Visualisation for Coastal Zone Management: A Case Study of the Norfolk Coast, England.

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Key issues & barriers

Coastal management in the UK is underpinned by the development and implementation of Shoreline Management Plans (SMPs). Introduced in 1995 to provide long-term sustainable coastal defence policies and management objectives for sediment cells or sub-cells, SMPs are developed through co-operative discussions between the numerous organisations involved in managing the coastline (Purnell 1996; Potts 1999). SMPs can encompass a range of management options (Ash *et al.* 1996). However, whilst they define the long-term management objectives, individual management schemes remain subject to economic and environmental appraisal as and when they are proposed.

Amongst the key challenges facing coastal zone managers are the need to widen public consultation and strengthen public participation during the selection of management options, and the requirement to improve the information dissemination process once decisions have been made. SMPs are complicated documents for those without prior technical knowledge of coastal processes, and the method in which they are prepared has been criticised for lacking scope for public participation. It has been argued that this has led to suspicion amongst local communities regarding the beneficiaries of the plans (O'Riordan & Ward 1997). Traditionally, SMPs and Environmental Assessments have been disseminated to a limited number of organisations and interested individuals. The dissemination is generally paper-based, with two-dimensional paper maps used for illustration. The British government realises that wider access to information contained within SMPs will be required in the future if they to gain support for the plans, as the policies outlined in the SMP must be seen to be acceptable to the general public (Potts 1999; O'Riordan & Ward 1997, Belfiore 2000). Indeed, a recent government review of the SMP process identified the difficulties associated with facilitating public participation as being very significant (MAFF 2000). In line with this, the review called for innovative new communication techniques to be developed and incorporated into future SMP documents and dissemination programmes (MAFF 2000). The problems found in the UK are mirrored elsewhere. For example, the European Union Demonstration Programme on Integrated Coastal Zone Management recently noted that stakeholders should be more involved in the development and implementation of coastal management plans (CEC 2000a); this view is now reflected in recent EU recommendations promoting participatory planning in coastal management and encouragement to develop systems that allow the monitoring and dissemination of coastal zone information (CEC 2000b).

There is a clear need for the further development of new methodologies that will help enable interested individuals and organisations to be informed of shoreline management decisions in the most inclusive manner possible (Belfiore 2000; MAFF 2000; CEC 2000a,b; King 1999) Indeed, King has specifically called for the use of *electronic* methods to facilitate communication between coastal managers and the public (King 1999), whilst many others have highlighted the need for research to exploit the potential of GIS in educating, promoting and involving the public in coastal planning and decision-making (Bartlett & Wright 2000). Certainly, traditional GIS packages are already widely used by organisations involved in coastal management and these systems are frequently cited as one of the tools associated with best practice (Bartlett 1994). However, GIS does not provide a universal solution despite its potential for assisting informed decision-making (O'Regan 1999; Bartlett 2000). Ultimately, a traditional GIS and its output is orientated towards experts with knowledge of complicated terminology, as opposed to those with the most to lose from management decisions. These limitations are compounded by the fact that coastal decision-makers are themselves often overwhelmed by the complexity of many GIS applications (Green 1995). Consequently, the GIS based coastal management systems that have been developed are often simply employed to produce thematic maps of coastal areas for SMPs, and much of the potential of the technology remains unrealised.

One technology with the potential to widen communication in shoreline management planning is Virtual Reality GIS (VRGIS). A VRGIS is in many aspects similar to a traditional GIS, but it encompasses Virtual Reality visualisations as a key output and interaction method. The virtual reality (VR) aspect of VRGIS has evolved mainly as an interface technology within which user interaction issues are of key importance. The more traditional GIS acts as a data storage and manipulation technology. The important role of visualisation in environmental decision-support has been recorded by a number of authors who have highlighted the need to develop such techniques to assist the in the public presentation of complex environmental process models (Bishop 1994; Bishop & Karadaglis 1997). We believe VRGIS provides an opportunity to further develop public involvement in coastal zone management by providing the functionality to produce realistic visualisations of different shoreline management outcomes. These may prove to be a significant advance on traditional methodologies. Using a case study of the north Norfolk coast, the potential of the technology is outlined below.

The research

The north Norfolk coast is an undeveloped low-lying barrier coastline that began to form in its current state around 6,000 to 7,000 years ago (Andrews *et al.* 2000). Management of the coastline is complicated, with numerous statutory and non-statutory bodies involved in overseeing a wide range of sites including a number of nature reserves. The development of a first generation SMP began in 1993 and was published in 1996. The SMP covers a very large area. Therefore, a number of smaller project-level study sites were identified through consultation with a range of statutory and non-statutory organisations involved in managing the coastline. In order to illustrate our work, a single scheme at Brancaster West Marshes is described here.

With the latest IPCC 3 estimates giving a predicted sea level rise of around 80cm by 2100, there is considerable concern regarding the potential for future active management of the coastline because of its vulnerability to North Sea storm surges (Thumerer *et al.* 2000). A possible option to accommodate future rises includes allowing reclaimed freshwater marshes to revert back to their natural state, a process known as managed retreat, setback, or coastal realignment. Coastal realignment has triggered considerable concern and debate amongst the public (Clayton 1993). although the European Habitats Directive does require such schemes to offset habitat losses by creating new habitats elsewhere along the coast. Brancaster West Marshes is a site currently under consideration for coastal realignment. The marshes comprise approximately 40ha of freshwater grazing meadows forming an SSSI and SPA under the European Union Birds Directive (Tyrrell & Dixon 2000). The site is flanked by earth flood embankments with its frontage protected by defences strengthening the natural dune frontage. The latter were constructed in 1981 to provide protection against storm surges but have degraded to such an extent that the Environment Agency have proposed a managed realignment scheme in which the frontage will be removed, with a new defence constructed 300m inland from the original location (Tyrrell & Dixon 2000). The freshwater marshes to the north of the new defence will subsequently be allowed to revert to saltmarsh.

The scheme has attracted considerable attention because it impacts a site protected under the Birds Directive. Furthermore, it could potentially interfere with the defences and frontage protecting the adjacent Royal Society for the Protection of Birds (RSPB) reserve at Titchwell. Additional complications arise from the privately owned defences belonging to the Royal West Norfolk Golf Club to the east, who plan to construct their own defence to protect their practice ground in response to the scheme.

An extensive GIS database was developed using ArcInfo and ArcView GIS packages. Data was obtained from a range of sources and included information on topography, land cover, intertidal zone characteristics, and the location of sea defences. Ordnance Survey digital topological data was used for the basis of the detailed visualisation work. Data on the coastline's evolution was provided from results of the Natural Environment Research Council's Land-Ocean Interaction Study (LOIS) together with historical mapping and aerial photography of the site. This was complimented with assessments of the potential impacts of future sea level rise on the site. Future sea level rise was calculated using the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC, Hulme *et al.* 1995) or each of the latest emissions scenarios from the Intergovernmental Panel on Climate Change (IPCC). Assessments were based on two scenarios representing the lowest and highest predicted rises. The assessment of sea level rise also accounted for isostatic changes in the land level and used mean isostatic adjustment rates as predicted for eastern England by Shennan (Shennan 1989).

Following construction of the GIS dataset, fieldwork was undertaken to both ground-truth the data and to collect digital photographs for use during the production of the visualisations. Plans for the realignment scheme were obtained from the Environment Agency and were digitised to create a new database reflecting proposed future state of the site. This information was appended to the pre-existing data to allow evaluations of the areas of habitat loss to be calculated, and for the individual environmental indicators to be assessed.

Visualisations of the scheme were produced using two techniques. Firstly interactive scenes were produced using ArcView 3D Analyst to provide 'fly through' Virtual Reality Modelling Language (VRML) experiences. Secondly, static visualisations were produced by exporting the GIS database into World Construction Set, a photorealistic-rendering package. Whilst the virtual fly-through is the most common output of VRGIS, the experience it provides dose not necessarily equate to the way members of the public are able to best perceive landscapes. Hence the two methodologies were chosen so as to allow an assessment to be made of their respective roles in widening public understanding of future coastal management schemes.

Results

The results of the assessment of the impacts of the scheme revealed that, although there will be a predicted loss of 8.6ha of freshwater grazing marsh following construction, this figure will most likely be offset by an increase in saltmarsh area of 6.4ha and 2.2ha for water channels and creeks. However, what is less certain from this analysis are the impacts on biodiversity that this change may bring about.

A comparison of the types of visualisation produced is given by Figures 1 to 4. In each case, viewing locations are used to illustrate the changes at the site following implementation of the realignment scheme. The immediate difference between the ArcView 3D Analyst and World Construction Set images is the level of detail; the former being more stylised in comparison to the latter. For example the ArcView 3D Analyst images do not contain the extensive colours, textures and 3D features found in World Construction Set. Likewise, the limited VRML functionality in ArcView 3D Analyst results in crude representations of the defences produced by extruding their features whilst, a system of Terrafectors available in World Construction Set rendered their detailed cross-sections. This trade-off in detail does, however, have important implications for the rendering times for each method with the ArcView 3D Analyst 3D scenes being continually updated in real-time as the scene was explored, whilst the static rendered images of World Construction Set took approximately 1 minute to render.

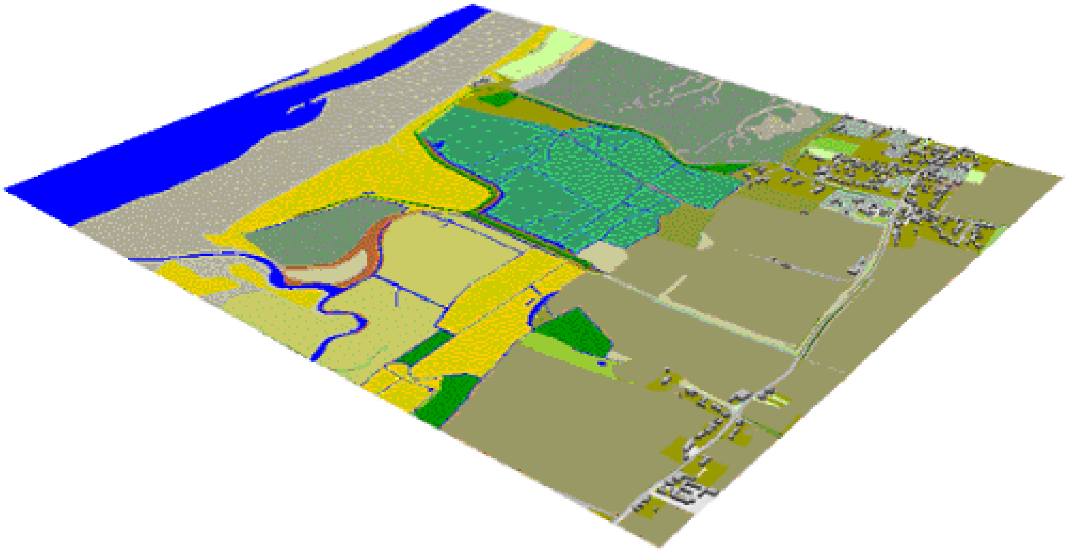

Figure 1. ArcView 3D Analyst view of the site prior to the scheme. © Crown Copyright Ordnance Survey. An EDINA Digimap / JISC supplied service.

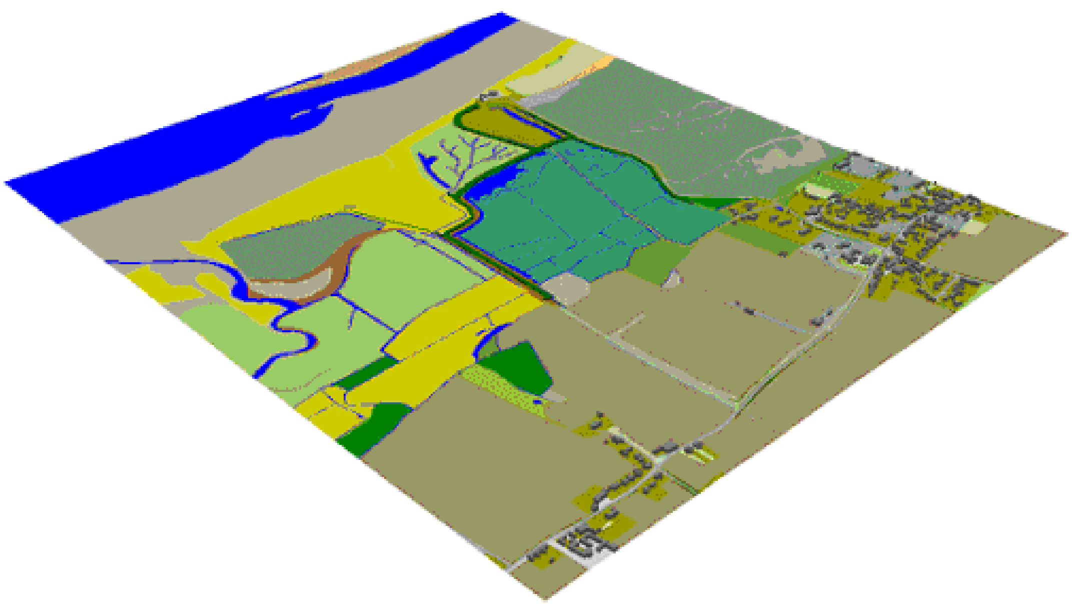

Figure 2. ArcView 3D Analyst view of the site following construction of the scheme**.**

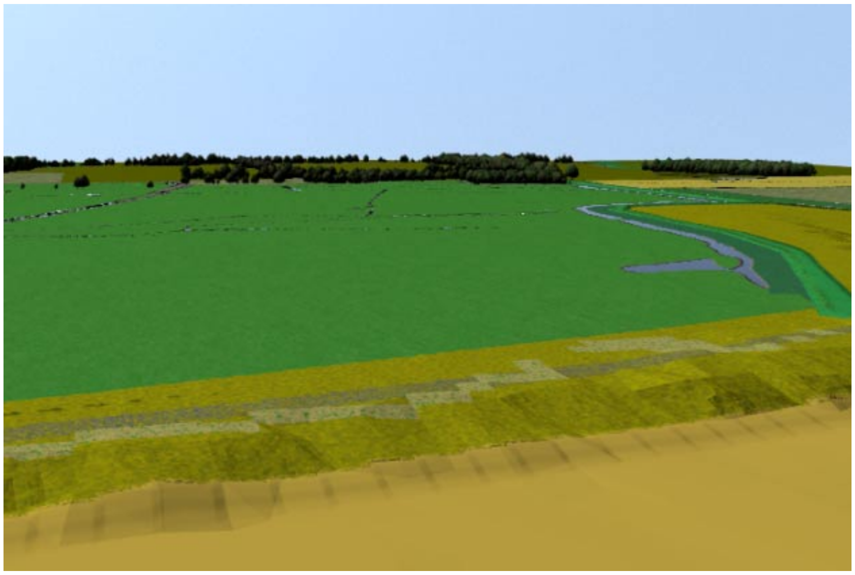

Figure 3. World Construction Set view looking south over Brancaster West Marshes prior to scheme**.**

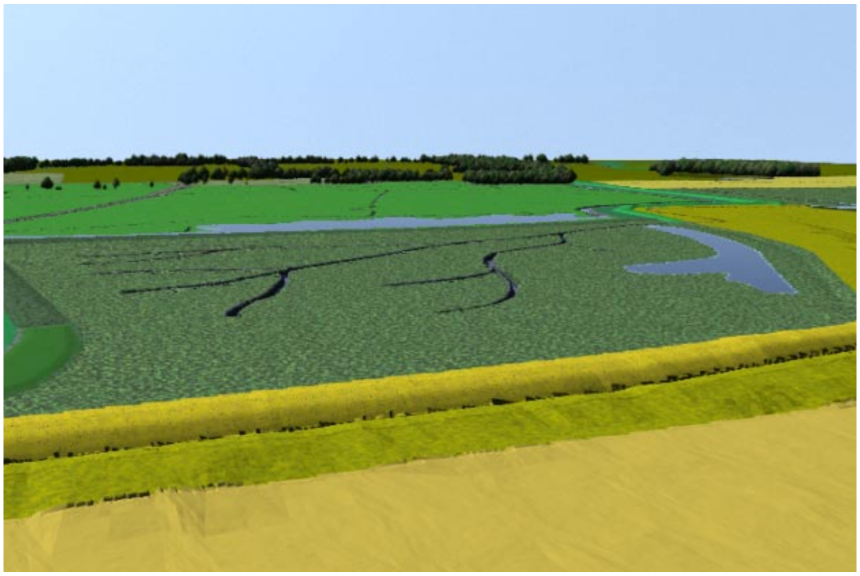

Figure 4. World Construction Set view looking south over Brancaster West Marshes following construction.

Discussion

One of the key criteria for the choice of study area here was that extensive coastal monitoring data was available from a range of organisations. Without such information, it would not have been possible to produce assessments and visualisations of future environments that would stand up to public scrutiny. However, even here there are problems in gaining access to some key documents. For example, whilst the Environment

Agency Regional Office housed the Shoreline Management System GIS, the project manager for the Brancaster West scheme was based at the local office leading to difficulties when trying to locate up-to-date plans for the scheme.

The two methods presented in this paper were chosen to represent alternative techniques that may be suited to different purposes in coastal management. The 3D Analyst visualisations are more dynamic and interactive, allowing the user to query the results. They may be more suited to those directly involved in the decision-making process and who wish to obtain quantitative information from them. Conversely, World Construction Set provides extremely realistic static images. These may be more suited to inclusion in management documents, such as Environmental Statements, where they could be used as an alternative to photomontages. With calls for SMPs to be distributed electronically (MAFF 2000), both techniques lend themselves well to dissemination via the Web. World Construction Set images could be displayed as bitmaps, whilst the virtual environments from 3D Analyst can be easily converted into VRML files, enabling the user to explore the policy impacts for themselves.

Visualisation techniques do pose a number of questions that reflect the numerous challenges facing the application of VRGIS. The concept of visualisations and virtual environments are relatively new and as such it has been argued that, until they are more widely used, knowledge of how best to design them will be lacking (Batty *et al.* 1998). This leads to the question of how the public, as opposed to experts, relate to visualisations, and whether simple visualisations like those produced by 3D Analyst are more effective than detailed photorealistic visualisations at conveying complicated information. It is obvious that visualisation techniques on their own will simply produce pretty images that are of little use if not used properly in coastal decision making. VRGIS will only achieve its full potential if it is integrated into the planning process (Lange 1994; Zube *et al.* 1987). It could potentially be used from the beginning of the SMP or project planning stage, assisting communication between management organisations during the development of alternative options. Later, VRGIS has an obvious use in public consultation and participation. However, such advances will only be achievable if the underlying planning process is opened up to the public to allow their participation, which in the UK would require major changes to coastal planning legislation. What visualisation techniques should *not* do is be used to sell a particular scheme to the public. This would be a wasted opportunity; visualisations have potential to *promote* discussion in initiatives to identify optimal solutions to management problems.

Virtual Reality GIS are not an immediate and universal solution to coastal management problems, as at present there is a lack of research understanding concerning the methods that can be used, and the effect of the different contexts in which they may be applied (Zube *et al.* 1987). Indeed as Williams notes, VRGIS has the potential to enhance conventional GIS but should not be viewed as a replacement (Williams 1999). Our research is, however, also investigating the potential application of the assessment methodology and visualisation techniques in the SMP and planning process. Focus groups and participation seminars are being run to gain feedback from both coastal managers and planners who may adopt these methodologies. Further surveys have been undertaken with the public, who have the most to gain from the use of visualisation techniques as a means of communication and a participatory tool. A second strand of the work is also investigating how the visualisations could be used in choice experiments to determine their utility in decision-making contexts such as that of extended cost-benefit analyses. A further area that warrants more research concerns the manner by which more subtle landscape changes, such as those associated with micro-scale changes in biodiversity, may be incorporated in the visualisations.

Although there is much work to be done before they become an integral part of the planning process, we believe that this research highlights the potential of GIS and VRGIS as integrated tools to assess potential future coastal landscapes. It also illustrates how VRGIS may communicate, educate, inform and involve the public and stakeholder groups in coastal management decisions by presenting information in a recognisable and understandable format. We firmly believe that the application of VRGIS can stimulate meaningful discussion and dialogue between groups traditionally associated with conflicting opinions. Coastal Zone Management can only benefit from its application.

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