GIS Applications for Nearshore Investigations

Site investigation surveys involving hydrographic or geotechnical data acquisition often generate high volumes of data and require handling through specialist software packages. The combination of volume of data and variety of software and formats may hinder the analysis and presentation of data. In order to attain a fluent operating system, many companies are choosing to integrate datasets and analyses through the implementation of structured data management solutions such as Geographical Information Systems (GIS).

In an industry within which the majority of primary data is spatially referenced, GIS offer the capability to merge datasets based on this fundamental property. However, the transition made by GIS from terrestrial roots to the marine environment has not been simple and many site-specific issues must be addressed.
Marine GIS are relatively few and far between but there is an increasing trend towards employing this mechanism for integrated digital data management. The fact that hydro-graphic surveys are inherently modular, due to the multitude of equipment required to undertake even the most simple of surveys, highlights the importance of integration. Once data has been collected and processed it will need to be integrated for site-wide analysis. As for many other types of investigation, this process can be lengthy, making apparent the opportunity for the utilisation of GIS to increase efficiency.

Marine GIS
Marine GIS differ from land-based GIS due to the inherent difficulties associated with mapping a 4D environment in a 2D, or possibly 3D, computer program. Very little marine data is simply 2D (x, y); it will usually include a third dimension of depth and possibly a fourth dimension of time. The fundamental difficulty when assessing 4D data is that of display in two dimensions. The availability of 3D plotting within GIS is increasing, thus allowing for the combination of 3D data. Four dimensional data may be displayed through the use of video sequences, although these may draw heavily on computer memory.
Unless the marine survey being undertaken is restricted to a very small area it is likely that it will collect a large volume of data. The specified resolution will obviously dictate this volume and whilst nearshore surveys may require a much higher resolution of data than surveys undertaken offshore this is often balanced by restricted spatial extent. Furthermore, the variety of equipment utilised for marine surveys, including multibeam swathe sounders and seismic sources, results in a multiplicity of formats. In most cases specialist software is required to interpret the data, although the product can often be exported to other systems. Side-scan sonar mosaics created in specialist packages can be exported as raster images to GIS but this process removes the flexibility of the original system and makes redundant the spatial analysis functions of the GIS.
Marine survey positional data may be collected in many different coordinate systems and the format in which the data is collected needs to be selected depending upon the extent and location of the survey. Investigations undertaken in the nearshore zone and coinciding with land investigations would be most appropriately collected in local grid coordinates. However, for a change in grid systems, or if cross-referencing with UKHO Admiralty chart data given as latitude and longitude, the issue of data transformations and the associated introduction of errors becomes a consideration. Variation in scale also poses a problem when analysing data; here it must be ensured that data from radically different scales are not used together without due care and attention.
The law and ethics relating to GIS will no doubt change in the foreseeable future, as the technology expands and is utilised by more diverse commercial and private sectors. In addition, consideration must be given to the development of digital technology for presentation. If GIS become more commonplace, will the output format change from hardcopy to digital reports? It seems unlikely that hardcopy responses will be eliminated due to the ease with which they convey data. Digital data may be useful for expanding upon simple issues discussed in a report but such data requires access to specific software. The advent of systems such as ArcIMS (Environmental Systems Research Institute Inc, 2002), with which selected facets of data may be displayed through an Internet backdrop, may go some way towards advancing the long-term use of GIS throughout the survey industry.

Research Example
As a small part of research undertaken at the University of Plymouth, the author investigated the use of GIS (ArcInfo 8) as an option for data storage and handling. The following text describes a few common issues faced by the author when utilising GIS as a digital mapping solution for marine survey data.
Bathymetric and geotechnical field data were collected and base map data taken from the Edina Digimap website, where Ordnance Survey (OS) data is available in a digital format for a variety of products. The Land-Line Plus dataset (1:2,500 for the specified area) provides detailed mapping for the region, with full delineation of jetties and routes for the local ferries. There is a high level of congestion in the Dart estuary due to numerous pleasure and commercial craft and the addition of over one hundred navigation markers located within the 7km stretch between the Range and Flat Owers (United Kingdom Hydrographic Office (UKHO)). The locations of the navigation marks were determined through digitisation of Admiralty Chart No. 2,253 (1:6,250), a process which inevitably leads to the introduction of positional error. At a scale of 1:6,250, a 0.5mm digitising error would lead to a positional error of 31m, a significant consideration if referencing the marks in the GIS.
A set of multibeam data collected in 2000 provided high-density bathymetric data which, after basic processing, was input to the GIS in x, y, z format allowing, in the simplest form, display of a survey coverage map (Figure 1).
Using the GIS as a simple digital mapping tool, Figure 1 illustrates the importance of quality control in nearshore bathymetric survey. Before contouring is undertaken it is critical to ensure that maximum coverage has been acquired to remove the possibility of spurious interpolation. The density of navigation marks in the nearshore zone, in particular anchor buoys, can dramatically reduce the ability to

obtain full data coverage. The effects of restricted access are visible in the data and it can be seen that the multibeam bathymetry coverage stops at the edge of the pontoons.

Using the contouring facilities contained within the GIS, a Triangular Irregular Network (TIN) model was created, allowing for the construction of a variety of contour maps. A section of a Dart estuary contour plot at a scale of 1:7,500 is shown in Figure 2.

The importance of data smoothing can be observed in Figure 2; adjustments may be necessary to improve the data representation. It is unlikely that the seabed changes in such a rapid and angular manner as is depicted in the figure. The data handling options offered in the 'off-the-shelf' GIS are less than those offered in specialist contouring packages and thus the ease with which data can be post-processed is also at present limited, although the GIS does offer a very quick and easily manipulated digital contouring output.

In addition to hydrographic information, in situ geotechnical and geophysical measurements, including shear vane and resistivity, were made and core samples were acquired. These data were centred on sites of approximately 1m2 (consisting of nine grid points) and thus poses the problem of a true-to-scale plot of a small object when compared to the estuary-wide multibeam data. Figure 3 shows two of the four in situ sampling sites with the geographical indictors of the coast visible. However, at this scale it is not apparent that each site consists of nine individual sampling points.

If a map image is created at a scale of 1:250 the grid of data points becomes apparent but the coastline as a reliable geographical indicator is lost (Figure 4). For highly site-specific engineering surveys, where ground coverage is not vast, this loss of a reference point is an important consideration even though the absolute positions are still obtainable through the presence of the cursor.

Summary

In the survey world, clients expect data to be presented in a clear and concise manner, all facets of information being displayed in the most appropriate fashion to allow for optimum interpretation. The final product, i.e. the map, plot or written report, will be a â€˜summaryâ€™ of the analysis undertaken, a process that may have involved collating data from many sources. The research undertaken illustrated the ease with which data may be displayed and manipulated in an 'off-the-shelf' GIS and highlighted the advantages of integrating data in a digital format.

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