a large number of examples and can incorporate more than one method of evidence collection, as required to achieve the specific goals (Gerring, 2007).

There are issues regarding the suitability for wider generalisation however the findings of case study research can be transferable depending on the similarity of contexts (Lincoln and Guba, 2000) and the degree of transparency of method and data (Donmoyer, 2000). Based on experience and reality, case studies can form the basis for further work and linked to action and changes in practice in real world projects (Blaxter, Hughes and Tight, 2001). The findings here could therefore have potential relevance to future research on 3D landscape visualisation or in the development of other catchment wide NFM projects.

A collaborative approach, through direct consultation with the ICG at the outset, was selected to enable the information requirements of stakeholders to be identified and incorporated into the landscape visualisations. These requirements were followed through the design process allowing reflection on the contribution of the process to the data and the visual presentation.

A pragmatic epistemology, using both inductive and deductive approaches, was considered appropriate for the research. The experience of developing a landscape visualisation product and usability evaluation were combined to consider both the accessibility and usability of the Google Earth virtual globe tour approach and the helpfulness of the visualisations for communicating information in the early stages of a NFM project. The usability testing aimed to collect both quantitative and qualitative data through a survey incorporating pre and post use questionnaires. Both closed and open-ended questions were formulated to determine the participants opinions on usability and the effectiveness of communication along with their understanding of the spatial information and level of interest. This approach was used to enable a deeper understanding than quantitative analysis alone as standard statistical analysis conducted on the survey data could be supported by the results of free text responses. It was also an approach used in previous evaluations of landscape visualisation (Berry *et al.*, 2011; Pettit *et al.*, 2011; Schroth, Pond*, et al.*, 2011; Salter *et al.*, 2009).

3.2. Choice of landscape visualisation tool

From the review of literature, it was clear that a variety of landscape visualisation tools and techniques were available for research into the communication of spatial data to facilitate understanding and stakeholder engagement. These include web-based GIS, bespoke software, licenced 3D software packages such as Visual Nature Studio and dynamic interactive virtual globe tours created with online platforms such as Google Earth and NASA World Wind (Lovett *et al.*, 2015).

The landscape visualisation technique selected for this research was a Google Earth virtual globe tour. This approach was considered potentially suitable for the following reasons: -

- Google Earth is a freely available platform. It is a familiar and technically accessible approach for non-expert participants offering 3D views from different angles, scales and perspectives (Tooth, 2015). Unlike specialist 3D software and GIS, it is also easily shared over the internet (Tooth, 2015), giving the potential to interact with a larger number of participants (McCall and Dunn, 2012).
- Virtual globe tours can be customised without the need for specialist software or hardware (Harwood, Lovett and Turner, 2015).
- It allows interactivity with exploratory visuals, textual information and guided navigation through virtual flight. This enables coverage over a wider spatial area than other tools that are more suitable for single viewpoints (Lovett *et al.*, 2015).
- It has been used successfully in previous research including the communication of catchment ecosystem services (Harwood, Lovett and

Turner, 2015), the impacts of climate change in landscape planning (Schroth, Pond*, et al.*, 2011) and resource management (Pettit *et al.*, 2011).

- Published guidance regarding 3D landscape visualisations includes what to include, when to use and how to display (Lovett *et al.*, 2015) and a suggested code of ethics for using Google Earth (Sheppard and Cizek, 2009) that can be applied to the development virtual globe tours in this research.

3.3. Creating virtual globe tours - method and resources used

Before embarking on the development of a virtual globe tour of the river catchment, it was first necessary to achieve a clear and thorough understanding of the operation and capabilities of the Google Earth platform and the scripting language used to create and customise components. This scripting enables additional styling and more complex tour animations beyond the basic functions of the Google Earth platforms. The scripting language used for Google Earth is KML which is accessible and readable. It is an XML (eXtensible Markup Language) file format language originally developed for use with Google Earth that has been adopted by the OGC and used by other browsers including NASA World Wind and ESRI ArcGIS Explorer. These browsers read and display the KML file components directly on their maps.

A detailed description of Google Earth and the structure of the KML scripting language, including the elements, application of styles, animation, incorporation of models and file distribution, can be found in Appendix D.

The Google Earth tour and data layers in this research were created using Google Earth Pro (v7.1.7.2606) on a Windows 10 laptop. All the data and the features of the tour in this research can be both created and viewed using Google Earth desktop or Google Earth Pro versions 6 or 7. Both versions are also available and supported for Mac and Linux. At the time of writing the Google Earth app for iOS and Android and Google Earth for Google Chrome (v9) did not support the viewing or creation of virtual globe tours (these do have limited capability to view simple KML features). See Appendix E for more information and links for downloading Google Earth.

The text editor Notepad++(v7.3.2) was used for scripting (with XML language) https://notepadplusplus.org/download/v7.3.2.html, and the output saved as KML files. No previous knowledge of coding was required to learn KML scripting. Various online resources available through Google (Google Developers, 2016) and other websites were used to learn KML (see Appendix E) along with a published guide, 'The KML Handbook' by Wernecke (2009). Other virtual globe tours, available to download or view online, were also explored to develop a deeper understanding of the available features and design options (see Appendix F).

Google Earth does not have the analytic capabilities of a GIS. ESRI ArcMap 10.4.1 was used for any required manipulation and analysis of GIS datasets and to export the required data using the Geoprocessing tool 'convert to KML'. This automatically transformed data from the projected British National Grid (EPSG: 27700) to the coordinate reference system used in Google Earth - WGS84 (EPSG: 4326), as defined in the Open Geospatial Consortium (OGC) 2.2 specification. ArcGIS is not open source software, however for those without access the open source alternative QGIS could be used to download, process and format the data and has a KML conversion tool.

3.4. Tour design

3.4.1. Design criteria

The design and development of the virtual globe tour took into consideration guidance on the use of 3D landscape visualisations from Lovett *et al.* (2015) and criteria suggested by Sheppard and Cizek (2009) in their review of the ethics of Google Earth.

The framework developed by Lovett *et al.* (2015) provides guidance on when to use visualisations, what to include in them and how to present them to meet the information requirements of credibility, salience and legitimacy in stakeholder communication (Table 5). They conclude that the target audience and available resources should have an influence and that design should also involve stakeholders. Practical implications raised in this research were considered in the design of the virtual globe tour for this thesis

Sheppard and Cizek (2009) also highlighted the importance of incorporating local opinion in design decisions when using Google Earth for landscape visualisation, to ensure that they are suitable for the community requirements and include representative views. Their suggested code of ethics includes important recommendations including the avoidance of distorting or manipulating the landscape, not being emotive or shocking and ensuring transparency of data and processes (Table 6).

The functionality of the tour in this research was also influenced by the research by Harwood, Lovett and Turner (2015) who, in addition to the ethical considerations outlined by Sheppard and Cizek (2009), noted practical considerations including the importance of building in adequate time for viewers to read and consider information and adding manual tour controls to pause the animations allowing exploration of interactive features.

The content of the virtual globe tour was affected by the availability of data and data licence conditions. The OS, Natural England and the NRFA were contacted to clarify the licence conditions for their data for the creation and distribution of Google Earth tours for this research purpose. The Google Earth licencing agreements were also checked for distribution restrictions (see Appendix G for data licencing requirements). Data sources were disclosed in the tour with attribution statements included in placemark balloons, and links to the relevant licence statements where required.

3.4.2. Prototype tour development

Much of the learning process for KML scripting for features and tour animations involved experimentation, using a cut, paste and script editing process, to determine what worked. A prototype tour was developed during this time to demonstrate how the Google Earth features (placemarks, overlays, models and animation) could be used to communicate information in sequence with guided navigation through the landscape. The aim was to show how GIS data, manually created elements and other information such as text and photographic images could be incorporated on the map screen. This tour also included some interactivity with links to websites and allowing the user to click on features to activate placemark text balloons to access further information.

ArcMap 10.4.1 was used to process GIS datasets and to export the required data. The output of this conversion was saved as KMZ archive file format. These files were opened in Google Earth and then, using the cut and paste technique, the relevant data extracted and copied into the text editor, Notepad++, to be added to the prototype tour script. Some formatting was undertaken in ArcGIS before the data conversion, however appropriate colours and transparency of features were set using a combination of Google Earth functions and manual KML scripting.

The scripting for the KML elements and tour animations were assembled using Google Earth Pro and the text editor Notepad++ . Screen overlays were created using Microsoft Publisher and saved as either JPEG or PNG files. Models of woodland areas, with multiple trees geolocated in the landscape, were created using SketchUp Make 2017, (v. 17.1.174) with the extension Tree Warehouse and a free trial version of the Skatter extension

Appendix D contains more detailed information on KML structure and scripting and Appendix E details of resources for creating and viewing virtual globe tours.

With a duration of 4 minutes and 34 seconds, the prototype tour demonstrated a variety of Google Earth features. Table 8 shows the KML features and elements used to generate map content and the datasets and other resources used.

The prototype tour loaded into Google Earth with screen overlays providing introductory and information pages. Once activated (by double clicking on the tour icon in the contents panel) the animation began at an altitude where the Cotswolds AONB dataset was animated into view on the map screen (Figure 13). During the navigation a series of screen overlays and placemark balloons provided linking explanatory dialogue. As it zoomed to the NRFA catchment area the OS Rivers and Watercourses datasets were animated into view on the map, followed by Cleeve Common SSSI (Figure 14).

Table 8. Content and features of the prototype tour.

Google Earth KML feature and elements	**On screen tour content**	**Data sources, process**
Placemark - Lines	Boundary lines Rivers	Cotswold AONB and NRFA catchment GIS datasets OS Rivers and Open Map Watercourses GIS datasets
Placemark - Polygon	Coloured/highlighted areas in a variety of colours and transparencies	EA Recorded Flood Outline and Natural England SSSI GIS datasets Polygons manually created in Google Earth and KML
Placemark - Points	Labels	Manually scripted river and place names
	Range of placemark information balloons incorporating text, images, links to websites and an embedded video clip	Scripted text, formatted colours and text fonts using KML styles. Links to EA and Natural England websites Google Earth screenshot historic imagery (1945), YouTube video
2D and 3D Models	Trees planted in woodland areas	Geolocated COLLADA model created in SketchUp Make
Screen Overlays	Introductory pages and instructions Linking text dialogue Inset location maps	Text information and photographic images- created in publisher and saved as JPEG images Screenshot Google Earth imagery, annotated in Paint
Tour instructions – (gx: TourPrimative)	Animating content in and out of view and navigation at customised speeds and durations, pause controls	Manually scripted KML tour instructions demonstrating a variety of customised speeds, altitudes and view angles

Figure 13. Screen shot of the prototype tour; showing the Cotswold AONB dataset, a screen overlay and the tour controls.

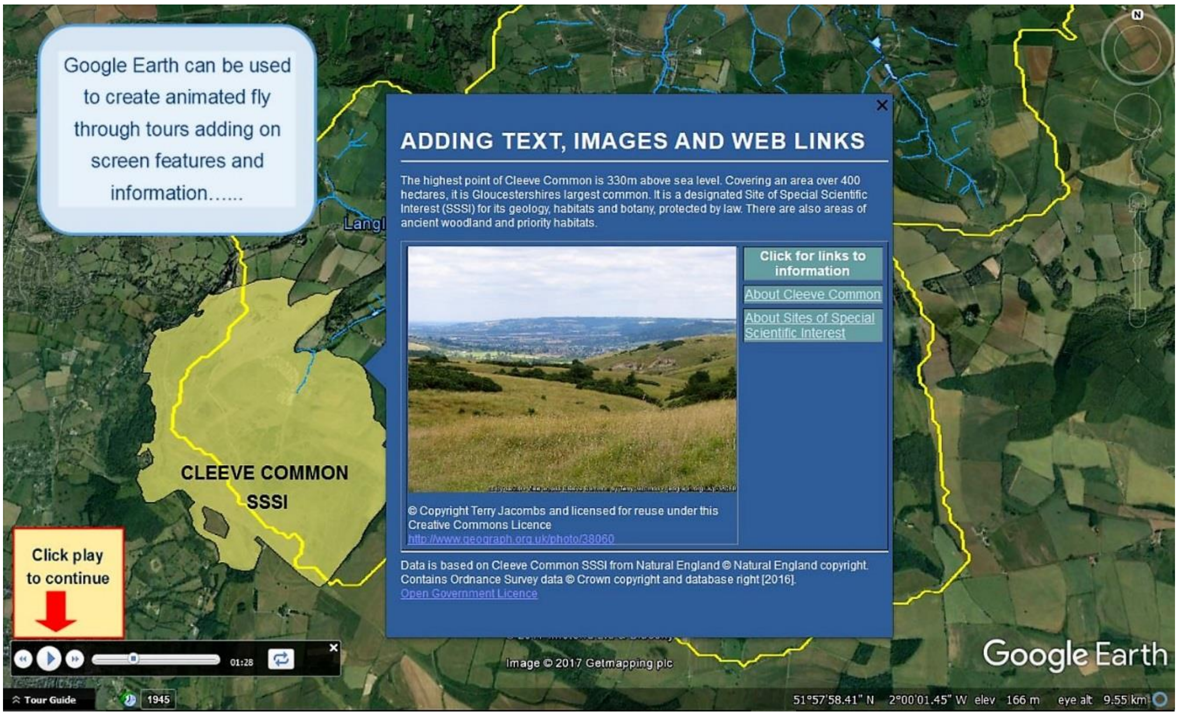


Figure 14. Screen shot of the prototype tour: showing data sets of the NRFA catchment boundary (used with permission), Cleeve Common SSSI and OS Rivers and Watercourses along with screen overlays and a placemark balloon.

The prototype tour navigates through the landscape at customised altitudes and speeds, and further Google Earth features were demonstrated; manually highlighted polygons (Figure 15), a screenshot of historical imagery, a transparent flood outline and a model of woodland trees geolocated into the landscape (Figure 16). At specified locations and view angles, placemark balloons opened on the map. These illustrated how visual information and text can be added on to the map screen. The viewer was directed to resume the navigation using the Google Earth tour controls with a ‘Click play to continue’ instruction (screen overlay) as used by Harwood, Lovett and Turner (2015). The tour ended with a placemark balloon providing acknowledgements and data attributions.

Figure 15. Screen shot of the prototype tour; showing manually created polygons and a placemark balloon, OS Open River and Open Map Watercourses.

3.4.3. Identifying information requirements

The information requirements for the final virtual globe tour were identified through a focus group meeting with members of the ICG, undertaken through the UoG as part of a wider research initiative. This enabled a degree of collaborative involvement in the design and creation, important particularly at the outset to enhance legitimacy (Lovett *et al.*, 2015). This meeting provided a forum to outline the purpose of the research and present the prototype tour to demonstrate the capabilities of the tool, promote discussion and generate ideas.

Figure 16. Screen shot of the prototype tour in perspective view, showing a 3D COLLADA model of multiple trees geolocated in the landscape and an inset location map.

A short questionnaire was prepared for the attendees to indicate their level of satisfaction with the design features of the prototype tour and to identify the information they saw as being salient (see Appendix H). The available data sets were listed allowing the participants to select the information would like to be included in the catchment tour and to identify what they considered most important. Participants were asked for feedback on the design elements of duration, speed of presentation, level of interactivity and the use of appropriate terminology as well as onscreen clarity, colour and layout. The feedback obtained from the focus group meeting is presented in section 4.1.

3.5. End user evaluation development

Two approaches were taken for end user evaluation, a facilitated group in an IT laboratory setting and a web based, online distribution. The facilitated group testing was undertaken before the survey and virtual globe tour were released online. This was considered expedient to confirm that the instructions for accessing and operating the tour on Google Earth were easily understood, allowing any necessary amendments to be made before the online release. The online, web-based approach aimed to reach a wider range of participants than the lab-based approach to maximise the potential number of survey respondents (Berry and Higgs, 2012) and cover a range of learning styles for generalisation (Wissen *et al.*, 2008). Using both facilitated group and web-based approaches enabled comparison of the results to identify any differences between the settings.

3.5.1. Questionnaire and survey development

The survey questionnaire was developed to consider two key aspects of the research: -

- the usability of the Google Earth virtual globe tour approach as a tool for communication and stakeholder engagement
- the effectiveness of the presentation format for enhancing the understanding the features of the catchment, issues it currently faces and the potential for NFM

With reference to papers in the landscape visualisation fields (Schroth, Pond and Sheppard, 2015; Berry *et al.*, 2011; Salter *et al.*, 2009) along with guidance on questionnaire construction (Sue and Ritter, 2007; Peterson, 2000) and end user evaluation (Tullis and Albert, 2013) the questionnaire was developed to assess the views of participants, using both pre and post use questions. Questions included:-

- single answer and Likert-type, semantic scale, used to enable basic quantitative analysis
- open ended questions designed to obtain a deeper understanding than quantitative analysis alone.

A section of the pre-use questionnaire was formulated to collect user metrics (including demographics, previous IT and Google Earth experience and existing knowledge of NFM) to enable statistical analysis and to permit further inferences from the data. The survey was created and hosted on Bristol Online Survey (BOS)[3]. Two versions of the survey were created, one for a facilitated group, IT laboratory setting and one for online distribution, to allow different instructions to be included.

The questionnaire was reviewed by three Human Geography academics with considerable experience of designing and working with questionnaires, to consider its robustness after discussing the research aims and viewing the Google Earth tour. Feedback from this review was used to make minor revisions to the language and terminology, and to modify the number of available answer options for questions. Where used, scale questions were given 6 options to compel the participants to take a positive or negative position rather than defer to a neutral position. This approach was taken to maximise the useable data from a potentially limited sample size. A 'Don't Know' option was given only on one set of questions specifically to ascertain the level of understanding of the content.

See Appendix K for the final survey questionnaire.

3.6. Ethical considerations

This research was conducted as per The University of Gloucestershire Handbook of Research Ethics. There were no specific requirements under professional codes of conduct however confidentiality was required due to the status of the Isbourne catchment project. The purpose of the research was clearly outlined at a workshop involving members of the ICG. Participation in the end user evaluation survey was voluntary and participants did not include vulnerable groups. The online survey was designed to protect anonymity using Bristol Online Survey, a secure online survey provider. The survey was undertaken with fully informed consent and full disclosure. Every measure was undertaken to maintain confidentiality.

[3] Bristol Online Survey https://www.onlinesurveys.ac.uk/

Chapter 4 Virtual globe tour development

4.1. Focus group collaborative design approach

Seven people from the ICG attended the focus group meeting. An introduction was given to outline the research and explain how Google Earth can be used beyond searching for places. The prototype tour was demonstrated, and the participants were asked to complete a feedback questionnaire (Appendix H).

Feedback during the demonstration and the following discussion indicated that the participants found the prototype tour to be interesting and saw the virtual globe tour approach to be a potentially powerful tool for communicating information to the wider public and displaying at meetings. Comments on the feedback questionnaire included "*impressive*" and "*fascinating*" and one user commented that it was "*brilliant - the ideal engagement tour*". Table 9 summarises the list of available data identified in the questionnaire and the number of responses indicating the information that the attendees wanted incorporate.

The group decided they would like two different tours to be prepared. The first tour could provide a brief overview of the catchment (around 1 minute), to highlight the complexity of the county, district and parish administration, the towns and villages and the flooding history. The second tour should further explore the technical detail for people interested in finding out more.

The layers of information identified as being most important to the attendees were the 2007 surface flood event, catchment boundary, land use change, the river outline and historic water features. This was supported by feedback in discussions that followed. There was some concern raised in discussion about the inclusion of photographic images showing the extent or damage of the flooding as there was no intention to shock or scare viewers, potentially upsetting residents or affecting property prices.

Table 9. Summary of questionnaire responses showing the number of participants selecting available data for inclusion in the virtual globe tour.

(number of completed questionnaires = 6)	**Participants selecting items**
River Isbourne outline	6
Surface flood extent	6
Land use change	5 / 1 *****
Catchment boundary	4
District boundaries (i.e. parish, county)	4
Historic water features	4
Historic land use	4
Tree coverage	4
Designated areas (i.e. SSSI, AONB)	3
Parks and gardens	3
Urban areas	2
Agricultural land classifications	1 / 1 *****
Ancient woodland	1
Geology	0 / 1 *****
Listed buildings	0 / 1 *****
Soils	0

***** one respondent indicated data items they would wish to be included in a basic tour and in a longer technical tour.

The survey responses indicated the attendees were less concerned with location of ancient woodland or listed buildings, the agricultural classification, geology, soils and urban areas. The agricultural land classification and the soils may ultimately determine areas that are appropriate for locating interventions, but they were not seen to be so important for communication and engagement at this stage. Urban areas are already evident on Google Earth however additional clear labelling of towns/village names was required.

In discussions, the participants were interested in identifying land areas that may be suitable for NFM interventions. However, given the status of the project where discussions had not happened with land owners, it was decided that a less specific approach would be more appropriate, incorporating introductory information about NFM measures with links to existing projects or further information. This would communicate the nature of NFM for those with limited or no knowledge, including measures such as woodland planting initiatives, in-channel woody debris dams, land and soil management practices, without identifying specific locations.

The demonstrated prototype tour included tree models that had been created in SketchUp and geolocated onto the landscape to show a large area of planted woodland. There was reference to this in the discussions and a decision was later made to exclude these features from the final tour as no specific land areas had been identified for a tree planting approach and changes to SketchUp had made this technically difficult to achieve (see Appendix D).

The attendees made suggestions about other information that would be helpful, including more detail on water quality, especially spatially distributed records if available, and flow pathways for run-off. These were not available at the time and it was decided that they could be added at a later stage of the project if they became available.

Responses to questions regarding the design of the tour were generally positive regarding the time available to consider the onscreen information, the speeds of movement and the textual information and links. There was however some disagreement on speed; one respondent thought movement may be too slow, another commented that if any faster could induce motion sickness. One comment on the text information balloons were that they may be too big, another that the text maybe too small. From this feedback, it was clear that a balance would be required to ensure that the text balloons did not obscure too much of the screen and that the text was concise and the font large enough to be read easily.

Following the meeting a decision was made to design 2 tours as follows: -

Tour 1 - A brief overview tour (around 1 minute only) to incorporate: -

- Catchment boundary
- River channel and surface water features (lakes/ponds etc)
- County and District authorities and parish councils
- Surface flood event for 2007
- Water quality issues
- Affected towns – labelled effectively, including Sedgeberrow

Tour 2 - A technical, in-depth, tour to incorporate the following in addition to the overview tour items above: -

- Land use change
- Designated areas
- Parks and gardens
- Listed buildings
- A brief overview of geology

The longer technical content tour was to focus on the upper reaches of the catchment, above Winchcombe where Langley Brook and Beesmor Brook converge with the River Isbourne. End user testing was restricted to this longer, technical tour as it contained all the information from the shorter introductory tour.

4.2. Tour development

Suitable data sets to fulfil the identified information requirements (section 4.1) were imported into ArcGIS. Freely available and Open Government Licence (OGL) data was used wherever possible to confirm the level of accessibility and to avoid data licencing issues as the virtual globe tour would be distributed online to non-licenced users (section 3.4.1).

All data sets from Ordnance Survey (OS), EA, Natural England, Historic England and NRFA (CEH) were manipulated in ArcMap 10.4.1 and converted to KML using the geoprocessing tool ‘Convert to KML’. The British Geological Survey (BGS) OGL ‘Bedrock’ 1:625,000 dataset was downloaded as a KML file, directly into Google Earth from the website.

See Appendix Q for the full metadata table for the final, technical content virtual globe tour.

Other resources and relevant information were also identified for incorporation, including hyper-links to relevant websites and images. Photographs were taken in May and June 2017 during catchment walkovers, in accordance with the recommendation by Sheppard and Cizek (2009) to use up-to-date and relevant images wherever possible.

Table 10 shows the data used to meet the information requirements. Introduction and instructions pages and linking text were created using Microsoft Publisher and saved as JPEG and PNG image files. Inset location maps were created using the Google Earth screenshot facility and the images annotated using Microsoft 'Paint' software. These images were incorporated and animated into the tour as screen overlays and not geolocated in the landscape. Data sources were disclosed in the tour within placemark balloons, with links to the relevant licence statements where required.

Table 10. GIS data sets and other resources used in the development of the final virtual globe tour of the River Isbourne catchment.

Information requirement	Selected data set	Other resources used
Catchment boundary	NRFA Catchment Boundary *	
Rivers and surface water	OS Open Map Rivers and Surface water	Photographic images
Flood outline	Environment Agency Recorded Flood Outline	Website links: - Government EA, ICG and NFF
Water quality		Website links for EA and WFD WFD summary table
Administrative boundaries	OS Administrative Boundaries for Counties, District Councils and Parish Council	
Land use change	CORINE Land Cover 2012	Link to Isbourne Community Report for data source
Designated areas and woodland cover (catchment and riparian)	Natural England: AONB, SSSI, Priority Habitats, Ancient Woodland	Photographic images Website links:- • Natural England • Forestry Commission • Cleeve Common • Glos. Wildlife Trust • Woodland Trust
Historic water features	Manually digitised data created by R. Berry at CCRI for scoping reports	Includes pop-up balloons and links to further information

Table 10. cont.

Information requirement	Selected data set	Other resources used
Parks and gardens	Historic England, Parks and Gardens	Sudeley Castle website Photographic images
Listed buildings	Historic England, Listed Buildings	
Geology	BGS 1:650k Bedrock	Photographic images Website links: - • BGS • Gloucestershire Geology Trust
Place names and railway line		Manually created using Google Earth and KML
Steepness of catchment	Google Earth imagery	Google Earth elevation profiles, screenshot using snipping tool Photographic images
Farming - land and soil management		Website links: - • FWAG South West projects • Soil management • Countryside Stewardship
Natural Flood Management		Photographic images Website links to a library of short films and a selection of existing NFM projects.

***** NRFA catchment boundary is not available for use under OGL. Permission was obtained to use this data set for this research purpose only.

See Appendix P regarding the final Isbourne catchment virtual globe tour and the KML script (both available to download from the enclosed disc).

4.3. Tour content and operation

The KMZ archive file for the final technical tour was hosted on a Dropbox account, in a public folder, with a link from the survey. From this the tour could be downloaded, saved to a computer and launched (by double clicking on the file or by dragging and dropping it directly onto the Google Earth map screen). The full length, technical catchment tour duration was 9 minutes, plus time the viewer spends reading the placemarks and exploring the onscreen information.

4.3.1. Operating instructions and navigation

The catchment tour loads into Google Earth zooming to a high-level view above the catchment (Figure 17). A screen overlay provides introductory instructions which include:

- directing attention to the side panel, the component folders of the tour will show here;
- minimising the ‘Tour Guide’ panel if showing at the bottom of the map screen (to maximise map visibility and see the manual tour controls);
- directing the user to view an additional screen overlay, available from the side panel, to view general advice on using Google Earth if they are not familiar with the features (after Harwood, Lovett and Turner (2015)).

The viewer is instructed to click the ‘OPEN TOUR’ button in the side panel and this opens the tour folder of the KMZ. Further instructions appear on-screen to inform the user how to operate of the tour (Figure 18). The tour is activated by double-clicking on a highlighted tour folder in the side panel.

Once activated an additional screen overlay recommends the viewer deselects all Google Earth own layers of data content, except for terrain in Google Earth Pro, to minimise unnecessary on-screen clutter (Figure 19). The viewer is prompted to resume the tour manually by clicking the play button in the tour controls. The tour moves independently through the landscape at varying altitudes and view angles, pausing at pre-set locations. Layers of data are animated in and out in sequence with linking text provided (using screen overlays).

Figure 17. Opening screen instructions for the River Isbourne virtual globe tour (screen overlay).

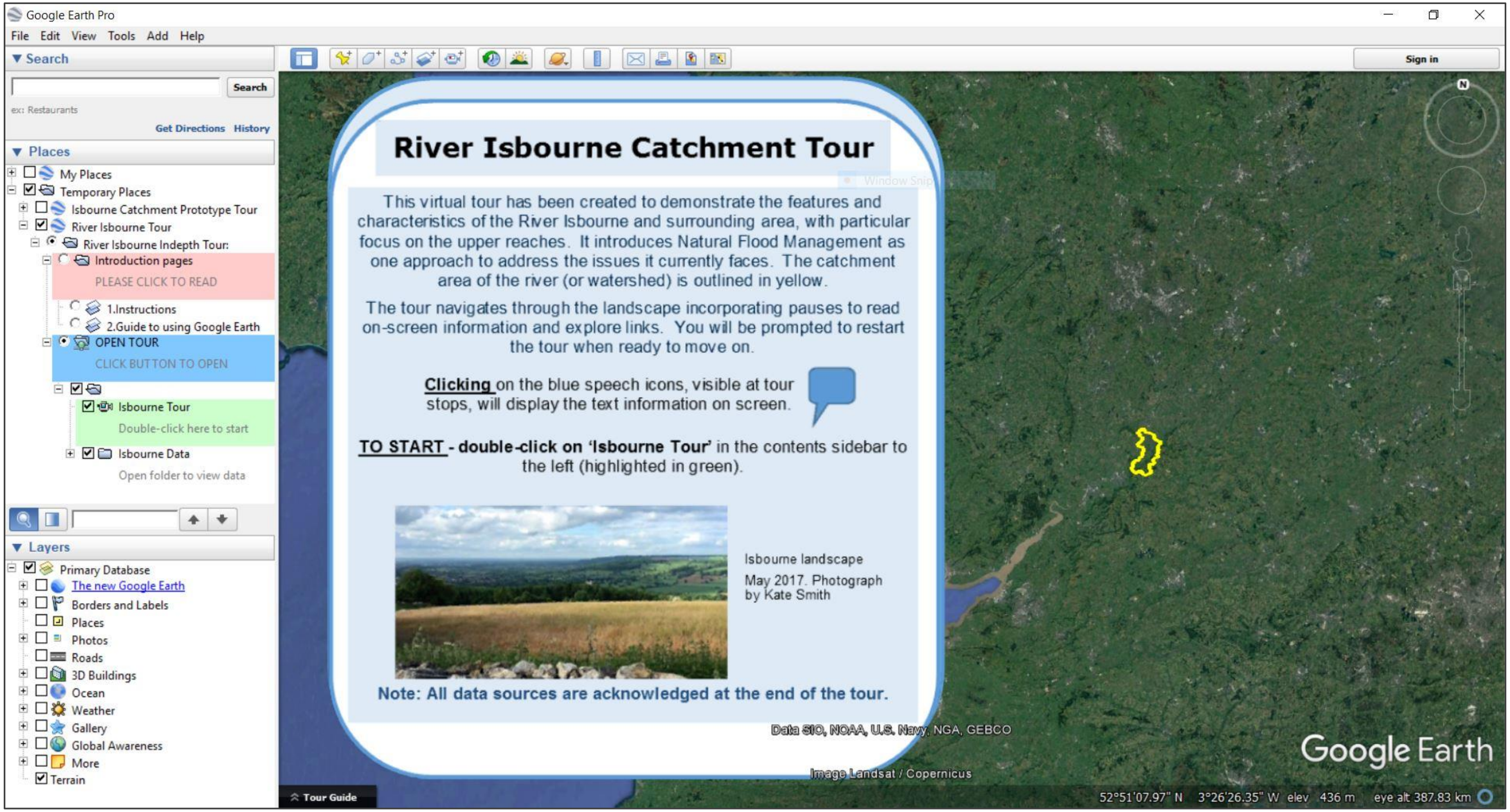


Figure 18. Introduction page for the River Isbourne virtual globe tour (screen overlay).

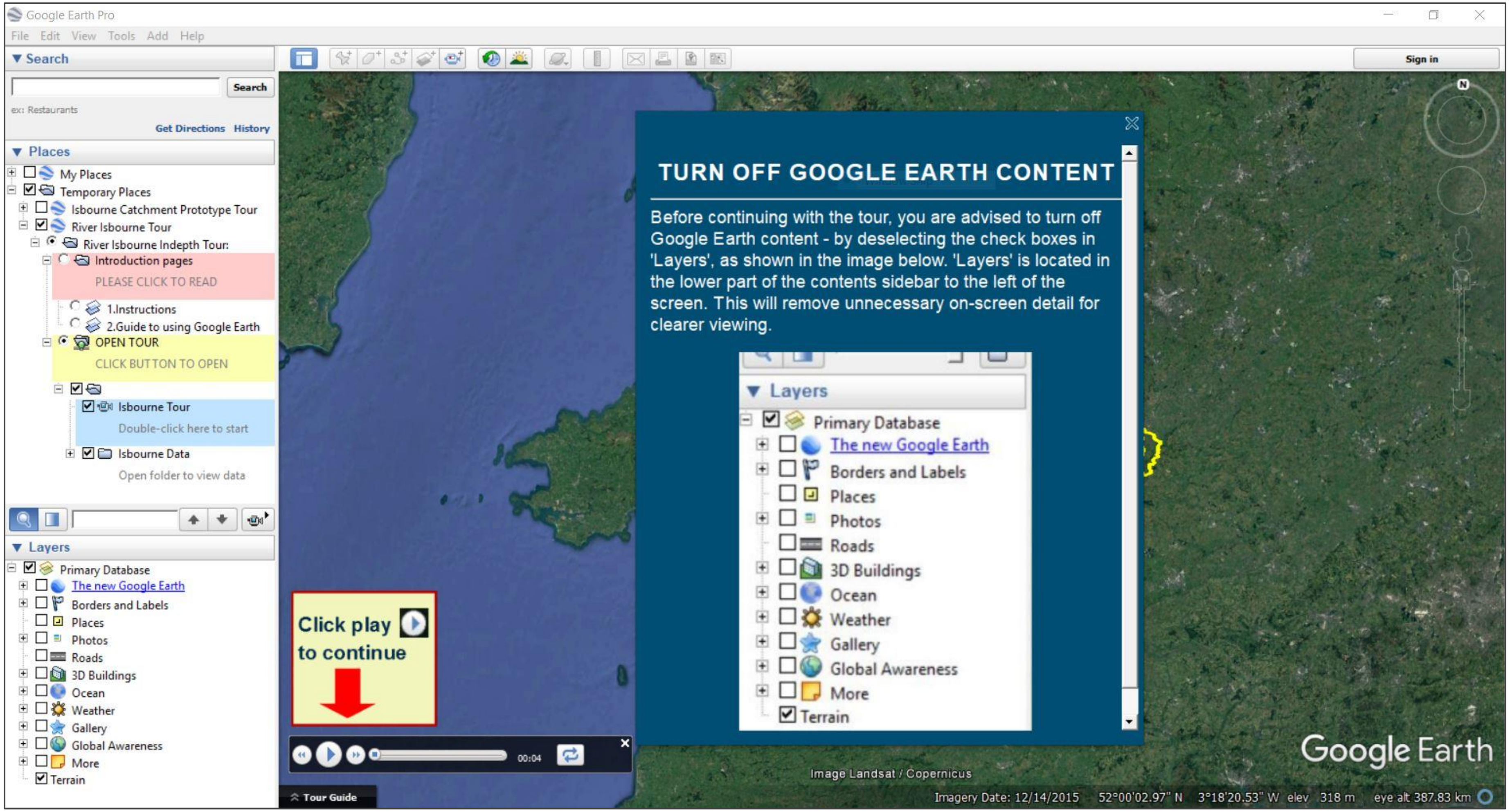


Figure 19. Additional instructions to turn off Google Earth content at the start of the virtual globe tour (placemark balloon).

The layers of data scripted into the tour (using formatted points, lines, polygons and overlays) allow the viewer to see boundaries, highlighted areas, place names and features on the map. These layers become visible at locations during the tour through a series of animated updates that activate the visibility or change the style of the feature using colour, transparency and size. The tour pauses at specified locations and placemark balloons pop-up on the map providing text information, images and hyper-links to useful resources (which will open in the web browser).

The speed and duration of the fly through movements, and the pauses allowing the viewer time to read onscreen text, were customised in the scripted tour animation controls. At several stages in the tour where placemark balloons are onscreen the tour pauses and the user is prompted to resume the tour manually using the Google Earth tour controls. This allows the user to explore the links or interactive features in their own time. The viewer is also able to pause at any time using the tour controls and can manually collapse the placemark balloons by clicking them off to view the landscape imagery and added data. Inset maps animated into view at set locations enable the user to locate their position within the catchment as they move around.

At the end of the tour a final placemark balloon suggests the user spend time exploring the landscape independently and view the individual data layers by selecting them in the contents side panel. It also provides acknowledgements, attributions and links to data licence information. (See Appendix G).

4.3.2. Catchment Boundary

The NRFA catchment boundary dataset is not available to non-licensed users to use or distribute. The OGL WFD River Waterbody Catchment (EA) data could be used however the spatial extent of the NRFA and the WFD boundary outline for the River Isbourne catchment are not identical (Figure 20). As other data sets used for the preparation of map illustrations for the Isbourne Scoping Report (Clarke, Short and Berry, 2016) and Isbourne Community Report (Clarke and Short, 2016) were previously clipped to the NRFA boundary extent this was used for consistency. Permission to use the catchment boundary data, for this use only, was obtained from the NRFA (see Appendix G).

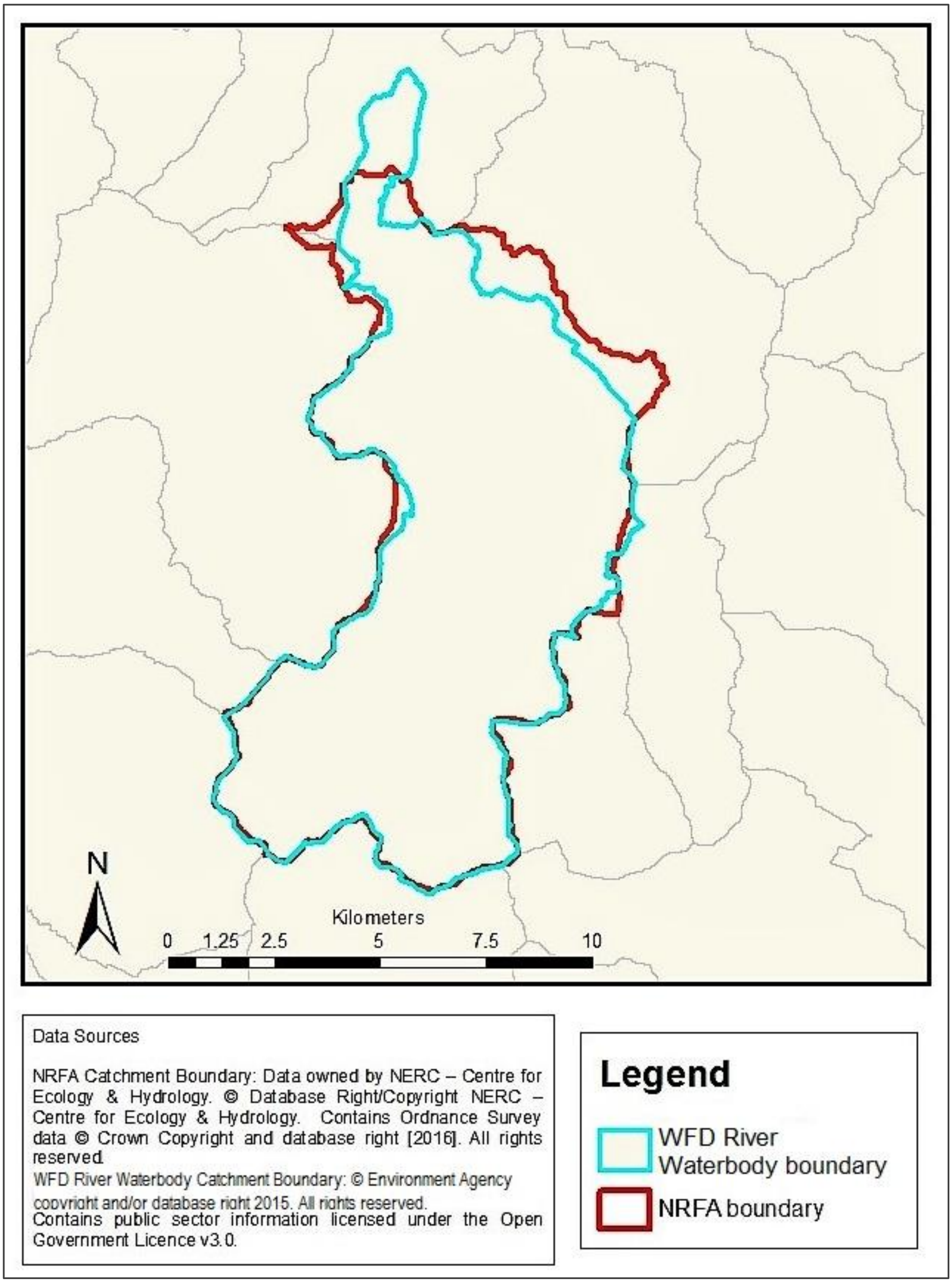


Figure 20. Environment Agency and NRFA catchment boundaries for the River Isbourne.

The catchment boundary was formatted in bright yellow for clear visibility in the tour (Figure 21). At different scales, as the animation zoomed in or out, the width of the line was animated to be thicker at high levels and finer in close up views; to be clearly visible but not distracting. There were some issues with lines distorting during the animation, particularly at close scales.

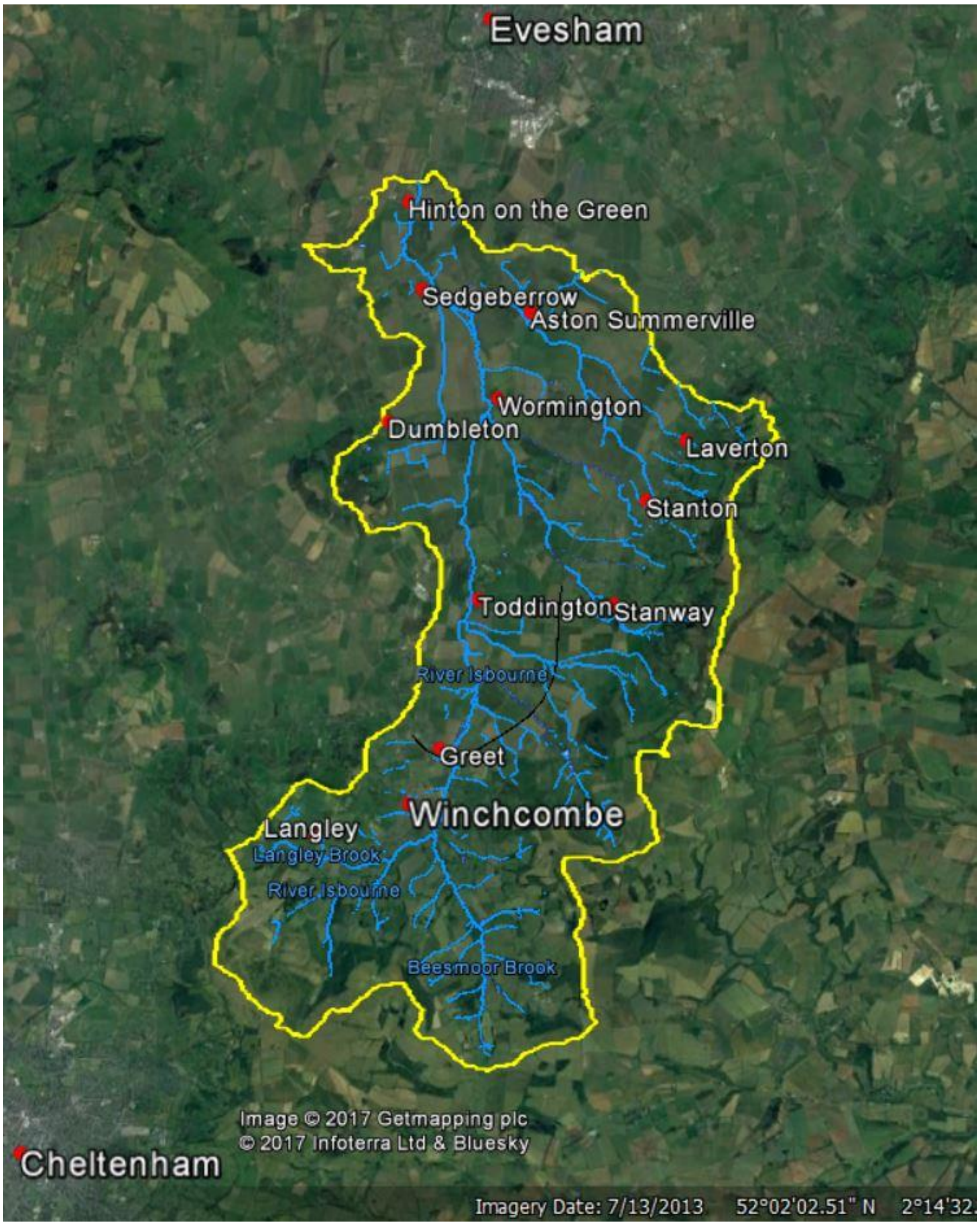


Figure 21. NRFA catchment boundary and OS Rivers and Surface Water data sets on Google Earth.

4.3.3. Rivers and surface water features

OS Open Rivers, Open Map Surface Water Area and Surface Water Line were used in combination to incorporate all surface water features including drainage ditches, ponds and main channels (Figure 21 above). The Open Rivers data was used in high level views and Open Map Surface Water layers at closer scales during the tour to provide appropriate levels of detail.

Red path lines were created and animated into the tour to demonstrate the direction of flow of the Isbourne and the Beesmoor and Langley Brook tributaries.

4.3.4. Flood outline

The EA Recorded Flood Outline was a key data set to show the extent of flooding along the length of the river. The 2007 event data was extracted from the dataset in ArcGIS and converted to KML. Design decisions were required for a suitable level of transparency and colour for the flood extent. Previous visualisations of river flooding extents (Todd *et al.*, 2014) have used a transparent brown colour for flood water as it was considered more realistic. A decision was taken here to use a transparent blue as brown did not contrast well on the Google Earth landscape and the colour may be emotive (Figure 22).

The tour navigated the length of the flood outline following the river using location coordinates at customised speeds, altitude and angle of view to give an appreciation of the extent and affected properties and land.

4.3.5. Water quality

WFD water quality records were only available for one hydrometric recording on the River Isbourne, located at Hinton on the Green. A table summarising the latest recorded WFD status and the failings for the river body was incorporated within a placemark balloon with links to relevant information sources.

4.3.6. Administrative boundaries

The ICG prioritised the county, district and parish council boundaries to demonstrate the complexity of the catchment with regards to the administration, promotion and potential funding of the NFM project. The relevant boundaries were extracted from the OGL OS Administrative Boundary data sets. Design decisions were made to customise the colours and thickness of the lines. Placemark labels were manually added for the county and district councils using KML scripting to add flexibility over their location on the map (Figure 23). The parish names (Figure 24) were extracted from the data set in ArcGIS and converted to KML as a composite image output and this was used to create a ground overlay. The different administrative boundary layers and names were animated into the tour as it progressed and zoomed in on Google Earth.

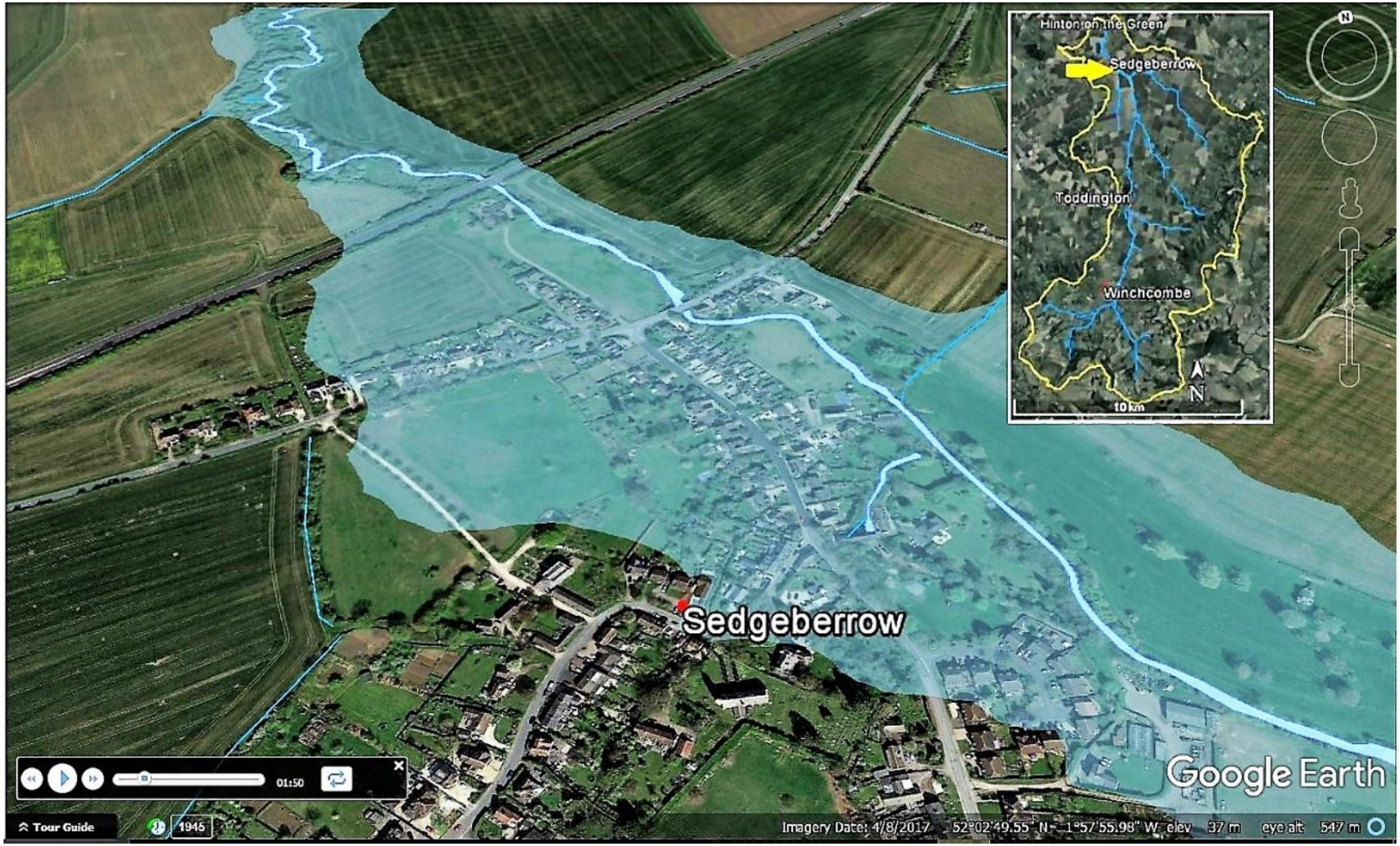


Figure 22. EA Recorded Flood Outline data for 2007 along the River Isbourne in Sedgeberrow.

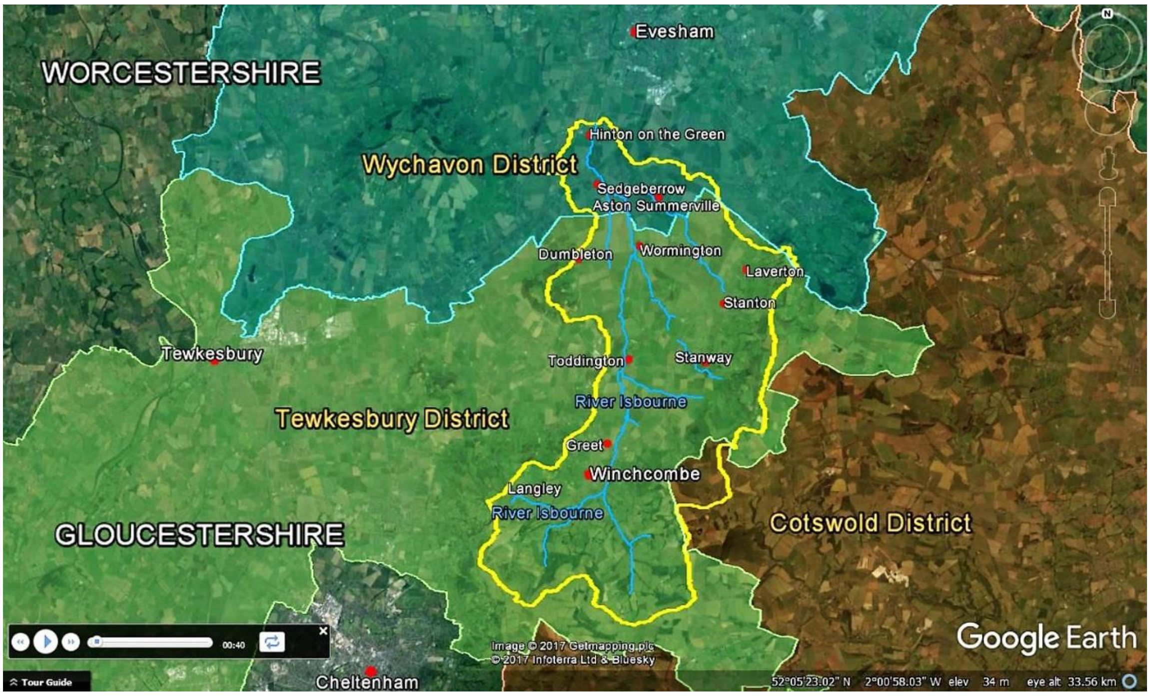


Figure 23. OS County and District boundaries data in the virtual globe tour.

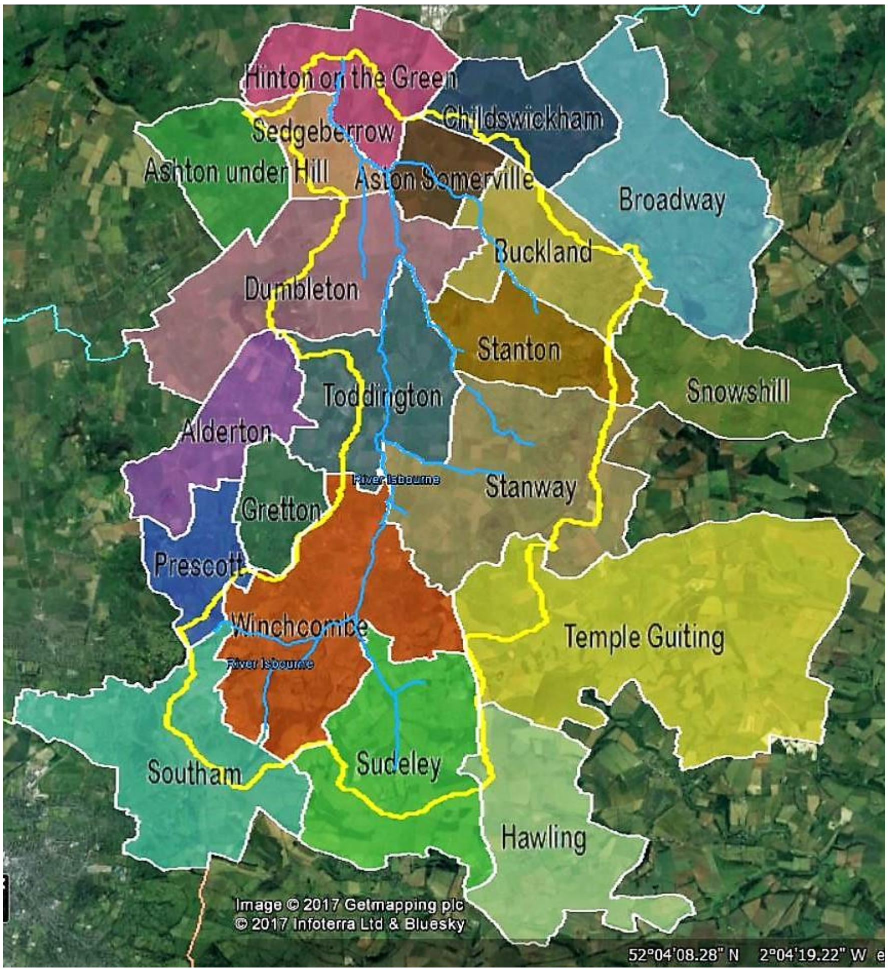


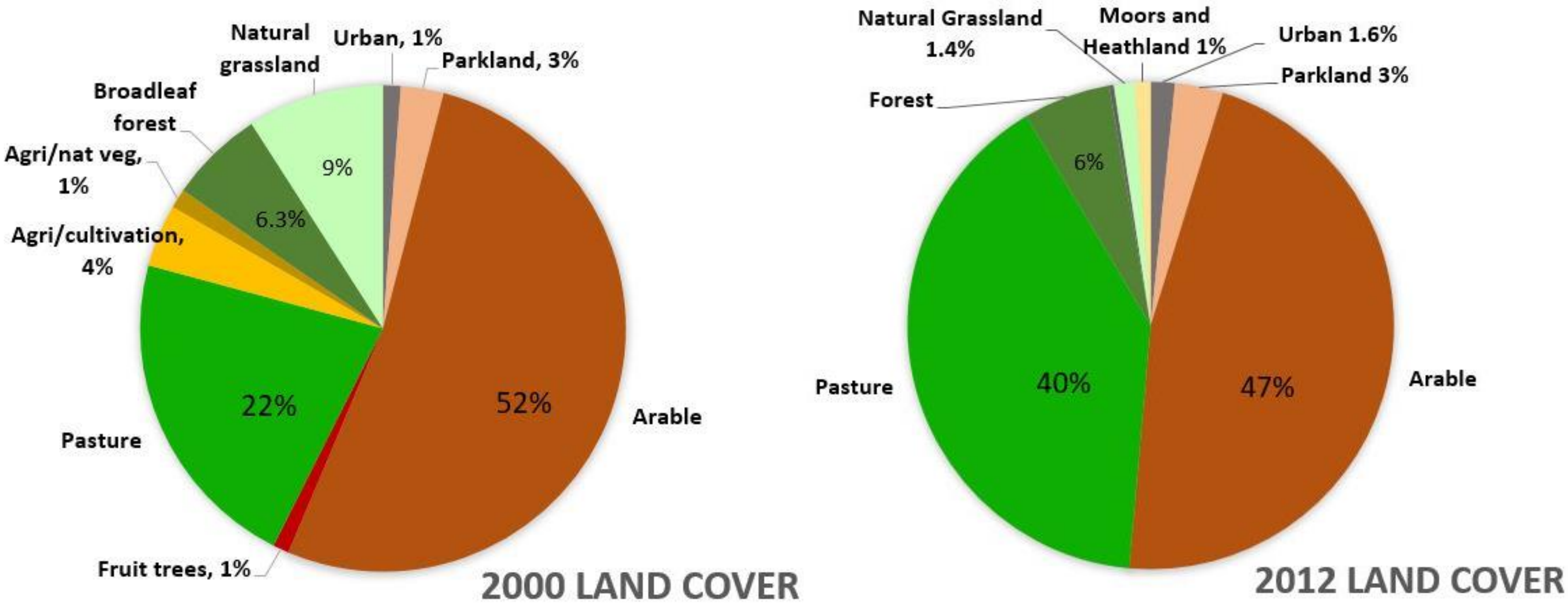
Figure 24. OS Parish Council boundaries data in the virtual globe tour.

4.3.7. Land use change

The change in land use was a key information requirement for the ICG, important for demonstrating how changes to the land cover (from natural grassland towards more cultivated improved pasture and arable) may be affecting catchment hydrology. The only available open licence data of land cover was the EU CORINE, 100m resolution, Land Cover data (Copernicus Programme, 2017). The data, downloaded in raster format, was converted to vector in ArcGIS before being converted to KML. To ensure the data was compatible with all the other data exported to Google Earth it was first re-projected from ETSR89 to Transverse Mercator before running the conversion to KML. The colours were formatted directly on the Google Earth map screen and the layer saved as a KML file

The CORINE data was analysed in ArcGIS to calculate the percentage land cover for each category in the years 2000, 2006 and 2012 (see Appendix I). Figure 25 shows the percentage land cover for 2000 and 2012. During this period, arable and cultivated land cover fell along with reductions in natural grassland and heathland, while improved pasture cover increased from 22% to 40%. The combined coverage of mixed and broadleaf forest also fell marginally by 2.8%.

The 2012 dataset for was used in the tour to show the current land use, along with the derived pie chart showing the percentage cover for each category (also used as a colour legend). As the CORINE records only started in 2000 it was not possible visualise longer term land cover change across the catchment using the CORINE data alone. A graphical representation of land cover change since 1930 (Appendix J), taken from the Isbourne Catchment Community Report (Clarke and Short, 2016), was presented in a placemark balloon to illustrate the significant increases in arable and pasture and reduction in natural grassland (Figure 26).



(Percentages derived from European Environment Agency CORINE Land Cover datasets)

Figure 25. CORINE Land Cover data for 2000 and 2012.

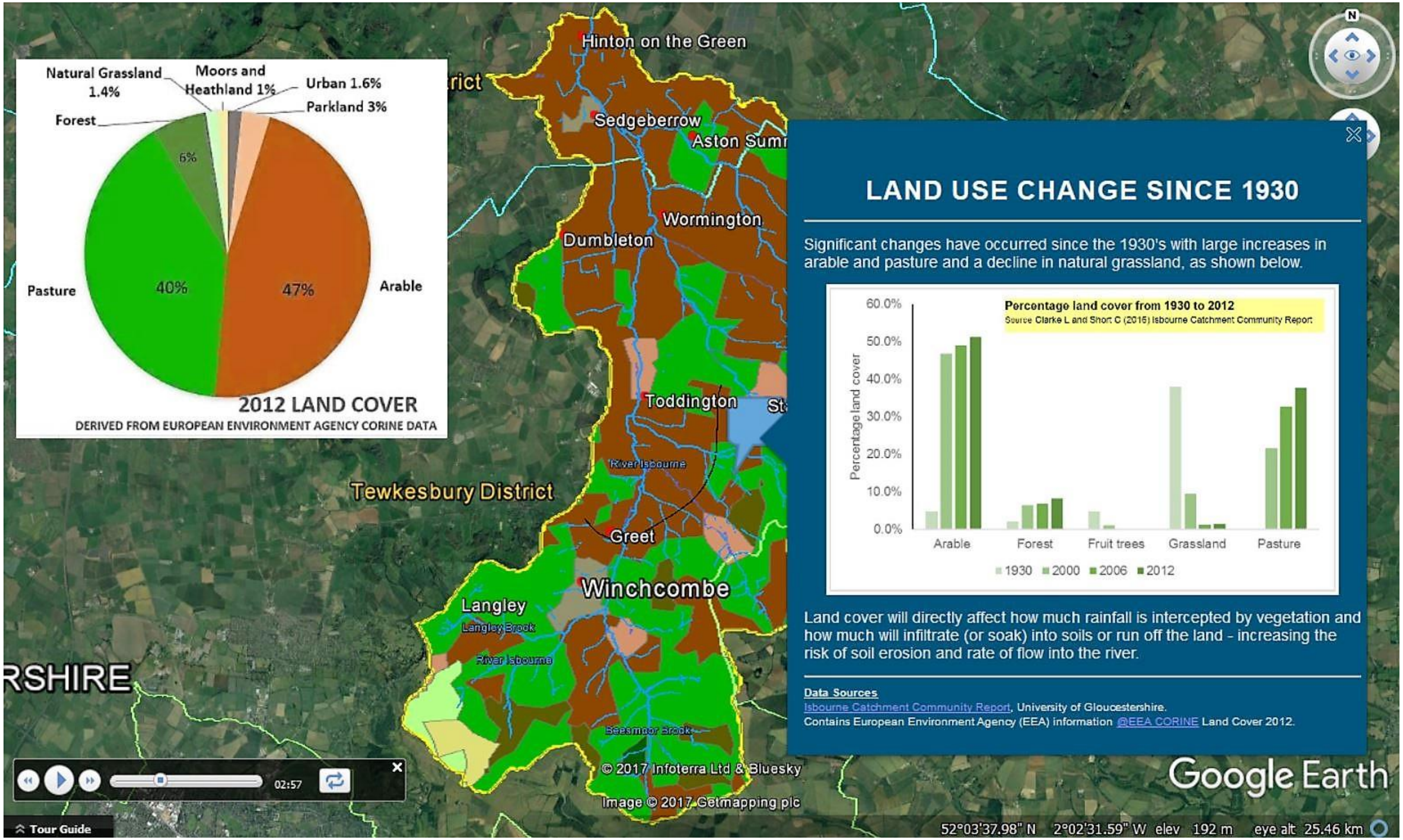


Figure 26. Land use change shown in the tour, using CORINE data, a screen overlay and placemark balloon

4.3.8. Designated areas and woodland cover

There are numerous areas in the Isbourne catchment with designations for their landscape and wildlife value. Designated areas and woodland cover are important as they may influence permissible future land use change or the location of NFM interventions, with consultation and approval being needed from government agencies. OGL datasets from Natural England for the AONB, SSSI, Priority Habitats and Ancient Woodland were animated into view. Design decisions were taken on the colours and transparency levels for effective presentation. A legend, created and edited using Google Earth screenshot feature, was incorporated in the animation as a screen overlay (Figure 27).

4.3.9. Historic water features

The Isbourne Catchment Scoping Study (Clarke, Short and Berry, 2016) and Community Report (Clarke and Short, 2016) suggested that relict or existing pools, ponds and reservoirs could potentially be utilised to increase run off storage if the conditions were found to be suitable on investigation. A manually digitised data set of historical sites, created at the UoG by reference to OS historical maps and other available resources, was included with an instruction that the viewer could click on the highlighted areas to find out more.

4.3.10. Parks, gardens and listed buildings

There are three large historic gardens within the Isbourne catchment, Sudeley Castle, Toddington Manor and Stanway House, which are all privately owned and managed estates. Permission would be required to access these estates or to incorporate them within a wider catchment project. Winchcombe is an ancient town that also has numerous listed buildings. Although these features were not seen as a priority by the ICG they were referred to briefly to provide context and demonstrate the important heritage of the area. OGL datasets available from Historic England were used to briefly show the extent of the historic gardens and location of the listed buildings (Figure 28).

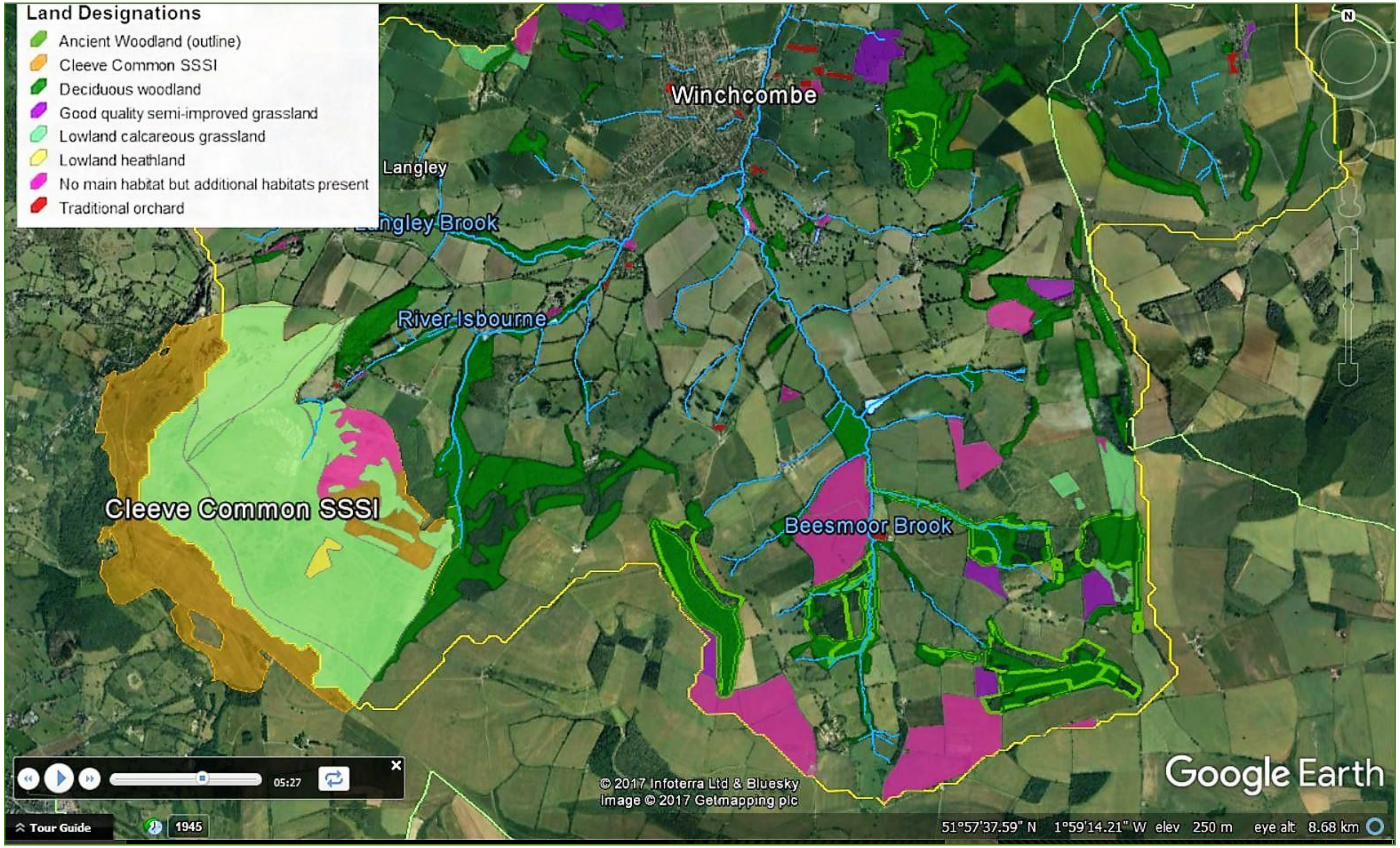


Figure 27. Designated land shown in the Google Earth virtual globe tour (Natural England SSSI, Ancient Woodland and Priority Habitats).

Figure 28. Historic England Listed Buildings (yellow diamonds) and Parks and Gardens (purple outline) data in the virtual globe tour

4.3.11. Geology

The main feature and significance of the geology in the Isbourne catchment is the permeability of the limestone uplands and the numerous springs that arise where they intersect with the less permeable mudstone, clay, layer and progressively feed into the main channels. There was limited interest from the ICG regarding the incorporation of geological information and there was a need to keep this content simple and accessible to non-technical viewers.

The OGL, national cover, 1:625k 'Bedrock' data was downloaded from BGS directly into Google Earth as a KMZ file. An annotated Google Earth screenshot image (Figure 29) was placed within a placemark balloon rather than adding the entire data set to avoid adding unnecessary map content (and reduce the data size of the file). A brief description of the importance of the geology and managing erosion of the permeable soils was also included with links to further sources of information.

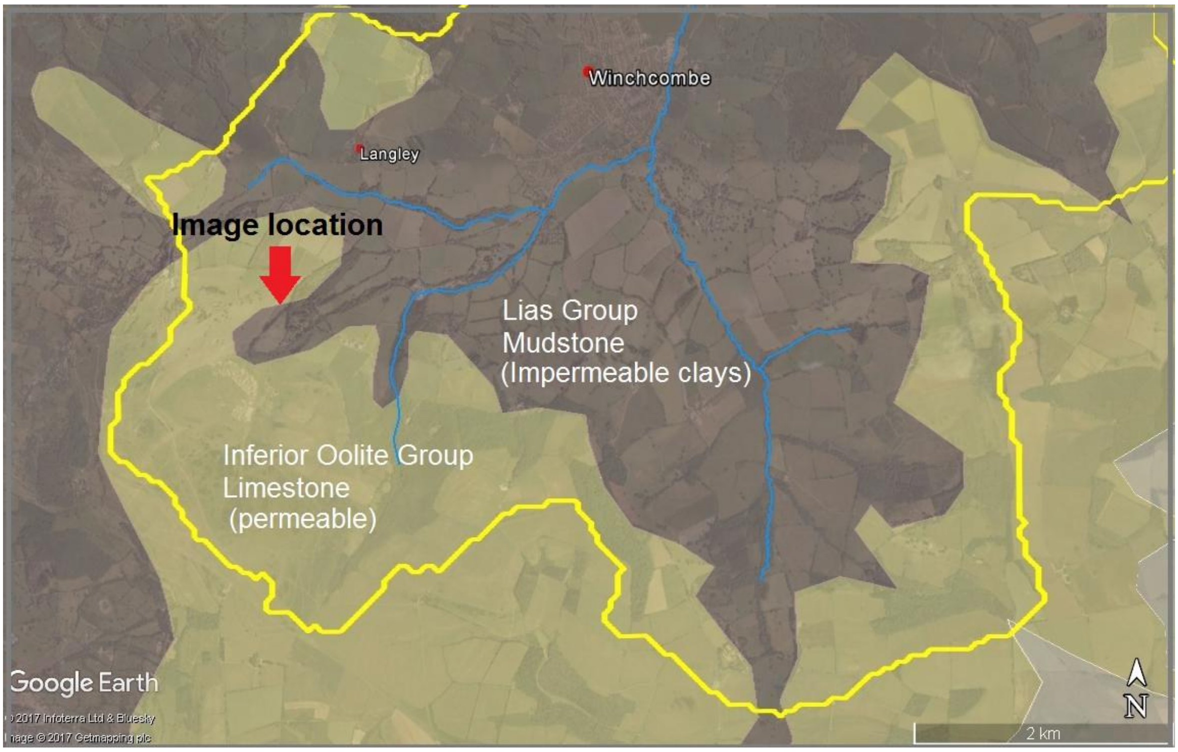


Figure 29. Bedrock data (BGS 1:625k) shown on Google Earth.

4.3.12. Place names, railway line and roads

The ICG were concerned that the visibility of names of towns and villages within Google Earths data layers was inconsistent at different zoom levels during the prototype tour. By disabling all Google Earth layers in the contents panel and manually scripting the place names within the tour files using KML, full control over the visibility and the size of place names at different elevations was achieved. Disabling Google Earth content also reduced on-screen clutter visible during the tour.

A railway line that crosses the catchment and the river was manually created in Google Earth with reference to the satellite map data (the OS Open Map railway line content contained too much detail for this purpose). Roads were not added to the tour script as they are available in the Google Earth data layers that can be activated by the viewer if required.

4.3.13. Steepness of the catchment

A significant feature of the Isbourne catchment on the Cotswold escarpment is the elevation and the steepness of the surrounding hills. The Google Earth map terrain enables some representation of this in perspective views, but it did not provide a full appreciation with the available landscape imagery quality for the area. Additional visual representation of the terrain was required to emphasise the steep hills. As contours are not always easily understood by non-map readers the elevation profile function of Google Earth was used from lines drawn to intersect the upper part of the catchment across Beesmoor Brook and Langley Brook. Screen shots of the elevation profiles were used to create screen overlays, and these were animated into the tour (Figure 30).

4.3.14. Farming practice and NFM

At the early stage of the NFM project, with funding and specific areas of land and interventions yet to be identified, a decision had been taken that all reference to NFM was kept as informative. Placemark balloons were incorporated providing basic information regarding the characteristics of farming in the catchment and sources of advice and funding for soil land management techniques and other NFM techniques. The farming placemark included links to FWAG websites. The NFM placemark included illustrative images and links to a library of short information films (High Water Film, 2016) and a selection of existing NFM projects (Figure 31).

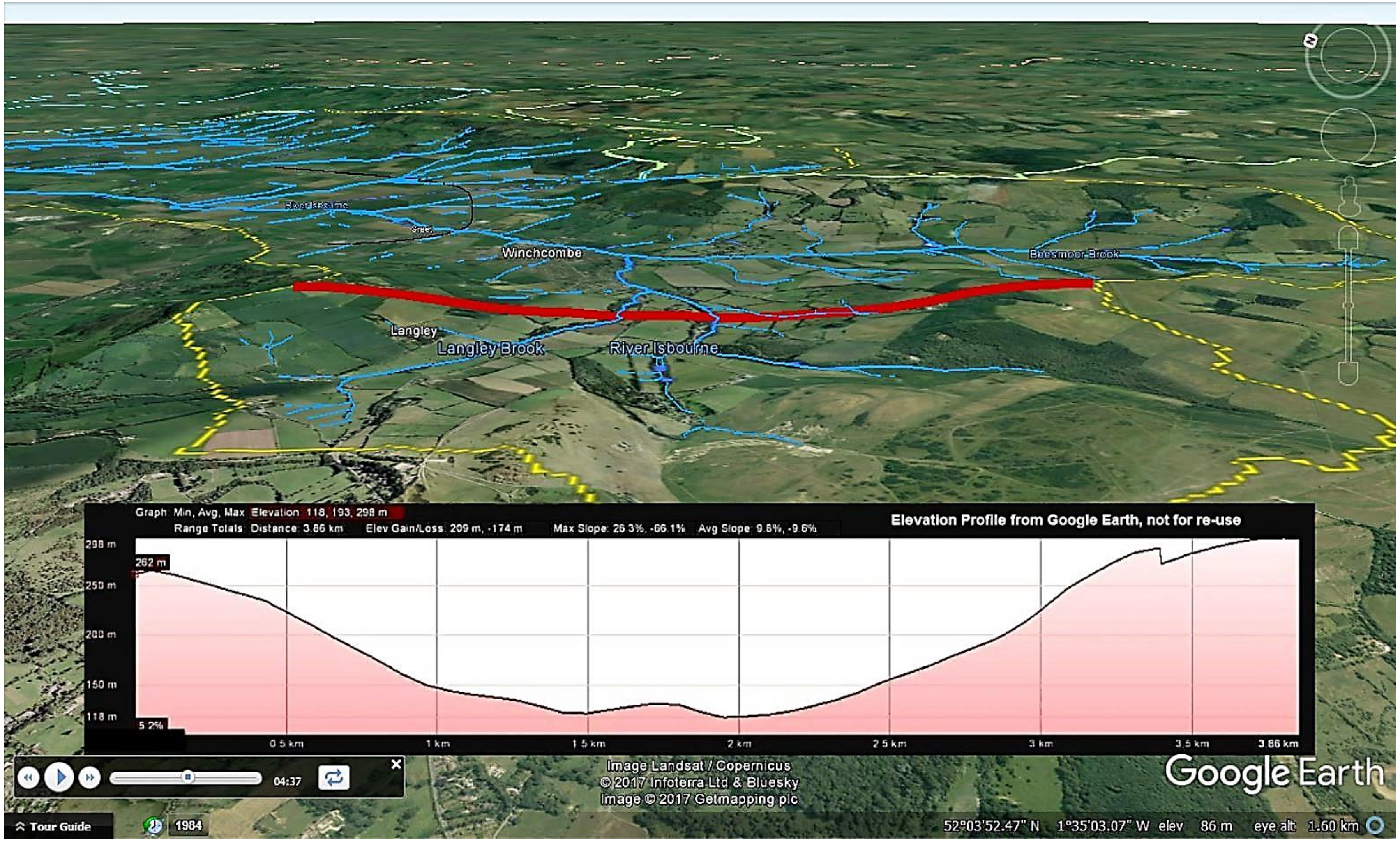


Figure 30. Elevation profile for the Landley Brook cross section (red line) in the virtual globe tour.

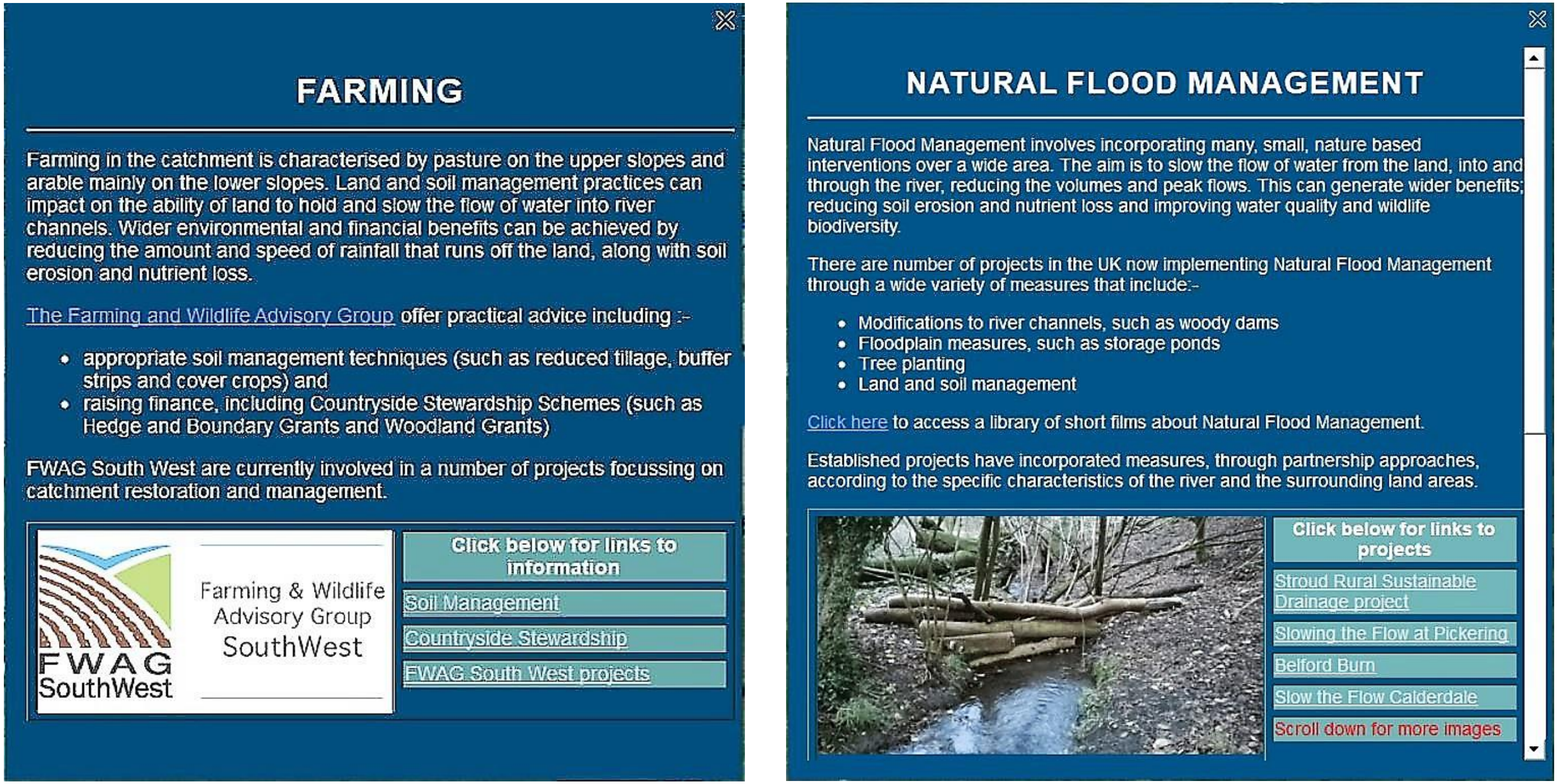


Figure 31. Placemarks added to the virtual globe tour to provide information regarding farming and NFM.

Chapter 5 End user evaluation

End user evaluation was undertaken through two settings; a facilitated group and non-facilitated online web-based access. Given the different settings for participation, along with the clear academic bias of the facilitated group, the results of these surveys were not combined. The results for each survey setting follows, with observations of use from the facilitated group session in section 5.1 followed by quantitative analysis of the results for each survey setting in 5.2 and 5.3 and a review of the free text responses in 5.4. Further discussion of the implications continues in Chapter 6.

5.1. End user evaluation – facilitated group session observations

Ten participants (five academics and five post-graduate students from the UoG) participated in a facilitated group session in an IT suite at the university on 29th June 2017.

After a brief introduction, participants accessed the online survey. They completed the initial questionnaire before downloading the KMZ file from the host Dropbox account and viewed it on Google Earth Pro before then completing the final questionnaire.

The purpose of the laboratory session was not only to generate usability data, but also to ensure that the instructions provided in the online survey and the introductory overlays could be followed remotely and observe how participants viewed and interacted with the tour. Assistance was provided when required and observations and participant comments noted so that any necessary amendments could be made to the instructions displayed at the start of the tour.

All participants downloaded the KMZ file successfully from the Dropbox account and opened it successfully on Google Earth, with some guidance provided where required.

After downloading, most participants proceeded to operate the tour (n=8) although two first explored independently on the Google Earth map before returning to the instructions. The main difficulties noted with the use of the tour related to the introductory screen overlay and following the instructions to turn off the Google Earth content and the ‘Tour Guide’ bar before continuing. Two asked for clarification and two proceeded without disabling the ‘Tour Guide’ bar or the Google Earth content.

Clicking on a hyper-link in a placemark balloon opens a web page automatically in the Google search engine. On return to the Google Earth map view the placemark balloons are no longer visible on the map screen. Some participants were not clear that they could be reactivated by clicking an icon.

The participants were largely able to follow the navigation, clicking to continue when prompted, through to the end of the tour. Two participants clicked on something that took them out of the tour and needed assistance to restart it.

The length of time participants took to view the tour and complete the survey was observed to ensure the suggested time duration for completion stated in the survey was realistic. Some participants took longer than others depending on the level of interaction with the links. The time to view the tour and complete the survey ranged from 20 to 40 minutes.

The following feedback was received during the session: -

- clearer instructions were needed for initialising the tour, (suggestions included refining the wording and offering a YouTube demonstration for the operation).
- the instructions needed to state that there was no audio content as some participants were expecting dialogue alongside the animation.
- there was a suggestion that the tour should also be distributed in video format making it accessible to individuals who either do not have Google Earth or don’t wish to interact with the visualisation.
- one participant was confused over the sources and dates for some data (although all data sources were disclosed in the final placemark and this was noted in the introduction) and one found the elevation profiles used to demonstrate the catchment slope difficult to understand.

The observations and feedback given in the session indicate that learning style may affect how participants approach the tour on Google Earth, with different preferences for levels of interaction with the map information as some people learn visually by watching and others by a more hands on approach. Minor adjustments were made to the survey and the introductory overlays of the tour to make instructions for the tour download and initialisation clearer for the non-facilitated questionnaire.

5.2. Facilitated group survey

5.2.1. Participant characteristics

Full details of the participant characteristics and survey results data can be found in Appendix L

Of the ten survey participants five were in the category 20 to 29, three in 40-49 and one each in the categories 30-39 and 50-59. The gender split was six males and four females.

All the participants had relatively high levels of computer/internet experience (rating their experience between 4 and 6 on a scale of 1 to 6) and all had used Google Earth before (occasionally or frequently) to look at places but not to generate content. The group were split across the home environment categories with three living in rural areas, two semi urban and five urban. After viewing the tour of the catchment four indicated that they had never heard of the Isbourne area and five had visited occasionally. None of the participants lived in the area.

Participants had a range of knowledge of NFM, two had never heard of it and two knew a lot about it, others indicated that they knew something about it. None had experienced flooding of their property, although four had friends or family affected.

5.2.2. User metrics

Figure 32 shows graphically the mean and standard deviation of ratings for the usability metrics for ease of use, visual clarity, speed of presentation and trust in the information. The results indicate that the participants rated the usability favourably. For the 'ease of use' 80% of participants rated the tour in the top two ratings of 5 and 6; the mean rating was 5.2. For 'visual clarity' 100% rated the top two ratings, with a mean of 5.7. Additionally, the rating of 'trust in the information' was high with 90% selecting the top two ratings and a mean of 5.3. No one rated these user metrics in the lower part of the rating scale (1 to 3). The ratings for 'presentation speed' (with 1 being too slow and 6 being too fast) were however lower, with a mean of 3.4. 60% of the participants rated this as 3 and 40% rated it as 4. This suggests that the participants found the tour marginally slow, however the survey did not provide a midpoint rating which may have affected the results and the mean of 3.4 indicated the speed was not unduly slow. Given the small sample size for the facilitated group survey cross tabulation was not undertaken to identify potential relationships.

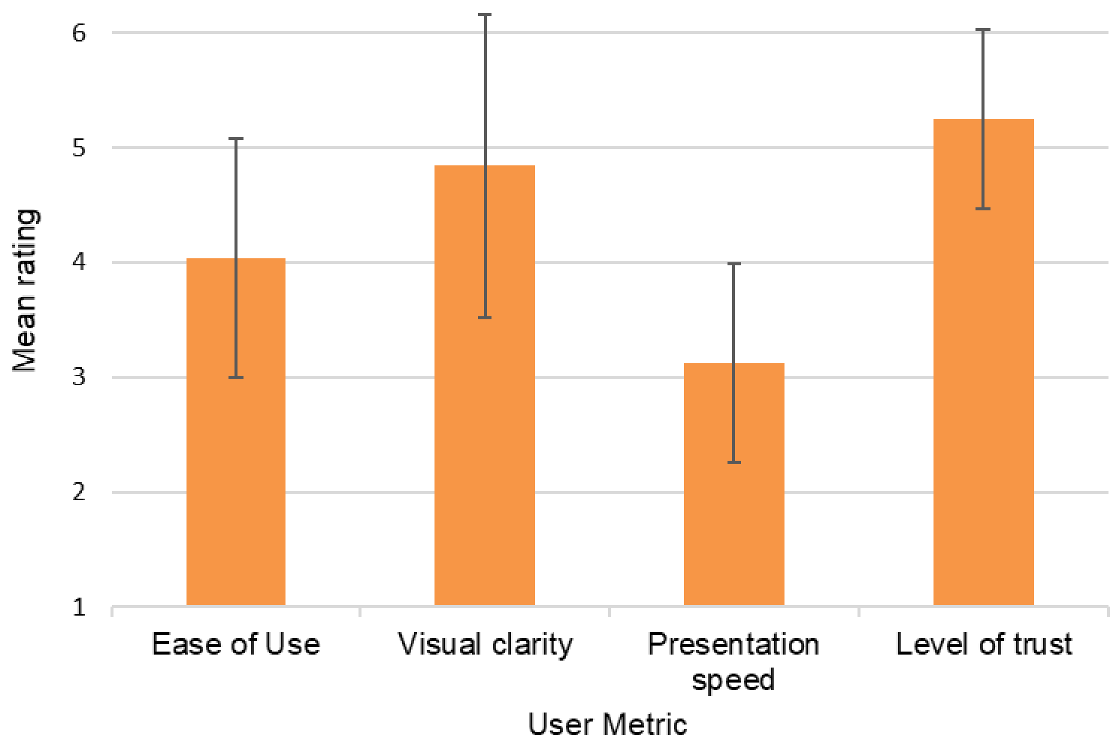


Figure 32. Facilitated group usability ratings (mean ratings with standard deviation bars).

5.2.3. Virtual globe tour elements

The mean ratings for effectiveness, on a scale of 1 to 6, for elements used to create the visualisation are shown in Figure 33. The survey asked about the boundary lines and areas, pop-up information, links to further information, fly through movement, close-up views and ground surface visual appearance. The mean ratings for effectiveness were all above 5, except for the close up/perspective views (mean = 4.9). The highest rating for effectiveness was the pop-up information (mean = 5.5) followed by the fly through movement (mean =

5.3). For all these elements at least 80% of participants rated effectiveness as 5 or 6.

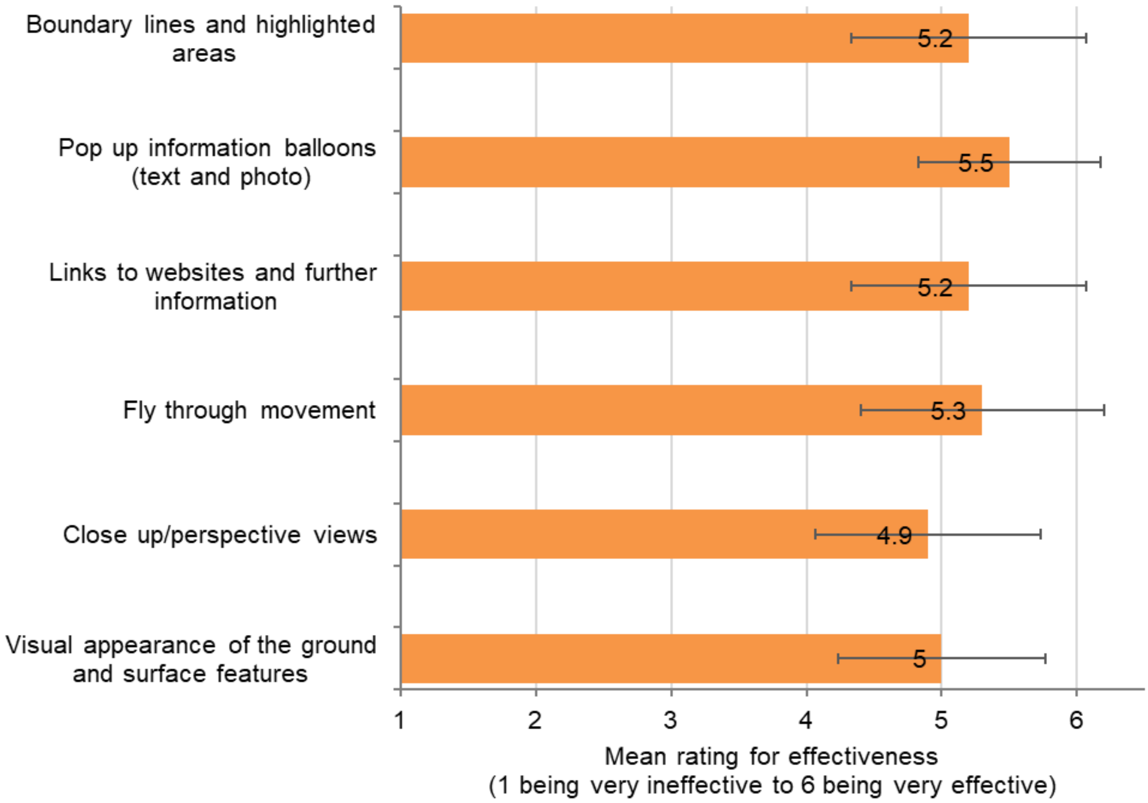


Figure 33. Mean ratings of effectiveness for the facilitated group (with standard deviation bars).

5.2.4. Helpfulness of the tour

Figure 34 shows graphically the mean ratings for how helpful the tour was to those in the facilitated group, using a scale of 1 to 6, to demonstrate the features and issues of the catchment, for understanding NFM techniques and the potential for using them. The mean ratings were all over 5, with the highest being 5.7 for demonstrating the catchment features. These ratings indicate that the tour was able to effectively communicate the features, issues and potential for NFM. None of the participants in the group selected the lowest two ratings for any of these survey questions. The rating for identifying sources of information was also high (mean = 5.4). The lowest mean rating was for understanding the NFM techniques (mean = 5.2).

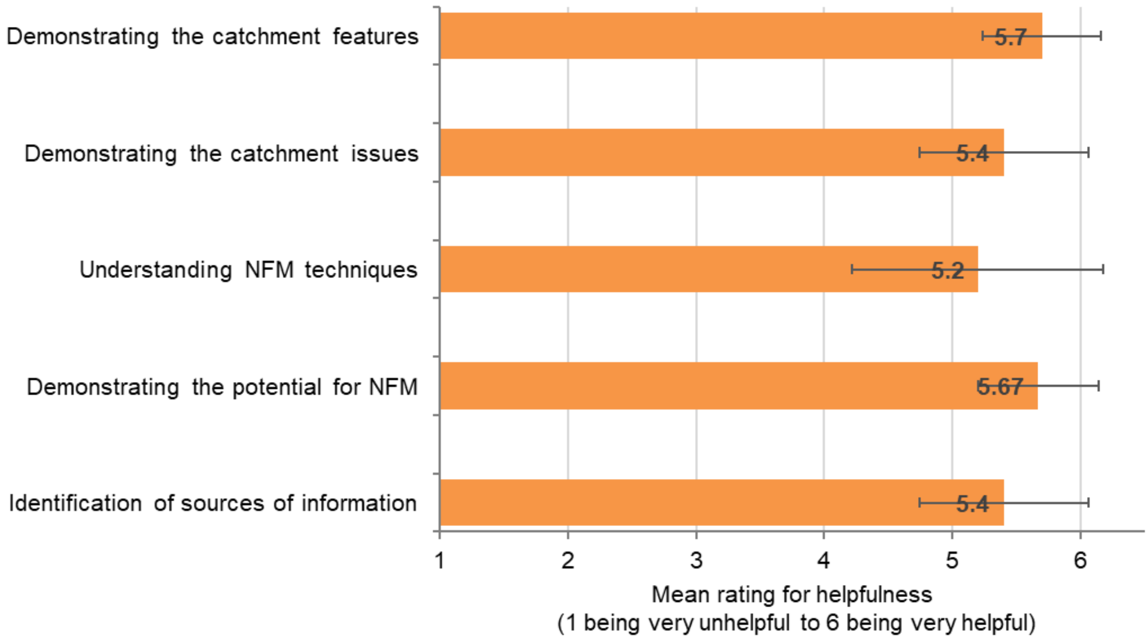


Figure 34. Mean ratings of helpfulness for the facilitated group (with standard deviation bars).

5.2.5. Facilitated group perceptions of the impact of NFM in the catchment

The survey also asked participants about their perceptions of the potential impact of NFM after viewing the tour. Figure 35 shows the results for the facilitated group. 100% of the facilitated group participants perceived that NFM would have a beneficial impact on flooding and wildlife/biodiversity, 90% beneficial for water quality and 80% beneficial to landscape views. There were no perceived detrimental impacts highlighted in this survey although the results showed a degree of uncertainty, particularly with regards to farming where 30% did not know the likely impact, demonstrating the complexity and indicating that the tour may not have communicated as effectively for this aspect.

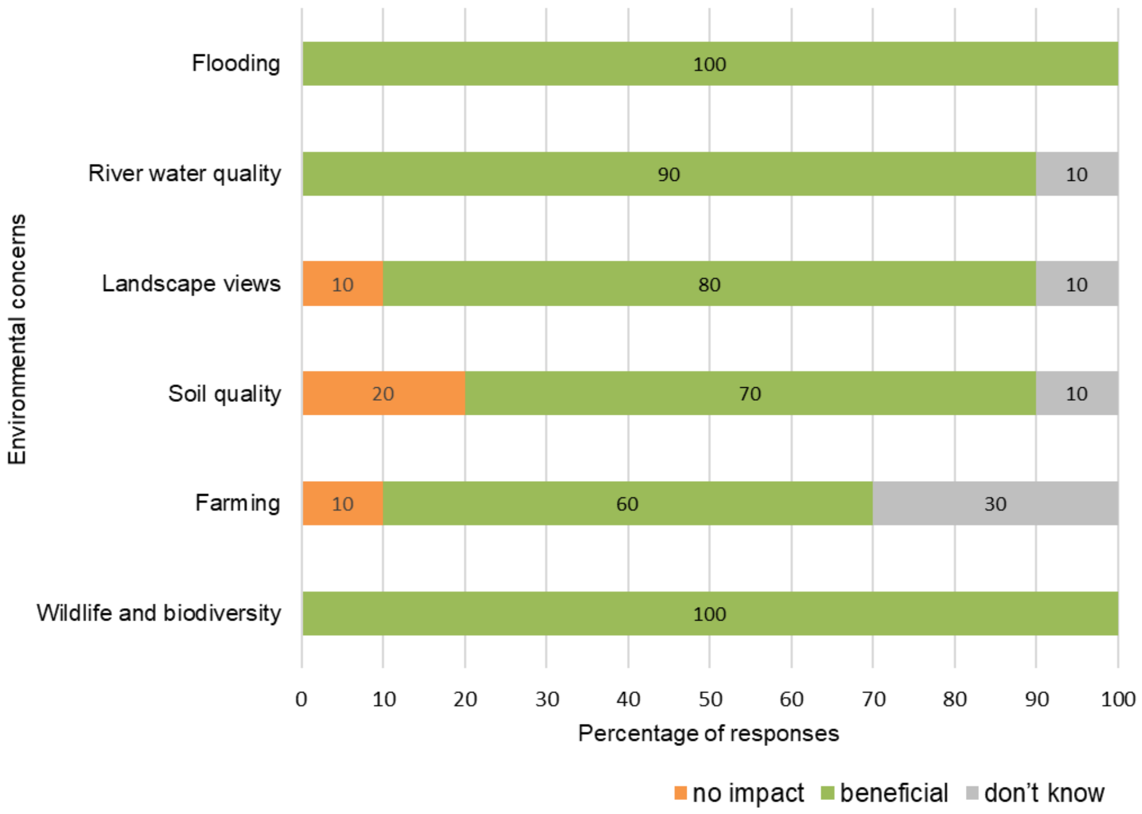


Figure 35. Facilitated group survey perceptions of the potential impact of NFM.

The final question asked participants their level of interest in finding out more about the potential benefits or opportunities for NFM, 60% of the facilitated group were very interested and 30% somewhat interested.

5.3. Online survey

A link to the online version of the survey was included in a CCRI blog[4] outlining the research, which was promoted using social media and email. The survey was available online from 7th July to 4th August 2017 during which time 25 people participated. Blog views numbered 365 by October 2017, indicating a good level of interest in the research.

4 http://www.ccri.ac.uk/survey-landscape-visualisation-technology/

5.3.1. Participant characteristics

For a full breakdown of the participant characteristics and the survey results see Appendix M.

60% of the participants were male and 40% female. They were spread across all age categories with the highest percentage in the age 50 to 59 category (32%) and the lowest in the under 20's (8%). The level of computer/internet expertise was the same as the facilitated group (mean=4.8), with a larger standard deviation (sd=1.1) as the participants selected a wider range of proficiency levels. The range of experience of Google Earth was also wider; one participant having never used it before and eight (32%) using it to generate content. The high level of Google Earth experience (68% being frequent users or generating content) may indicate that the survey participation was biased to those with an interest in this field.

The home environment for participants was split into 40% rural, 44% semi urban and 16% urban. Only one had personally experienced flooding in their property and thirteen (52%) had no experience of flooding. One person identified that they live in the area, 27% visited occasionally and a total of 68% had either never visited or not heard of the area before viewing the tour. 28% knew a lot about NFM before viewing and 8% had never heard of it. The highest proportion of participants knew a little about it (44%).

The main occupation category was professional (48%) followed by academic and student (both 16%) and retired (12%). The most identified sectors of involvement for participants were environmental (n=11), GIS (n=10) flood related (n=8) and wildlife (n=8) and others were involved in agriculture, planning, fishing and forestry demonstrating a wide coverage of interests.

5.3.2. User metrics

The mean values for the user metrics (rated 1 to 6 from low to high) of 'ease of use', 'visual clarity', 'presentation speed'' and 'level of trust' from the non-facilitated online survey are shown in Figure 36. The facilitated group results (presented in section 5.2.2) are included for comparison. The mean rating for 'ease of use' in the non-facilitated online survey was 4. 72% of participants rated it at the higher end of the scale, (5 or 6), however a greater percentage rated it more difficult to use (12% selecting a rating of 2) than in the facilitated group where the mean rating was 5.2. Similarly, for 'visual clarity' the rating (mean = 4.8) was lower than for the facilitated group (mean = 5.7), however 68% of participants did select the top two ratings, with only 8 % rating it as low as 2. The rating for 'trust in information' was high (mean = 5.3) indicating that the participants trusted the content of the visualisation. The mean rating for 'speed of presentation' was 3.1, with 48% rating it as 3 and 28% as 4. The results indicate that tour may be marginally slow (as in the facilitated group survey). The variances were higher for all the user metrics in the non-facilitated online survey possibly due to a wider range of participant backgrounds and interests than the academic and student based facilitated group.

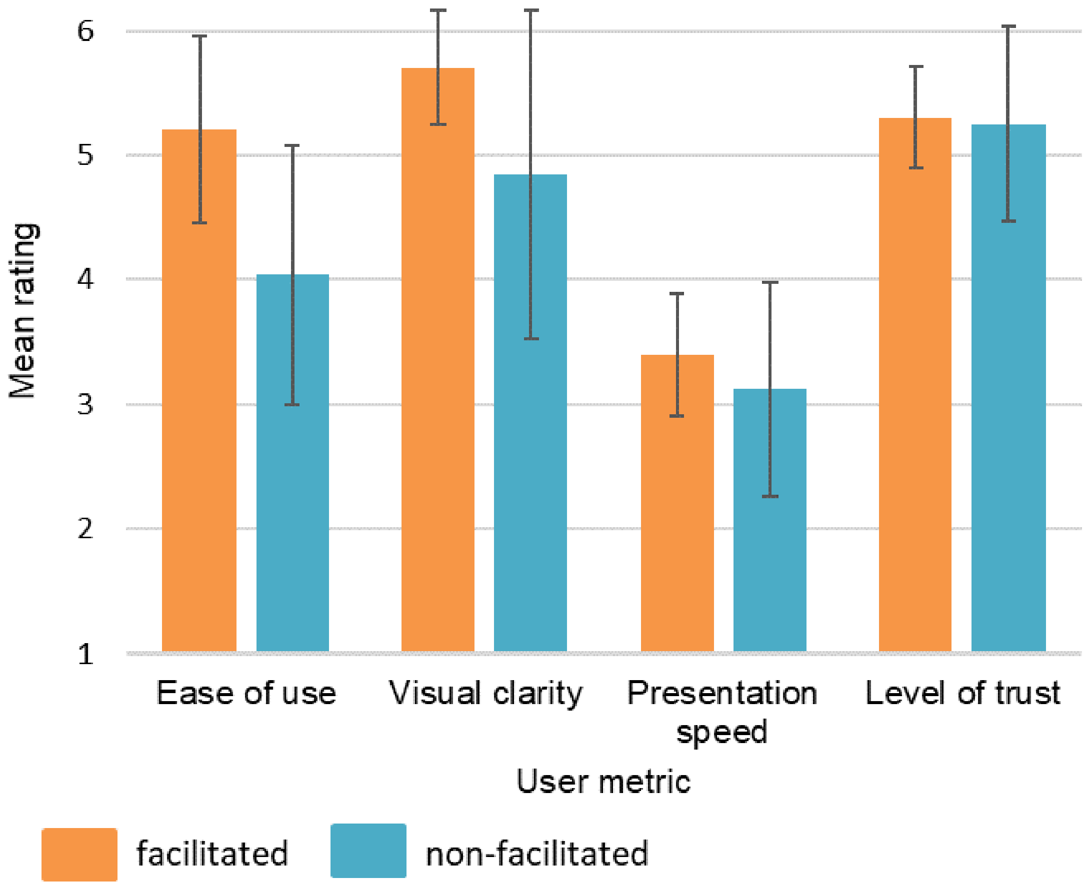


Figure 36. Non-facilitated online survey usability ratings compared with the facilitated group (mean ratings and standard deviation bars).

Cross tabulated results for the non-facilitated group user metrics can be found in Appendix M. There were no obvious relationships noted in the results for the ‘ease of use’ with age, gender, occupation, experience of computers or Google Earth and interest in GIS. For the age categories both participants from the category ‘Under 20’ rated the tour very easy to use (6 in the scale), and two of the three participants in the ’60 and over’ category rated it as 5 or 6. Male and female participants rated the ease of use similarly, with 33% of males and 30% of females rating it as 5 and 40% of each gender rating it as 6.

For Google Earth experience, 63% of those identifying their experience as viewing and generating content and 67% of frequent users rated it highly (5 or 6). Similarly, of the ten participants identifying an interest in GIS, 60% rated it as 5 or 6. As 72% of the total online survey population rated the ease of use as 5 or 6 it appears that greater levels of experience with Google Earth or interest in GIS did not increase the rating for ease of use, indeed a larger proportion of the occasional users of Google Earth rated it highly (86%). The level of computer experience also did not appear to affect the rating of the ease of use, although there were fewer less experienced participants (only three people rated their experience below 4), making comparison difficult.

There were no notable relationships regarding the rating for visual clarity, presentation speed, or trust in the information according to the age or gender of participants. However, for the speed of presentation a third of those who identified as frequent users of Google Earth and 25% of those who use it to generate content rated it as very slow (1 or 2). This was greater than the result for the total survey population where 20% rated it very slow. Those with an interest in GIS also rated the level of trust in the information lower; 50% rated it as 5 or 6 compared to 79% of the total survey population.

5.3.3. Virtual globe tour elements

The mean ratings for the non-facilitated online survey of the effectiveness of the Google Earth tour elements (on a scale of 1 to 6) is shown in Figure 37 (including the facilitated group ratings presented in section 5.2.3 for comparison). All mean ratings in the non-facilitated group were above 4. As in the facilitated group survey the element with the highest mean rating was the pop-up information (mean = 5.1) and this was followed by the links to further information (mean=4.9). The lowest mean ratings in this group were also the visual appearance of the ground (mean = 4.3) and close up/perspective views (mean=4.6). The figure shows clearly that the mean ratings were lower than those in the facilitated group survey for all the elements and the standard deviations higher, showing greater variance.

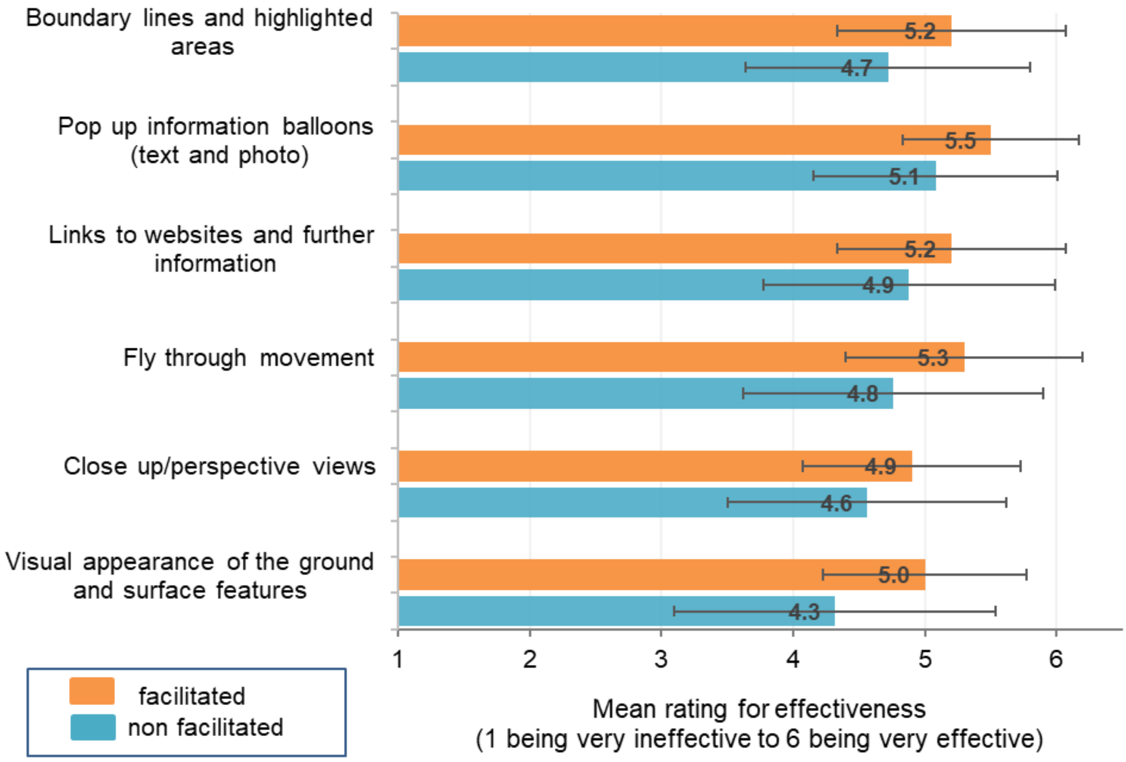


Figure 37 Mean ratings of effectiveness for both the non-facilitated online and facilitated survey groups (with standard deviation bars).

5.3.4. Helpfulness of the tour

Figure 38 shows the mean ratings of helpfulness of the tour for communicating the catchment features and NFM for those in the non-facilitated online survey, which were all above 4 (the facilitated group results presented in section 5.2.4 are included in the graph for comparison). The ratings were highest for demonstrating the catchment features (mean = 5.2), where 80% rated it very as 5 or 6, and for identifying sources of information (mean =5). The lowest mean ratings were for helpfulness in understanding NFM techniques (mean=4.2) where 20% of the survey participants rated this on the lower end of the scale (at 2 or 3) and for demonstrating the potential for NFM (mean 4.5) where 12% rated it below 4. This figure shows clearly that the results of the online survey provided lower mean ratings and greater variance as shown by the standard deviation bars. This is particularly notable in the rating of demonstrating the potential for NFM and understanding the techniques.

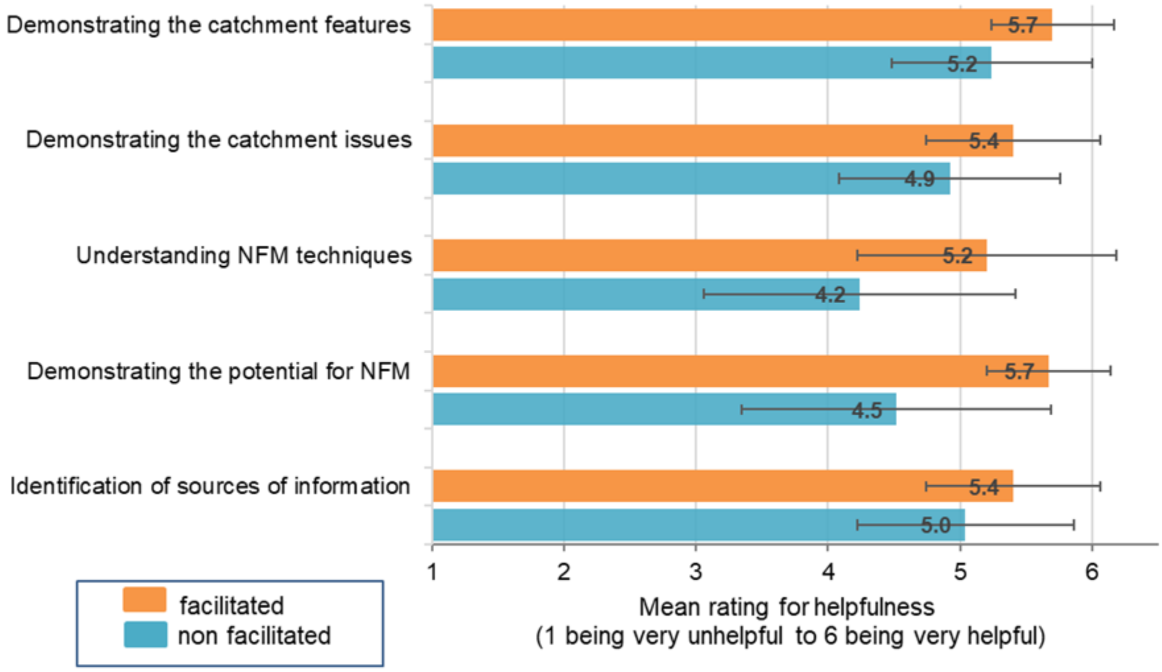


Figure 38 Mean ratings of helpfulness for the non-facilitated online and the facilitated survey groups (with standard deviation bars).

Tables 11 and 12 show the participants familiarity with the Isbourne catchment cross tabulated with the helpfulness of the visualisation for demonstrating the features and issues of the catchment. Eleven online participants identified as not having heard of the area before and 64% of them rated the tour highly (5 or 6) for demonstrating both its features and the issues. One participant was resident in the area and rated the helpfulness as 6 for the features and 5 for the issues. All of those who live in or visit the area occasionally and 83% of those who had heard of the area before rated it as 5 or 6 for demonstrating the features. The results were lower for demonstrating the issues (86% of occasional visitors and 50% who heard of the area). These results indicate that familiarity with the area may influence perceptions about the communication of information and that the tour may have been slightly more effective for demonstrating the catchment features than the issues. Due to the lack of residents and frequent visitors participating this could not be explored further.

Table 11. Cross tabulated results for the helpfulness for demonstrating catchment features and connection with the area (percentage).

	Connection with the catchment area				
Helpfulness for demonstrating features	Live there (n=1)	Visit frequently (n=0)	Visit occasionally (n=7)	Heard of it (n=6)	Not heard of it (n=11)
1	-	-	-	-	-
2	-	-	-	-	-
3	-	-	-	-	-
4	-	-	-	17	36
5	-	-	43	66	18
6	100	-	57	17	46

Table 12. Cross tabulated results for the helpfulness for demonstrating catchment issues and connection with the area (percentage).

	Connection with the catchment area				
Helpfulness for demonstrating issues	Live there (n=1)	Visit frequently (n=0)	Visit occasionally (n=7)	Heard of it (n=6)	Not heard of it (n=11)
1	-	-	-	-	-
2	-	-	-	-	-
3	-	-	-	-	9
4	-	-	14	50	27
5	100		43	50	27
6	-	-	43	-	37

Non-facilitated, online group participants with little or no prior knowledge of NFM rated the tour higher for its helpfulness for understanding the techniques than those who knew a lot about it (Table 13). Five of the seven (71%) of those who knew nothing about NFM rated it highly (as 5 or 6) compared to 45% of those who knew a little and none of those who know a lot about it (with 57% of this category rating it as 2 or 3).

Table 13. Cross tabulated results for the helpfulness for demonstrating NFM techniques and prior knowledge of NFM (percentage).

	Prior knowledge of NMF			
Helpfulness for demonstrating NFM techniques	None (n=2)	Heard of it only (n=5)	Know a little (n=11)	Know a lot (n=7)
1	-	-	-	-
2	-	-	9	28.5
3	-	-	-	28.5
4	50	20	46	43
5	50	20	36	
6	-	60	9	-

5.3.5. Participants perceptions of the impact of NFM in the catchment

The online survey ratings for the perceived impact of NFM after viewing the tour are shown in Figure 39. 9% considered the impact to be detrimental to landscape views and 16.5% thought it would be detrimental to farming. The greatest uncertainties regarding the potential impacts were for farming (21% don't know) and soil quality (17% don't know). For those who responded the impacts were perceived to be more beneficial for flooding (96%), water quality (88%) and wildlife (87.5%). Fewer (58.5%) thought that NFM would be beneficial for farming.

Only one participant had personally experienced flooding to their property and no observable relationship was noted regarding the perceived impact of NFM measures on flooding according to their level of flood experience.

As no specific data was collected from the survey participants before they viewed the visualisation, it is not possible to say from the results how much influence it actually had on changing their perceptions of the potential impact of NFM on the surrounding environment.

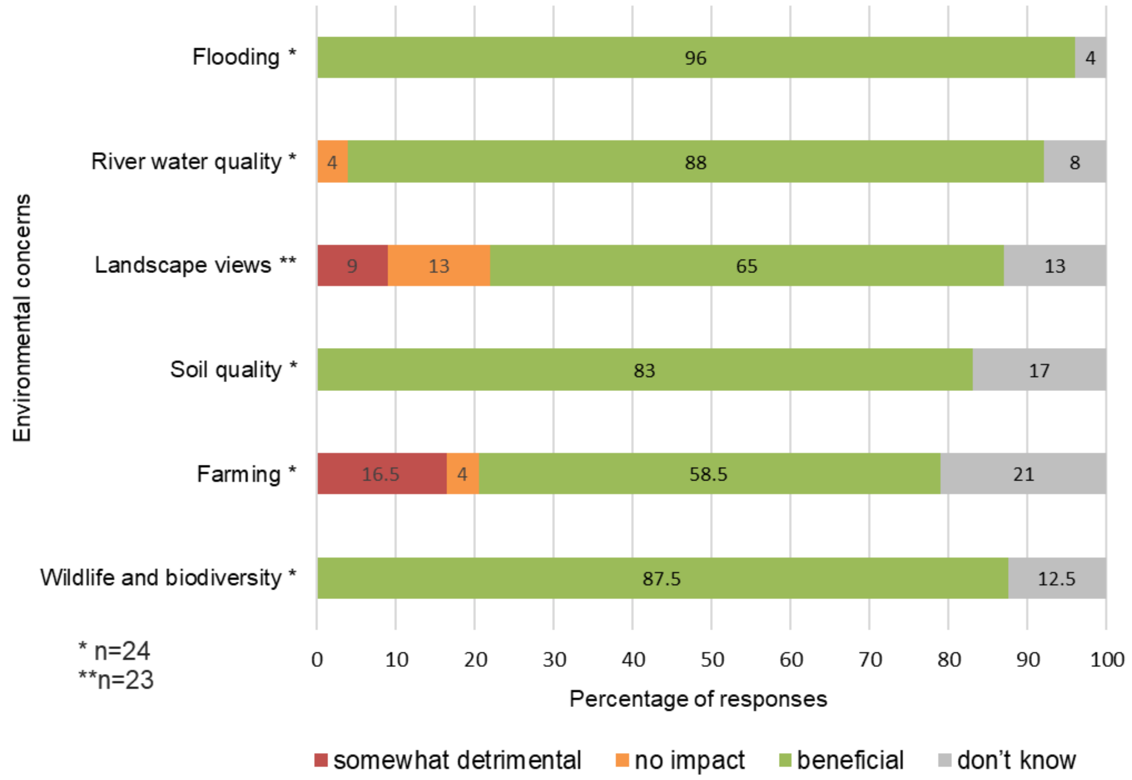


Figure 39. Non-facilitated online survey perceptions of the potential impact of NFM.

After viewing the tour 38% of the non-facilitated online survey participants indicated they were 'very interested' in finding out more about the potential benefits and opportunities for NFM and 58% 'somewhat interested' (see Appendix M for the data). Of those who identified as having some level of familiarity with the area a higher proportion were 'very interested' in finding out more (50%) than for those who had not heard of the area (18%) (Table 14).

Table 14. Cross tabulated results for the level of interest in finding out more about NFM and the familiarity with the Isbourne catchment area (percentage).

	Familiarity with the catchment area		
Interest in finding out more about NFM	Live in or visit the area	Heard of the area	Not heard of the area
Not interested	-	-	9
Somewhat interested	50	50	63
Very interested	50	50	18

5.4. Free text responses

Free text questions were included in the survey to gain a deeper understanding of the participants opinions on the virtual globe tour format and the content that stood out for them regarding the River Isbourne catchment. Full details of the free text responses can be found in Appendices N (facilitated group survey) and O (online non-facilitated survey). Table 15 shows a selection of comments from the free text questions in the survey regarding the most and least useful features of the virtual globe tour.

Table 15. Illustrative comments on the format and presentation of the virtual globe tour.

Usefulness of the format and presentation
Very easy to see the relationship of features to one another, with extra information and chance to explore if you are interested
I really liked the tour - a fun way of learning and a good way to get to know the area.
It is a clear and easy way to present a lot of information in a visually pleasing format that a layperson can access easily and hopefully understand. Unlike a video fly through the user can stop, go back and explore the project area at their leisure.
Good to have further information in the information bubbles. It made the whole experience more interactive
Incredibly easy to follow instructions. It was easy to navigate through the tour. The tour was rich in information and there were different levels which could be accessed according to need.
Issues with format and presentation
The cross-section of steep slopes was a bit unclear. Look forward to a 3D format in the future
Some of the lines were very hazy in the close-up details
Content: I thought there would be something about how NFM is being implemented in the area. NFM only came in at the very end. I was left wondering why I needed to know all of the tour information in such detail. Technical: Overlays were very confusing, e.g. yellow diamonds, colours overlaying imagery during initial orientation tour. Can't see the district boundaries due to the parishes. Flickering/jumping effect of boundaries and text, and low resolution of overlays in perspective view.

Comments about the format and presentation can be divided into those covering the technical features and operation of Google Earth and those about the content. Three comments referred to the tour being easy to use, and one noted it easy to download. Other comments about the technical aspects related largely to the level of interactivity and the visual clarity. Participants commented positively on the pop-up placemarks (n=2) and having the ability to pause to consider the information (n=4) with links allowing them to view or access additional information according to their level of interest (n=4) and one specifically noted the ability to further explore the data interactively after viewing. However, there was also one comment about it not having enough interactive features and one thought there were too many links that were not relevant to them.

Some participants noted issues regarding visual clarity (n=6), with comments on the loss of quality of the graphics in close up views on Google Earth with "*flickering/jumping effect of boundaries and text*" and "*the river line appeared to flash like lightening*" and poor quality of images in perspective views. Computer hardware limitations may have caused problems with download for the online participants, with one finding it did not operate on initial download resulting in "*black rectangles on the map*" and others noting slow rendering and jerky movement.

For one user all the data layers were activated on screen when the tour was started as the "*overlays were very confusing, e.g. yellow diamonds, colours overlaying imagery during initial orientation tour.*" This issue occurs when the user switches back to the information pages after the 'OPEN TOUR' button has been clicked as all the layers in the animation sequences become activated.

The content was well received for providing context and comprehensive coverage (n=3), showing a "*highly descriptive view of the area*" and *"the relationship of features*" (n=3). Some of the content was less well received, including the slope cross sections (n=3) and lack of 3D topography on the Google Earth map with one suggestion that vertical exaggeration may help the perspective views, although this had been disregarded during design to avoid being misleading (Sheppard and Cizek, 2009).

One participant commented that they "*did not know that Google Earth Pro could be used in this fashion*". Another, identifying themselves "*an expert level user of Google Earth*", noted that they found the tour accessible but that others may "*need* *a more web-native version*". There were no comments identifying that a video presentation format would be preferred, unlike verbal feedback received in the facilitated group session.

Table 16 shows a selection of comments received in the survey on the features and issues that stood out most and other information that were identified as potentially useful for improving the understanding of factors influencing the catchment.

Table 16. Illustrative comments on the content of the virtual globe tour.

Issues and features that stand out about the area
The complexity of managing water in the catchment.
Interesting to see the network being identified, and the issues that faced different areas - the flood risk was very clear.
When looking at catchments I think the topographic view is important for people to see and understand the lay of the land. The flood layer over the aerial is also good as it shows the area covering houses creating a greater impact on the flood risk to real houses.
The range of issues which need to be taken into account before any flood management can be undertaken e.g. designated landscapes.
Other information that would be useful
Additional images of the river and tributaries in context - and their location to properties etc.
More specific examples of the NFM measures that could be implemented in this catchment and how they would impact on the environmental designations and farming practices
Some photographs from the flood of 2007 would help to illustrate the problems better. Number of floods and severity - (costs, homes affected etc) in recent history.

The flood area and flood risk were the most noted issues for the catchment (n=8) with references to seeing the properties that were flooded and also the influence of the catchment topography (n=6): -

"I wasn't aware of the direction and shape of the catchment before. I also have a flood story audio recording from someone whose family are from

Winchcombe and I didn't really understand their plight before this. The geospatial overview really puts it into context.”

Other issues and features that stood out in the comments were the impact of changes in land use and management (n=6) and the complexity of issues (n=3): -

“the range of issues which need to be taken into account before any flood management can be undertaken e.g. designated landscapes”

There were also comments recognising the importance of the ecological features of the catchment (n=4), the issues of water quality(n=2), and the historic environment n=2).

The main suggestions regarding information to improve participants understanding of the area were the inclusion of more photographic images of the river and of the 2007 flooding (n=5) (with one suggesting drone footage). Others suggested information on historical water management (n=3) how land management and agriculture have affected flood risk (n=3), the costs of flooding events, the incorporation of rainfall data, and the replay of a flood event. There was also interest in more information on the application of NFM (n=2) with a comment: -

“More specific examples of the NFM measures that could be implemented in this catchment and how they would impact on the environmental designations and farming practices”.

A word cloud (Figure 40) illustrates the most common words from all the responses to both facilitated and online surveys combined. The largest and therefore most frequently used words were “*area”, “information”, “flood”, “tour”, “management”,” land” and “see”*. While this does not provide additional analysis, it does confirm the focus of the responses received around the amount of information that was made visible to participants and the attention drawn to flooding in the catchment area. With the limited sample size and level of content of the responses further detailed qualitative analysis was not undertaken.

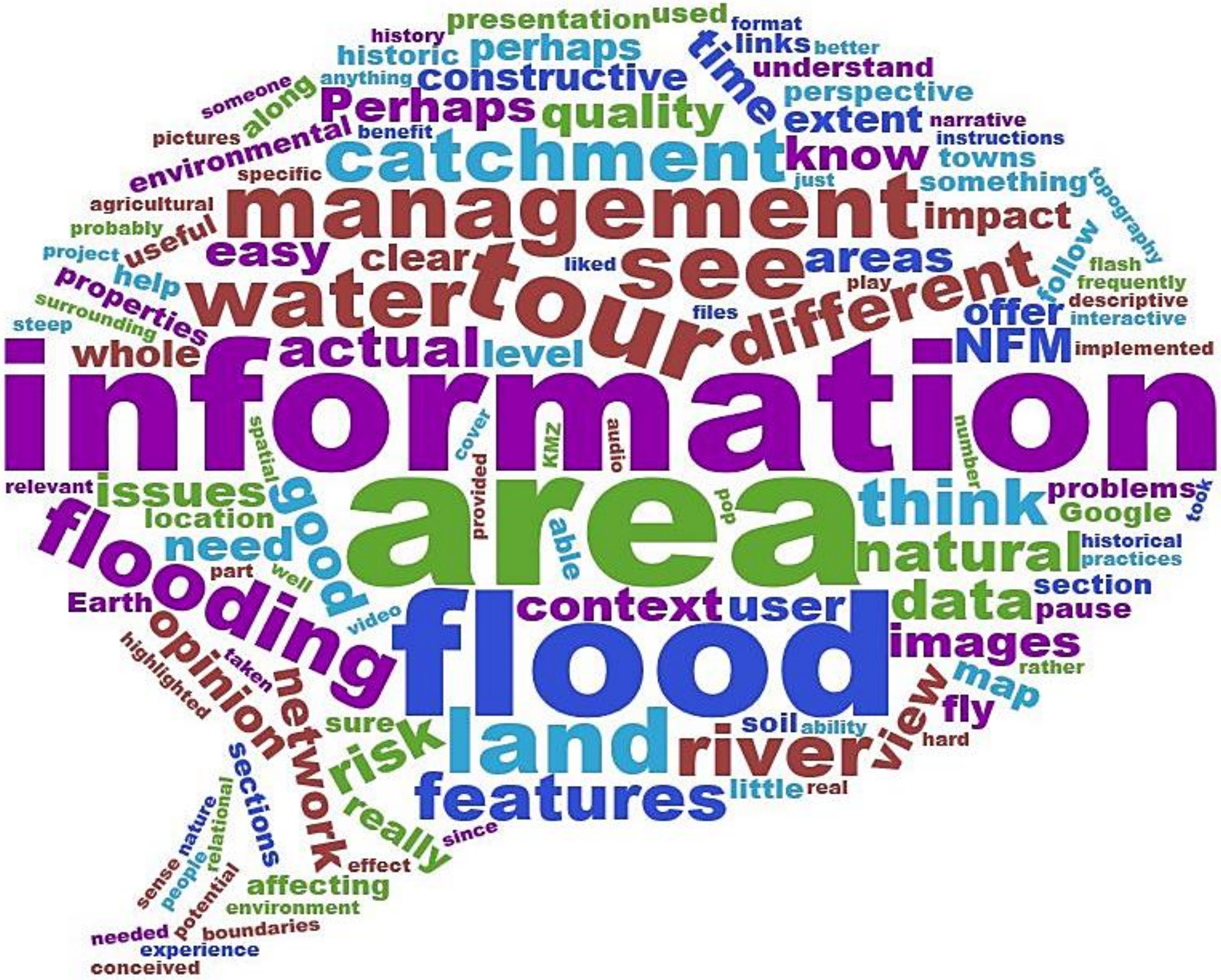


Figure 40. Word cloud created from the free text responses.

5.5. Summary of end user evaluation results

The end user evaluation was undertaken in two settings, with ten participating in a facilitated group in an academic setting and twenty-five participating online non-facilitated survey. Observations and feedback from the group session revealed that that clear instructions were essential to avoid confusion in the set up and operation of the virtual globe tour.

Scale questions in the end user survey were rated 1 to 6 and designed to obtain feedback on the usability of the tour, the effectiveness of specific elements, and the helpfulness for communicating both the features and issues of the catchment and the potential for NFM in the catchment. The survey also asked about viewers perceptions of the impact of NFM on the environment.

Usability ratings in both settings were high for ease of use, visual clarity and level of trust, although they were slightly lower in the online survey. The mean ratings for these metrics were above 5 for the facilitated group. The mean value for level of trust was also above 5 in the online survey, whereas the ease of use and visual clarity were above 4. The ratings for presentation speed were lower, (mean values of 3.4 in the group and 3.2 in the online survey). This may indicate the participants found the tour slightly slow or reflect that the rating scale had no neutral rating.

The mean ratings for effectiveness of the tour elements were all high, above 4 in both the group and online surveys. The lowest ratings were for the close up/perspective views (mean = 4.9 group/5.0 online) and the visual appearance of surface features (mean = 4.6 group/4.3 online). The highest ratings were the pop-up information balloons (mean = 5.5 group/5.1 online). The mean ratings for effectiveness were consistently higher (and the variance lower) in the facilitated group than the online group for all the elements.

Comments made in free text questions supported the usability metrics, indicating the tour was easy to use - "*clear and easy way to present a lot of information*", novel - a "*fun way of learning*", with clear instructions, although several referred to issues with visual appearance of flashy lines and images during movement (n=6) and the slope cross sections (n=3). Participants commented that they liked the pop-up balloons (n=2), the interactivity with links to further information (n=4) and the ability to pause and rewind (n=4) in addition to the fly through navigation.

There was some disagreement on the level of interactivity with one noting there was not enough and another that many of the links were not relevant to them. Only one participant referred to the Google Earth imagery noting that it did not give an adequate view of the topography.

Among the online participants there was no notable relationship between age, gender, occupation or experience levels for Google Earth or computers with the rating of ease of use or visual clarity. Those with higher Google Earth experience or interest in GIS did rate the speed of presentation lower and those with GIS interest also rated the level of trust in information lower.

Mean ratings for helpfulness were all above 5 in the group setting survey and above 4 in the online group. The highest ratings were for demonstrating the catchment features (mean = 5.7 group/5.2 online). The lowest ratings were for the understanding of NFM techniques (mean = 5.2 group/4.2 online) although the ratings for demonstrating the potential for NFM were higher (mean = 5.4 group/ 4.9 online). Ratings were also high for identifying sources of information (mean = 5.4 group/5.0 online).

Free text comments supported the survey ratings that the tour was helpful for communicating the catchment features including the topography (n=6), the ecology (n=4) and historical environment (n=2), with several referring to being able to see the flood area (n=8). They also commented on the issues of land management change (n=6), the complexity of multiple agencies (n=3) and the potential for using NFM (n=2). Others did however note that they would like more photographs to improve their understanding of the area (n=5) and had expected more specific information on NFM techniques and where they could be used in the catchment (n=2).

In the online survey there was a noted difference in the rating of helpfulness for demonstrating NFM techniques according to the participants levels of prior knowledge. None of those stating they know a lot about NFM rated it above 5 whereas 71% of those knowing nothing, and 45% of those knowing a little, rated it above 5.

The sample size was not large enough for detailed analysis and not all categories were well represented (such as those aged under twenty, resident in the area or personally affected by flooding). However, there was an indication that the rating of helpfulness for demonstrating the features and issues of the catchment was higher among those with some familiarity of the area; a higher proportion of participants who visit occasionally rated it highly (5 or 6) for demonstrating the features (100%) than those who didn't know the area (64%).

The results showed that after viewing the tour participants perceived that NFM would be beneficial to flooding (100% in the group and 96% of the online participants) and to water quality (88% in the group and 90% of the online participants). There was more variance in the perceived impact on landscape, soil quality, farming and wildlife. 21% of online participants selected 'Don't know' for the impact on farming and 16.5% believed there would be a detrimental impact. As these questions were only asked after viewing the tour it was not clear how much the tour had influenced these perceptions although the ratings for helpfulness had indicated that it was useful for demonstrating NFM for those with little or no previous knowledge.

Only one participant had personally experience flooding to their property and the results showed no obvious difference in the rating of the helpfulness of the tour for communicating features or issues for the catchment or the perceived impact of NFM according to personal experience of flooding.

38% of non-facilitated online participants indicated that they were 'very' interested in finding out more about NFM and 58% 'somewhat' interested. Of those with some level of familiarity with the catchment area 50% were 'very' interested in finding out more compared to just 18% of those who had not heard of the area.

Chapter 6 Discussion

The aim of this research was to explore the potential for using 3D landscape visualisation for communication and engagement in the early development of a catchment NFM scheme, using the Isbourne catchment as a case study. With recognition of the diversity of interests in the Isbourne catchment, due to the complex administrative roles (with multiple county and parish boundaries falling within the catchment) and the range of natural features, it is essential to engage a wide range of stakeholders in the development of this project.

There are a number of resources now available detailing the range of techniques that work with nature to reduce flood risk while providing wider benefits to the environment (SEPA, 2015; Avery, 2012). The EA has recently published the current status of the evidence base for these techniques (Environment Agency, 2017b). Recently, published research has considered other identified gaps in research (Environment Agency, 2014) such as the collection of catchment scale data (Starkey *et al.*, 2017) and barriers to the implementation of NFM (Holstead *et al.*, 2017; Waylen *et al.*, 2017). No research was identified during the literature review on effective methods or software tools for communicating information to engage stakeholders in an NFM project.

Landscape visualisation, representing places and spatial data digitally, is recognised as having the ability to make things more meaningful to the viewer (Grainger, Mao and Buytaert, 2016) and has been used for communication and engagement at a variety of scales (Lovett *et al.*, 2015) including catchment scale (Harwood, Lovett and Turner, 2015). The Google Earth virtual globe tour approach was selected for the previously identified benefits of accessibility and interactivity, with satellite coverage able to add context and generate interest (Pettit *et al.*, 2011; Sheppard and Cizek, 2009).

To reflect on the extent to which the research met the objectives of (i) identifying the key information requirements and (ii) exploring whether the visualisation could enhance the communication and understanding of spatial information for the catchment, this discussion has been divided into two parts: section 6.1 reflecting on the experience of creating the virtual globe tour and section 6.2 exploring how effective it was for communicating the catchment features and NFM. It also identifies the limitations of the Google Earth virtual globe tour approach used in the research and the methodology (section 6.3).

6.1. Creating virtual globe tours

Google Earth is a free platform for viewing satellite imagery, aerial photography, maps and data and enables annotation of these on a desktop computer or device. Google Earth Pro (also free to download) has additional features including the ability to import ESRI shape files and make movies. It was clear from feedback in the survey that although participants were familiar with using Google Earth to view places, there was less awareness of the ability to visualise data and create tours.

The virtual globe tour approach has been recognised as accessible for non-experts to use (Sheppard and Cizek, 2009). The tours prepared during this research were created after learning the basics of KML scripting from freely available online and published resources with no previous programming knowledge. Basic features can be created on the map screen and data sets can be imported into Google Earth. However, as Schroth, Pond*, et al.* (2011) noted, knowledge and skills are required to prepare the data and other elements. GIS experience was certainly beneficial for understanding spatial data, downloading and manipulating datasets and converting shapefiles to KML. Using GIS made the downloaded data easier to manage, enabling required data to be extracted or clipped to an area with some formatting possible before conversion. These functions can be performed in the open source QGIS but the need to use GIS to prepare data could reduce the level of accessibility for those with no previous experience.

Some online resources for KML scripting were difficult to locate and they varied in technical content. The learning process was time consuming, through trial and error with a script editor, making changes and seeing what works. To get beyond the basic skills the resources become more technical - for animation instructions, the addition of models and features such as network links and the use of time spans. The tours did take a considerable amount of time and effort to construct to incorporate all the information requirements to communicate the catchment features. The full-length, technical tour contained over 6000 lines of scripting in

Notepad++. It is a repetitive process, using a cut, copy and paste process with the Google Earth map and the text editor along with manual scripting, however this does speed up with experience. The Google Earth KML error handling function, that identifies lines of scripting that contain errors when files are loaded onto the map, was helpful and other tools were invaluable for customising elements including the location of screen overlays and defining coordinates, view angles and altitudes for locations (see Appendix E). There was recognition in the survey of the amount of work involved with an experienced Google Earth user commenting they *"commend who ever took the time to put this together".*

6.1.1. Information requirements and data availability

Previous research has recommended involving stakeholders in the development of visualisations (Harwood, Lovett and Turner, 2015; Sheppard *et al.*, 2011) and cyclical reviews can enhance efficacy (Lovett *et al.*, 2015). However, as noted by Ingram *et al.* (2016) collaboration may reduce credibility if there is doubt on the science or any perception of bias. In this research an element of collaboration was achieved by involving the ICG in a focus group at the outset. They identified the information that would be helpful for communicating the catchment issues and engagement with the NFM project. The group decided that two tours would be useful; a short tour to demonstrate the administrative complexity and the flood outline, and a longer technical tour to communicate more technical information, the issues the catchment is facing and the potential for NFM. The overall feedback on the prototype was positive – with the ICG members present excited by its potential for communication.

It has been noted previously that virtual globe tours are limited by the availability of suitable, open access data to be freely distributed to non-licenced users (Berry *et al.*, 2011). The availability of free and open data is improving with OS data such as Open Map Local, Open Rivers and Boundaries available to download directly from the OS website in shapefile format that can be imported directly into Google Earth Pro. Some datasets from sources including the BGS, Natural England and the EA are available to download in KML format, however large national or tiled datasets necessitate additional effort to extract the required features for the area of interest.

OGL data from the OS, EA, Natural England, Historic England and the BGS was located to meet most of the information requirements identified by the ICG in the focus group to demonstrate the catchment features. The most notable data limitation was the availability of land cover data, a key requirement to demonstrate how land use change may have impacted the hydrological processes, flood risk and water quality. There was no alternative open access dataset for land cover to the EU CORINE data. With only three sets of CORINE data available for the UK, (2000, 2006 and 2012), it was not possible to show long-term changes and other open access data sources were not available to visualise longer term historic changes on the map. The CEH Land Cover Map data is currently licenced.

There were also potential issues with the accuracy of the CORINE land cover data. With the thematic accuracy of the raster format data level (>85%) and conversion to vector format the level of accuracy may be unsuitable for close scales although for demonstrating high level land cover in this catchment the level of accuracy was considered suitable. CORINE data has been prepared from different satellite sources in each of the available years (Copernicus Programme, 2017) and variations in recording may also affect the comparability of data.

Although the ICG did not request that geology and soils data be included if it had been this too would be restricted as many of these datasets are licenced, such as the BGS Permeability and Soil Parent Material Model data and the Cranfield Soil and AgriFood Institute (CSAFI) Soil Series data.

The ICG and survey comments indicated that additional gauge data for river levels and water quality, as well as rainfall data, may be useful for better understanding the Isbourne catchment. With only one recording station currently existing on the river this was not possible to incorporate. Additional catchment data has been collected successfully by Starkey *et al.* (2017) using a citizen science approach and there is potential to add recorded gauge data into a Google Earth map layer in the future.

6.1.2. Tour design and construction

The virtual globe approach enabled a considerable amount of information to be incorporated in a single landscape visualisation at the catchment scale. The final KMZ archive file was a manageable size for online distribution (8.26 MB) enabling a lay audience access to data, using the Google Earth base map and imagery, that is not normally accessible - a benefit recognised by Phadke (2010) and Sheppard and Cizek (2009).

The visualisation was designed to demonstrate existing catchment features and highlight relevant historic changes along with flooding and water quality issues. As such, the format was suitable for the purpose; allowing relevant data and additional text information to be incorporated with navigation and zooming to view locations at suitable levels. It was possible to construct a visualisation to direct the viewers' attention to relevant information at different scales; using customised navigation, views, styles and labels, supported by the addition of textual information and narrative. Links to access suitable sources of supporting information could also be incorporated providing a level of interactivity enabling the user to explore further according to their interests and keeping the onscreen text to a minimum. Some information was harder to represent on the map screen, such as the potential impact of farming and land management practice on soil health, flooding and water quality in the catchment. The content for these issues was limited to information placemarks with links to further information.

During the initial stage of the Isbourne NFM project (with uncertainty over target locations and approaches) this visualisation was not designed to show future landscape scenarios, which may have the capacity to be emotive or misleading (Sheppard and Cizek, 2009). It suggests to the viewer potential solutions, along with the wider benefits of NFM, to stimulate thought and interest. Demonstrating future landscapes of NFM measures with the virtual globe tour approach may be harder to achieve other than identifying target areas and suggesting suitable techniques. Investigations into the addition of trees in the prototype tour indicated that it may less effective for visualising woodland planting, in-channel or floodplain measures at closer scales and perspective views due to limitations of the incorporation and appearance of 3D models in the landscape (section 6.3.1). However, as the project advances and NFM techniques are proposed, placemarks could be added at target locations incorporating text and photographs to illustrate both the local and potential catchment-wide impacts.

An important recommendation for any landscape visualisation is transparency of data (Lovett *et al.*, 2015; Sheppard and Cizek, 2009). It was possible to include details of data sources within placemarks, with links to attribution statements where required and the survey participants rated their trust in content as high (non-facilitated survey mean = 5.3).

Introductory pages were built in to facilitate set up, an approach used by Harwood, Lovett and Turner (2015). These needed to be clear enough to be followed by all users including those with little or no experience of using Google Earth. Refinements were made following observations of use and feedback gained from the facilitated group session, before the online survey release, to improve usability - a key requirement for technology acceptance (Bresciani and Eppler, 2015). The main issues here were the need to disable any unnecessary Google Earth content before viewing the tour; both the “Tour Guide” bar that loads automatically at the bottom of the map screen (to enable access to the full map and the tour controls), and the superfluous layers content which would be distracting. A note was also added to draw attention to the map icons that can be clicked on to activate placemarks.

The virtual globe tour included many different data layers to cover the identified information requirements. The layers of data could not all be shown on the map screen in one view as there were too many overlapping features. Instead the features were animated in and out of view when and where required during the navigation and this complexity may make elements of the tour scripting difficult for others to update in the future, a design aim of Harwood, Lovett and Turner (2015). This may be more achievable by creating a range of shorter tours, each covering a specific theme, however this could reduce the ability to demonstrate the complexity and the relationship of features.

One consequence of the complex script for the tour was not resolved during the research timescale. If the viewer clicked the button to open the tour and then went back to view the information pages before returning to the tour to start it, all the data layers became activated and visible on the map and this would restrict the ability to see the relevant layers of data in the correct order as the navigation and animation started. From the questionnaire feedback in the online survey it appears one participant may have encountered this issue although it was not raised in the facilitated group session. More effort may be required to solve this issue or alternatively a note could be added to alert the viewer not to return to instructions page after activating the tour.

Pettit *et al.* (2011) found the end user testing of visualisations useful for refining their effectiveness, whereas Harwood, Lovett and Turner (2015) and Sheppard *et al.* (2011) used an iterative workshop development process to incorporate the preferences of stakeholders. A potential limitation to the design process in this research was having only one meeting with the ICG due to the time frame involved and the early stage of the project. Attempts were made in the focus group session with the ICG to identify any issues with style and speed presentation in the prototype tour. Follow up meetings may have given more opportunity to highlight issues, allowing refinement to content, representative view angles, styles and speed of presentation. Achieving effective levels of collaboration can be challenging in the time available, balancing between too few or too many iterations (Grainger, Mao and Buytaert, 2016).

The end user testing method did identify additional information that viewers may require to better understand the catchment and its issues. Participants suggested additional photographs of the river and flood events (which had been excluded at the request of the ICG so not to shock viewers), more specific information on the cost of flooding and the historical aspects of land use, rainfall data and target areas for NFM.

A recognised limitation of the virtual globe tour approach is developer bias for content and presentation (Sheppard and Cizek, 2009). It was difficult during the development of the visualisations here not to be influenced by personal preferences. Content was incorporated that were less important to the members of the ICG that attended the focus group session, such as the gardens and listed buildings which were added to provide context regarding the historical nature of the area and the designated areas. However, other stakeholders may have been interested in incorporating these features, and they were noted to be of interest to some survey participants. This confirms that broad representation is required for stakeholder engagement to ensure a range of realistic interests are incorporated (Grainger, Mao and Buytaert, 2016). It would be useful to obtain feedback from the ICG on whether the final visualisation matched their expectations and requirements.

6.2. Capacity of virtual globe tours to communicate catchment features and NFM

According to information systems theories (TAM and TID) users will accept technology based on perceptions of usefulness and ease of use, with usefulness initially more important than usability (Davis, Bagozzi and Warshaw, 1989). The ability of the virtual globe tour to effectively communicate the features and issues of the catchment is therefore of primary importance but it should also be easy to start, use and interact with. (Bresciani and Eppler, 2015) added that information visualisation also requires perceived authority to be accepted.

Feedback comments in this research did indicate that there was an interest in the virtual globe format as a novel and visually pleasing way of learning. It was able to communicate and put into context the catchment features and issues (mean ratings for helpfulness for demonstrating features 5.2 and issues 4.9) with participants commenting on the ability to see the flood extent with the affected properties (n=8) and the relationships of features (n=3) and also to understand causal influences, including the topography (n=6) and land use change (n=6). This supports the recognised benefit of the virtual globe approach of the ability to generate interest beyond that of a 2D map (Pettit *et al.*, 2011; Sheppard and Cizek, 2009).

Newell and Canessa (2015) have described how visualisations can connect individuals with a sense of place, drawing from memory and understanding to stimulate meaning and emotional response. This research did indicate that a sense of place may have influenced responses, with the majority of those who live in or visit the catchment area rating the helpfulness of the virtual globe tour 5 or 6 for demonstrating both features (100%) and issues (86%) compared to those who had not previously heard of the area (64% for features and issues). With the small sample size and only one participant living in the catchment area it is not possible to draw any conclusions on this.

The participants also found the virtual globe tour helpful to demonstrate the techniques and potential for NFM, although less so than the catchment features and issues (with online survey mean ratings >4). Some did comment on the complexity of interests and agencies in the catchment relating to the application of NFM. Not all those who viewed it were satisfied with the content; two commented they expected more specific NFM information to demonstrate how it can be applied in the catchment. The purpose of the visualisation at the stage of the project could have been clearer to viewers to avoid confusion. Specific areas and techniques were not identified to avoid negative associations as landowners had not yet been approached. As the project progresses additional information could be added to communicate target locations with suggested measures.

Those with less knowledge of NFM prior to viewing the tour did find it more helpful for demonstrating the techniques, showing it to be a useful tool for education, raising awareness and understanding as found in previous research (Harwood, Lovett and Turner, 2015; Schroth, Pond, *et al.*, 2011). In the online survey 71% of those who knew nothing about NFM found it very helpful (rated 5 or 6), whereas none of those who previously knew a lot rated it as high, indicating that it could be used for learning and engagement of those with no previous knowledge. The tour also interested the participants in finding out more about NFM, with 38% 'very' interested and of those with some familiarity with the area 50% were very interested. As noted earlier there was only one participant resident in the area and one who experience flooded property however the results indicate that the visualisation has potential for communication and early stakeholder engagement.

While it is not possible to identify whether the visualisation changed the perceptions of the impact of NFM in the catchment for those who already had some knowledge, after viewing it there was a clear perception from the online survey that it would be beneficial to flooding (96%) and water quality (88%). There was less consensus of the potential impact on landscape views, where 65% thought it would be beneficial and for farming where 58.5% perceived it beneficial and, 16.5% thought it would be detrimental and 21% were uncertain what the impact might be. Impacts to landscape views and farming were not so easy to represent on the map or the limited space available in pop-up information balloons, although links were included to additional sources of information. More effort may be required to communicate the wider benefits of NFM or to follow up with other engagement measures as any visualisation is only as good as the process it is part of (Lovett *et al.*, 2015).

Google Earth is now a familiar platform that is accessible to users who look at locations and explore on the map screen and those that viewed the virtual globe tour found it easy to use, supporting the previously highlighted benefit of accessibility (Pettit *et al.*, 2011). Survey feedback indicated that the download and instructions were accessible, with one commenting "...incredibly easy to follow instructions. It was easy to navigate through the tour", however virtual globe tours may be complicated to download and set up remotely for users with limited experience. Comprehensive instructions were incorporated but may have been confusing or off-putting to some, as observations in the facilitated group highlighted that some participants (20%) required support. Bresciani and Eppler (2015) recognised that the adoption of a visualisation would depend on the perceived usefulness as well as ease of use therefore the willingness to view this visualisation will depend not only on the interest in exploring the catchment features but also how clear and understandable it appears to those with no previous knowledge. The survey did not question the experience of downloading or setting up the tour and although a large proportion rated it very easy to use (76% of online participants rated it as 5 or 6), the number of individuals who attempted and abandoned it was not captured. Only three people rated their computer experience low (below 4) and only one of these rated it difficult to use. Greater participation from those with lower skills would be needed to evaluate this further. With 365 blog views by October 2017 there was interest in the research however only twenty-five participated during the four-week survey period and this may have been due to the perceived effort and time required to download and view the visualisation. Confidence and determination may be required for remote use.

Weaknesses identified by Pettit *et al.* (2011) included the blurring and pixilation of boundaries and other added elements, particularly in flythrough movement. These issues were also identified here (six participants commented on visual issues). Although not totally avoidable this blurring can be reduced by careful selection of speeds, viewpoints angles and altitudes. It is worth noting that the appearance of elements and placement on the screen also varies according to the computer screen dimensions and image resolution. Despite this all the Google Earth virtual globe tour elements were found to be effective in the online survey with mean ratings all above 4, ranging from the highest, pop-up information balloons (mean=5.1) to the lowest - visual appearance of the ground (mean=4.3).

Different learning styles may affect how individuals prefer to interact with the visualisation, as noted in observations of use (section 5.1) and the variety of comments in the survey (section 5.4). Participants highlighted the effectiveness of the pop-up balloons and links to websites (n=4), the ability to control and explore independently (n=4), the ability to see the visual data in overview on the map (n=2), and the navigated flythrough (n=1). Schroth, Pond*, et al.* (2011) found that individuals had different preferences for stills, animated presentation or interactive formats. Alternative formats may be required to communicate catchment features and NFM, to meet individual learning styles or interest levels, and further research could identify whether some people would prefer a video presentation rather than the full interactive version.

End user testing of the final tour indicated the presentation may have been marginally slow (mean =3.2). With a large proportion of the online survey participants having experience of Google Earth (68% using frequent or generating content), GIS (40% paid or unpaid interest) or NFM (72% knowing a little or a lot), additional feedback from less experienced viewers may be prudent before any refinements are considered.

6.2.1. End user assessment and survey limitations

One of the benefits identified by Sheppard and Cizek (2009) of the Google Earth virtual globe approach was the ability to share with a wider audience, enabling earlier participation in projects. Here the online, web-based approach was suitable for communicating the catchment features and issues, subject to successful download and set up. The limitation of this approach, communicating remotely via the internet, is not having the opportunity to generate discussion or a co-production of knowledge (Lovett *et al.*, 2015). This could be more achievable in a workshop setting, as used by Schroth, Hayek*, et al.* (2011), Sheppard *et al.* (2011) and Pettit *et al.* (2011), where the causes of flooding and water quality failure along with the impacts and wider benefits of NFM could be explored to achieve a deeper understanding. Discussion was limited in the facilitated group session as the participants provided their feedback anonymously through the survey. An online discussion forum may be one possible way to follow up with interested participants after remote viewing.

The setting for the end user assessment (facilitated or web based) appears to have influenced the survey results. Mean ratings were lower and variance higher in the online survey than in facilitated group for all the usability metrics, attribute effectiveness and the helpfulness for communication. This may be due to more honesty in anonymity when participating remotely or the composition of the participant group, where academics and students had experience and interest in sustainability and environmental management issues. Wissen *et al.* (2008) noted that a group environment limits the results to those participants. Testing in groups with a broader range of participant interests or a non-academic setting would be necessary to explore this further (Glaas *et al.*, 2017; Pettit *et al.*, 2011).

According to Tullis and Albert (2013), with under twenty participants variance will be high and it will be difficult to generalise, however 80% of usability issues can be identified by as few as five participants. There were too few participants in the online survey to allow more than basic statistical analysis and inference. Having a greater number of participants may have reduced the variance in ratings. Even with the small sample size potential usability issues were identified in the facilitated group observations and feedback and the non-facilitated online survey.

The survey did include participants from a variety of sectors of interest. It also attracted attention from those already experienced or interested in Google Earth, GIS or NFM as it relied on the blog and survey link being circulated online using existing networks largely through academic channels. Within the time limitation of this research a wider participation with less experienced individuals was not achieved. There were several under represented categories including the under twenty age group, residents of the catchment area, and those with property that has flooded. Of the total survey responses two of the participants were under twenty, only one had experienced flooding and one lived in the catchment area (with no frequent visitors and only seven occasional visitors to the area). Greater participation from these groups would have enabled more analysis of: -

- the influence of age and confidence with technology on the acceptance of the virtual globe tour format, as considered by Harwood, Lovett and Turner (2015) and Pettit *et al.* (2011);
- the ability of the visualisation to connect viewers who live in the area with a sense of place (Newell and Canessa, 2015) to generate interest in an NFM approach;
- differences in the interest and perceptions of the impact of NFM between individuals affected by flooding and those with no personal flooding experience or those with a professional interest (Bracken *et al.*, 2016).

Todd *et al.* (2014) found that 3D visualisations could educate and engage communities to consider local flood risk and resilience measures but suggested that alone they were not enough and noted that follow up discussions and a commitment of resources were required to both motivate and to maintain engagement. If the virtual globe tour visualisation was used to generate an interest in the NFM approach in the Isbourne catchment, follow up events or other measures would be required to maintain the engagement of individuals.

6.3. Technical limitations

Technical limitations relating to Google Earth were identified during this research relating to the creation and geolocation of models in the landscape, the satellite imagery available for the Isbourne catchment area and the ability of new Google Earth versions to support virtual globe tours. These limitations could also affect the use of the approach in other research.

6.3.1. SketchUp and geolocation of 3D models

Although previous research has incorporated 3D models of buildings or other objects in the landscape, such as boats and a loading facility, high-rise buildings and houses (Schroth, Pond*, et al.*, 2011) and a landmark ruined church (Harwood, Lovett and Turner, 2015), they were not used in the final virtual globe tour here. 3D buildings or other structures were not required to demonstrate the features or issues affecting this catchment. The potential for creating and using 2D or 3D models to represent planted woodland areas in the catchment landscape was explored for the prototype tour (see section 3.4.2). As no specific areas had been identified for a tree planting approach for NFM they were not incorporated in the final visualisation.

Adding multiple trees or woodland areas into the landscape on Google Earth was difficult and the results were not visually effective. These can be modelled in COLLADA format using 2D or 3D trees, however with Google Earth no longer supporting SketchUp this has become more challenging; with geolocation limited to the licenced Pro version and satellite imagery provided by an alternative source (see Appendix D). Location terrain can only be imported into SketchUp Pro – this feature provides a snapshot of the topography of a selected area including geographic coordinates, coloured aerial imagery and 3D terrain data that enables objects to be located into the landscape. COLLADA models can also be added by manually specifying coordinates within SketchUp and adjusting the siting directly on the Google Earth map, but this process is awkward.

Where tree models are placed in the Google Earth landscape there is a visual discrepancy with the base imagery. Figure 41 shows tree models geolocated into the landscape. This model was created manually on imported Google Earth terrain in SketchUp Make, before the geolocation feature was removed, using 2D trees from the Tree Warehouse extension. Adding 3D models slows the rendering speeds in Google Earth, adversely affecting the visuals.

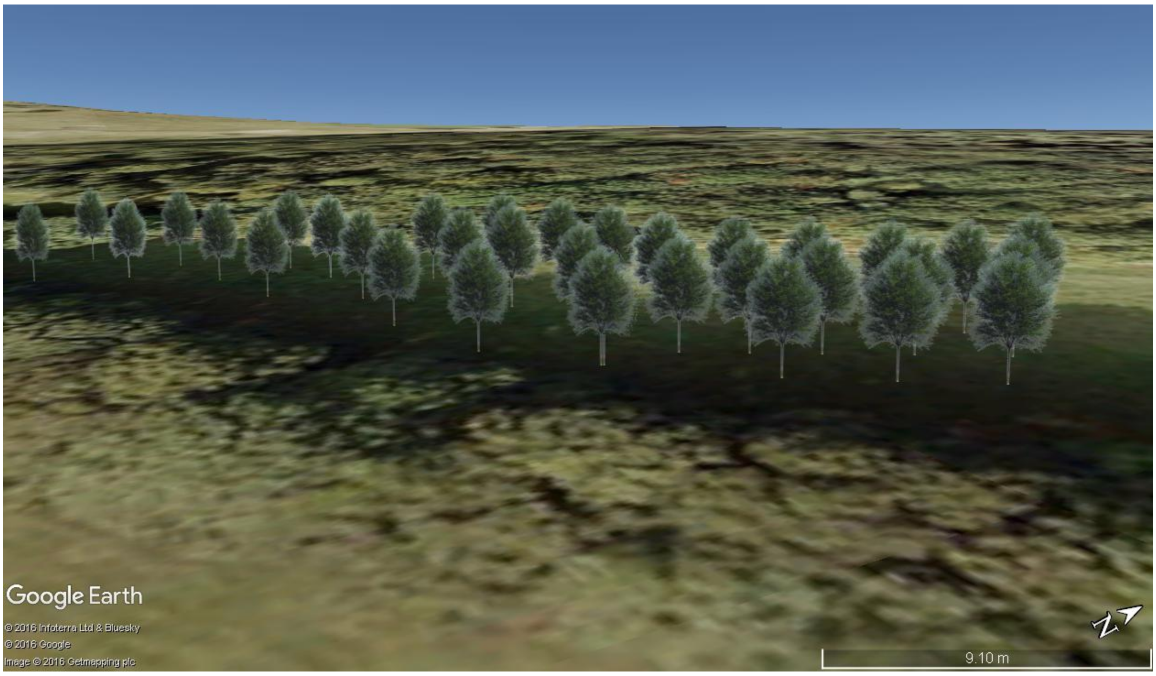


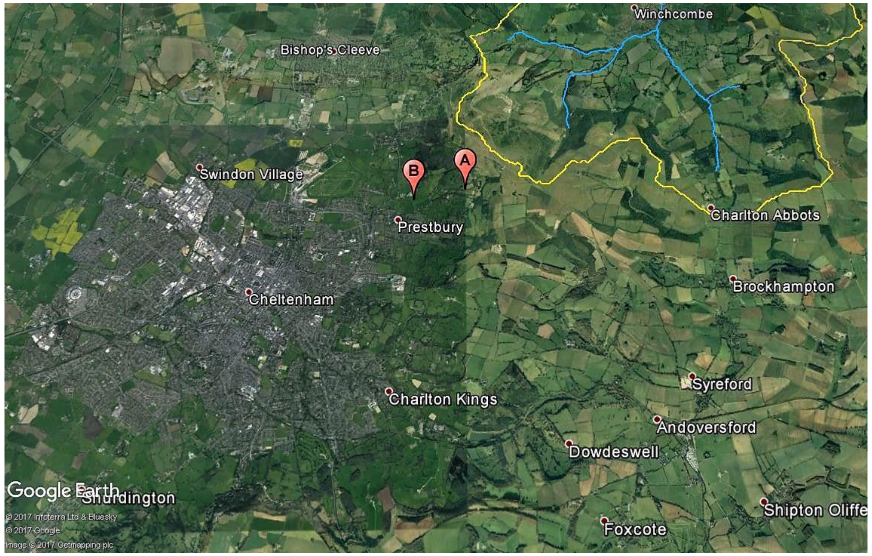
Figure 41. COLLADA tree model (created with 2D trees from Tree Warehouse using SketchUp Make and geolocated onto Google Earth.

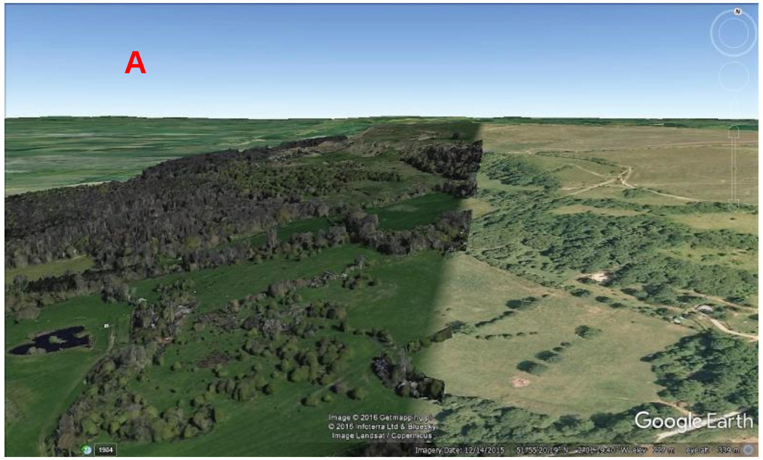
A COLLADA model for a larger woodland area was created for the prototype tour (see section 3.4.2), using SketchUp Make and Skatter (a licenced extension, see Appendix E) to distribute 2D trees in a repeat pattern, and geolocated in the Google Earth landscape (Figure 16). Without the geolocation feature, using imported Google Earth terrain, this would be more difficult to achieve. The loss of this feature in SketchUp Make (and the removal of Google Earth satellite imagery from SketchUp Pro) will reduce the access to incorporate objects into virtual globe tours in the future. A potential alternative to adding 3D COLLADA models is to drape georeferenced images on the landscape as ground overlays. This technique, used by Schroth, Pond*, et al.* (2011) to add scanned hand drawn images, was not explored here. If tree planting becomes a key part of this NFM project specialist software may be more suitable for realistic representation of localised landscape views, such as 3D Nature, Visual Nature Studio (Berry *et al.*, 2011) or Biosphere 3D (Schroth, Pond*, et al.*, 2011).

6.3.2. Google Earth imagery

Sheppard and Cizek (2009) noted that the level of resolution in Google Earth can be poor, especially at low elevation. Image quality and coverage of 3D content is improving (Schroth, Pond*, et al.*, 2011) however the imagery in the region of the Isbourne catchment area has not been frequently, or recently, updated. At the time of this research the most up to date imagery for the area was dated between 2005 and 2007. The urban area of Cheltenham, to the south west of the catchment, has 2016 imagery and includes 3D trees, buildings and terrain – this may have added interest with more detail for visualisation purposes (Figure 42), however it has been noted that such 3D imagery lacks contextual information and could be distracting (Sheppard and Cizek, 2009).

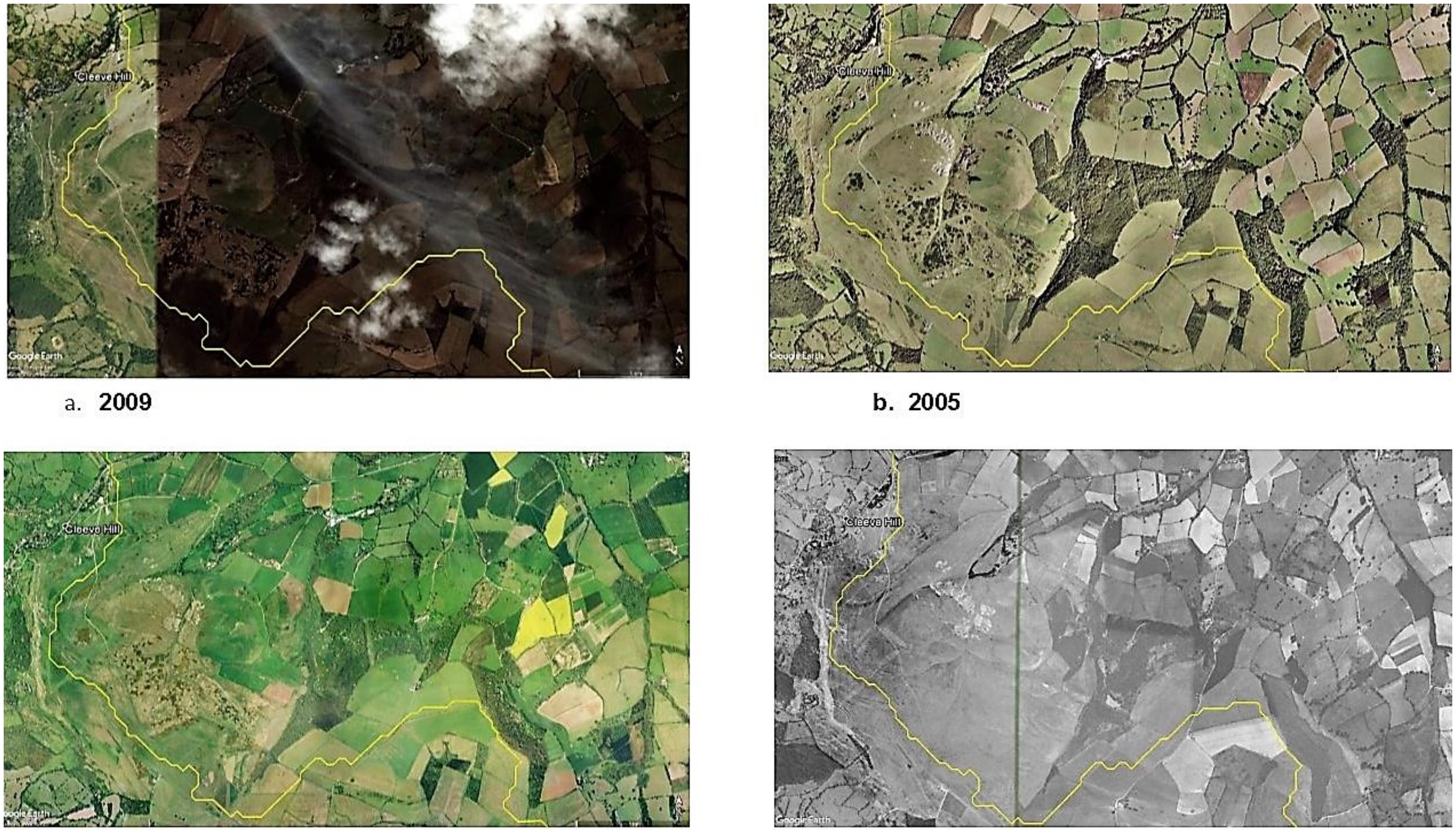
The lack of available Google Earth historical imagery for the catchment area also limits the investigation and the visualisation of land use change, urban growth and infrastructure development using the base map imagery, with no usable imagery available between 1945 and 1999. The quality of the available imagery is also dependent on the atmospheric conditions and the timing (time of day and seasonality) of the satellite coverage (Figure 43).





Extent of 3D coverage in the Cheltenham area (above) to the southwest of the Isbourne Catchment area, outlined in yellow, and close and perspective views (right) for the identified locations 'A' (the boundary of 3D coverage) and 'B' (showing 3D trees and buildings).

Figure 42. Google Earth 3D imagery available in the Cheltenham area



a. **2009**

b. **2005**

c. **1999**

d. **1945**

Figure 43. Google Earth historical imagery in the Isbourne catchment, demonstrating the poor quality

6.3.3. Google Earth versions

The KMZ virtual globe tour will operate on Google Earth and Google Earth Pro, versions 6 and above. It was not tested on earlier versions but was tested for use on the 2017 release of Google Earth web for Google Chrome (v9) and on the Android and iOS Google Earth Apps. These versions did not support the KMZ virtual globe tour (although the web version has limited KML compatibility for basic features only). This limitation was clearly stated in the instructions for the online survey but the lack of support for KMZ tours may limit the distribution and accessibility of virtual globe tours if there is any confusion regarding the different versions available or if participants do not wish to download the desktop versions. It is not clear how much support will be given to these desktop versions and KMZ files in the future, given the current promotion of the web and app versions; the desktop version is now found through a page to download older versions on the Google Earth website. If support for the desktop versions is discontinued and the web or device versions do not extend their KML/KMZ capabilities this would limit both the creation and access to the virtual globe tour as a communication tool.

Chapter 7 Conclusions

7.1. Reflecting on research objectives and key findings

One of the previously identified research gaps in NFM is the investigation of methods and suitable tools for effective communication of (often complex) data (Environment Agency, 2014). The aim of this research was to explore the potential of the Google Earth virtual globe tour approach for landscape visualisation as an engagement tool to communicate the potential for NFM in the Isbourne catchment. This catchment suffered significant flooding in 2007 and has a failing WFD status, partially attributed to ongoing diffuse phosphates pollution from agriculture. As the NFM project progresses, communication with a wide range of stakeholders throughout the catchment will be required to engage and motivate them to get involved.

The first objective of this research was to identify the information requirements that could facilitate positive stakeholder engagement. By collaborating with members of a community group, the ICG, early in the visualisation design process it was possible to identify relevant data that also satisfied the requirement of being free and open to enable online distribution. End user evaluation indicated that the tour content satisfied these information requirements with 38% of online participants very interested and 58% somewhat interested in finding out more about NFM.

Suitable open data was available to meet most of the identified information requirements. Information that participants identified would improve their understanding of the catchment included additional details of historical flood events and ground level photographic imagery of the river, to support the Google Earth satellite imagery which lacks required levels of realism at close scale and perspective views.

The main limitation to the content was the availability of open licence data to demonstrate historical land use change, with deficiencies in the historical availability and resolution of the open licence EU CORINE Land Cover data. Some information was more difficult to represent visually, such as the impact of land management on the environment and the NFM techniques and potential impacts. However, it was possible to add photographs and text information with links to relevant websites that could be explored independently as required for viewers to gain a better understanding of these. Although at this stage of the project it was not appropriate to identify locations or specific NFM techniques, further details on these could be provided using placemark balloons in the future.

The second objective was to establish whether landscape visualisation can enhance the communication and understanding of spatial information related to NFM. Although the sample size (n=25) was not large enough for detailed statistical analysis some inferences were possible from the end user analysis. The online survey results (using a rating scale of 1 to 6) indicate that the virtual globe tour was helpful for demonstrating the catchment features (mean rating = 5.24) and the issues it faces (mean = 4.92), with participants commenting positively on the ability to see the flood extent and to understand the influence of the topography and changes in land use. It was also helpful, although to a lesser extent, for improving the understanding NFM techniques (mean =4.24) and the potential for using it in the Isbourne catchment (mean = 4.92). Participants commented that the tour demonstrated the complexity of solutions for the issues in the catchment along with the potential number of agencies involved. Supporting findings from previous research (Harwood, Lovett and Turner, 2015; Schroth, Pond*, et al.*, 2011) this research found that the Google Earth tour approach shows good potential as an educational tool for enhancing communication and understanding in collaborative catchment management. It was particularly effective for demonstrating NFM for those with little or no prior knowledge; 71% of these participants rated it 5 or 6 whereas none of those with prior expertise rated it as high.

There was a lack of participation from local residents (only one participant lived in the catchment area) however, the interest in finding out more about NFM was greater for those who occasionally visit the area, 50% were very interested compared to just 18% of those who had not heard of the area, giving an indication of the potential of the virtual globe tour for early engagement of stakeholders in the Isbourne catchment.

Although from the results it is not possible to determine the extent to which the virtual globe tour influenced the online users' opinions, after viewing the visualisation NFM was perceived to be beneficial for the environment, particularly for flooding (96%) and water quality (88%) but less so for landscape views (65%)

and farming (58.5%) where there was greater uncertainty. It was harder to communicate the impacts of these effectively and more effort may be required to communicate the multiple benefits of NFM through carefully prepared text and links to supporting information or explore these in follow up engagement settings.

As the Isbourne catchment project progresses the virtual globe tour format offers the potential to incorporate additional spatial information, as it becomes available. It could also be used to identify designated locations for NFM approaches but would be less effective for visualising future scenarios, such as showing specific NFM measures in the landscape. The work conducted in this research showed that adding vegetation and tree models into the landscape in Google Earth is not straightforward and they lack the visual realism possible with more sophisticated 3D landscape visualisation software. In-channel or floodplain measures would also be difficult to represent using 3D models at suitable scales.

Programming experience was not required to learn KML scripting. It was possible to design and construct a virtual globe tour using a combination of elements to incorporate and style external spatial data in Google Earth and to customise navigation, viewing angles, text and images. The approach was accessible, but it was time-consuming and, beyond the addition of basic features, complex to create, as previously noted by Schroth, Pond*, et al.* (2011). The understanding and use of GIS is invaluable for manipulating external spatial data efficiently to use in custom Google Earth tours. With the wide range of overlapping spatial data incorporated in the final technical tour, there was too much information to show in Google Earth in one view. This problem was overcome by animating features in and out of view during the navigation, however it could make future updates to the content or the animation difficult due to the length and complexity of the KML scripting.

Feedback from the online survey indicated that some refinements may be required to the speed of the presentation (mean = 3.1), and to the content used to visualise topography and land use change. Other inherent limitations to the virtual globe tour format are more difficult to address, such as the poor-quality satellite imagery for the catchment area and the hazy appearance of elements during navigation. However, those who participated not only found the tour relatively easy to use (mean=4), but also found it visually clear (mean=4.8) and trusted the information presented (mean=5.3). The highest rated Google Earth elements were the pop-up information balloons (mean =5.08) and links to websites (mean = 4.88). Users also commented positively on the ability to control aspects of the presentation, including pausing and exploring data independently on the map screen. This indicates that interactive features are important to viewers (Lovett *et al.*, 2015). Less well received were the close up/perspective views (mean=4.56) and the visual appearance of the ground (mean = 4.32) demonstrating the limitations of the Google Earth imagery for the area and supporting the findings of Pettit *et al.* (2011) along with Appleton and Lovett (2003), who highlighted the importance of foreground appearance in landscape visualisation.

The Google Earth KMZ file was accessible for remote online use, with a file size of 8MB and detailed instructions which had been refined following user feedback in the facilitated group session. There were however limitations to the analysis of the ease of use, due to the small sample size and a high proportion of participants having previous experience of Google Earth/GIS interest and high levels of IT literacy (and therefore an underrepresentation of participants with lower computer skills). It is also worth noting that unsuccessful attempts to download and view the tour were not captured.

The contrasting results obtained from end user evaluation in the two settings confirmed that care must be taken to ensure a broad representation in group settings to capture views from a wide variety of interests and experience levels (Grainger, Mao and Buytaert, 2016). However, the group setting was helpful for observing users, collecting feedback and highlighting potential usability issues and snags in the instructions.

7.2. Further work

This research was undertaken in the early stages of the development of the NFM project for the Isbourne catchment, before areas had been targeted for specific approaches and within the time constraints of an MSc by Research project. There are opportunities for further development of the Google Earth tour as this project progresses. Having prepared the tour based on a limited collaborative approach with one focus group meeting, further consultation with the ICG would be useful to explore their views on the extent to which it met their needs and expectations, and to reflect on the effectiveness of the design process. This could also help to identify any adjustments they feel may be necessary to communicate the information more clearly.

Additional research could further investigate the importance of the interactive features, identified as a key benefit of the virtual globe tour (Lovett *et al.*, 2015), by comparing the experience with that of a pre-recorded video version (suggested in the facilitated group session). The potential for adding audio commentary with MP3 files could also be explored (audio was included in the Google Earth Outreach, Surui tribe tour[5]).

The ability to incorporate additional data or create supporting tours could be explored as the project progresses. This could include run-off and flood modelling data. The format could also be used to visualise information such as rainfall or river flow gauge data collected through citizen science approaches (Starkey *et al.*, 2017), or sharing photographs of the catchment in a similar way to the 'Slow the Flow, Calderdale' project photo map[6]. The capability of the approach to depict future landscapes could be followed up, examining the effectiveness of tree models for woodland planting and how other NFM measures could be represented effectively on the map.

More effort could be made to obtain the views of under-represented participant groups, which was not possible within the time limitations in this research. This could be achieved by promoting the survey through additional channels. It may be possible to reach under 20's through secondary schools. Previously Harwood, Lovett and Turner (2015) involved primary school children and Pettit *et al.* (2011) included undergraduate students in their research. A-level students could be involved as part of efforts to introduce GIS or sustainable catchment management. Feedback could be used to explore the acceptance of the technology in relation to older age groups. During this research residents of the Isbourne catchment were not approached due to sensitivity issues as the main catchment project funding had still not been secured. In the future, residents, including those previously flooded, could be targeted to explore the effects of sense of place and perceptions of flood risk.

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[5] Google Earth Outreach, Surui Tribe tour https://www.google.com/earth/outreach/success-stories/chief-almir-and-the-surui-tribe-of-the-amazon/
[6] Slow the Flow Calderdale http://slowtheflow.net/river-surveys/

Alternative landscape visualisations tools could be compared with the virtual globe tour created here to gain further insight into user preferences for the communication of catchment features and NFM, considering levels of realism and interactivity. This could include GIS story maps and advanced 3D landscape visualisation software, such as 3D Nature's Visual Nature Studio, which can render landscape models with higher levels of realism, particularly vegetation and trees. The use of mobile computing and smartphones coupled with augmented reality (AR) technology to enable a multi-sensory on-site experience not achievable online (Gill and Lange, 2015) could also be explored.

There are also opportunities for further investigation into the potential future use of the Google Earth platforms for communicating spatial information. Tools previously identified as having potential for application in landscape visualisation, such as Google Earth Engine and Google Earth Tour Builder (Schroth, Pond*, et al.*, 2011), have not generated obvious interest in research and are not well promoted online. With an increased promotion of the new web-based Google Earth (version 9), and the apps for mobile devices, it is unclear how much interest there will be, or what future support will be offered, for the desktop versions and the KMZ format. This may limit future interest in the virtual globe tour approach. The mobile device versions currently have only limited KML support and their capabilities should be assessed and monitored in the future as they are developed.

The virtual globe tour visualisation approach has demonstrated a good potential for wider application to support the Catchment Based Approach (CaBA, 2017), where the involvement of communities and partnership-building is required for the delivery of the WFD. As an accessible approach that can generate interest and improve awareness, it could assist with meeting the policy requirements for public participation.

7.3. Summary

This research explored the potential of the Google Earth virtual globe tour approach as an early engagement tool to communicate the potential for NFM, using the Isbourne catchment as a case study. Involving early collaboration with the ICG it was possible to identify the key information requirements and to create an effective Google Earth-based landscape visualisation tool using available open data and customised navigation and views. The virtual globe tour approach was accessible but not simple to develop. Weaknesses regarding the representation of historical land use changes and future scenarios in the landscape can be partly addressed with the addition of descriptive text, photography and interactive links to supporting information. End user evaluation, used to collect both quantitative and supporting qualitative data, not only indicated that the format was easy to use and visually clear but also that it generated interest in the project. It was helpful for developing an understanding of the catchment and, particularly for those with no prior knowledge, helpful for demonstrating NFM techniques.

The small sample size and underrepresentation of some groups limited the statistical evaluation, and further input from residents and those with less computer or GIS experience could add more understanding of the potential for downloading and interacting with the virtual globe tour remotely, to engage a wide range of stakeholders within the catchment.

Further opportunities have been identified for research involving the NFM project, such as considering the importance of interactivity in the virtual globe tour over a video format, following the approach through the development of the project and incorporating additional information as it becomes available and comparing its effectiveness with other available landscape visualisation software/GIS approaches. Customised Google Earth tours may also have related applications elsewhere, such as assisting partnership approaches through CaBA in the wider delivery of the WFD.

In July 2017, towards the completion of this research, the catchment scale project 'Worcestershire Avon/Cotswold Escarpment Tributaries' (which includes the River Isbourne) was allocated £500k as part of the £15million funding for NFM from the Government announced in 2016 (Defra, 2017). The success of the project will depend on the ability to communicate the potential for NFM in this catchment to generate interest and long-term involvement of a wide range of stakeholders. This research shows that the virtual globe tour approach could play a part in this engagement process; improving access and assisting with the understanding of complex spatial information.

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9. Appendices

(Appendices can also be found on the enclosed disc)

A Natural Flood Management techniques and interventions

Table 17 Natural flood management techniques and interventions adapted from Avery (2012) and SEPA (2015)

NFM Options	Benefits	Limitations	
IN CHANNEL MEASURES			
In stream barriers Includes woody debris, weirs and steps. Varying scales are possible. Should be anchored artificially if there is a risk of movement or being washed downstream.	Provides hydraulic resistance and flow attenuation Biodiversity and habitat benefits - may allow fish movement	Uncertainty over effectiveness, care must be taken to ensure that the flow blockages do not increase flood risks	 igure 2.28. An instream structure, secured with a wooden stake, in the Pickering Beck catchment, North Yorkshire (©Forest Research). Source : SEPA (2015)
Sediment trap Small containment area, excavated to intercept run off and hold it temporarily to allow particulates to settle out before water discharges through outflow Use where sediment loss is high and upstream of other NFM measures to prolong their life	Low cost construction (excavation and safety fencing) and low maintenance (erosion and removal of sediment build up) Highly cost effective Some ability for retention and water quality improvements from TP and pesticide (not N)	Needs a large surface area for construction	 Source: SEPA (2015)
Wetlands within ditches/channels Widening and planting in channel/ ditches to create wetland zone to aid sedimentation and denitrification through nutrient uptake	Once set up requires little maintenance Reduces flow and assists with pollution control Good amenity and habitat value	Mixed results, can be expensive to set up with widening, barriers and planting. Needs advisory input Not very cost effective	

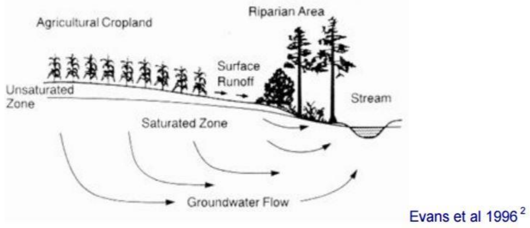
NFM Options	Benefits	Limitations	
Ditch and swale barriers Retain ditch water and encourage sedimentation and pollutant removal Uses natural wood/straw or concrete, plastic, stone, earth	Low set up and maintenance unless using additional filters	Various design guidelines depending on materials used and site conditions	 Figure 2.18. Small wooden ditch structures used to show flows and encourage settling out of sediment in ditches in the Belford catchment, Northumberland (© Newcastle University). Source: SEPA (2015)
Gully/Grip Blocking Blocking drainage ditches in peatlands	Reduce nutrient concentrations and excess colouration in run off Biodiversity benefits	Limited flow attenuation Need suitable slope angle and ditch dimensions for optimum use	 Source:Avery (2012)

NFM Options	Benefits	Limitations	
FLOODPLAIN MEASURES			
Swales Broad, shallow, vegetated channels to convey and slow discharge Can also be enhanced, dry (drained soils) or wet Can incorporate dams and filter strips Use along field boundaries/ tracks and roads on gentle slopes	Low set up and maintenance costs, high cost effectiveness. Can slow run off and trap particulates and pollutants (TP, N and pesticide). Some biodiversity benefit/habitat creation.	Not suitable for storms greater than 1 in 10 years Only suitable if groundwater below 1m Not suitable for coarse sandy soils	 © California stormwater quality association Source: Avery (2012)
Infiltration Basin Depression that accumulates run off that infiltrates naturally into the ground Sediment traps can reduce clogging Use at base of fields	Low set cost Low maintenance - sediment removal and scarification to encourage drainage Effective flow reduction and pollutant removal through infiltration and groundwater recharge	May require construction of a levee or berm to hold back the run off Needs permeable soils and gentle sloping sides Should half empty over 24 hours to maintain vegetation	 Photograph © Newcastle University[2] Source:Avery (2012)
Retention ponds Wet ponds with some level of permanent water but allowance for variable levels. Suited to low permeability soils and larger catchment area to maintain the water levels	Long lifespan if well maintained Good flow control and sediment removal. Good amenity and biodiversity/habitat value	High cost of set up - needs engineering to ideal set up, requires bank and plant maintenance and sediment removal to maintain storage capacity	 Source: Avery (2012)

NFM Options	Benefits	Limitations	
Constructed/restored wetlands Permanent water, variable levels	Water quality benefits Biodiversity/habitat/amenity benefit	High set up costs, especially if require membrane to reduce soil permeability Needs space and low water table	 A farm wetland (photograph courtesy of Miklas Sholtz, University of Edinburgh) Source :Avery (2012)
Filter Drains Move run off to a watercourse, with gravel/stone infill which can provide some filtration.	Aid attenuation and removal of sediment and pollutant. Useful for intercepting and guiding run off to a retention pond.	Not so cost effective due to stone and gravel cost and maintenance Use for short lengths only not for cultivated fields	
Berms and diversions Low ridges and banks to deflect runoff Useful to direct run off to other NFM measures	Low set up cost of earth moving and low maintenance removal of sediment build up	Little benefit for water quality Low cost effectiveness used alone	
Infiltration Trench Shallow trench, 1-2m deep, filled with stone or drainage material allowing slow infiltration of detained runoff into the soil. Locate at field boundary or trackside/along hard standing	Can remove fine sediment, need to be used after swales or retention ponds, sediment trap or buffer strip which can remove coarse sediment to improve performance .	Less cost effective as need stone in the set up and need periodic unclogging Not suitable for low permeability soils or high water table.	

NFM Options	Benefits	Limitations	
Detention basin/ponds Normally dry, runoff detention for temporary storage and slow release. Permanent pool is smaller than a retention pond or not present at all Use at base of fields or with other NFM run off routing	Low maintenance costs and good longevity Excellent flow control and sedimentation potential Potentially good habitat value Suitable for all soils and geology though may need impermeable liner in some situations	Needs shallow gradient sides or they will need stabilising High set up costs of construction and outflow control, Requires expert advice Needs space and should not intercept water table	
PLANTING MEASURES			
Woodland Planting Smaller blocks carefully placed may be more beneficial than large scale planting. SEPA (2015).	Good potential for flood mitigation	Requires careful planning to ensure that flood peaks are not synchronised	
Riparian woodland planting Bankside buffer zone	Increases evapotranspiration, hydraulic roughness, infiltration Provides woody debris to slow flows	Need to avoid creating blockages/adding to pinch points	
Catchment woodland planting Wider area planting	Useful on waterlogged or compacted soils and where water has rapid run off into streams	Need deep rooting systems to aid infiltration and soil stabilisation	

NFM Options	Benefits	Limitations	
Woodland shelterbelts Planting mixed woodland in target strips Forestry Commission guidance available on planting Uses deciduous native trees (damp ground willow and alder)	Reduces wind speeds, increases infiltration and reduces soil erosion Biodiversity and amenity value Use to break up exposed or long slopes	High set up cost for planting and fencing, maintenance of woodland areas Potential shading and interference with local water balance. Needs soil depths and suitable spacing	 Recently planted riparian woodland in the Bowmont Water catchment, Scottish Borders (© Tweed Forum). Source : SEPA, (2015)
Buffer strips Hedgerows (native species) or drystone walling/dykes and tussock grass filter strips - use at field boundaries or for splitting large field susceptible to erosion.	Prevent erosion and run off Planting increases infiltration and uptake of nutrients Low maintenance costs of hedges Habitat/amenity value	Set up costs Not especially beneficial for water quality	
Dry grass buffer strips/filter strips Grass/vegetation strips on gentle slopes to intercept run off in vulnerable areas and around farm Use upstream of other NFM measures	Low set up and maintenance costs - seed planting and herbicide Cost effective even though no significant reduction to flows		
Riparian buffer strips - Dry Natural vegetation strips along water bodies. Keeps livestock and machinery use to minimum reducing compaction and allowing infiltration and pollution/sediment removal	Low cost of set up and maintenance Biodiversity/habitat/amenity value	Loss of productive land Less effective where overland flow creates hollows	

NFM Options	Benefits	Limitations	
Riparian buffer strips -Wet Natural wetland/wet woodland along waterbody	Good for nutrient removal, some flow attenuation and sediment removal Biodiversity/habitat/amenity benefit	Restricted grazing/ coppicing/ grass cutting, increases de-nitrification High set up costs make it restrictive Ineffective in freely draining soils	 Source: Avery (2012)

LAND MANAGEMENT PRACTICES		
Description	**Benefits**	**Limitations**
SEPA (2015) Measures for improving soil structure and increasing infiltration rates techniques include:- • Reduce stocking density and heavy machinery to reduce compaction, fencing off riparian strips • Winter planting to ensure soils are not left exposed to erosion • Run off control measures - zero/reduced tillage, contour ploughing, tramlines, riparian buffer strips, subdividing fields with hedgerows/barriers • Converting arable to grassland • Using soil aerators • Restoration of bog and moorland	Reduce run off, sedimentation and pollutant loss.	Variable in effectiveness and cost

FARMYARD INTERVENTIONS		
Description	**Benefits**	**Limitations**
Rainwater harvesting and diversion Collect from hard surfaces and roofs Store in soak away for slow release or in tank for use	Sustainable water supply for grey water	Set up costs for soak away or tank and pipe work, may need filters and eclectic pumps
Green roof Vegetation on roof to intercept run off - attenuation of flow until reaches saturation	Biodiversity/amenity benefit	High set up costs No water quality value Needs correct roof angle
Permeable and porous surfaces Allows run off and rainwater to penetrate through to underlying temporary storage Could be diverted to soak away	Pervious surfaces can be costly for set up (porous paving, woodchip, recycled plastic)	no water quality benefits
Cross drains Convey water across a path or track Use to redirect flow to ponds and wetlands	Low set up and low maintenance	Unsuitable for high flow rates that will top the drains
Biobeds Collect retain and degrade pesticides. Lined pit with straw, soil and peat free compost - turfed over	Water quality	No flow benefits. Must seal from other drainage systems.
Sedimentation Boxes Tank with a permeable base, intercept run off and allow gravitational settlement Similar to infiltration basin but not grassed	Some flow storage and water quality improvement	Effective for coarse not fine particles
Soak away Traditional drainage method involving Infiltration drain filled with rubble	Good for flow attenuation	Must discharge effectively to allow for refilling Need stable ground and low water table

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B Notable Natural Flood Management projects

Table 18 Details of existing NFM schemes

Scheme Information	Catchment Characteristics and Flooding History	NFM Measures (as at March 2017)	Notable research and References
Pickering, North Yorkshire ‘*Slowing the Flow*’ - established 2009 Defra/EA demonstration project Phase I - main bund and run off attenuation Phase II - additional run off attenuation and planting Partnerships/involvement of: • Forestry Commission England • The Environment Agency • Durham University • Natural England • North York Moors National Park • Community Project also includes neighbouring R Seven	70km2 Jurassic sandstone and gritstone escarpment of the North Yorkshire Moors national park and glacial-lacustrine deposits of the Vale of Pickering Catchment suffers diffuse water pollution and is a ‘Priority Catchment’ for improving land management Pickering Beck flooded 1993, 1999, 2000, 2002 2007, came close to flooding 2008/2009/2010 Up to 50 properties affected in flood events	2 timber storage bunds 167 large woody debris dams 187 heather bale check dams Riparian and farm woodland planting (44ha) Moorland and woodland management Farm storage improvements Pickering flood risk reduced from 25% to 4% in any year.	Defra demonstration project reports Nisbet *et al.* (2015) Nisbet *et al.* (2011) https://www.forestry.gov.uk/fr/slowingtheflow Early academic research involving Ryedale Flood Research Group (2008) Lane *et al.* (2011) Odoni and Lane (2010) Whatmore (2009)
Holnicote, Devon ‘*Source to Sea*’ - inception 2010 Defra/EA demonstration project with National Trust co funding Partnerships/Involvement of: • University of Exeter and Cranfield • Wessex water • Natural England	Horner Water catchment 22km^2 Aller catchment 18km^2 Characterised by flow constriction Rainfall and flow monitoring network established	Off line bunds, pond restoration Course woody debris Woodland planting and arable reversion	National Trust (2015) Extensive catchment modelling and ecosystem services approach Research on water quality effects

Scheme Information	Catchment Characteristics and Flooding History	NFM Measures (as at March 2017)	Notable research and References
Edale, Derbyshire *Making Space for Water/Moors for the future* Defra/EA demonstration project Collaboration with • University of Manchester • University of Durham	River Derwent valley flooding	Blanket bog restoration Gully blocking and re-vegetation	http://www.moorsforthefuture.org.uk/making-space-water-2 Pilkington *et al.* (2015)
Stroud, Gloucestershire *Rural Sustainable Drainage (RSuDS)* Stroud Council Project Partnerships/involvement of:- • Environment Agency • Regional Flood Coastal Committee • Gloucestershire County Council • National Trust • Atkins Ltd scoping report • Butterfly Conservation and Woodland Trust • Gloucestershire Wildlife Trust • University of Gloucestershire	252km2 River Frome Upland, upper river valleys, floodplain river valleys Permeable soils, groundwater interactions, multiple spring sources, lack of floodplain features and extensive development in valleys Flooding in 2007, 2012 1992, 1993, 2000	Installed Dec 2014 to March 2016 130 leaky dams 50 minor CWD/deflectors 7 dry gulleys filled with CWD 6 spring fed troughs 4 drinking bays 4 large earth bunds 7 small earth bunds 8 culvert/soakaways Streamside fencing and track drainage cost approx. £215k Peak flow lower in a 2016 rainfall event	https://www.stroud.gov.uk/rsuds Atkins (2013)

Scheme Information	Catchment Characteristics and Flooding History	NFM Measures (as at March 2017)	Notable research and References
Haltwhistle Burn, Northumberland Tyne Rivers Trust project Partnerships/Involvement of • Newcastle University • Defra • NERC • CaBA	42km2 Flashy nature Peaty, loams and clay soils, waterlogging Flooding 2007, 2012, 2013, 2014	Various measures, riparian corridor, forestry and farm management to improve water quality and reduce run off	Tyne Rivers Trust (2015) Starkey and Parkin (2015) Starkey *et al.* (2017) http://www.catchmentbasedapproach.org/deliver/use-data/haltwhistle-burn Citizen Science based monitoring approach supporting Tyne Rivers Trust, Haltwhistle Burn Total Catchment Approach
Calderdale, West Yorkshire *Slow the Flow Calderdale* Partnerships/involvement of:- • The Source partnership • Environment Agency • National Trust • Calderdale Council • University of Leeds • University of Nottingham	957km2 River Calder To protect Calder Valley inc. Hebden Bridge and Mytholmroyd Flooding most significant in 2015	Tree planting Blanket bog restoration Leaky dams Wetland areas	http://slowtheflow.net/
Belford, Northumberland *Belford Catchment Solutions Project* Partnerships/involvement of:- • Newcastle University • Environment Agency • Local landowners Part of 'The Flow Partnership'	5.7km2 Belford Burn Rural land Soils prone to waterlogging Flooding 1997, 2002, 2005, 2007 31 properties, transport links affected	20 runoff attenuation features Permeable timber barrier, offline storage ponds, overland flow disconnection pond, Instream woody debris Project cost approx. £200k	https://www.theflowpartnership.org/belford/ Academic research using FARM matrix to identify locations Nicholson *et al* (2012) Wilkinson *et al.* (2014); Wilkinson, Quinn and Hewett (2013) Barber and Quinn (2012)

Scheme Information	Catchment Characteristics and Flooding History	NFM Measures (as at March 2017)	Notable research and References
Eddleston Water Project, Tweed Forum Partnerships/involvement of:- • Scottish Government • SEPA • University of Dundee • British Geological Survey • Forestry Commission • Woodland Trust • NFU and landowners	69km2 Tributary of the River Tweed Scoping study 2010	Riparian woodland tree planting (hectares/200,000 trees) and 16,000m of fencing 22 leaky ponds 101 high flow restrictors 2.8km river re-meandering Rain, groundwater and river level gauges for monitoring 17 farms involved	University of Dundee (2010) http://tweedforum.org/projects/current-projects/eddleston_progress

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C WFD Classifications for the River Isbourne

Table 19 River Isbourne WFD classifications (2009-2016)

Year	Overall water body status	Failing on (elements)
Isbourne source to confluence with R Avon (Cycle 2) GB109054039631 (Environment Agency, 2017)		
2013	Moderate	Biological (moderate)
2014	Poor	Biological (poor) Physico chemical (moderate)
2015	Poor	Biological (poor) Physico chemical (moderate)
2016	Poor	Biological (poor) Physico chemical (moderate)
R Isbourne source to confluence with Laverton Brook (Cycle 1) GB109054039580 (obtained through correspondence with EA)		
2009	Poor	Biological (poor) Physico chemical (moderate)
2010	Poor	Biological (poor) Physico chemical (moderate)
2011	Poor	Biological (poor) Physico chemical (moderate)
2012	Moderate	Physico chemical (moderate)
2013	Moderate	Biological (moderate) Physico chemical (moderate)
2014	Moderate	Biological (moderate) Physico chemical (moderate)
2015	Moderate	Biological (moderate) Physico chemical (moderate)
R Isbourne Laverton Brook to confluence with R Avon (Cycle 1) GB109054039630 (obtained through correspondence with EA)		
2009	Poor	Biological (poor)
2010	Poor	Biological (poor)
2011	Poor	Biological (poor)
2012	Poor	Biological (poor)
2013	Poor	Biological (poor)
2014	Moderate	Biological (moderate) Physico chemical (moderate)
2015	Moderate	Biological (moderate) Physico chemical (moderate)

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D Google Earth and KML scripting

Google Earth is a virtual globe platform providing satellite imagery that allows exploration of the surface of the earth at a range of spatial and temporal scales; zooming, navigating and viewing available historical imagery. Google Earth Pro is also now a free version (previously licenced) of Google Earth which has some additional functions (such as the ability to directly import different file formats, including ESRI Shapefiles, and saving higher resolution images).

Both versions offer users the ability to add elements directly to the map browser: -

points – to name features and to add placemarks with text information
lines – to add linear features such as roads or boundaries
polygons – to add colour filled or outlined areas
models – to add 3D objects, such as buildings or trees (in COLLADA file format)
Ground overlays – to drape imagery over the landscape
Network links - to enable dynamic updates of data from web servers

Simple animated tours can also be created directly on Google Earth that allow virtual flight between features at prescribed speeds and angles enabling the viewer to see different perspectives. Any content created on Google Earth can be saved on a desktop computer as KML files and can also be uploaded and shared on the Google Earth platform.

Google Earth is not a GIS. It does not have the analytic capabilities of a GIS such as ESRI ArcGIS or QGIS. It does have some basic measurement functions - measuring length and areas of lines and paths (and additional measurement functions for polygons, circles and 3D shapes in Google Earth Pro). However, map data can be processed in ArcGIS or QGIS and converted to KML files for use in Google Earth (Google Earth Pro has the additional function to directly import ESRI Arc shapefiles).

The coordinate reference system used in Google Earth is WGS84, defined in the Open Geospatial Consortium (OGC) 2.2 specification. When geospatial data is converted to KML from ArcGIS or QGIS it is automatically transformed to this coordinate system.

KML is an accessible, readable, scripting language. It is an XML (eXtensible Markup Language) file format language originally developed for use with Google Earth that has been adopted by the OGC and used by other browsers including NASA World Wind and ESRI ArcGIS Explorer. These browsers read and display the KML file components directly on their maps.

Scripting, using a text editor, enables the customisation of components allowing additional styling and animated tours beyond the basic functions of the Google Earth platforms. These animated tours can display information in an easily accessible format combining navigation through the landscape with text, images, GIS map data, links, interactive features and on-screen user instructions. The ‘KML Handbook’ (Wernecke, 2009) includes downloadable examples that explain how to use and create KML, from basic features such as placemarks through to handling large data sets and the use of web servers.

KML structure

KML, as an XML language, has a structure with specific components, known as elements. The KML element tree (Figure 44) shows the elements and derived elements. Abstract elements (shown in boxes) categorise groups of elements. The following ‘Geometry’ elements all have fundamental shapes and geographical locations (coordinates) associated with them: -

- Points
- Polygons
- Lines
- Models

The scripting language incorporates angled brackets and slash delimiters before and after the element name. There are some general rules when scripting – order and case are significant. Elements can be complex (*parent)* or simple *(child)*. A complex element can contain other elements and is distinguishable as it begins with a capital letter. For example, the <Point> element contains the <coordinates> element.

```
<Point>
<coordinates> xxxxxx </coordinates>
</Point>
```

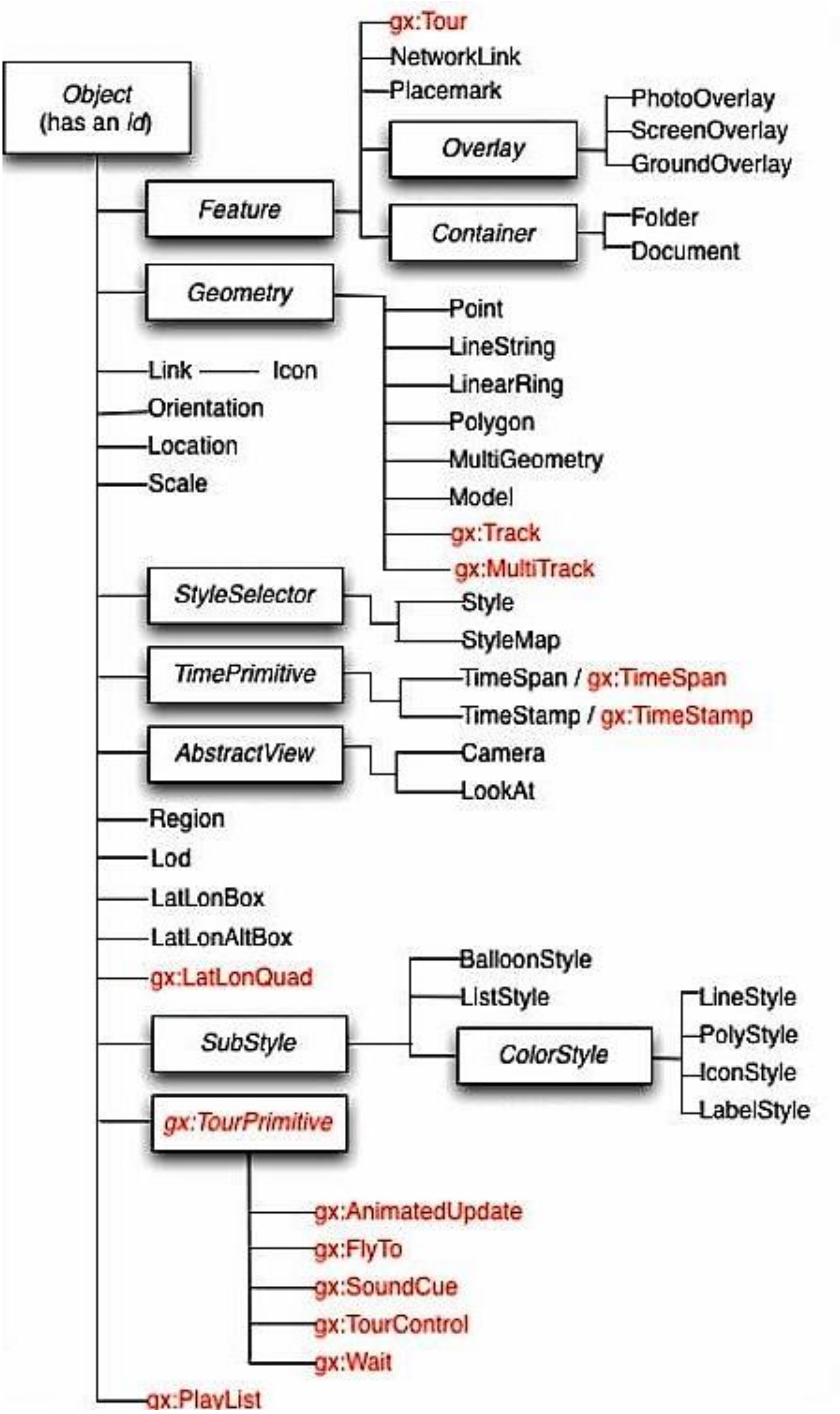

Figure 44. KML element tree (Google Developers, 2016). Reproduced from work created and [shared by Google](#) and used according to terms described in the [Creative Commons 3.0 Attribution License](#).

The element ‘Placemark’ is the only feature to have associated ‘Geometry’ elements. In addition to the location coordinates, the tilt and rotation of view, the altitude relative to the ground or sea level and styles can be specified for how these features will be viewed on the map browser. The GroundOverlay feature contains specific elements for the altitude and a bounding latitude longitude box.

Non-geometry elements have no coordinates or geographical location attached: -

- Screen Overlays – on-screen imagery - made visible at specified locations on the screen using x and y data (in pixels or fraction values)
- Network links – reference to dynamic input of data located within the associated data files or linked to an external server location

Styles

Features such as placemarks can be customised by adding styles to the geometry elements. The lines, polygons, icons and labels can be all customised in colour and size. Text balloons associated with placemarks can also be formatted to appear structured into tables and incorporate not only written information but also images (such as jpeg, png and gif) and URL hyper- links to websites and videos.

Styles such as colour (and transparency) are incorporated using hexadecimal notation and text format using standard HTML tags.

Animated tours

Animated tours are created by using a series of scripted instructions. Instructions include: -

- <gx:AnimatedUpdate> to update and change the visibility of elements such as geometry features, overlays, models or text balloons
- <gx:FlyTo> to move to a specified coordinate location and view angle
- <gx:Wait> to wait for the next instruction in the script

A duration (in seconds) can be applied to these instructions (which will control the speed of movement or change) and the manner of movement (bounce or smooth) can also be specified.

- A <gx:TourControl> to pause the tour and allow the viewer to manually resume the tour, using the time controls, when ready to continue.

Models

3D objects created in COLLADA format, can be added into the landscape at specified coordinate locations in Google Earth. These 3D models can be created using SketchUp software and exported as COLLADA files http://www.sketchup.com/. A free version SketchUp Make is available for non-commercial use. SketchUp Pro is a commercial, licenced version. Both versions have previously enabled geolocation of models by importing a location from Google Earth. Models could be created on copied sections of landscape terrain and exported as KMZ archive files to load onto Google Earth. As of May 2017, Google Earth has ceased to support SketchUp. The geolocation function was removed from SketchUp Make and the terrain feature was limited to the licenced SketchUp Pro, using an alternative satellite imaging source, making it difficult to locate COLLADA models in the 3D terrain using the free version (adding coordinates manually to the model element).

The SketchUp extensions '3D Warehouse' and 'Tree Warehouse' have tree models available to download, in 2D and 3D formats. Licenced extensions are available that can distribute multiple features, such as trees and vegetation, in a landscape including Skatter, https://extensions.sketchup.com/en/content/skatter.

COLLADA models can be animated within a virtual tour by using a KML tag <TimeSpan>, incorporating several stages allowing the viewer to drag a model up from the ground. The COLLADA model must be created in negative z space in SketchUp and set in Google Earth at an altitude at or below zero (De Paor and Whitmeyer, 2011). Models can also be animated into view above ground level by varying the altitude of the model at its location. This technique was used by Harwood, Lovett and Turner (2015) to animate models of roads, directional arrows and geological cross sections.

The KML script for any component or tour on Google Earth can be viewed by using a copy and paste technique directly from the browser (highlight and right click the feature from either the 3D map viewer or the places panel) into the text editor. The full script for the item can be saved as a KML file that can then be inspected, copied and edited. This feature is useful for developing an understanding of scripting and file structures but also for copying styles of components (such as colour or transparency) or identifying coordinates or view angles/altitudes.

File structure and distribution

The KML files for a tour can be distributed as zipped KMZ archive files. These can be emailed or downloaded from a website and viewed by anyone with Google Earth installed on their desktop computer. A KMZ archive file consists of a core KML file (named ‘doc.kml’ by default) containing the scripted animated tour instructions zipped together with a file (or files) of all associated data; images, data sets, screen overlays, icons and COLLADA models which are referenced in the core KML file (Figure 45).

KMZ archive files can also be distributed as ZIP files which must first have the file extension changed manually from ‘.zip’ to ‘.kmz’ before opening in Google Earth. Relative file path names must be used within KML scripting (unless the files are hosted on an external website and not distributed with the KMZ archive). KMZ archive files can be loaded either by double clicking the file or by dragging and dropping the file directly onto the open Google Earth map. The KMZ archives in this research were created using the free to download 7-ZIP application and manually changing the zip file extension to ‘.kmz’. KMZ archives can also be unzipped using 7-ZIP to inspect the constituent folders, files documents and for the KML files to be inspected using the text editor Notepad++.

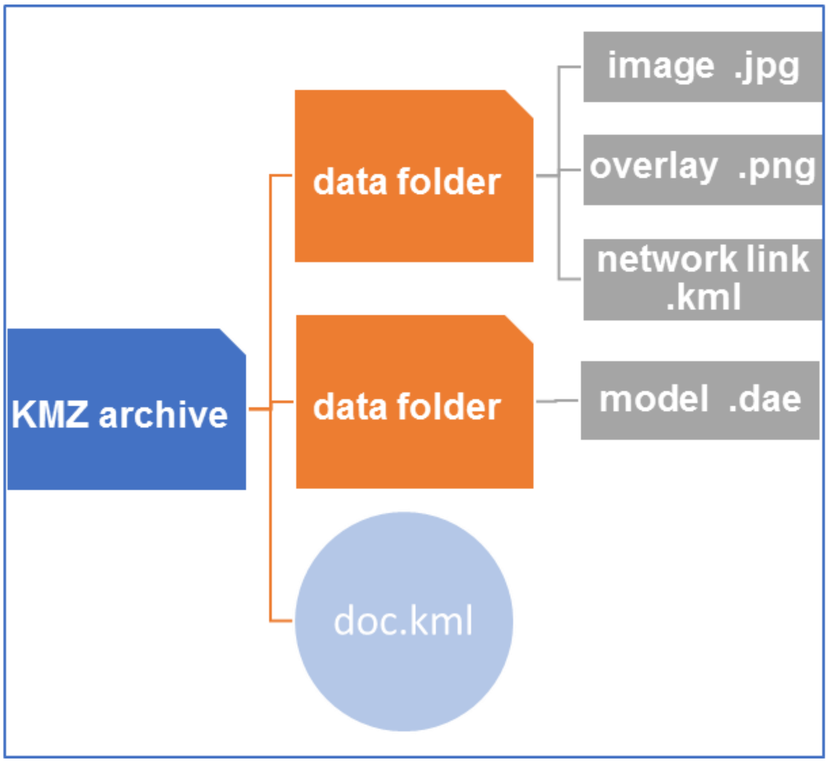

Figure 45. KMZ archive file and folder structure.

E Useful resources for Google Earth and KML

Google Earth/Google Earth Pro

The tours created in this research can be viewed using Google Earth versions 6 or 7. Current versions of Google Earth or Google Earth Pro can be downloaded free from: -

Google Earth software (latest version - v7.1.8 as at June 2017)
https://www.google.com/earth/download/ge/agree.html

Google Earth Pro (latest version - 7.1.8 as at June 2017)
https://www.google.co.uk/earth/download/gep/agree.html

For updating earlier versions that have not had automatic updates
https://support.google.com/earth/answer/168344?hl=en&ref_topic=4363014

Notepad++
https://notepad-plus-plus.org/download/v7.3.2.html

SketchUp Make 2017 (version 17.1.174)
http://www.sketchup.com/

Skatter (extension) for SketchUp)
https://extensions.sketchup.com/en/content/skatter

Additional Online Resources for creating KML and tours

KML developers guide (including tutorial guides, references, samples and support)
https://developers.google.com/kml/

Carleton College Google Earth teaching materials available at :-
http://serc.carleton.edu/NAGTWorkshops/visualize04/tool_examples/google_earth.html

Blogs: www.gearthblog.com; www.ogleearth.com

Other helpful tools for KML scripting:

http://earth.tryse.net

Google Earth ScreenOverlay 1.03 – small program enables location of screen overlays, showing in google earth.

Google Earth Tiler 1.08 – small program to create high resolution ground overlay in small tiles for location on GE for higher performance and lower bandwidth usage.

view_info.kml – provides coordinate strings, look at and fly to strings, also provides information on the google earth imagery for a location.

Earth point tools for Google Earth - http://www.earthpoint.us/ExcelToKml.aspx - import a spreadsheet of coordinates for large numbers of point records.

Alternatives to KML scripted tours

Google Earth Tour Builder

Offers a basic web browser method (using a Google account) of adding photos or videos to a sequence of locations using Google Earth that can then be shared online.

https://tourbuilder.withgoogle.com/

F Google Earth virtual globe tours, examples

Table 20 Useful tours available online for exploring features and learning KML scripting

Google Earth tour	Useful features
Chief Almir and the Surui tribe of the Amazon A *Google Outreach* project created with the Surui people to document the cultural history of the Amazon tribe. https://www.google.com/nonprofits/stories/surui-tribe.html http://sites.google.com/a/earthoutreach.org/screenshots/Home/surui_tribe_tour.kmz	-Screen and ground overlays -Placemark boundaries and icons and lines along -Placemark balloon information and links to videos and other resources -Animated tour enables overlays to turn on and off using animated changes in location coordinates, scales and colours (making items transparent) -Includes audio (mp3 files)
Cathedrals Tour 8 cathedrals throughout the world http://earth.google.com/gallery/kmz/cathedrals-3d-tour.kmz	-Views of 3D building and trees at various elevations including ground level views.
Gaywood Valley Tour (Harwood, Lovett and Turner, 2015) An animated geological tour to demonstrate the landscape benefits and ecosystem services of a the Gaywood River Catchment http://tinyurl.com/GE-UEA-blog	-Textual information in placemark balloons and screen overlays (animated in and out through varying the visibility) -Coloured style polygons and lines -COLLADA models - animated in by being created in negative space (below ground surface level) and changing the altitude
St James park, London (Lindquist, Lange and Kang, 2016) Considers the contribution of sound to the perception of virtual environments. Landscape and Urban Planning, Volume 148, April 2016, pp216–231	3 ground level views each with 3 scenarios for realism and preference Shows 3D view capability in an urban setting
Heroes of Google Earth https://www.google.co.uk/intl/en_uk/earth/explore/showcase/changetheworld.html	Various showcase projects showing the use of Google Earth

Harwood, A. R., Lovett, A. A. and Turner, J. A. (2015) 'Research paper: Customising virtual globe tours to enhance community awareness of local landscape benefits', *Landscape and Urban Planning,* 142, pp. 106-119.

Lindquist, M., Lange, E. and Kang, J. (2016) 'Research paper: From 3D landscape visualization to environmental simulation: The contribution of sound to the perception of virtual environments', *Landscape and Urban Planning,* 148, pp. 216-231.

G Data licencing permissions and attributions

Google Earth

Using Google Earth to create virtual globe tours and kml/kmz data files is subject to standard Google Earth terms available from:- http://maps.google.com/help/terms_maps.html

The following clauses apply specifically to research creating and distributing tours:-

*1**. License**. Subject to the Agreement's terms, Google grants you a non-exclusive, non-transferable license to use Google Maps/Google Earth, including features that allow you to:*

view and annotate maps;

create KML files and map layers;

publicly display Content with proper attribution online, in video, and in print; and

do many other things described in the Using Google Maps, Google Earth, and Street View permissions page.

*4**. Your Content in Google Maps/Google Earth**. Content you upload, submit, store, send, or receive through Google Maps/Google Earth is subject to Google's Universal Terms, including the license in the section entitled "Your Content in our Services".* ***However, content that remains exclusively local to your device (such as a locally-stored KML file) is not uploaded or submitted to Google, and is therefore not subject to that license.***

Screen shots and printed materials are subject to Google Earth attributions guidelines available at https://www.google.com/permissions/geoguidelines/attr-guide.html

"If you are not using the text provided directly on Google Maps and Google Earth imagery, the text of your attribution must say the name "Google" and the relevant data provider(s), such as "Map data: Google, DigitalGlobe". You may customize

the style and placement of the attribution text, just so long as the text is legible to the average viewer or reader. Note that Google logos cannot be used in-line (e.g. "These maps from [Google logo].")"

Natural England

Natural England data contains the following licence clauses:-

Data available under an Open Government Licence. Free to: 1) copy, publish and distribute and transmit the information; 2) adapt the information; 3) exploit the information commercially. See full terms of use here: http://webarchive.nationalarchives.gov.uk/20140605090108/http:/www.naturalengland.org.uk/Images/open-government-licence-NE-OS_tcm6-30743.pdf

You must acknowledge the source of the Information in your product or application by including or linking to any attribution statement specified by the Information Provider(s): You must always use the following attribution statements to acknowledge the source of the information, in this case: © Natural England copyright. Contains Ordnance Survey data © Crown copyright and database right [year] and, where possible, provide a link to the licence

Response to a request to use Natural England datasets for preparing and distributing a Google Earth tour for research purpose: -

"I can confirm that your proposed use of the data is within the terms of the Open Government Licence (OGL)

Just to reiterate, you will need to acknowledge Natural England as the source of any data you obtain and use from us. You will also need to link to the OGL."

Ordnance Survey

Ordnance Survey Open Government Licence data is subject to the open government licence available at http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/

There are no restrictions on the use or distribution other than using the appropriate attribution statement and links.

Response to a request to use Open Government Licence data for preparing and distributing a Google Earth tour for research purpose: -

"There will be no restrictions on distributing the OGL data (other than including or linking to any attribution statement specified by the Information Provider(s) and, where possible, providing a link to the OGL)."

"My colleague is legal has provided the following advice:

Regarding the use of OS Licenced Data:-

I am happy that there is no issue with Ms Smith using the relevant OS Licensed Data with Google Earth in the manner in which she describes. As Ms Smith points, out, clause 4 of the Google Maps/Google Earth Additional Terms of Service is the relevant provision here.

*In terms of the question concerning distribution of her dataset for end user evaluation, the Digimap End User Licence Agreement (**Digimap EUL**) permits distribution to Authorised Users. The Digimap EUL does not permit distribution to non-Authorised Users, save in certain prescribed circumstances, and Ms Smith's proposed distribution does not fall within these. However, if this is going to present a problem, I would suggest that Ms Smith informs us how many non-Authorised Users she would wish to pass her dataset to, and we can make an assessment as to whether to permit this on a one-off basis. Note that compliance with the conditions set out in clause 5.1.4 of the Digimap EUL will be relevant in making this assessment.*

Based on this we would like you to let us know before you use our data and give it to non-authorised users."

<u>NRFA</u>

NRFA catchment boundary data use is permitted only for licensees for personal use and for distribution in reports and not for unlicensed distribution.

Response to a request to use the Isbourne catchment boundary data for preparing and distributing a Google Earth tour for research purpose: -

"Thank you for contacting the National River Flow Archive at the Centre for Ecology & Hydrology.

For a single catchment boundary your indicated usage is fine. If, however, you wished to make use of a large number of NRFA catchment boundaries we would appreciated it if you would contact us so we can discuss the intended usage in more detail."

H Focus group questionnaire

UNIVERSITY OF GLOUCESTERSHIRE

Online GIS ICG focus group

University of Gloucestershire, 22nd March 2017

ccri

Data sources:

	Include
Agricultural land classifications	
Ancient woodland	
Catchment boundary	
Designated areas (i.e. SSSI, AONB)	
District boundaries (i.e. parish, county)	
Geology	
Historic water features	
Historic land use	

	Include
Land use change	
Listed buildings	
Parks and gardens	
River Isbourne outline	
Soils	
Surface flood extent	
Tree coverage	
Urban areas	

Which layer of information do you think is the most important to include on an online map?

Google Earth Tour:

Please circle the most appropriate answer:

How was the time available to take in the information	Too short	Suitable	Too long
How did you find the speed during the tour?	Too slow	Appropriate	Too fast
How would you rate the level of interactivity? (i.e. available hyperlinks, user-driven tasks)	Not enough	Suitable	Too much
How did you find the level of the terminology?	Too simple	Appropriate	Too technical

Could you comment of how you found the presentation of the information on the screen.

Was this clear:

The use of colour:

The layout of text balloons:

Amount of onscreen detail:

Any other comments:

I Analysis of CORINE Land Cover data for the Isbourne catchment

Table 21 CORINE land cover data analysis (data converted to vector format and analysed in ArcGIS)

Corine land use code	Land Use Class	2000 Total area km^2	2000 % of total area	2006 Total area km^2	2006 % of total area	2012 Total area km^2	2012 % of total area	% change 2000 - 2012	notes
2	Urban	1.09423	1.18	1.07372	1.16	1.485758	1.60	35.8%	1
11	Parkland	2.645635	2.85	3.200576	3.45	2.968335	3.20	12.2%	2
12	Arable	48.600495	52.35	48.58137	52.36	43.275519	46.61	-11.0%	
16	Fruit trees	0.99245	1.07					-100.0%	2
18	Pasture	20.181134	21.74	29.367007	31.65	37.171868	40.04	84.2%	
20	Agri/cultivation	3.858900	4.16					-100.0%	3
21	Agri/nat veg	1.18388	1.28	2.90193	3.13			-100.0%	3
23	Broadleaf forest	5.842457	6.29	4.836352	5.21	5.384681	5.80	-7.8%	4
25	Mixed forest			0.63607	0.69	0.296519	0.32	100.0%	4
26	Natural grassland	8.44305	9.09	0.86628	0.93	1.277181	1.38	-84.9%	5
27	Moor and heathland			1.316650	1.42	0.980067	1.06	100.0%	5
	TOTAL	92.84223	100.00	92.77996	100.00	92.839928	100.00		

1 Sedgeberrow village became classified urban land use in 2012
2 Areas identified as fruit trees in 2000 were classified as parkland in 2012
3 Agricultural cultivation and natural vegetation areas in 2000 were largely replaced by pasture in 2012 classification
4 Combined forest/woodland area reduced by 2.8% from 2000 to 2012
5 Combined grassland/heath area reduced by 73% from 2000 to 2012

J Land cover changes, 1930 to 2012

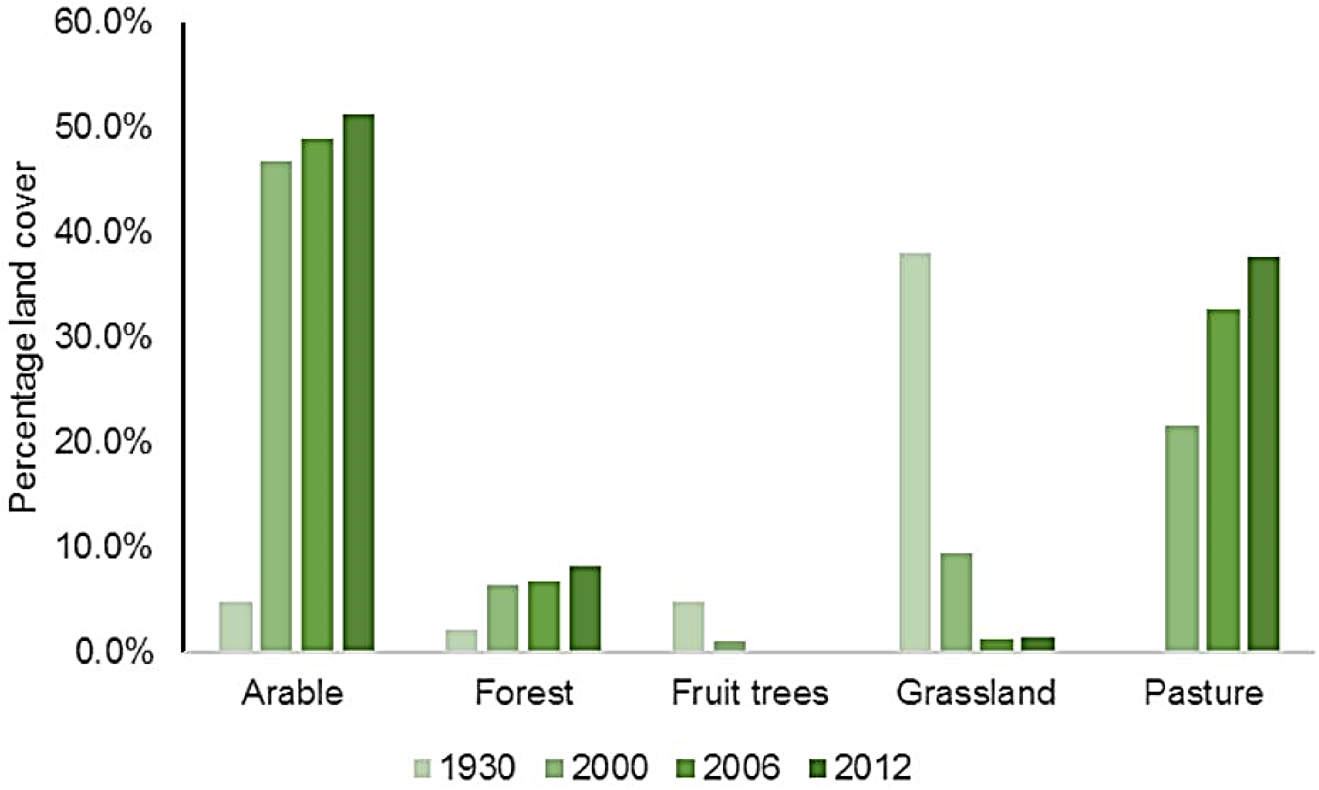

Figure 46 Percentage land cover since 1930 in the River Isbourne catchment (Clarke and Short, 2016)

Clarke, L. and Short, C. (2016) *Isbourne Catchment Community Report: Potential for Natural Flood Management in the Catchment (Final). Report to the Isbourne Catchment Group. School of Natural and Social Sciences, University of Gloucestershire & CCRI: Gloucestershire, UK.*

K End user evaluation survey questionnaire

Using Google Earth to promote understanding of Natural Flood Management

Consent to participate in a questionnaire

The University of Gloucestershire and Countryside and Community Research Institute (CCRI) invite you to participate in a research study.

This is a Masters by Research project investigating the potential role of landscape visualisation as an interactive tool to promote understanding and generate interest in a catchment wide Natural Flood Management scheme. The landscape visualisation used in this research is a Google Earth Virtual Globe tour.

The research findings will be used to refine the format and content of this landscape visualisation tool.

In order to complete this survey your participation will involve:-

- downloading and saving a file from a Dropbox account via a link (the link will be provided in the survey)
- opening the file in Google Earth desktop/Google Earth Pro
- viewing and exploring interactive features of a virtual globe tour

A short initial questionnaire and a final questionnaire will be used to obtain feedback.
The questionnaire contains a total of 24 questions.

The landscape visualisation will take approximately 15-20 minutes to view and the total time for participation will be approximately 30-40 minutes.

Your participation is subject to the following conditions: -
1. It is voluntary
2. You may withdraw at any stage
3. Your right to privacy will be protected
4. All responses are given anonymously and with no personal identification attached to the questionnaire
5. All data is limited to use in academic research

If you have any questions or additional comments regarding this research project or require further information regarding the content or methods used, please contact Katherine Smith (s1513157@connect.glos.ac.uk).

By completing the questionnaire, you give your explicit consent to participate in the research, with the above conditions.

(instructions for downloading Google Earth included here)

Initial questionnaire

Please complete the following questions before viewing the interactive Google Earth tour.

1. **My level of computer and internet experience is:-**
Please select a rating from 1 to 6, where 1 is 'Very limited experience' and 6 is 'Very experienced'.
Please do not select more than one answer.

Very limited experience					Very experienced
1	2	3	4	5	6

2. **Have you used Google Earth before now?**

No, I have never used Google Earth

Yes, I have used it occasionally to look at places

Yes, I have used it frequently to look at places

Yes, I have use it to look at places and to generated content

3. **Have you heard the term Natural Flood Management before now?**

No, I have not heard of it

Yes, I have heard of it but I don't know anything about it

Yes, I know a little about it

Yes, I know a lot about it

Questions about you (for statistical analysis purposes)

4. **What age group are you in?**

Under 20

20 to 29

30 to 39

40 to 49

50 to 59

60 and over

5. **What is your gender?**

Male

Female

Other

Prefer not to say

6. **What environment best describes the area where you live?**

Rural

Semi-Urban

Urban

7. **Have you ever experienced flooding?**

Yes, property I own has been flooded

Yes, property I rent has been flooded

Yes, in my locality

Yes, my family or friends have been flooded

No

8. **Which of the following best describes your occupation?**

Business owner

Land owner

Managerial

Professional

Academic

Clerical/Administrative

Manual labour

Student

Retired

Other

9. **Are you employed or involved in any of the following sectors? Please select all relevant answers.**

	Paid Employment	Other Interest
Agriculture		
Forestry		
Fishing		
Environment		
Wildlife		
Flood related organisation		
Planning		
Government organisation		
Geographical information systems		

Please view the interactive Google Earth tour before moving on to the next section

This virtual globe tour will operate on Google Earth for desktop or Google Earth Pro.

Please click on the link below and download the KMZ file from Dropbox. Save the file
to your computer. To open the file, double-click on it and it will automatically load in
Google Earth. Please read the onscreen instructions that will open in Google Earth before viewing the tour. Once you have viewed the tour please return to this survey and complete the final questionnaire.

http://bit.ly/2tg9Yni

Final Questionnaire

This questionnaire requires your feedback after viewing and exploring the interactive Google Earth tour.

10. **Do you have any connection with the River Isbourne and surrounding area?**

    I live there

    I visit the area frequently

    I visit the area occasionally

    I had heard of the area before viewing this tour, but have never been there

    I had not heard about this area before viewing the tour

11. **Overall, regarding the Google Earth Virtual Globe Tour format how would you rate the following?**

    For each row please select a rating on a scale from 1 to 6. Please don't select more than 1 answer(s) per row.

	1	2	3	4	5	6	
Difficult to use							Easy to use
Visually unclear							Visually clear
Presentation too slow							Presentation too fast

12. **Please rate the level of effectiveness of the following onscreen and interactive features of the Google Earth tour.**

For each item please select a rating from 1 to 6, where 1 is 'Very ineffective' and 6 is 'Very effective'. Please don't select more than 1 answer(s) per row.

	Very Ineffective					Very Effective
	1	2	3	4	5	6
Boundary lines and highlighted areas						
Pop up information balloons (text and photographs)						
Links to websites and further information						
Fly-through movement						
Closeup/perspective views						
Visual appearance of the ground and surface features						

13. **How would you rate your level of trust in the information presented in the tour?**

Please select a rating from 1 to 6, where 1 is 'Very low' and 6 is 'Very high'. Do not select more than one answer.

	1	2	3	4	5	6	
Very low trust							Very high trust

14. **What did you find most useful about the format and presentation of information in the Google Earth tour?**

Open text question

15. **What did you find least useful in the format and presentation of information in the Google Earth tour?**

    Open text question

16. **How helpful has this interactive Google Earth tour been for demonstrating the features of the River Isbourne and surrounding area?**

    Please select a rating from 1 to 6, where 1 is 'Extremely unhelpful' and 6 is 'Extremely helpful'. Do not select more than one answer.

	1	2	3	4	5	6	
Extremely unhelpful							Extremely helpful

17. **How helpful has this interactive Google Earth tour been for identifying the issues currently affecting the River Isbourne and surrounding area?**

    Please select a rating from 1 to 6, where 1 is 'Extremely unhelpful' and 6 is 'Extremely helpful'. Do not select more than one answer.

	1	2	3	4	5	6	
Extremely unhelpful							Extremely helpful

18. **What features or issues about the River Isbourne and the surrounding area stood out for you most in this tour?**

    Open text question

19. **What other information (if any) do you think would be useful to improve your understanding of the River Isbourne and the factors influencing it?**

    Open text question

20. **How helpful was the information in assisting your understanding of Natural Flood Management techniques?**
    Please select a rating from 1 to 6, where 1 is 'Extremely unhelpful' and 6 is 'Extremely helpful'.

	1	2	3	4	5	6	
Extremely unhelpful							Extremely helpful

21. **After viewing the tour how do you think the incorporation of Natural Flood Management techniques within a river catchment may impact on the following:-**
Please don't select more than 1 answer(s) per row.

	Very detrimental	Somewhat detrimental	No impact	Somewhat beneficial	Very beneficial	Don't know
Flooding						
River water quality						
Landscape views						
Soil						
Farming						
Wildlife habitats and biodiversity						

22. **How helpful was the tour in demonstrating the potential for Natural Flood Management techniques in the River Isbourne catchment?**

Please select a rating from 1 to 6, where 1 is 'Extremely unhelpful' and 6 is 'Extremely helpful'. Do not select more than one answer.

	1	2	3	4	5	6	
Extremely unhelpful							Extremely helpful

23. **How helpful was the tour in identifying where to get further information if required?**

Please select a rating from 1 to 4, where 1 is 'Extremely unhelpful' and 6 is 'Extremely helpful'. Do not select more than one answer.

	1	2	3	4	5	6	
Extremely unhelpful							Extremely helpful

24. **Having viewed the tour, how interested would you be in finding out more about the potential benefits and opportunities for Natural Flood Management techniques?**

Not interested
Somewhat interested
Very interested

The End

L Survey results - Facilitated group

Level of computer/internet experience, rated from very limited (1) to very experienced (6)		
rating	**Count (n)**	**%**
1	0	0
2	0	0
3	0	0
4	3	30
5	6	60
6	1	10
Total	**10**	**100**
mean	**4.8**	
standard deviation	**0.6**	

Google Earth Experience	n	%
None	0	0
Used occasionally to look	7	70
Used frequently to look	3	30
Used to look and generate content	0	0
Total	10	100

Knowledge of NFM	n	%
Not heard of it	2	20
Heard of it but don't know anything	1	10
Know a little about it	5	50
Know a lot about it	2	20
Total	10	100

Age Group	n	%
Under 20	0	0
20 to 29	5	50
30 to 39	1	10
40 to 49	3	30
50 to 59	1	10
60 and over	0	0
Total	10	100

Gender	n	%
Male	6	60
Female	4	40
Other		
Total	10	100

Home environment	n	%
Rural	3	30
Semi Urban	2	20
Urban	5	50
Total	10	100

Experience of flooding	n	%
Yes, at owned property	0	0
Yes, at rented property	0	0
Yes, in locality	4	40
Yes, family or friends	0	0
No	6	60
Total	10	100

Occupation	n	%
Business owner	0	0
Land owner	0	0
Managerial	0	0
Professional	0	0
Academic	5	50
Clerical/administrative	0	0
Manual labour	0	0
Student	5	50
Retired	0	0
other	0	0
Total	10	100

	Involvement/interest	
Sector of interest	**Paid** (n)	**Other** (n)
Agriculture	1	2
Forestry	0	0
Fishery	0	0
Environment	2	3
Wildlife	0	2
Flood related organisation	0	2
Planning	1	0
Government organisation	2	0

Connection with the Isbourne area	**n**	**%**
Live there	0	0
Visit frequently	1	10
Visit occasionally	5	50
Heard of it but not visited	0	0
Never heard of it before	4	40
Total	10	100

Facilitated group ratings for usability (% of participants)

(n = 10)	**Ease of use (a)**	**Visual clarity (b)**	**Presentation speed (c)**	**Trust in information (d)**
rating	% of participants			
1	0	0	0	0
2	0	0	0	0
3	0	0	60	0
4	20	0	40	10
5	40	30	0	50
6	40	70	0	40
total	100	100	100	100
Mean rating	**5.2**	**5.7**	**3.4**	**5.3**
SD	0.75	0.46	0.49	0.41

a. Ease of use from very difficult to use (1) to very easy to use (6)
b. Visual clarity from very unclear (1) to very clear (6)
c. Presentation speed from too slow (1) to too fast (6)
d. Trust in the information from very low trust (1) to very high trust (6)

Facilitated group ratings for effectiveness of tour elements (% of participants)

(n=10)	Rating of effectiveness from very low (1) to very high (6)						Mean rating	SD
Google Earth element	1	2	3	4	5	6		
Boundary lines and highlighted areas	0	0	10	0	50	40	**5.2**	0.87
Pop up information balloons	0	0	0	10	30	60	**5.5**	0.67
Links to websites and information	0	0	10	0	50	40	**5.2**	0.87
Fly through movement	0	0	10	0	40	50	**5.3**	0.9
Close up / perspective views	0	0	10	10	60	20	**4.9**	0.83
Visual appearance of the ground and surface features	0	0	10	0	70	20	**5**	0.77

Facilitated group ratings for helpfulness of the tour (% of participants)

N=10	Rating of helpfulness from very low (1) to very high (6)						Mean rating	SD
	1	2	3	4	5	6		
Demonstrating the catchment features	0	0	0	0	30	70	**5.7**	0.46
Demonstrating the catchment issues	0	0	0	10	40	50	**5.4**	0.66
Understanding NFM techniques	0	0	10	10	30	50	**5.2**	0.98
Demonstrating the potential for NFM [1]	0	0	0	0	30	60	**5.67**	0.47
Identifying sources for more info	0	0	0	10	40	50	**5.4**	0.66

1. 1 participant did not answer

Facilitated group perceptions of the impact of NFM in the catchment (% of participants)

N=10	very detrimental	somewhat detrimental	no impact	somewhat beneficial	very beneficial	don't know
flooding	0	0	0	10	90	0
river water quality	0	0	0	40	50	10
landscape views	0	0	10	40	40	10
soil quality	0	0	20	20	50	10
farming	0	0	10	10	50	30
wildlife and biodiversity	0	0	0	40	60	0

Interest in finding out more about NFM after viewing the tour (facilitated group)

(n=25)

Not interested	10%
Somewhat interested	30%
Very interested	60%

M Survey results – Non-facilitated online survey

Level of computer/internet experience, rated from very limited (1) to very experienced (6)		
rating	**Count (n)**	**%**
1	0	0
2	2	8
3	1	4
4	4	16
5	11	44
6	7	28
Total	**25**	**100**
mean	**4.8**	
standard deviation	**1.13**	

Google Earth experience	**n**	**%**
None	1	4
Used occasionally to look	7	28
Used frequently to look	9	36
Used to look and generate content	8	32
Total	25	100

Knowledge of NFM	**n**	**%**
Not heard of it	2	8
Heard of it but don't know anything	5	20
Know a little about it	11	44
Know a lot about it	7	28
Total	25	100

Age Group	**n**	**%**
Under 20	2	8
20 to 29	5	20
30 to 39	2	8
40 to 49	5	20
50 to 59	8	32
60 and over	3	12
Total	25	100

Gender	n	%
Male	15	60
Female	10	40
Other	0	
Total	25	100

Home environment	n	%
Rural	10	40
Semi Urban	11	44
Urban	4	16
Total	25	100

Experience of flooding	n	%
Yes, at owned property	1	4
Yes, at rented property	0	0
Yes, in locality	7	28
Yes, family or friends	4	16
No	13	52
Total	25	100

Occupation	n	%
Business owner	1	4
Land owner	0	0
Managerial	1	4
Professional	12	48
Academic	4	16
Clerical/administrative	0	0
Manual labour	0	0
Student	4	16
Retired	3	12
other	0	0
Total	25	100

Sector of interest	Involvement/interest Paid (n)	Involvement/interest Other (n)
Agriculture	3	2
Forestry	1	2
Fishery	1	3
Environment	7	4
Wildlife	4	4
Flood related org	4	4
Planning	3	1
Government org	3	0
GIS	7	3

Connection with the Isbourne area	n	%
Live there	1	4
Visit frequently	0	0
Visit occasionally	7	28
Heard of it but not visited	6	24
Never heard of it before	11	44
Total	25	100

Online survey group ratings for usability (% of participants)

	Ease of use a	Visual clarity b	Presentation speed c	Trust in information d
rating	% of participants			
1	0	0	4	0
2	12	8	16	0
3	8	12	48	0
4	8	12	28	21
5	32	24	4	33
6	40	44	0	46
total	100	100	100	100
Mean rating	**4.04**	**4.84**	**3.12**	**5.25**
SD	1.04	1.32	0.86	0.78
n	25	25	25	24

a. Ease of use from very difficult to use (1) to very easy to use (6)
b. Visual clarity from very unclear (1) to very clear (6)
c. Presentation speed from too slow (1) to too fast (6)
d. Trust in the information from very low trust (1) to very high trust (6)

Online survey ratings for effectiveness of the tour (% of participants)

n=25	Rating of effectiveness from very low (1) to very high (6)						Mean rating	SD
	1	2	3	4	5	6		
Boundary lines and highlighted areas	0	4	8	28	32	28	4.72	1.08
Pop up information balloons	0	0	8	16	36	40	5.08	0.93
Links to websites and information	0	4	8	20	32	36	4.88	1.11
Fly through movement	0	4	8	32	20	36	4.76	1.14
Close up/ perspective views	0	0	16	40	16	28	4.56	1.06
Visual appearance of the ground and surface features	0	8	20	24	28	20	4.32	1.22

Online survey ratings for helpfulness of the tour (% of participants)

n=25	Rating of helpfulness from very low (1) to very high (6)						Mean rating	SD
	1	2	3	4	5	6		
Demonstrating the catchment features	0	0	0	20	36	44	5.24	0.76
Demonstrating the catchment issues	0	0	4	28	40	28	4.92	0.84
Understanding NFM techniques	0	12	8	40	24	16	4.24	1.18
Demonstrating the potential for NFM	4	4	4	28	44	16	4.52	1.17
Identifying sources for more information	0	0	4	20	44	32	5.04	0.82

Online survey perceptions of the impact of NFM in the catchment (%of participants)

	very detrimental	somewhat detrimental	no impact	somewhat beneficial	very beneficial	don't know	n
flooding	0	0	0	50	46	4	24
river water quality	0	0	4	46	42	8	24
landscape views	0	9	13	52	13	13	23
soil quality	0	0	0	37	46	17	24
farming	0	16.5	4	42	16.5	21	24
wildlife and biodiversity	0	0	0	37.5	50	12.5	24

Interest in finding out more about NFM after viewing the tour (online survey) (n=25)

Not interested	4%
Somewhat interested	58%
Very interested	38%

Cross tabulated ratings for ease of use (non-facilitated online survey)
(Showing the percentage of participants for each category rating the ease of use)

		Ease of use – scale of 1 to 6					
		1	**2**	**3**	**4**	**5**	**6**
Age (n=25)	Under 20	-	-	-	-	-	100
	20-29	-	40	-	-	40	20
	30-49	-	-	-	50	-	50
	40-49	-	20	-	20	40	20
	50-59	-	-	12.5	-	37.5	50
	Over 60	-	-	33.33	-	33.33	33.33
Gender (n=25)	Male	-	6.67	13.33	6.67	33.33	40
	Female	-	20	-	10	30	40
Occupation (n=25)	Business owner	-	100	-	-	-	-
	Land owner	-	-	-	-	-	-
	Managerial	-	-	-	-	-	100
	Professional	-	8.33	8.33	8.33	41.67	33.33
	Academic	-	25	-	25	-	50
	Clerical	-	-	-	-	-	-
	Manual labour	-	-	-	-	-	-
	Student	-	-	-	-	50	50
	Retired	-	-	33.33	-	33.33	33.33
Google Earth use (n=25)	Never	-	-	-	-	100	-
	occasionally	-	-	14.29	-	42.86	42.86
	frequently	-	11.11	11.11	11.11	33.33	33.33
	view and generate content	-	25	-	12.5	12.5	50
Interest in GIS (n=10)	(n=10)	-	20	-	20	10	50
Level of computer experience (on a scale of 1 to 6)	1 (n=0)	-	-	-	-	-	-
	2 (n=2)	-	-	50	-	50	-
	3 (n=1)	-	-	-	-	100	-
	4 (n=4)	-	25	25	-	-	50
	5 (n=11)	-	9.09	-	-	54.36	36.36
	6 (n=7)	-	14.29	-	28.57	-	57.14

Cross tabulated ratings for the speed of presentation (non-facilitated online survey)
(Showing the percentage of participants for each category rating the speed)

		Presentation speed – scale of 1 to 6					
		1	**2**	**3**	**4**	**5**	**6**
Age (n=25)	Under 20	-	50	50	-	-	-
	20-29	20	-	60	20	-	-
	30-49	-	50	-	50	-	-
	40-49	-	-	60	40	-	-
	50-59	-	12.5	50	37.5	-	-
	Over 60	-	33.33	33.33	-	33.33	-
Gender (n=25)	Male	-	13.33	46.67	33.33	6.67	-
	Female	10	20	50	20	-	-
Occupation (n=25)	Business owner	-	-	-	100	-	-
	Land owner	-	-	-	-	-	-
	Managerial	-	-	-	100	-	-
	Professional	-	16.67	66.67	16.67	-	-
	Academic	25	-	50	25	-	-
	Clerical	-	-	-	-	-	-
	Manual labour	-	-	-	-	-	-
	Student	--	25	25	50	-	-
	Retired	-	33.33	33.33	-	33.33	-
Google Earth Experience (n=25)	Never used	-	-	-	100	-	-
	Used occasionally	-	-	57.14	28.57	14.29	-
	Used frequently	-	33.33	55.56	11.11	-	-
	Used to view and generate content	12.5	12.5	37.5	37.5	-	-
Interest in GIS (n=10)	Paid or other	10	20	30	40	-	-

Cross tabulated ratings for trust in the information (online survey)
(Showing the percentage of participants for each category rating level of trust)

		Trust in information – scale of 1 to 6						
		1	**2**	**3**	**4**	**5**	**6**	**No reply**
Age (n=25)	Under 20	-	-	-	-	-	100	-
	20-29	-	-	-	-	60	40	-
	30-49	-	-	-	100	-	-	-
	40-49	-	-	-	20	40	20	20
	50-59	-	-	-	-	37.5	62.5	-
	Over 60	-	-	-	66.67	-	33.33	-
Gender (n=25)	Male	-	-	-	26.67	33.33	40	-
	Female	-	-	-	10	30	50	10
Occupation (n=25)	Business owner	-	-	-	-	100	-	-
	Land owner	-	-	-	-	-		-
	Managerial	-	-	-	-	-	100	-
	Professional	-	-	-	25	41.67	33.33	-
	Academic	-	-	-	-	25	50	25
	Clerical	-	-	-	-	-	-	-
	Manual labour	-	-	-	-	-	-	-
	Student	-	-	-	-	25	75	-
	Retired	-	-	-	66.67	-	33.33	-
Google Earth Experience (n=25)	Never used	-	-	-	-	100	-	-
	Used occasionally	-	-	-	28.57	14.29	57.14	-
	Used frequently	-	-	-	11.11	44.44	44.44	-
	Used to view and generate content	-	-	-	25	25	37.5	12.5
Interest in GIS (n=10)	Paid or other	-	-	-	40	20	30	10

N Survey, free text comments - Facilitated group

(note: unedited response text)

Ref	Q 14. What did you find most useful about the format and presentation of information in the Google Earth tour?
F1	Very easy to see the relationship of features to one another, with extra information and chance to explore if you are interested
F2	I think it's very clear the way in which the land-use features of the area were mapped. And also the ways in which information have been selected in the narrative of the simulation.
F3	The interactive part, by moving from one spot to another and with the blue information balloons opening.
F4	I really liked the tour - a fun way of learning and a good way to get to know the area.
F5	different land classification and use of it and the elevation of the cut through areas
F6	The combination of spatial data, and historical, admin. and technical information. It's relevant to have a changing multi-layers spatial visualization of the different kinds of data and causal/temporal connections influencing processes. It makes really clear the relational features of something to be conceived as a process.
F9	Does help put a location in context, but I am very familiar with the area, so I wonder how it would relate to someone who has no familiarity with the area.
F10	comprehensive nature of the coverage

Ref	Q 15. What did you find least useful in the format and presentation of information in the Google Earth tour?
F1	Wasn't sure where it was going, a sense of narrative would have been helpful - a walk rather than a roam.
F2	I would have liked to have more info about the slope of the area (maybe more territorial sections and diagrams)
F3	All the information links, some were not very useful for me.
F4	Can't think of anything. Good tool!
F5	I couldn't see the date of the data that this tour represent about. Is it different each year or does it keep the same all the time.
F6	The cross-section of steep slopes was a bit unclear. Look forward for a 3D format in the future
F10	some of the lines were very hazy in the close up details

Ref	Q 18. What features or issues about the River Isbourne and the surrounding area stood out for you most in this tour?
F1	The complexity of managing water in the catchment.
F2	the natural and ecological features of the area
F3	The flooding area and how avoid it without affecting the natural environment
F4	I found the flood buffer area illustration along the river very useful and interesting, as well as the information about water quality and erosion challenges in the area (probably partly because this is my field).
F5	I like the information that pop-up from the tour
F6	The relational features of something to be conceived as a process. It accounts for the holistic perspective to be followed in dealing with flood risk and eco-systemic issues.
F10	the flooding map - was the the extent of the 2007 or the EA model?

Ref	Q 19. What other information (if any) do you think would be useful to improve your understanding of the River Isbourne and the factors influencing it?
F1	Voices of some of the stakeholders and some of what it means to them, a qualitative or poetic feel of the place.
F2	more pictures at "street level", I mean at the level of the river to see how it looks like from the ground level
F4	Perhaps more information about flood prediction and intensity in the area and how that link to water quality issues. Perhaps a little more information about the actual natural flood management measures and documented effect of implementing them. Perhaps use soil conservation instead of soil quality? Flood management is affecting erosion rates more than the actual quality (in my opinion)
F5	what good is if the whole flood area animation can be divided into different locations by towns and villages name. So that when people want to go back to view the specific area they can just by click the name of the town and play the flood report that happened with in that local area instead of the whole video.
F6	The historical aspects and aspects of environmental history could play a bigger role
F9	Additional images of the river and tributaries in context - and their location to properties etc.
F10	more pictures?

O Survey, free text comments – Non-facilitated online survey

(note: unedited response text)

Ref.	Q 14. What did you find most useful about the format and presentation of information in the Google Earth tour?
NF1	The on-screen features were very relevant and provided a lot of information without the user having to pro-actively search for it. Was condensed enough to bore the user.
NF3	The context and setting
NF4	A good aid to see what is happening in our world.
NF5	Placement in relation to other areas I know. Ability to see perspective views, to some extent (although I think it would benefit from some vertical exaggeration).
NF8	Geographically and socially framing the problem, then examining the potential impacts of the solution. Also being able to use the data interactively afterwards. I commend whoever took the time to put this together.
NF9	Understanding the network of rivers, and also the topography. The pop up graphs are a little hard to apply in the context of google earth, perhaps they could be visualised through animating the land cover change on the map surface.
NF10	I did not know that Google Earth Pro could be used in this fashion
NF11	The information was ordered and well laid out. Very easy to follow.
NF12	The tour provided a highly descriptive view of the area under review, with the 3D aspect revealing the contours of the land making it obvious why the area is prone to flooding. The descriptive pop ups of the SSI's etc highlighted the inherent problems of land management and the number of bodies involved in decision making in an area of outstanding natural beauty and the highlighted areas visually enhanced the written descriptions.
NF13	Could pause if required.
NF14	Being able to pause to read and re-read information, and to study the image at my own pace.
NF16	The over view and data layers
NF17	It is a clear and easy way to present a lot of information in a visually pleasing format that a layperson can access easily and hopefully understand. Unlike a video fly through the user can stop, go back and explore the project area at their leisure.
NF18	Incredibly easy to follow instructions. It was easy to navigate through the tour. The tour was rich in information and there were different levels which could be accessed according to need.
NF19	Visualising where the water came from and how the surrounding land would impact this
NF20	the overview of the catchment and the ability to cover a wide range of information with additional links if further informatin was required.
NF21	The fly through and the ability to pause and think about the presentation.
NF22	No constructive opinion to offer

NF24	good to have further information in the information bubbles. It made the whole experience more interactive.

Ref	Q 15. What did you find least useful in the format and presentation of information in the Google Earth tour?
NF1	The graphics lose quality, however this down to the zoom capabilities of Google Earth software and not the actual presentation
NF3	The prescriptive nature of the tour
NF5	Content: I thought there would be something about how NFM is being implemented in the area. NFM only came in at the very end. I was left wondering why I needed to know all of the tour information in such detail. Technical: Overlays were very confusing, e.g. yellow diamonds, colours overlaying imagery during initial orientation tour. Can't see the district boundaries due to the parishes. Flickering/jumping effect of boundaries and text, and low resolution of overlays in perspective view.
NF7	Too much information for one tour when my personal interest would only have been focused on one area
NF8	Although I am an expert level user of GE it's still a struggle to work with KML and KMZ files and load the tour, run it and follow the instructions on the bubbles/overlays. It must have taken ages to do, unless there's an export from a GIS. The benefit is that it's accessible to me, but all but the most determined probably need a more web-native version. As far as I can tell Google Earth desktop is no longer being developed, in favour of a web-based version which amounts to not much more than a toy map explorer. KMZ files are hard to come by and network links are breaking frequently.
NF9	It was slow to get to the outputs section
NF10	Nothing
NF11	Perhaps there could have been more information / examples about NFM in this catchment? Perhaps a theoretical example?
NF12	I found the whole presentation engaging and useful
NF13	Pace of my own network connection keeping up with the images as they were rendered
NF14	Could you perhaps add drone footage and actually fly, low down, along part of the river catchment? Did you add images of the actual real flooding? if you did, I missed them. if not then perhaps you might add some?
NF16	Lack of interactivity. Not sure how it could inform which and the extent of NFM measure s to be used in the landscape
NF17	I do not know whether it was a result of the animation but during the panning, the river line appeared to flash like lightning. If this was intended it was not needed.
NF18	There were black rectangles on the map which may have been due to my operating system. (MacBook). When I reloaded the tour they disappeared. I think an audio element would have enhanced the experience.
NF19	You need to be able to see the topography more. It took some time to realise what were hills and what was flatter

NF20	on some of the images - cross sections bit - the screen image was not very good
NF22	No constructive opinion to offer
NF24	sometimes the movement would jar for a couple of seconds.

Ref	**Q 18. What features or issues about the River Isbourne and the surrounding area stood out for you most in this tour?**
NF3	Varying land use mixed with potential for natural flood risk managment
NF4	The eco. results
NF5	The historic environment (listed buildings, historic water features).
NF6	The History (Mills etc)
NF7	none
NF8	I wasn't aware of the direction and shape of the catchment before. I also have a flood story audio recording from someone whose family are from winchcombe and I didn't really understand their plight before this. The geospatial overview really puts it into context.
NF9	The properties that flooded in 2007
NF10	The realisation of how steep the surrounding countryside is around some of the featured towns like Winchcombe
NF11	Steepness of the terrain
NF12	The extent of the water catchment, the diversity of sensitive environmental areas and the flood risk zones
NF13	Interesting to see the network being identified, and the issues that faced different areas - the flood risk was very clear
NF14	The poor land management, for agricultural ends with little regards for the consequences for water (or soil).
NF16	landuses and wfd status
NF17	When looking at catchments I think the topographic view is important for people to see and understand the lay of the land. The flood layer over the aerial is also good as it shows the area covering houses creating a greater impact on the flood risk to real houses.
NF18	The elevational cross-sections. The changes in type of vegetation/ land use since 1930 The problems arising from the flow of water into the river from all points rather than just at its source(s) The number of different agencies/vested interests that need to work together if natural flood management is to succeed.
NF19	Land management and lack of trees in many sections
NF20	the change in farming practices since the 1930s
NF21	The range of issues which need to be taken into account before any flood management can be undertaken e.g designated landscapes.
NF22	No constructive opinion to offer
NF24	the location of towns and cities.

Ref	Q 19. What other information (if any) do you think would be useful to improve your understanding of the River Isbourne and the factors influencing it?
NF3	Depends on the end user
NF7	historic use of the area and its water management
NF8	Allowing a replay of a flood event and its progress downstream, along with the impact to properties as it progressed.
NF10	None
NF12	Rainfall data to provide an insight into the pattern of flooding, eg how often does the area flood, does flooding occur more frequently after prolonged rainfall where the catchment becomes waterlogged or is it more susceptible to flash flooding after storms.
NF14	As above - actual images of the actual flooding and a fly down a river corridor to help me see the river better - perhaps through a wooded section and an open section to get a betters sense of the difference?
NF16	Mre about how agricultural management of the fields/farms has changed over time Historic flooding records
NF17	What flood layers are used? Land drainage network, ditches etc, and the issues affecting them?
NF18	Some photographs from the flood of 2007 would help to illustrate the problems better. Number of floods and severity - (costs, homes affected etc) in recent history. (possibly outside scope of project)
NF19	Visualisation of how land management has changed over time and the corresponding changes in flood risk
NF20	More specific examples of the NFM measures that could be implemented in this catchment and how they would impact on the environmental desingations and farming practices
NF21	I can't think of anything.
NF22	No constructive opinion to offer
NF24	I'm not sure.

P Virtual Globe tour and KML script

The final virtual globe tour for the Isbourne catchment and the xml script files (which can be viewed on a text editor) can be found on the enclosed disc.

Virtual globe tour:-

IsbourneTour.kmz

Please download the file and save to your computer. To view virtual globe tour, double-click on the IsbourneTour.kmz file or drag and drop it onto Google Earth/Google Earth pro desktop versions (see Appendix E for download resources).

Script files:-

Isbourne_main_tour.xml

doc.xml

The KMZ file can also be unzipped to inspect the component files (script and images). To unzip the file first manually change the file extension to '.zip'.

Q. Metadata

SPATIAL REFERENCE: **KML**: WGS 84 Datum (EPSG: 4326) / **ArcGIS** : OSGB British National Grid (ESPG: 27700)

LICENCE STATUS: **OPEN**: free to use, share and publish (with attribution statement) **RESTRICTED**: data and derived data cannot be shared with third parties (that do not have appropriate public-sector data sharing agreement or are Digimap Authorised Users)

Virtual Globe Tour KML layer	Source (and licence status)	Description	Temporal extent	Dataset reference date	Lineage/Organisation	Extent	Spatial reference system prior to KML conversion	Format	Original Scale/Tile Size	Frequency of update	Constraints	Metadata date
Catchment Boundary	**NRFA Catchment Boundary (River Isbourne)**	Isbourne catchment boundary data from the National River Flow Archive	2015	2016-02	Downloaded from the National River Flow Archive	River Isbourne catchment	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile			Permission obtained to use single catchment boundary for the purposes of this research project. Standard terms: Data cannot be used for commercial purposes, only internal commercial use. Data must not be made available on internet sites. You may disseminate publications and reports based upon the Data to third parties, including to third party internet sites. Full licence details available here: http://nrfa.ceh.ac.uk/sites/default/files/nrfa_catchment_licence.pdf	15/02/2016
2007 Flood Outline	**Recorded Flood Outline**	Recorded flood outlines since 1946	2004-01	2015-10	Downloaded from Environment Agency (Data.gov.uk) Recorded Flood Outlines	Clipped to the catchment area	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile			Attribution statement: © Environment Agency copyright and/or database right 2015. All rights reserved. Contains Ordnance Survey data © Crown copyright and database right [2012].	
Main River	**OS Open Rivers**	High-level generalised network view of GB watercourses. Free and open data from the Ordnance Survey. Two separate layers: network nodes and links.	2015-03	2016-2	Downloaded from Ordnance Survey (Open Data) Digimap	Clipped to the catchment area	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile	1:15 000 to 1:30 000	biannually	Data available under an Open Government Licence (**OGL**). Free to: 1) copy, publish and distribute and transmit the information; 2) adapt the information; 3) exploit the information commercially. See full terms of use here: http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/. You must acknowledge the source of the Information in your product or application by including or linking to any attribution statement specified by the Information Provider(s) and, where possible, provide a link to this licence; You are able to use the OS OpenData datasets in any way and for any purpose. We simply ask that you acknowledge the copyright and the source of the data by including the following attribution statement: "Contains OS data © Crown copyright [and database right] (year)"	16/02/2016
Watercourses	**OS OpenMap Local**	OS Open Map Local is the most detailed 'street level' vector mapping product available from the OS within the open data arena. See: https://www.ordnancesurvey.co.uk/docs/user-guides/os-open-map-local-user-guide.pdf	2015-03	2016-02	Downloaded from Ordnance Survey (Open Data) Digimap	Clipped to the catchment area	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile	1:10000	biannually	OGL as above	17/02/2016
Cotswolds AONB	**Cotswolds AONB Boundary**	Spatial extent of the Cotswolds AONB (much of the Isbourne catchment lies within the AONB)	2016-02	2016-02	Downloaded from Natural England	Cotswolds AONB extent	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile			OGL as above	15/02/2016
SSSI	**SSSI (Cleeve Common)**	A Site of Special Scientific Interest (SSSI) is the land notified as an SSSI under the Wildlife and Countryside Act (1981), as amended. Sites notified under the 1949 Act only are not included in the Data set. SSSI are the finest sites for wildlife and natural features in England, supporting many characteristic, rare and endangered species, habitats and natural features. The data do not include "proposed" sites. Boundaries are generally mapped against Ordnance Survey MasterMap.	2010-2015	2015-05	Downloaded from Natural England	Intersecting with the catchment area	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile		monthly	OGL as above	23/02/2016

Virtual Globe Tour KML layer	Source (and licence status)	Description	Temporal extent	Dataset reference date	Lineage/Organisation	Extent	Spatial reference system prior to KML conversion	Format	Original Scale/Tile Size	Frequency of update	Constraints	Metadata date
Priority Habitats	**Priority Habitats**	This is a spatial dataset that describes the geographic extent and location of Natural Environment and Rural Communities Act (2006) Section 41 habitats of principal importance.	1966-2015	2015-12	Downloaded from Natural England	Clipped to the catchment area	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile			OGL as above	24/02/2016
Ancient Woodlands	**Ancient Woodland**	The inventory identifies over 22,000 ancient woodland sites in England. Ancient woodland is identified using presence or absence of woods from old maps, information about the wood's name, shape, internal boundaries, location relative to other features, ground survey, and aerial photography. The information recorded about each wood and stored on the Inventory Database includes its grid reference, its area in hectares and how much is semi-natural or replanted. Prior to the digitisation of the boundaries, only paper maps depicting each ancient wood at 1:50 000 scale were available.			Downloaded from Natural England	Clipped to the catchment area	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile			OGL as above	24/02/2016
Parish Boundaries, Glos Boundary, Worcs Boundary, Cotswold boundary, Wychavon boundary, Tewkesbury boundary	**OS Admin Boundaries (county, district borough and parish)**	A range of local government administrative and electoral boundaries (parishes, community wards, district borough wards, district boroughs, electoral divisions, counties)	2016-10	2016-10	Downloaded from Ordnance Survey (OpenData) Digimap	Intersecting with the catchment area	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile			OGL as above	28/03/2017
Historic Water Features	**Manually derived by R.Berry @CCRI**	Historic water-related industrial sites on the Isbourne - mainly watermills and their mill ponds. Also includes a tannery, ornamental lakes, weirs and sheep ponds.	1066-1950	2016-02	Features based on those described in the book "The River Isbourne: In the Service of Mankind" and digitised using various Ordnance Survey Historic Maps downloaded from Digimap	Clipped to the catchment area	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile	1:2500		Derived data digitised from Ordnance Survey Historic Maps (various 1:2500 and 1:10560 County Series and National Grid map tiles) 1884-1955	16/02/2016
Listed Buildings	**Listed Buildings**	Point locations of listed buildings from Historic England		2007-01	Downloaded from Historic England	Clipped to the catchment area	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile			Subject to the terms below, you are now granted a worldwide, perpetual, nonexclusive licence to use this Historic England GIS Data. You may: 1) copy, publish, distribute and transmit the Historic England GIS Data 2) adapt or modify the Historic England GIS Data 3) exploit the Historic England GIS Data commercially for example by combining it with other information or by including it in your own product or application. You must always use the following attribution statements to acknowledge the source of the information: © Historic England [year]. Contains Ordnance Survey data © Crown copyright and database right [year]	23/02/2016
Parks and Gardens	**Registered Parks and Gardens**	Locations (polygons) of registered parks and gardens from Historic England		2012-10	Downloaded from Historic England	Clipped to the catchment area	OSGB British National Grid (ESPG: 27700)	Vector, from ESRI shapefile			Subject to the terms below, you are now granted a worldwide, perpetual, nonexclusive licence to use this Historic England GIS Data. You may: 1) copy, publish, distribute and transmit the Historic England GIS Data 2) adapt or modify the Historic England GIS Data 3) exploit the Historic England GIS Data commercially for example by combining it with other information or by including it in your own product or application. You must always use the following attribution statements to acknowledge the source of the information: © Historic England [year]. Contains Ordnance Survey data © Crown copyright and database right [year]	23/02/2016

Virtual Globe Tour KML layer	Source (and licence status)	Description	Temporal extent	Dataset reference date	Lineage/Organisation	Extent	Spatial reference system prior to KML conversion	Format	Original Scale/Tile Size	Frequency of update	Constraints	Metadata date
Land Cover	**CORINE Land Cover**	Corine 2012/Corine 2006/Corine 2000, land cover change from the European Environment Agency, Downloaded as Raster format, converted to Vector in ArcGIS	2000-2012	2000/2006/2012	Downloaded from European Environment Agency	Clipped to the catchment area	ETRS 89 LAEA	Vector, from ESRI shapefile		6 years	No Constraints	
Geology - bedrock	**BGS 1:625k Bedrock**	British Geological Society data, bedrock		2007	Downloaded as kml file from British Geological Survey	England and Isle of Man	WGS 84	KML from BGS	1:625000	unknown	No Constraints. 'Reproduced with the permission of the British Geological Survey ©NERC. All rights Reserved'. 'Based upon [source details], with the permission of the British Geological Survey'. "Contains British Geological Survey materials © NERC [year]". Under the Open Government Licence.	12/05/2017
Railway	**Manually created on Google Earth**	Path of the railway that intersects the catchment area			Manually created line on Google Earth	Isbourne catchment area	WGS 84	KML			None	12/05/2017
Additional data used for map creation												
	OS 1:250000 Raster Basemap	1:250000 raster base mapping from the Ordnance Survey	2016-06	2016-06	Downloaded from Ordnance Survey (Open Data)	OS Grid tiles SO and SP. Extends beyond project study area and provides regional mapping overview	OSGB British National Grid (ESPG: 27700)	Raster TIFF	1:250000, 100kmx100km	annually	OGL as above	09/03/2017
	GREAT BRITAIN National outline	1:250000 vector base National outlines from the Ordnance Survey	2005	2005	Downloaded from Ordnance Survey (Open Data)	national coverage	OSGB British National Grid (ESPG: 27700)	Vector SHP	1:250000, national		OGL as above	28/03/2017
	WFD River Waterbody catchment boundary	WFD Environment Agency catchment boundary outline	2013	2015-10	Downloaded from Environment Agency (Data.gov.uk) WFD River Waterbody Catchments Cycle 2	River Isbourne catchment	OSGB British National Grid (ESPG: 27700)	Vector SHP		unknown	Attribution statement © Environment Agency copyright and/or database right 2015. All rights reserved. Open Government Licence	01/06/2017
	Isbourne Hydrometric Monitoring		2016-02	2016-02	Downloaded from Environment Agency (Data.gov.uk)	Clipped to the catchment area					Attribution statement © Environment Agency copyright and/or database right 2015. All rights reserved. Open Government Licence	