EXPLORING THE POTENTIAL OF GOOGLE EARTH AS A COMMUNICATION AND ENGAGEMENT TOOL IN COLLABORATIVE NATURAL FLOOD MANAGEMENT PLANNING

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ABSTRACT

This paper considers the development and evaluation of a Google Earth 'virtual globe' tour for communicating spatial data and engaging stakeholders in the early stages of a natural flood management (NFM) planning scenario, based on a rural UK river catchment that suffered significant flooding in 2007. With a range of diverse stakeholder interests to consider, early engagement and the development of trust before decision-making is essential for the long-term success of such catchment-wide projects. A local catchment group was consulted to identify key information requirements, and from this a 'virtual globe' tour was created. The process involved specialist skills and expert leadership, but the end result was accessible to a range of audiences. User evaluation indicated that the 'virtual globe' tour was easy to navigate and can be used to stimulate interest and engage stakeholders. Participants trusted the content and valued the interactivity of the tour. It was helpful for communicating and educating participants about the catchment, the issues it faces and the potential to incorporate NFM, particularly for those with little or no prior knowledge. More abstract information was harder to convey and there were limitations in the availability of suitable data for some variables and the quality of satellite imagery. This exploratory research found that a Google Earth 'virtual globe' tour can be a valuable tool in the initial stages of an NFM project, but there are also opportunities to use this technique in the more advanced stages of the planning process. The approach could be used as part of a wider toolkit for communication and engagement and has potential as a decision support tool in other environmental management scenarios with requirements for public participation; enabling the views of a range of participants to be captured through online distribution and to generate discussion in workshop settings.

KEYWORDS:

Google Earth, ‘virtual globe’ tour, stakeholder engagement, Natural Flood Management, communication, Isbourne

1 INTRODUCTION

This paper presents the findings of exploratory research, based on a case study for a catchment in the early stages of a Natural Flood Management (NFM) scheme where the potential has been determined but the specific interventions are yet to be identified. A Google Earth-based visualisation was developed to identify methods of effectively communicating the potential benefits of NFM in the catchment, including reducing flood risk and delivering wider ecological benefits (Environment Agency 2014). A local community catchment group was consulted during the development. Facilitated and non-facilitated settings were then used to evaluate the usability and effectiveness of the visualisation and its potential for improving the communication of complex catchment information and encouraging engagement with an NFM project in its early stages.

NFM covers a set of interventions and soft engineering approaches that work to attenuate the flow of water in river catchments, by manipulating runoff pathways and in-channel hydraulic flow regimes (SEPA 2015). Aiming to reduce flood risk with a suite of nature-based techniques, it could be used independently or applied alongside conventional measures (Wilkinson *et al.* 2014). Unlike hard engineered flood defences (i.e. levees and walls), which tend to focus on the use of single sites to protect large areas, NFM uses multiple interventions over a wider landscape (i.e. catchment scale), building on natural landscape characteristics to achieve a targeted threshold of change (SEPA 2015). It also has potential to provide multiple benefits for water quality, biodiversity and society (Wentworth 2011).

Considerable interest has been generated by recent schemes in the UK, such as Pickering, North Yorkshire (Forestry Commission 2017) and Stroud, Gloucestershire (Stroud District Council 2017). This provided the catalyst for financial backing for NFM from the UK Government, with a £15 million government commitment from the Department for the Environment, Food and Rural Affairs (Kaminski 2016). Recent research using modelling approaches has focussed on the effectiveness of NFM interventions; engineered log jams and woody debris (Dixon *et al.* 2016; Thomas & Nisbet, 2012), forest restoration (Dixon *et al.* 2016), land management (O'Donnell *et al.* 2011) and mixed catchment approaches (Metcalfe *et al.* 2017). Building this evidence-base is required (Environment Agency 2017; Lane 2017), and also needs to consider the wider benefits (Iacob, 2014; Wilkinson *et al.* 2014) and to identify suitable methods of communication to engender positive stakeholder engagement, including the potential for employing computer-based approaches and visual aids (Environment Agency 2014).

Achieving early engagement with stakeholders, and maintaining their support, is a critical component of NFM planning (Ball 2008; Reed 2008; Reed *et al.* 2014), as the implementation of a range of measures across a catchment requires a collaborative partnership approach to be successful (Wentworth 2011). Stakeholders include anyone with an interest in or concern with an environmental decision-making process (Reed 2008; Whitman et al. 2015) and may include people who are not directly associated with a catchment. It is important to involve a wide range of diverse interest groups (including wildlife and landscape organisations, local authorities, landowners, farmers and the wider community) and to try to incorporate, as far as possible, all stakeholder knowledge and values (Ball 2008; Evers *et al.* 2016; Richards *et al.* 2017; Sterling *et al.* 2017). 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. Holstead *et al.* (2017) found that 60% of farmers surveyed about NFM uptake in Scotland had never heard of NFM, or had limited knowledge of it, with doubt from those familiar with the term about how their actions could have an impact downstream. Local stakeholder involvement is also central to the policy directives of both the European Union Water Framework (2000/60/EC) Directive (WFD) and Floods (2007/60/EC) Directive, introduced to protect water bodies in Europe, which recognise the potential role of the land in retaining water.

Raising awareness of flood risk may not be easy, particularly where there is perceived blame or a lack of direct experience (Hopkins & Warburton 2015), but this can be improved with the participation of a wide range of stakeholders (Bracken *et al.* 2016). Communication and access to data are recognised as barriers to stakeholder engagement and implementation of NFM (Waylen *et al.* 2017). Therefore, widening and improving participation could be linked to development of better, more accessible methods of communicating the rich and varied spatial information associated with both catchments and NFM projects.

Disciplines related to NFM are conventionally communicated to stakeholders *via* formats familiar to expert users (e.g. technical reports, static maps, statistical data) (Grainger *et al.* 2016; Lovett *et al.* 2015). There is a need to communicate more effectively to non-experts in an accessible, transparent, and engaging way both to promote engagement in an NFM scheme, and to improve understanding of the issues among stakeholders (and thus the overall quality of the decision-making) (Grainger *et al.* 2016). Spatial information, which is key in environmental decision-making, no longer needs to be confined to paper maps but can be viewed and analysed interactively using Geographical Information Systems (GIS) software. Access to GIS-based technology is no longer restricted to experts, with ubiquitous web-based mapping systems and bespoke Public Participation/Participatory GIS projects enabling communities to view and map spatial information, expanding access to data used for research and decision-making (Brown & Kyttä 2014). However, access to information alone is not enough; it must be communicated sufficiently clearly to be understood by non-expert users for it to be employed effectively in participatory decision-making scenarios (Defra 2003; Smith *et al.* 2013).

Spatial environmental data can be visualised using three-dimensional (3D) computer-based systems, created using GIS or specialist landscape visualisation software, or through a ‘virtual globe’ approach where data can be overlaid on a freely-available 3D representation of the Earth based on satellite imagery (Lovett *et al.* 2015; Sheppard & Cizek 2009). By representing data in this way, two-dimensional (2D) spatial data that might previously be considered ‘abstract’ can be made more meaningful and accessible, and these types of visualisation can help features to become more “seeable to the eye” (Grainger *et al.* 2016, 301). Such visualisations have been recognised to attract stakeholders by connecting them with familiar environments and engaging their sense of place (Newell & Canessa 2015), providing they are deemed to be credible (i.e. not being misleading and using appropriate levels of realism), salient, and legitimate (Lovett *et al.* 2015). Ultimately visualisations will only be as helpful as the information they contain or the scenario in which they are applied, and they must be scrutinised, evaluated and discussed to maintain legitimacy and engagement throughout the decision-making process (Lovett *et al.* 2015; Schroth *et al.* 2015; Todd *et al.* 2014).

This paper describes a study utilising the Google Earth web-based platform, which offers the ability to view spatial data and objects geo-located onto a satellite image base map *via* a virtual ‘tour’ through a 3D landscape (Harwood *et al.* 2015; Schroth *et al.* 2011). These tours can be shared freely over the internet, and the ubiquity of Google

Earth offers the potential for interaction with large numbers of people at varying geographical scales (Harwood *et al.* 2015; McCall & Dunn 2012; Pettit *et al.* 2011; Schroth *et al.* 2011; Sheppard & Cizek 2009). Google Earth ‘virtual globe’ tours have been shown to raise community awareness in both facilitated workshops (Pettit *et al.* 2011; Schroth *et al.* 2011) and remote online settings (Harwood *et al.* 2015; Pettit *et al.* 2011), and can be useful for strategic planning (Pettit *et al.* 2011) and environmental education (Harwood *et al.* 2015). The approach has the potential to change the traditional relationship between experts and the lay public in decision-making scenarios (Lange 2011).

The aim of this paper is to explore the potential role of a Google Earth ‘virtual globe’ tour in the early development stages of a NFM scheme. It considers the extent to which this type of interactive 3D landscape visualisation can enhance the communication of spatial data related to NFM and promote early stakeholder engagement in such projects.

2 STUDY AREA

This research used the River Isbourne catchment as a case study. The Isbourne flows in a northerly direction for 30km through Gloucestershire and Worcestershire, UK, with several watercourses joining along its length before converging with the River Avon at Evesham. A large part of the 88 km^2 catchment (Figure 1) sits within the Cotswolds Area of Outstanding Natural Beauty (AONB) which is subject to planning and management guidelines (Cotswolds AONB 2017).

The catchment contains a range of designated areas including priority habitats, ancient woodlands and a Site of Special Scientific Interest (SSSI). The Isbourne originates from springs rising on the valley sides below the permeable limestone geology of a steep escarpment approximately 300m above sea level. The river has many historical industrial and agricultural features, especially associated with water power generation for milling, some of which are still in use (Lovatt 2013). There is a history of flood events, with significant flooding occurring in July 2007. The Isbourne Catchment Group (ICG), established in response to these floods, has been working alongside the Environment Agency and the University of Gloucestershire to promote the implementation of NFM interventions to reduce flooding. In 2017, UK Government funding was secured to meet this aim (Defra 2017).

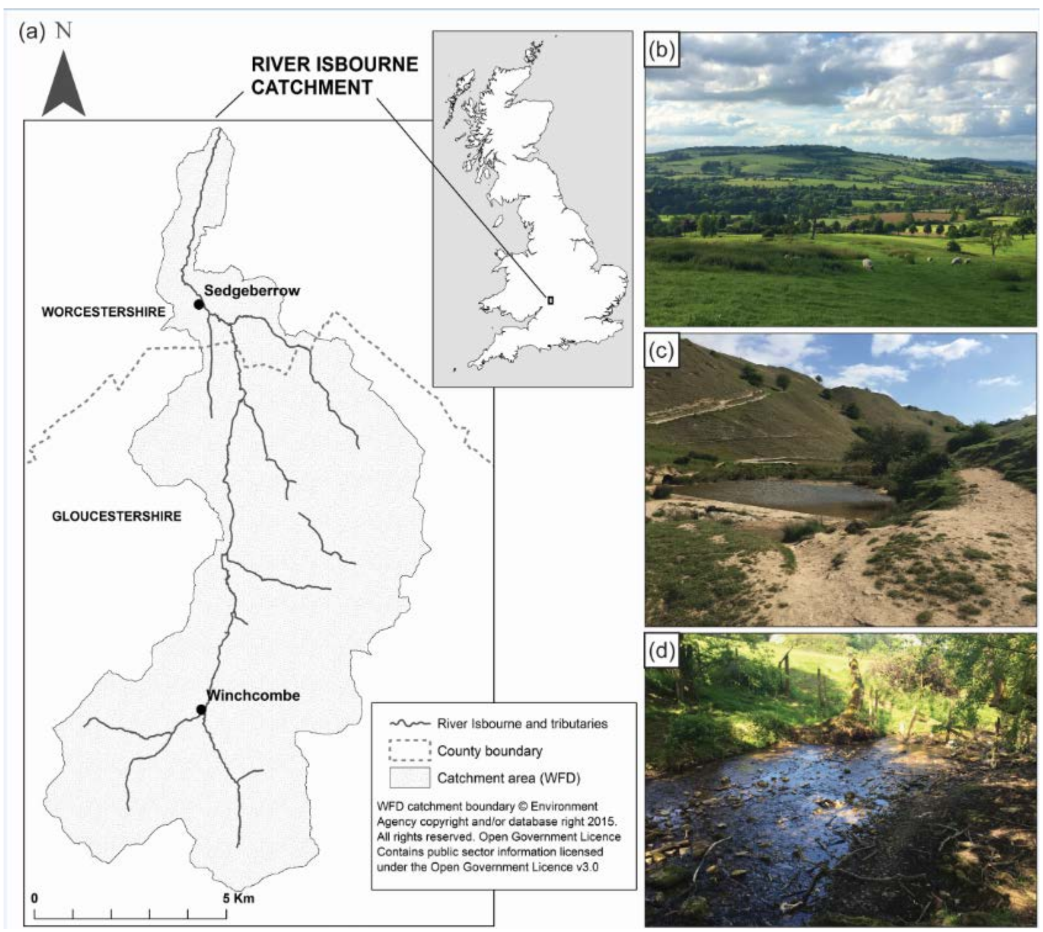

Figure 1 (a) Map showing the location and catchment boundary of the River Isbourne, and photographs of (b) the scenery in the upper catchment, (c) the source of the Isbourne on Cleeve Hill, and (d) a section of the river

3 METHODS

A Google Earth ‘virtual globe’ tour was created to highlight key features of the area and the potential to implement NFM in the catchment. The technical components and the content of the tour were evaluated through end-user assessment, using an online survey in two facilitated group sessions, where the participants were observed and guided through the process, and in a non-facilitated environment where participants downloaded and explored the tour independently on their own computers.

3.1 Google Earth ‘virtual globe’ tours

‘Virtual globes’, viewed on flat 2D screens, provide users with a digital representation of the Earths’ surface in 3D (Elvidge & Tuttle 2008), which can be viewed from different angles and altitudes. Google Earth is a freely-available, online ‘virtual globe’ platform that enables users to view seamless satellite imagery of the entire Earth (Ballagh *et al.* 2011) and allows interactive exploration of spatial and temporal changes at different scales and perspectives (Ballagh *et al.* 2011; Tooth 2015). It has a place name search function and tools to annotate locations with placemarks, labels, and photographs, and can facilitate the import of external spatial data (including GPS files) (Google Earth Outreach 2017). Animated ‘virtual globe’ tours can be used to create navigated ‘fly-throughs’, where users are taken on a predetermined journey through the landscape, pausing at specified locations to view added information/multimedia. Users can have some degree of control over the tours, including the ability to pause, rewind, and fast-forward (Harwood *et al.* 2015).

Simple features can be created directly on the Google Earth platform and saved as Keyhole Markup Language (KML) files; this open and readable XML-based scripting language is designed for spatial data management and visualisation in web-based systems, and is structured using a set of specific components, known as elements. Point, polygon, line, and 3D model elements have geographical locations (coordinates) associated with them. Ground overlays can be draped over the base imagery according to defined latitude and longitude, and screen overlays enable images to be visible at specified locations on the screen (see Harwood *et al.* 2015 for further information on this). Basic animated tours can be created without advanced programming knowledge or additional specialist software, though more complex tours involving precise navigation and complex multimedia content, and the addition of external GIS data, require a greater level of skill to produce (Harwood *et al.* 2015). However once these tours have been developed they can be reviewed and updated by non-experts with appropriate guidance. For this research, the text editor Notepad++ (v7.3.2) was used for scripting KML code, enabling the customisation of components and the addition of bespoke styling and animated tour instructions that went beyond the basic functions of the Google Earth platform (see Google Developers 2016; Wernecke 2009 for further information on KML scripting). The KML script, containing the tour animation instructions and associated data, was zipped to create a KMZ archive that can be easily distributed online (provided as Supporting Information 1).

The manipulation and analysis of GIS datasets was undertaken in ArcMap v10.4.1; this included conversion of shapefiles to KML, transforming the data from the projected British National Grid (EPSG: 27700) to the geographic WGS84 (EPSG: 4326) coordinate reference system used by Google Earth. The tour was created using Google Earth Pro (v7.1.7.2606) and can be viewed using desktop versions 6 or 7; at the time of writing the Google Earth mobile app and desktop v9 for Google Chrome did not support 'virtual globe' tours.

3.2 Tour design

When designing the tour, a collaborative approach was undertaken involving direct consultation with the ICG (in a workshop with 7 participants) to identify stakeholderinformation requirements at the outset, to capture local knowledge and opinion, and to enhance the transparency and legitimacy of the process (Lovett *et al.* 2015). After demonstrating a short prototype tour of the Isbourne catchment to demonstrate the functionality and components of Google Earth tours, attendees provided feedback on the content and styling through a short questionnaire and discussion. The final, longer tour was designed to provide an overview of the physical characteristics of the catchment, the administrative complexity (i.e. crosses two county and 12 parish boundaries) and outline flooding-related issues, as prioritised by a prior scoping report of the catchment (Clarke *et al.* 2016).

The design and development of the tour took into consideration previous recommendations on producing visualisations for collaborative environmental management (Lovett *et al.* 2015; Sheppard & Cizek 2009), including avoiding deliberate distortion of the landscape and being transparent about data sources. The data requirements identified by the ICG (and included in the final tour) are summarised in Table 1. To ensure accessibility, as the tour will ultimately be freely distributed online, efforts were made to use open licence data. The data sources were disclosed during the tour and links were provided to licence statements. Photographs were incorporated into placemarks along with text, figures and links to relevant websites. A decision was taken by members of the ICG to avoid the use of photographs showing the impact of the 2007 flooding, as these could be emotive for some residents.

Table 1: Summary of the information requirements and subsequent datasets included in the Google Earth tour of the Isbourne catchment

Information requirement	Datasets and other resources
Administrative boundaries	Ordnance Survey Boundary-Line (administrative boundaries): Counties, District Council and Parish Council boundaries
Catchment boundary	National River Flow Archive catchment boundary (used with permission of Centre for Ecology and Hydrology)
Catchment topography	Google Earth imagery and screenshot elevation profiles
Designated areas	Natural England: AONB, SSSI, Priority Habitats, Ancient Woodland
Geology	British Geological Survey (BGS) 1:650,000 Bedrock
Historical features	Historic England: Parks and Gardens, Listed Buildings
Historic water features	Digitised data created by University of Gloucestershire
Land use	CORINE Land Cover 2012
Placemarks and railway line	Manually created on Google Earth
Watercourses	Ordnance Survey OpenMap Local: Rivers and Surface Water
Water quality	EA: Water Framework Directive status (summarised extract within a placemark)
2007 Flood extent	EA Recorded Flood Outline

The tour functionality was influenced by practical considerations (Harwood *et al.* 2015); animating at suitable speed and building in pauses to allow viewers to digest information at their own pace before manually restarting (Figure 2). Opening screen overlays (using JPEG images created with MS Publisher) providing clear instructions for navigating the tour (Figure 2) were incorporated to improve usability (Bresciani & Eppler 2015), especially for individuals with no prior experience of Google Earth. These included guidance for disabling superfluous and potentially distracting content before viewing (e.g. photos, place names, and roads). Placemarks were designed to pop up at locations throughout the tour to signpost the relevant facts. Inset location maps, to aid orientation, and Google Earth elevation profiles were created using the screenshot facility and incorporated as screen overlays (Figure 2). The duration of the final tour was 9 minutes.

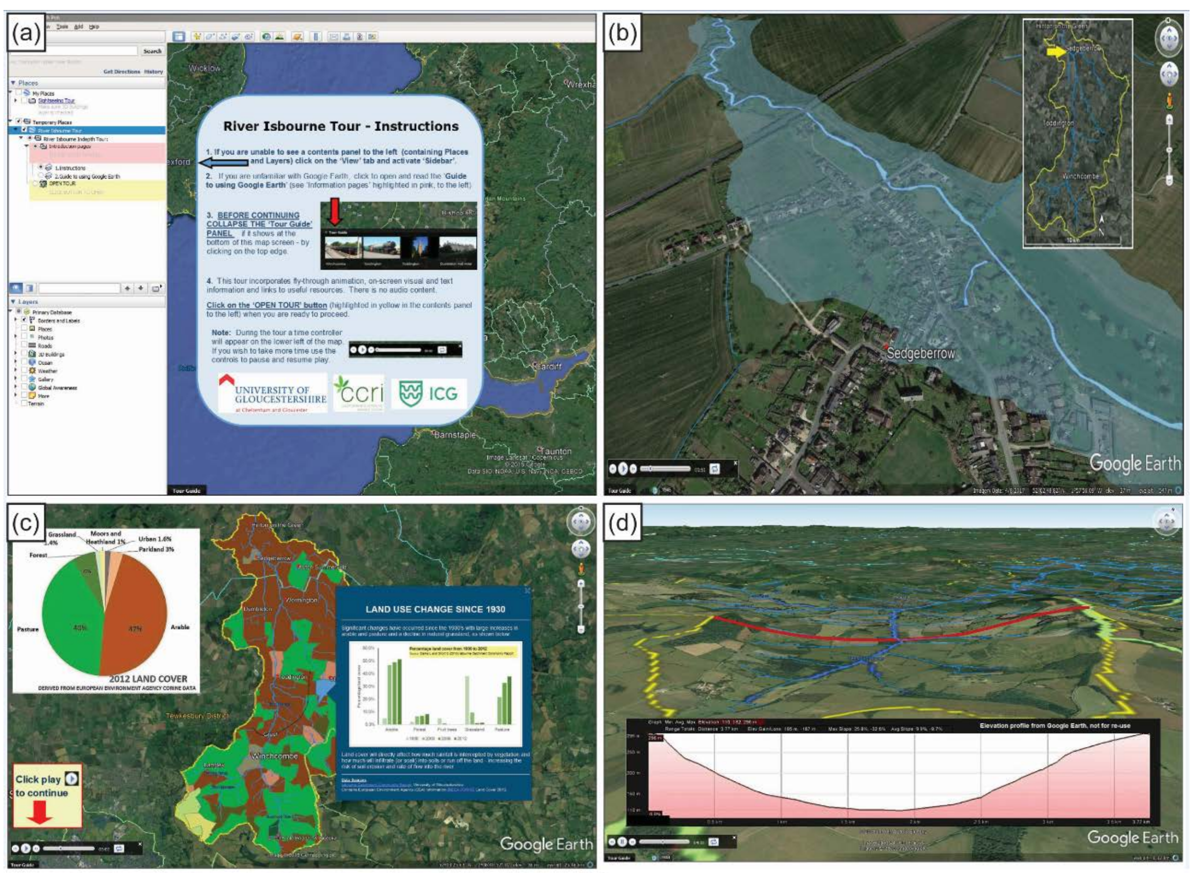

Figure 2 Screenshots showing examples of the Google Earth tour: (a) screen overlays,

3.3 End-user evaluation

Forty-five individuals participated in the end-user evaluation, completing an online survey developed and hosted on the Bristol Online Survey website (https://www.onlinesurveys.ac.uk/). This was undertaken in two settings; facilitated groups (F) (n=20) including an academic workshop (n=10) and another with members of the ICG and local stakeholders (n=10), and a non-facilitated online survey (NF) (n=25) with participants recruited through a blog post, social media and email. The results from the two settings have been analysed separately to evaluate the influence of guidance and support on the user experience. The end-user evaluation questionnaire (Berry *et al.* 2011; Schroth *et al.* 2015; Tullis & Albert 2013) was designed to capture participants' opinions on *usability* (the ease of use) to identify issues that may affect the adoption of the visualisation format (Bresciani & Eppler 2015), *effectiveness* (how useful they found the individual components of the Google Earth format) and *helpfulness* (how well the format and content communicated information about the features and issues influencing the catchment). The survey was designed to capture the opinions of those both familiar and unfamiliar with the subject and the location. The respondents were provided with instructions on how to access the tour using a link to download and launch the KMZ file. The survey incorporated sections to be completed before (to capture participant characteristics) and after viewing the tour using a combination of closed-ended questions, with 6-point Likert scale responses (1 to 6: low to high), and open-ended questions with free-text responses. Respondents were also asked about their perceptions of the impact of NFM on the environment and their interest in finding out more about it.

4 RESULTS

Both the F and NF groups were balanced in terms of gender, age and whether participants lived in rural or urban areas (full details provided in the Supporting Information 2). A higher proportion of the F group lived in or had visited the Isbourne catchment (80%) compared with the NF group (32%). Participants in the F group were academics (25%), students (25%), professionals (30%) or retirees (20%) whereas in the NF group the main occupation category was professional (48%). The surveys captured a range of Google Earth experience with the majority having used it to view places (47% occasionally and 31% frequently) and while some of the NF respondents had higher skill levels, with 32% using it to generate content, the views of less experienced participants were captured in both settings.

4.1 Usability

Figure 3a shows that the usability ratings in both settings were high (mean rating >4) for *ease of use*, *visual clarity* and *level of trust*. The ratings for *presentation speed* were lower (mean rating: F=3.4, NF=3.1), indicating that participants found the tour slightly slow; alternatively it could reflect the lack of a neutral rating. The mean ratings for *effectiveness* of the Google Earth components were all high (see Figure 3b); above 4 for both F and NF. The lowest ratings were for the *close up/perspective views* and the *visual appearance of the ground and surface features*, with the highest ratings for the *pop-up information balloons* . The mean ratings for both usability and effectiveness of the components were consistently higher (and the variance lower) for F than NF.

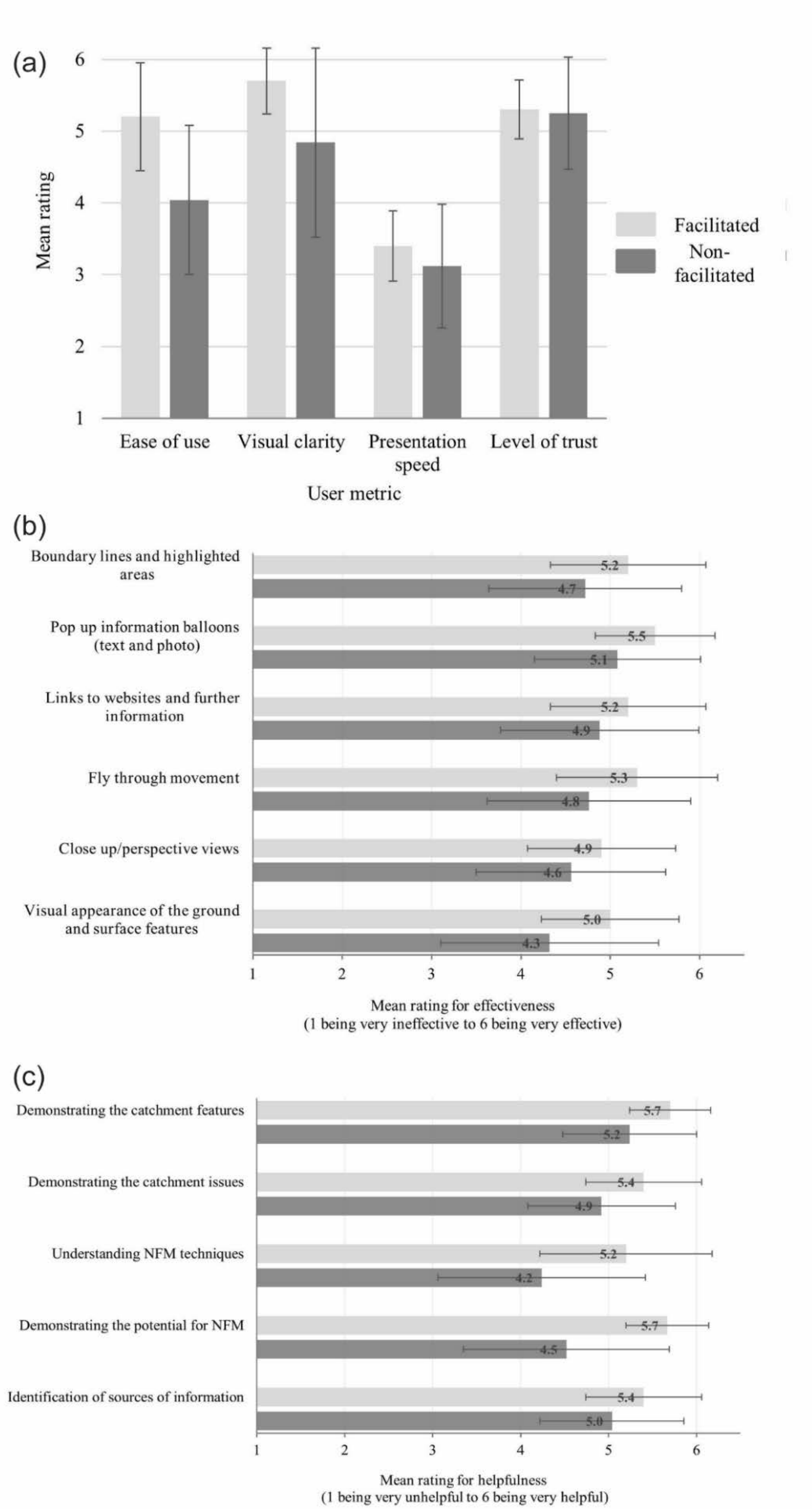

Figure 3 Survey responses summarising the (a) usability, (b) effectiveness of the tour element, and (c) helpfulness of the tour for the facilitated respondents, F, and the non- facilitated online respondents, NF

Comments made in free text questions supported the usability metrics (Table 2). Participants (from both F and NF) commented that they liked the pop up placemarks with interactivity provided through links to further information (n=10), the ability to see the area covered by the 2007 flood (n=9) and boundary lines on the landscape imagery, and the ability to pause and rewind (n=6) in addition to the fly through navigation.

Table 2: A representative selection of quotes from the end-user surveys (F and NF)

Positive
"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"
"The tour was rich in information and there were different levels which could be accessed according to need"
"Interesting to see the network being identified, and the issues that faced different areas - the flood risk was very clear"
"Visualising where the water came from and how the surrounding land would impact this"
Negative
"You need to be able to see the topography more. It took some time to realise what were hills and what was flatter"
"Too much information for one tour when my personal interest would only have been focused on one area"
"On some of the images - cross sections bit - the screen image was not very good"
"Perhaps there could have been more information / examples about NFM in this catchment"

4.2 Communicating catchment features and NFM

Figure 3c shows that for the helpfulness for communication the mean ratings in both F and NF settings were high (>4), with the highest mean rating given for *demonstrating the catchment features* followed by the *identification of sources of information*, and the lowest for the *understanding of NFM techniques*. While sample size limited the analysis of participants' characteristics, an apparent relationship between participants' prior knowledge of NFM and their rating of *helpfulness for demonstrating NFM techniques* was noted; 21% of those with *a lot of prior NFM knowledge* rated it above 5, whereas 75% of those *knowing nothing*, and 58% of those *knowing a little*, rated it above 5. The rating for *demonstrating the features and issues of the catchment* was also higher among those with some familiarity of the area; a higher proportion of participants who reside or visit occasionally selected a rating of 5 or 6 for demonstrating the features (96%) than those who did not previously know the area (76%).

The respondents comments (Table 2) also indicated that the tour content was effective in providing context and comprehensive coverage showing a "*highly descriptive view of the area"* and *"the relationship of features*". Some of the content was less well-received, including negative comments on the slope cross-sections (n=3) and 3D topography,with one respondent suggesting that "*increased vertical exaggeration of the land surface might improve the perspective views"* - this was considered, and rejected, during the design stage to avoid extreme misrepresentation of the landscape (Sheppard and Cizek 2009). Others requested more photographs to improve their understanding of the area and the 2007 flooding (n=7), and more specific information on NFM techniques and where they could be used in the catchment (n=4).

After viewing the tour, participants perceived that NFM (Figure 4) would be beneficial for flood management (combined=98%; F=100%, NF= 96%) and improving water quality (combined=89%; F=90%, NF= 88%). There was greater uncertainty regarding other environmental impacts, with 20% of participants unsure of the impact it could have on farming, demonstrating the complexity of these issues. There were no perceived detrimental impacts of NFM highlighted in the F survey, while in the NF survey the impact of NFM was perceived as detrimental to landscape views (9%) and to farming (16%). These questions were only asked after viewing the tour, therefore it was not clear how much the tour influenced previously held opinions.

Participants were also asked about their level of interest in finding out more about the benefits and opportunities for NFM, and this received a positive response (*very interested*: F=75% NF=38% and *somewhat interested*: F=20% NF=58%), highlighting that the tour was successful as an engagement tool.

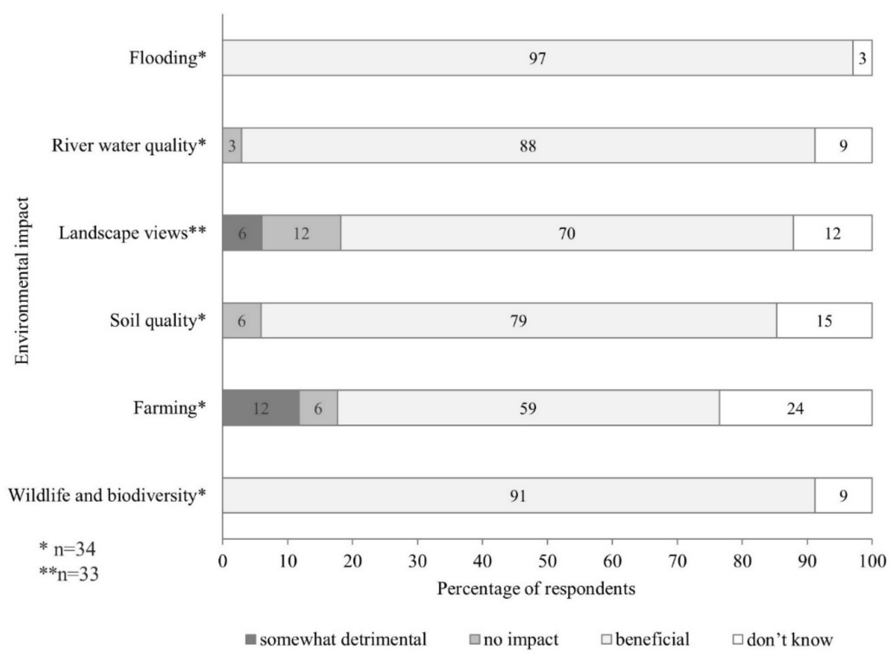

Figure 4 Perceptions of the impact of NFM for the facilitated (F) and the non-facilitated online (NF) respondents combined.

4.3 ICG responses

Feedback from the F session containing ICG members and related parties was positive. They rated the tour more highly than those from the NF setting for communicating both the features of the catchment (mean = 5.6) and NFM techniques (mean = 4.8). In the free text comments participants noted that the tour was "*pitched at an appropriate level*" providing a "v*ery good introduction to the catchment*" and was "*a much more effective method of communication than a written report*", as well as providing a "*useful way of engaging the community*". There was keen interest in how the tool could be developed as the NFM project progressed, including adding specific NFM interventions as opportunities are identified and implemented, as well as expanding the spatial coverage. The ICG was positive about hosting the tours on their website for the public to access and acknowledged that this would not replace 2D maps and reports but would be a valuable alternative source of information for the group.

5 DISCUSSION

5.1 Creating 'virtual globe' tours

A Google Earth 'virtual globe' tour was chosen as the landscape visualisation tool in this research due to its accessibility, interactivity, and capacity to stimulate interest in environmental decision-making scenarios (Pettit *et al.* 2011; Sheppard & Cizek 2009). The technology for creating these tours is ubiquitous and accessible, but considerable effort and expert-level GIS knowledge is required to produce a complex tour like the one in this study. Basic features can be created directly in Google Earth, but non-expert users would be likely to struggle with GIS data acquisition, management and processing. KML scripting would also present a significant challenge to a lay-person, and, although it can be learned by those with no previous programming experience, it does require a significant commitment (Harwood *et al.* 2015). However, once the tour has been created it can be viewed, reviewed and adapted with relative ease by those with some prior knowledge.

The KMZ file of the tour was small enough (8.26 MB) to allow easy online distribution, enabling a lay audience to access the data (Phadke 2010; Sheppard & Cizek 2009). Designed to demonstrate existing catchment features and relevant historic change, flooding and water quality issues, the tour directed viewer attention to a range of relevant information covering the catchment at different scales, and using customized navigation. It also provided interactivity, enabling the viewer to explore information by following embedded links to relevant websites according to their interests.

The use of open data to allow unlimited online distribution of GIS-based landscape visualisations can impose restrictions (Berry *et al.* 2011). In this study, for example, the historic land cover data required to demonstrate the impact of land-use change on catchment processes, was not freely available. EU CORINE data (showing dominant land cover types) was only available between 2000 and 2012 at the time of creation, and so could not be used to visualise long-term changes. Accessibility of soil and geology data was also restricted, with BGS Permeability and Soil Parent Material Model not available as open data. Data for some aspects may also not exist; gauge data for river levels[1], water quality[2] and rainfall[3] would have been useful additions but these were not available for the Isbourne. To fully realise the potential of technological approaches to improving communication and decision-making in environmental planning there must also be a ‘freeing-up’ of digital spatial data *via* open licenses. Similarly, image quality and 3D coverage on Google Earth is improving (Schroth et al. 2011), but there was limited recent satellite coverage for the Isbourne catchment (in 2018 imagery from 2017 was available for the upper catchment but restricted to 2005-2007 for the remainder of the catchment). The resolution was variable, and a lack of available historic imagery restricted the investigation of historic change. Higher-quality and more up-to-date imagery, including the new 3D models (i.e. 3D buildings and vegetation) available for some places in Google Earth, may enhance the visual appearance of such tours.

A recognised limitation of the ‘virtual globe’ tour approach (and indeed any landscape visualisation) is developer bias (Sheppard & Cizek 2009), which can be minimised by incorporating the views of a broad range of stakeholders (Grainger *et al.* 2016). For this reason, a significant effort was made to engage with identified and active stakeholders from the ICG early in the design stages to obtain feedback on content and styling. However, even with high-quality stakeholder input, it was impossible to maintain impartiality throughout the design process (i.e. decisions on styling elements of the tour

[1] In the UK river gauge data are freely available from the National River Flow Archive: https://nrfa.ceh.ac.uk/
[2] In the UK water quality data are accessed through the EA Catchment Data Explorer: https://environment.data.gov.uk/catchment-planning/
[3] Rainfall data are provided by the Meterological Office in the UK: https://www.metoffice.gov.uk/climate/uk/data/ukcp09/datasets

were taken without consultation and some layers that the authors felt were important were included despite not being prioritised by the ICG); setting a goal of complete impartiality is unrealistic.

A design aim suggested by Harwood *et al.* (2015) was to make the ‘virtual globe’ tour easy to modify. Here several data layers were animated in and out of view on the map during the navigation to reduce the level of on-screen detail. Preparing a range of simplified tours could make future updates easier but might reduce the ability to communicate the complexity of, and relationships between, features; and would be more effort for the viewer to download. Offering pre-recorded tours in video format, *via* YouTube or a similar platform, could be investigated to circumvent the need for Google Earth access and set-up. These can be created with little additional effort and could make the tours more accessible to a wider audience, but would limit interactivity.

5.2 Usability

Overall, this study found that the participants enjoyed the tour, finding it easy to use and visually clear. Wider participation may have reduced the variance in ratings; nevertheless, previous research has found that 80% of software usability issues can be identified by as few as five participants (Tullis & Albert 2013). The results were notably different for the two survey settings, with higher ratings in the facilitated group (F) for *usability*, the *effectiveness of tour elements,* and *helpfulness for communication*. Incorporating a broad range of backgrounds in evaluation is crucial to reduce the risk of bias (Glaas *et al.* 2017; Pettit *et al.* 2011), and a group environment limits the results to those participants (Wissen *et al.* 2008). However, the end-user processes applied here highlight the benefits of evaluating the tour in a facilitated workshop setting prior to online dissemination; this enables critical usability issues to be identified before a wider roll-out and ensures that collaboration is still being seen to be done further on in the design process. The group forum can also provide technical support for those participants who are less ‘tech-savvy’.

Feedback indicated that although all elements of the tour were effective, individuals did have different preferences (e.g. interactivity levels) for accessing information types within the tour (recognised by Schroth *et al.* 2011). The pop-up information balloons (placemarks) received the highest ratings, demonstrating that participants appreciated the addition of text, photographs and the ability to access links to relevant websites. These placemarks also allowed full disclosure of data sources, aiding transparency and trust in information, a key requirement to aid the legitimacy of landscape visualisations (Lovett *et al.* 2015; Sheppard & Cizek 2009). Interactivity was rated highly; being ‘free’ to explore different resources is a key aspect, and this is an area where fully-interactive tours may have an advantage over pre-recorded video tours. Of course, as complexity increases, so does the risk of deterring or even excluding some people from the process, so the most effective approach is likely to involve a mix of media format types (Berry & Higgs 2012).

What is apparent, from observations and feedback in the facilitated group session, is that a clear set of opening instructions is vital for ensuring that people can engage with

Google Earth tours without supervision. The lack of support for KMZ files on the latest Google Earth web and app versions may limit accessibility if participants do not wish to download the desktop version or work with a tablet rather than a computer.

There are issues with appearance in Google Earth that cannot be eliminated (i.e. blurring and pixellation of elements such as boundary lines, particularly in close-ups and fly-throughs) due to the processing power of individual computers, the monitor/screen resolution being used and the performance of the Google Earth platform itself. Despite this, *visual clarity* was well rated. Follow-up meetings could enable refinements to address presentation issues, such as animation speed (Harwood *et al.* 2015; Sheppard *et al.* 2011); however, balancing iterative user feedback with project/design practicalities can be problematic (Grainger *et al.* 2016).

5.3 Communicating catchment features and NFM

In comparison to conventional methods of communicating NFM, such as written reports and maps, the Google Earth tour has some significant advantages in the visually engaging way of learning about catchment processes and the landscape. The novel and interactive way in which often complex 2D spatial data are ‘brought to life’ using virtual tours clearly has good potential for educating people about, and engaging them with, their river catchments (Pettit *et al.*, 2011; Sheppard & Cizek, 2009). Survey responses indicated that it was helpful for communicating both the catchment features and issues impacting the Isbourne, as well as adding context; with participants able to see the relationship between features and the impact of flooding, and also to understand causal influences such as topography and land use change. The tour was also helpful in demonstrating the techniques and potential for NFM, with participants remarking on the complexity and range of interests and agencies involved in the development of the NFM project. Some respondents expected more specific information regarding intended locations and techniques; a clear set of project objectives should therefore be included in the introduction to the tour.

This tour was designed to improve understanding of the catchment area and communicate the potential benefits of NFM rather than propose specific NFM interventions (before they had been finalised with the EA and relevant landowners), thus avoiding any emotive or misleading future landscape scenarios (Sheppard & Cizek 2009). One can imagine, for example, that a farmer who is yet to be engaged in the process might take exception to seeing his field covered in 3D tree models as part of a possible future NFM planning scenario. That said, the next step in this research is to evaluate the use of 3D landscape visualisations as a decision-making aid, where they could be used to display specific proposed interventions and alternative NFM planning scenarios at a more advanced state in the planning process. This can only be done within a robust ethical framework, and any data or materials that have the potential to mislead or cause a negative reaction should not be included.

The tour demonstrated the potential for improving the communication of information and promoting early stakeholder engagement (Harwood *et al.* 2015; Schroth *et al.* 2011). Viewers having less prior knowledge of NFM found the tour more helpful in providing catchment information, showing its usefulness for education and improving understanding. After viewing the tour, participants were interested in finding out more about NFM; follow-up discussions and a commitment of resources will be required to both motivate and to maintain engagement (Todd *et al.* 2014).

There was a clear perception among all survey respondents that NFM would be beneficial for alleviating flooding and improving water quality, but there was less consensus regarding the potential impact on landscape aesthetics or farming. These issues were more difficult to represent on the base map without identifying specific target locations or techniques, and although additional information was provided in the pop-ups and screen overlays, these may not have been the most effective forms of communication. Remote participation does limit the opportunity for in-depth discussion and co-production of knowledge (Lovett *et al.* 2015), which can be more achievable in a workshop/focus group (Pettit *et al.* 2011; Schroth *et al.* 2011); thus using the tour in a facilitated setting can provide a useful forum to start conversations about aspects of the NFM process, whilst in a non-facilitated setting further communication or follow-up engagement may be required to build on feedback and ideas and achieve a level of consensus.

6 CONCLUSION

This research has explored the potential of a Google Earth ‘virtual globe’ tour for enhancing communication of spatial data in a NFM planning scenario, using the River Isbourne Catchment, UK as a case study. Survey results indicated that the tour was helpful for developing an understanding of the catchment, its features and the issues it faces, as well as for demonstrating the potential of different NFM measures, particularly for those participants with no prior knowledge; it helped participants to recognise the complexity of solutions in the catchment and the number of agencies involved. This supports the finding of previous related research - that Google Earth is useful for enhancing environmental education, by helping to improve the communication of complex spatial data to lay audiences (Harwood *et al.* 2015; Schroth *et al.* 2011). This has the potential to impact on the future of collaborative environmental management, because having a diverse group of well-informed, highly-engaged stakeholders is more likely to lead to better decision-making (Grainger *et al.* 2016; Reed 2008; Wilkinson *et al.* 2014).

Although not simple to develop, the tour itself was accessible; it was suitable for online distribution using relevant available open data and, using custom navigation and views, was both useable and clear. The process of creating the tour ultimately needs to be expert led, with input and guidance from appropriate stakeholders, but the end result can be used to engage a wide range of people, from those who are completely new to a topic to those with more specialist knowledge. This paper has discussed the potential of using the tour in the initial stages of project planning to educate people about the catchment and NFM as a concept; however, as this project progresses the tour will be used to engage stakeholders actively through incorporation of supplementary spatial data and details of the NFM interventions prior to and after implementation. There is also potential to embed the tour as part of the decision-making process; to test alternative planning scenarios and interventions, and to gather stakeholder feedback.

Feedback indicated that interactivity of the tour was valued by the respondents, but there are other output formats available (such as videos, audio commentary and screenshots) that could appeal to those unable or unwilling to use the desktop version of Google Earth; once the tour is developed it takes minimal additional effort to create these. Future research could investigate the importance of the interactive features by comparing the experience with that of a pre-recorded video version and the effect of adding audio commentary. Ongoing review of support for the Google Earth desktop platform is required; the mobile device apps and web version (v.9) currently have limited KML support, which may impact on future public interest in accessing ‘virtual globe’ tours. Alternative landscape visualisation tools could be also be investigated to gain further insight into user preferences for the communication of catchment features and NFM, exploring the impact of levels of realism and interactivity (Lovett *et al.*, 2015); this could include GIS-based story maps, and specialist 3D landscape visualisation software (e.g. Visual Nature Studio) which can render landscape models with higher levels of realism, particularly ground textures and surface features such as vegetation and trees. The use of mobile computing and smartphones coupled with augmented reality (AR) technology, enabling a multi-sensory on-site experience, also has potential for engaging people within a facilitated session for those with access to the appropriate technology (Gill and Lange 2015).

For the tour created in this paper, the success will ultimately depend on the ability to communicate the potential benefits for incorporating NFM in the Isbourne catchment, to generate both interest and long-term involvement from a wide range of stakeholders. The UK Government has committed to support more than 50 NFM projects across the country as part of its drive to roll out innovative techniques to reduce flood risk and build resilience (Kaminski 2016). The ‘virtual globe’ tour approach could play an important role in the engagement process through the planning stages; improving access and assisting with the understanding of complex spatial information and helping to generate trust. In a facilitated environment the tour can be used to encourage discussion and gain feedback, whilst the ease of distributing the tour online allows for the capture of views and opinion from a wide variety of respondents; this approach could therefore become part of a wider toolkit of engagement and communication as part of the policy requirements for public participation.

REFERENCES

Ball T 2008 Management approaches to floodplain restoration and stakeholder engagement in the UK: a survey *Ecohydrology & Hydrobiology* 8 273-280 doi 10.2478/v10104-009-0021-0

Ballagh L M Raup B H Duerr R E Khalsa S J Helm C Fowler D and Gupte A 2011 Representing scientific data sets in KML: Methods and challenges *Computers and Geosciences* 37 57-64 doi 10.1016/j.cageo.2010.05.004

Berry R and Higgs G 2012 Gauging levels of public acceptance of the use of visualisation tools in promoting public participation; a case study of wind farm planning in South Wales, UK *Journal of Environmental Planning & Management* 55 229-251 doi 10.1080/09640568.2011.591925

Berry R Higgs G Fry R and Langford M 2011 Web-based GIS Approaches to Enhance Public Participation in Wind Farm Planning *Transactions in GIS* 15 147-172 doi 10.1111/j.1467-9671.2011.01240.x

Bracken L J Oughton E A Donaldson A Cook B Forrester J Spray C Cinderby S Passmore D and Bissett N 2016 Flood risk management, an approach to managing cross-border hazards *Natural Hazards* 82 217-240 doi 10.1007/s11069-016-2284-2

Bresciani S and Eppler M 2015 Extending tam to information visualization: A framework for evaluation *Electronic Journal of Information Systems Evaluation* 18 46-58

Brown G and Kyttä M 2014 Key issues and research priorities for public participation GIS (PPGIS): A synthesis based on empirical research *Applied Geography* 46 122-136 doi 10.1016/j.apgeog.2013.11.004

Clarke L Short C and Berry R 2016 *Isbourne Catchment Project: Scoping Study* Report to Isbourne Catchment Partnership & Environment Agency School of Natural and Social Sciences & CCRI, University of Gloucestershire: Gloucestershire, UK

Cotswolds AONB 2017 Planning, development and other consultations (http://www.cotswoldsaonb.org.uk/planning/land-management-advice/.html) Accessed 15 May 2018

Defra 2003 *Community and Public Participation: Risk Communication and Improving Decision-Making in Flood and Coastal Defence* R&D Technical Report FD2007/TR

Defra 2017 *Schemes across the country to receive £15 million of natural flood management funding* (https://www.gov.uk/government/news/schemes-across-the-country-to-receive-15-million-of-natural-flood-management-funding.html) Accessed 27 October 2017

Dixon S J Sear D A Odoni N A Sykes T and Lane S N 2016 The effects of river restoration on catchment scale flood risk and flood hydrology *Earth Surface Process and Landforms* 41 997-1008 doi 10.1002/esp.3919

Elvidge C D and Tuttle B T 2008 How virtual globes are revolutionizing Earth observation data access and integration *International Archives of the Photogrammetry Remote Sensing and Spatial Information Sciences* 37 137-140

Environment Agency 2014 *Delivering benefits through evidence: Working with natural processes to reduce flood risk. R&D framework: Initiation report* (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/338434/SC130004_R1.pdf) Accessed 26 October 2017

Environment Agency 2017 *Working with Natural Processes: Evidence Directory.* (https://www.gov.uk/government/publications/working-with-natural-processes-to-reduce-flood-risk.html) Accessed 3 November 2017

Evers M Jonoski A Almoradie A and Lange L 2016 Collaborative decision making in sustainable flood risk management: A socio-technical approach and tools for participatory governance *Environmental Science and Policy* 55 335-344 doi 10.1016/j.envsci.2015.09.009

Forestry Commission 2017 *Slowing the Flow at Pickering* (https://www.forestry.gov.uk/fr/slowingtheflow.html) Accessed 28 September 2017

Gill L and Lange E 2015 Getting virtual 3D landscapes out of the lab *Computers, Environment and Urban Systems* 54 356-362 doi 10.1016/j.compenvurbsys.2015.09.012

Glaas E Ballantyne A G Neset T-S and Linnér B-O 2017 Visualization for supporting individual climate change adaptation planning: Assessment of a web-based tool *Landscape and Urban Planning* 158 1-11 doi 10.1016/j.landurbplan.2016.09.018

Google Developers 2016 *Keyhole Markup Language-Reference* (https://developers.google.com/kml/documentation/kmlreference.html) Accessed 29 September 2017

Google Earth Outreach 2017 *Become a Google mapping expert* (https://www.google.com/earth/outreach/learn/.html) Accessed 16 October 2017

Grainger S Mao F and Buytaert W 2016 Environmental data visualisation for non-scientific contexts: Literature review and design framework *Environmental Modelling and Software* 85 299-318 doi 10.1016/j.envsoft.2016.09.004

Harwood A R Lovett A A and Turner J A 2015 Customising virtual globe tours to enhance community awareness of local landscape benefits *Landscape and Urban Planning* 142 106-119 doi 10.1016/j.landurbplan.2015.08.008

Holstead K L Kenyon W Rouillard J J Hopkins J and Galán-Díaz C 2017 Natural flood management from the farmer's perspective: criteria that affect uptake *Journal of Flood Risk Management* 10 205-218 doi 10.1111/jfr3.12129

Hopkins J and Warburton J 2015 Local perception of infrequent, extreme upland flash flooding: prisoners of experience? *Disasters* 39 546-569 doi 10.1111/disa.12120

Iacob O Rowan J S Brown I and Ellis C 2014 Evaluating wider benefits of natural flood management strategies: an ecosystem-based adaptation perspective *Hydrology Research* 45 774 doi 10.2166/nh.2014.184

Kaminski I 2016 The Ends Report. Government commits £15m to natural flood management *The Guardian* 25 November 2016

Lane S N 2017). Natural Flood Management *WIREs Water* 4(3) e1211 doi 10.1002/wat2.1211

Lange E 2011 99 volumes later: We can visualise. Now what? *Landscape and Urban Planning* 100 403-406 doi 10.1016/j.landurbplan.2011.02.016

Lovatt M 2013 *The River Isbourne: In the Service of Mankind* Amberley Publishing, Stroud

Lovett A Appleton K Warren-Kretzschmar B and von Haaren C 2015 Using 3D visualization methods in landscape planning: An evaluation of options and practical issues *Landscape and Urban Planning* 142 85-94 doi 10.1016/j.landurbplan.2015.02.021

McCall M K and Dunn C E 2012 Geo-information tools for participatory spatial planning: Fulfilling the criteria for ‘good’ governance? *Geoforum* 43 81-94 doi 10.1016/j.geoforum.2011.07.007

Metcalfe P Beven K Hankin B and Lamb R 2017 A modelling framework for evaluation of the hydrological impacts of nature-based approaches to flood risk management, with application to in-channel interventions across a 29-km2 scale catchment in the United Kingdom *Hydrological Processes* 31 1734-1748 doi 10.1002/hyp.11140

Newell R and Canessa R 2015 Seeing, believing, and feeling: The relationship between sense of place and geovisualization research *Spaces and Flows: An International Journal of Urban and Extra Urban Studies* 6 15-30

O’Donnell G Ewen J and O’Connell P E 2011 Sensitivity maps for impacts of land management on an extreme flood in the Hodder catchment, UK *Physics and Chemistry of the Earth* 36 630-637 doi 10.1016/j.pce.2011.06.005

Pettit C J Raymond C M Bryan B A and Lewis H 2011 Identifying strengths and weaknesses of landscape visualisation for effective communication of future alternatives *Landscape and Urban Planning* 100 231-241 doi 10.1016/j.landurbplan.2011.01.001

Phadke R 2010 Defending place in the Google Earth Age *Ethics, Place and Environment* 13 267-281

Reed M S 2008 Stakeholder participation for environmental management: A literature review *Biological Conservation* 141 2417-2431 doi 10.1016/j.biocon.2008.07.014

Reed M S Stringer L C Fazey I Evely A C and Kruijsen J H 2014 Five principles for the practice of knowledge exchange in environmental management *Journal of Environmental Management* 146 337-345 doi 10.1016/j.jenvman.2014.07.021

R**ichards D R Warren P H Maltby L and Moggridge H L** 2017 Awareness of greater numbers of ecosystem services affects preferences for floodplain management *Ecosystem Services* 24 138-146 doi 10.1016/j.ecoser.2017.02.001

Schroth O Pond E Campbell C Cizek P Bohus S and Sheppard R J 2011 Tool or Toy? Virtual Globes in Landscape Planning *Future Internet* 3 204-227

Schroth O Pond E and Sheppard S R 2015 Evaluating presentation formats of local climate change in community planning with regard to process and outcomes *Landscape and Urban Planning* 142 147-158 doi 10.1016/j.landurbplan.2015.03.011

SEPA 2015 *Natural Flood Management Handbook* Scottish Environmental Protection Agency, Sterling.

Sheppard S R and Cizek P 2009 The ethics of Google Earth: Crossing thresholds from spatial data to landscape visualisation *Journal of Environmental Management* 90 2102-2117 doi 10.1016/j.jenvman.2007.09.012

Sheppard S R Shaw A Flanders D Flanders D Burcha S Wiek A Carmichael J Robinson J and Cohene S 2011 Future visioning of local climate change: A framework for community engagement and planning with scenarios and visualisation *Futures* 43 400-412 doi 10.1016/j.futures.2011.01.009

Smith H M Wall G and Blackstock K L 2013 The role of map-based environmental information in supporting integration between river basin planning and spatial planning *Environmental Science and Policy* 30 81-89 doi 10.1016/j.envsci.2012.07.018

Sterling E J Betley E Sigouin A Gomez A Toomey A Cullmana G Malone C Pekord A Arengo F Blair M Filardie C Landrigan K and Porzecanskia A L 2017 Assessing the evidence for stakeholder engagement in biodiversity conservation *Biological Conservation* 209 159-171 doi 10.1016/j.biocon.2017.02.008

Stroud District Council 2017 *Stroud Rural Sustainable Drainage (RSuDS) project* (https://www.stroud.gov.uk/rsuds.html) Accessed 28 September 2017

Thomas H and Nisbet T 2012 Modelling the hydraulic impact of reintroducing large woody debris into watercourses *Journal of Flood Risk Management* 5 164-174 doi 10.1111/j.1753-318X.2012.01137.x

Todd M Baines I Hunt T Evans S Y and Morrison G 2014 Communicating flood risk through three-dimensional visualisation *Proceedings of the Institution of Civil Engineers. Civil Engineering* 167 48-55

Tooth S 2015 Google Earth as a resource *Geography* 100 51-56

Tullis T and Albert B 2013 *Measuring the user experience: collecting, analyzing and presenting usability metrics* Morgan Kaufmann, Amsterdam

Waylen K A Holstead K L Colley K and Hopkins J 2017 Challenges to enabling and implementing Natural Flood Management in Scotland *Journal of Flood Risk Management* 11 e.12301 doi 10.1111/jfr3.12301

Wentworth J 2011 *Natural Flood Management* The Parliamentary Office of Science and Technology POSTNOTE 396 December 2011

Wernecke J 2009 *The KML Handbook: Geographic Visualization for the Web* Addison-Wesley, New Jersey

Whitman G P Pain R and Milledge D G 2015 Going with the flow? Using participatory action research in physical geography *Progress in Physical Geography* 39 622-639 doi 10.1177/0309133315589707

Wilkinson M E Quinn P F Barber N J and Jonczyk J 2014 A framework for managing runoff and pollution in the rural landscape using a Catchment Systems Engineering approach *Science of the Total Environment* 468-469 1245-1254 doi 10.1016/j.scitotenv.2013.07.055

Wissen U Schroth O Lange E and Schmid W A 2008 Approaches to integrating indicators into 3D landscape visualisations and their benefits for participative planning situations *Journal of Environmental Management* 89 184-196 doi 10.1016/j.jenvman.2007.01.062