International Hydrographic Review, Monaco, LXVIII(1), January 1991

THE UK DIGITAL MARINE ATLAS PROJECT: AN EVOLUTIONARY APPROACH TOWARDS A MARINE INFORMATION SYSTEM

by G.J. ROBINSON (*)

Abstract

In common with many organizations the United Kingdom Natural Environment Research Council (NERC) collects large quantities of spatial data. Within the marine sciences the cataloguing, promotion, and dissemination of information is a major undertaking. In order to assist with, and develop this task, a recent study has looked at the potential use of computerised information systems, ranging from simple digital catalogues to geographic information systems. This paper discusses the characteristics and problems involved in handling and disseminating marine information and outlines the results of trials with a simple demonstrator system based on a digital version of an existing paper-based marine atlas and the development of an operational digital marine atlas system. More recent experiments with a proprietary Geographic Information System (GIS) suggest that current GIS technology can only go so far in providing a solution and that new techniques must be developed for coping with the diverse spatial nature of marine information.

1. INTRODUCTION

The United Kingdom Natural Environment Research Council (NERC) undertakes research, on both a pure science and a commissioned basis, into the physical, chemical and biological processes in the natural environment. In the course of this work large quantities of spatial data, a growing proportion of which are in digital form, are captured each year. The presentation of the results of this research as, for example, thematic maps is a key feature of many NERC scientific programmes, since these greatly facilitate the understanding of complex

(*) NERC Unit for Thematic Information Systems, Department of Geography, University of Reading, U.K.

environmental phenomena. Moreover, maps or charts are frequently presented in an atlas format because they allow different parameters to be compared in order to deduce possible correlations, trends, etc.

This paper discusses some of the problems of handling information within the marine science environment and the dissemination of this information to the outside world, and outlines a possible solution based on the work of a NERC-led working group on marine atlases of resources and environment. A brief summary of the current progress in implementing this solution is also presented.

2. MARINE INFORMATION

A feature of marine information which often makes it difficult to handle different types of data in a consistent fashion is the number of dimensions they occupy. For example bathymetry can be considered static and two dimensional, whereas sea temperature varies both spatially and temporally (although the latter variation is reasonably periodic). Sampling distribution, resolution and frequency, which in principle should be matched to the phenomena being investigated, also present problems in terms of data storage, manipulation and presentation. In many ways the problems involved in handling marine information are similar to those encountered in other disciplines such as the geological sciences.

The processing, cataloguing and dissemination of spatial data is a major undertaking. Several mechanisms exist within NERC to carry this out. Within marine sciences this function is split between the two main laboratories. The British Oceanographic Data Centre (BODC) located with the Proudman Oceanographic Laboratory at Bidston, Birkenhead, England, deals with the capture, processing and distribution of marine data. The Marine Information and Advisory Service (MIAS) located at the Deacon Oceanographic Laboratory at Wormley, Surrey, England, provides a consultancy service for customers on many aspects of the marine environment, and may direct the user to scientists at the BODC as appropriate.

Because this process is demand driven by enquiries about specific problems (for example an oil exploration company might require information on tides, currents and waves, on and around the UK continental shelf region) there is a danger that a significant amount of potentially valuable data collected each year by the NERC is not made immediately available to the wider user community. Although this is due primarily to the limitations on available resources, it is also a result of not always knowing the size (or even the existence) of the complete market spectrum for this information.

Paradoxically, there is an ever-increasing requirement for up-to-date and accurate information. For example the advent of the Exclusive Economic and Fishing Zones has greatly increased the opportunity for commercial exploitation of the seas. This in turn has led to an increased awareness by various UK government bodies of their responsibility for the management of the resources of the sea and the resolution of potential conflicts. At a lower level, there is interest in more general information about the marine environment, particularly in education. Un-

fortunately, these agencies have the difficulties of finding out who has the data they require, in what form it is held, and how to interpret the results when they are able to obtain and process the data.

The need for a resolution of this problem was reinforced by the Committee of Enquiry on the Handling of Geographic Information, which concluded that:

> 'Government Departments and other organisations should adopt a positive approach to the marketing of their data... ... Data registers are needed to provide potential users with information about information.' (No. 12 in the summary of Conclusions, HMSO 1987).

There is therefore an urgent need for the better promotion of available data sets, coupled with improved data management facilities to enable more efficient access to the ever-increasing volume of spatial data. At the same time there is a requirement for data integration within and amongst organisations in an increasingly multi-disciplinary environment.

3. THE MARINE ATLAS PROJECT

In an attempt to resolve this dilemma of inability to supply an unsatisfied demand, the NERC set up a working party, composed of representatives of the NERC and other interested parties. The working party was asked to investigate the use of computer-based atlases as spatial indices, or 'windows', into the underlying data sets from which many paper atlases are already derived. More specifically the working party was charged with examining: the scope and objectives of marine atlases; their value to NERC science; the state of national and overseas developments; the options, costs and sources of funding for a UK national atlas; and the role of NERC in such a project. This indexing extension of the atlas medium was believed to provide a potential avenue for the simultaneous promotion of NERC data holdings and scientific expertise and the stimulation of further data processing and cataloguing activity.

The initial report by the working party centred on the concept of a 'Marine Information System' (MIS), the actual design and development of which would be based on the results of further studies to be carried out in parallel, namely: a detailed design study of a marine information system and a demonstrator system based on the 'Atlas of the Seas Around the British Isles' produced by the Fisheries Laboratory of the Ministry of Agriculture, Fisheries and Food (MAFF). On the basis of these studies the next step would then be to prepare a detailed programme proposal for the implementation of an MIS. The working party also noted that there was scope for participation in the project by industry — both as a potential customer and also in the funding and development of the system.

The working group identified three main benefits that would be gained in developing an MIS: wider and more efficient use of NERC data by the marine science community; more opportunities for future commissioned research and greater public awareness of the value of NERC science. Similar benefits were seen as applying to other organisations that became involved in the project.

In discussions with key marine scientists in NERC and elsewhere the working group established the two principal objectives for a marine atlas of resources and environment: provision of a spatially-oriented catalogue of marine data and expertise held by NERC and other organisations and the presentation of the results of NERC supported research in a readily accessible and scientifically valid form. At first sight these objectives appear complementary: the first entails the promotion of data sets and their access by users whereas the second is concerned with the atlas itself as an end product. However, many scientists are understandably sceptical of the value of an atlas — especially one that performs such a dual function, since atlases by their nature tend to 'gloss over' much of the subtle characteristics of the phenomena they attempt to portray. The working party therefore concluded that in order to reconcile such conflicting objectives a series of distinct atlas products would be necessary — general ones to cater for most uses and more esoteric ones for specialised purposes. However, these products would be produced from a single information system, fed by existing digital and analogue data archives where appropriate.

It was also thought essential to the success of the project that the system should be capable of handling and portraying information from a wider range of scales than that normally found in traditional atlases. This reflects the scientific interests of the NERC, from global projects such as the World Ocean Circulation Experiment (WOCE) to local studies of lugworm distribution in tidal estuaries. Aspects such as data quality, coverage, sampling strategy and interpretation by the scientists of his data would also need to be included, since these are essential to the proper understanding of the marine environment. Another fundamental requirement of the system would be sufficient flexibility in order that it would be expanded and developed to handle new data sets and to suit changing needs — especially when other organisations became involved.

With marine information increasingly being captured directly in digital form these days, it appeared sensible to use a single data base system rather than a variety of systems as is the situation at present. In fact the NERC has standardised on the Oracle relational data base management system (RDBMS) and many users are in the process of converting their existing data holdings, or are converting non-digital data, directly into an Oracle RDBMS. The advantages of using a single data base system, or at least using the same type, are evident from the point of view of data base system management. However, the introduction of a common system also allows much better control of the way in which data are captured and stored, reduces data redundancy and can highlight areas of data sparsity. A longer term objective of this project was therefore seen as the rationalisation of the way in which the NERC gathers, stores and processes marine information. Whether this would be achieved independently of this project is debatable though.

For the MIS to get off the ground — let alone succeed — the working group believed that the project should be self-financing, or at the very least require minimal initial funding in order to get around the information exchange dilemma described earlier. This had implications for the project as a whole, and led to the adoption of a staged strategy, in which each phase could be tackled as a distinct task with clearly identified sub-goals and well-defined financial commitments from those involved.

4. CURRENT DEVELOPMENTS

The obvious place to start such a project as this was to look at what others had done. This took the shape of a review of marine atlases, paying particular attention to their scope, objectives and limitations. A similar approach was applied to commercial and non-commercial GIS and digital cataloguing systems.

4.1 Marine Atlases

Increasingly marine atlases, in common with land based equivalents, are being produced with the help of computers. The working group was especially interested in the activities of the Ocean Assessments Division of the National Oceanographic and Atmospheric Administration (NOAA) which has produced a series of charts on the Health and Use of Coastal Waters of the USA. Of particular interest was the way in which teams of scientists, statisticians and cartographers were co-ordinated to produce individual charts. However, apart from having different objectives to the marine atlas project the scale and cost of the NOAA undertaking precludes a similar UK operation.

In the UK, the 'Atlas of the Seas Around the British Isles' published by the Ministry of Agriculture, Fisheries and Food (Lee and Ramster, 1981) attempts to bring together various physical, chemical, biological and environmental properties, resources and uses of the waters around the British Isles. Despite providing only a general picture because of the small scale used (about 1:10M) and the need to time average certain data sets, it was this atlas which led indirectly to the initiation of the marine atlas project, after an approach by MAFF to the NERC in 1986 to collaborate in the production of a new version of the atlas using computerised techniques.

4.2 Geographic Information Systems and Digital Catalogues

The working group also looked at what GIS technology had to offer, not necessarily as a complete solution per se, but mainly to determine whether the technology was sufficiently advanced and appropriate to the problem in hand. The NERC, along with various organisations within the UK, has been interested in GIS technology for some time and currently has a working group looking at broader GIS developments. More directly the NERC has funded a conceptual GIS user needs study undertaken by the Geography Department, Birkbeck College, London which was recently completed (Rhind and Green, 1988).

Although ostensibly a European land-based GIS, the CORINE (Coordination of Information on the European Environment) project (Wiggins et al., 1987) had sufficiently similar objectives to those of the marine atlas project to merit close inspection by the working group. One of its major principles is to use existing data sets where possible. Secondly, its success depended on the collaboration of many geographically dispersed organisations. Thirdly, and most impor-

tantly, is its ability to cope with a wide range of scales, from a European-wide level down to the order of 1 km². One of the most interesting findings of the CORINE study is the uncertainty of user needs and their wide range of familiarity with computers and the interpretation of environmental information.

As an alternative to a full GIS the working group considered computerised cataloguing systems. Several of these exist or are currently under development. The Carto-net system (Morris, 1987) developed at Edinburgh for the management of map libraries was of particular interest to the working group, especially as it makes use of the Oracle RDBMS. Unfortunately, although systems like Carto-net satisfy some of the objectives of the marine atlas project, they are not designed to handle the contents of the maps they index. Also, they are often based on large single computer systems with access by the physical proximity of the user or via a computer network. Consequently the objective of promoting information widely and conveniently cannot be easily satisfied.

5. DESIGN OF THE MARINE INFORMATION SYSTEM

The successful design and implementation of an information system relies on establishing sensible objectives and correct estimates of the size of the final system and resources required at the outset. However, because the very nature of the marine atlas project precluded the estimation of the size of the final system, the working group adopted a cautious, evolutionary approach in the design and implementation strategy of the system. One of the first actions was to draw up a hypothetical 'Marine Information System' on which various ideas could be tried out. This 'ideal' MIS was effectively a very large marine equivalent of a GIS, containing all available marine data and performing all the usual functions of a GIS. The design of such a system was acknowledged to be technically possible, but was decided to be too costly and time consuming to implement for a number of reasons: not all marine data are in digital form; even if they are it may not be in a form suitable for incorporation in a GIS. i.e. it needs pre-processing; the data may be held by someone unaware of their value to others and therefore are hidden; the data may be captured at a wide variety of scales; the data may have been acquired on a commercial basis and not be available for general use; and similarly, the data may be politically sensitive and therefore deliberately 'hidden'.

A major drawback to a central MIS is user familiarity with GIS technology. Even where a user has easy access to a GIS, he needs to be aware of the capabilities and limitations of the system — in other words he needs educating. For the person who is likely to use the system many times the training process can be cost effective, especially if it is done using computer based techniques such as those ably demonstrated with the ARC-Info based ARCDEMO system (Green, 1987) and the more recent GIST! GIS tutorial system (Raper, 1989). For the one-off or infrequent user however the situation is entirely different. The system must be simple to use and 'user-friendly' as possible, and this raises further questions against the suitability of existing GIS for the marine atlas project. However this is not to say that GIS will not have a future role.

Having discounted the use of existing GIS and cataloguing systems in the immediate term, the working group drew up a more realistic design for an MIS which would satisfy the objectives of the project. The design (Fig. 1) consists of three distinct elements: a central repository for digital maps and associated catalogue information; the databanks from which the maps and catalogue information are derived; and output products in the form of traditional atlases, digital catalogues and digital atlases. By employing a modular design the working group believed that each component could be developed more easily than if it were part of a single system, and this is reflected in the implementation of the system.

5.1 Central Repository

The role of the central repository is to facilitate the presentation of marine information in a systematic way. However, the manner in which the information is presented is the responsibility of the individual scientists and organisations concerned, since these are the people best equipped to analyse and interpret their own data.

Information held within the system was expected at first to be little more than a collection of digital maps and associated information fulfilling the dual objective of summary and indexing role. Since the MIS would therefore resemble a traditional mapping system more than a GIS it was decided to implement the initial MIS using a proprietary digital mapping system. As the project progressed, it was foreseen that there would be a trend towards holding certain information, particularly that of a fairly static or commonly used nature (bathymetry is a good example), directly within the MIS. A system capable of holding increasingly larger and more complicated data sets was therefore called for. In addition, the later stages of the project would require the system to be enhanced in order to provide more sophisticated manipulation and enquiry functions. In this way the system was expected to gradually evolve towards a GIS type environment in a reasonably controlled manner.

5.2 Data Sources

In order for the content of each data set being catalogued in the MIS to be controlled by the appropriate scientists it was decided to initially restrict input to maps and ancillary textual information, either generated directly from digital data, or more frequently by digitising existing maps and charts. To simplify the generation of these digital maps, and also to maintain consistency between data sets, common data sets such as coastlines, graticules and bathymetric contours at an agreed set of fixed scales were to be used. As data will increasingly be accessed via data-base systems the incorporation of data into the MIS will become easier, although it will still need to be substantially processed to allow the correct interpretations to be made by the appropriate scientists.

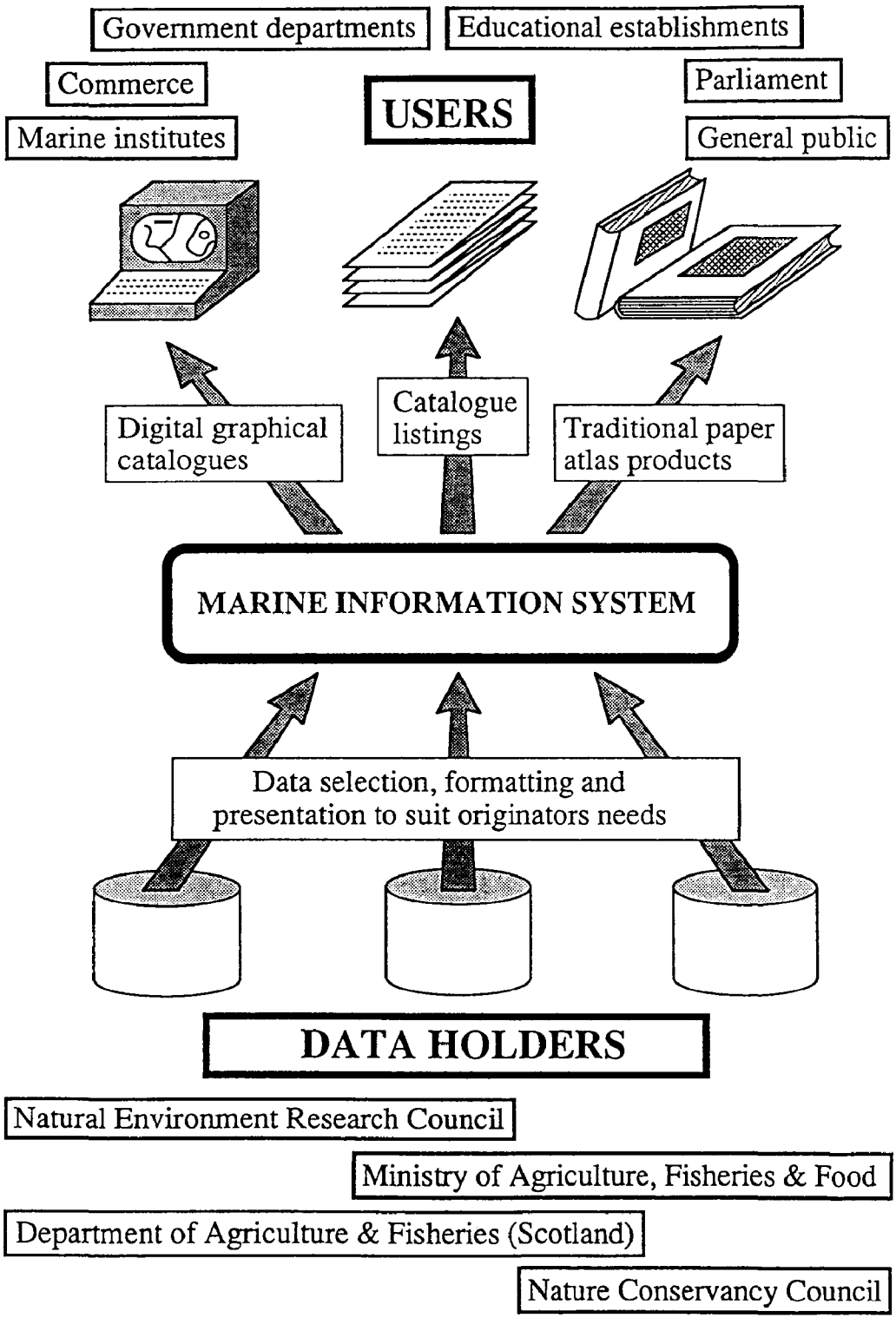

FIG. 1.— Schematic design of the UK Digital Marine Atlas system.

5.3 Output Products

A variety of output products was required to be generated from the MIS, ranging from simple catalogue listing to specialised hardcopy atlases and computer readable products. Producing these from a single system was seen as providing one of the key objectives of the project, namely to allow a flexible and timely response to user needs and priorities.

One of the main reasons for introducing GIS technology into the project is the ability to derive new products and present information held within the MIS in different ways. For example a perspective view of the UK continental shelf region (Fig. 2) provides a new insight into the way the morphology of the sea floor determines the deep water circulation pattern and thereby influences properties such as water temperature and salinity.

5.4 Data Transfer

The flow of information from the data holders to the MIS will be carried out, at least to start with, in rather an ad hoc manner because of the diverse nature of the data holdings. Some data may be directly manipulable in digital form, but a significant proportion will have to be digitised from manually produced maps. Even where data are held in digital form transfer will be difficult because very few common standards for data exchange exist. The most convenient form, especially from the point of view of the data holders, is expected to be paper maps and charts!

The situation with the generation of output products is somewhat easier, since there is greater control over the process. For atlas production there are obviously few format problems. The digital atlas and catalogue products will be distributed on floppy disks or compact disks, using one or more of a range of widely used industry standards. The adoption therefore as soon as possible of an agreed exchange format standard will be important. Various standards for the transfer of digital map data already exist, and the working group has looked at the UK National Transfer Format (Sowton and Haywood, 1986) as a possible candidate, especially as the NERC was involved in its formulation.

5.5 User Interface

The interface between the end users and the MIS concerned the working group. This arose because of a 'Catch 22' situation, namely the inability to increase the resources needed in order to satisfy the expected increased level of enquiries about marine information. This predicament is potentially more serious because without adequate enquiry facilities the users would go to the scientists providing the information in the first place. Thus the flow of new information into the MIS would be interrupted. This problem can be reduced substantially by filtering or intercepting user enquiries at the appropriate level. In this way the flow of enquiries resulting from the promotion of marine information can be controlled

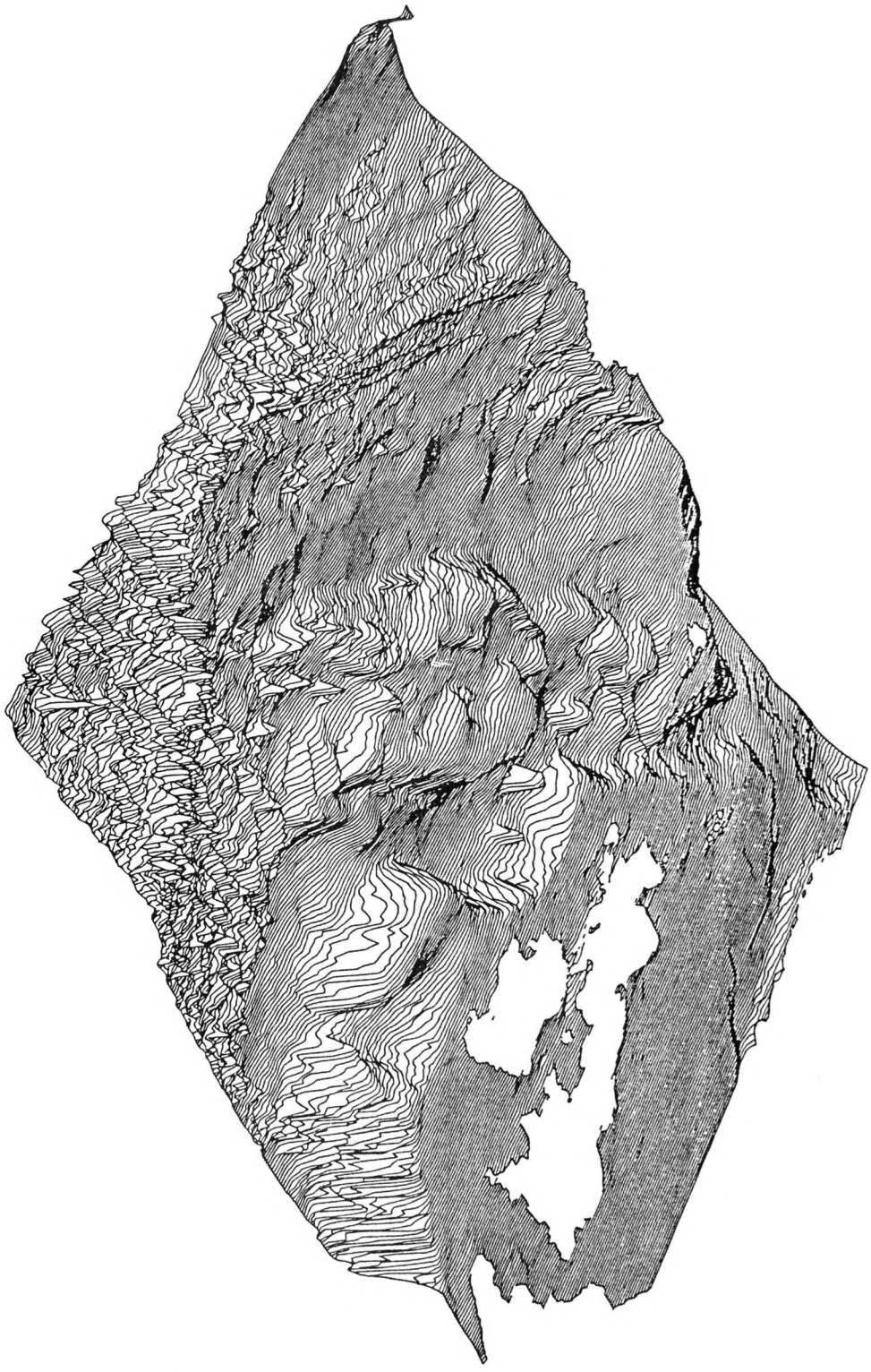

FIG. 2.— Perspective view of the UK continental shelf region.

systematically. One way of achieving this is by providing only the minimum level of information on data sources for each output product, concomitant with the likely market and usage of that product. For example, users of a general purpose atlas would probably only require superficial details about the sources used. If further information was required then the user would be directed by the information in the product to a more sophisticated enquiry system. To some extent this already happens with existing atlases and data sets, but usually in a haphazard, non-directed way. In contrast, specialised atlas products would contain information about who holds the detailed data, where it is held, how it is held, in what format, its accuracy, completeness, availability, cost, licensing arrangements, copyright restrictions etc. The product type also has a bearing on the timeliness of the catalogue information, since for example a paper atlas would generally be less up-to-date than a digital one.

6. IMPLEMENTATION OF THE MARINE INFORMATION SYSTEM

The implementation of the MIS is being carried out using a staged approach for the reasons discussed above. The first stage involves the capture and processing of the existing MAFF atlas using a proprietary digital mapping system and the development of a personal computer (PC) based sample output product. The second stage deals with the development of the MIS and PC system to handle other data sets and the introduction of indexing or cataloguing functions. The third stage concerns the enhancement of the MIS to allow more sophisticated operations, more akin to those available in GIS. In particular, the introduction of an intelligent 'front-end' to assist both the end users and data holders is a key element.

More detailed accounts of these phases will appear in subsequent publications.

6.1 Phase 1: Demonstrator System

The reason for developing a demonstrator system was threefold: to attract interest in the project from within NERC and outside; to allow a survey of likely users and their requirements to be carried out, and to enable experimentation with various ideas on how the eventual system would work. A decision was taken very early on in the project to concentrate on the central MIS and a single output product, namely a PC-based graphical catalogue. Despite being small-scale, heavily generalised and pre-classified the MAFF 'Atlas of the Seas around the British Isles' was selected as the initial data source for the demonstrator since it contains a wide variery of physical, chemical, biological and resource information of interest to potential partners and end users. An advantage of using a digital version of an existing atlas was that the issues involved in interfacing to other data holdings could be put off until the user requirements and likely system size were known.

Conversion of the paper atlas to an electronic format posed many interesting problems. Most of these involved design considerations, such as changing from a negative to positive contrast medium and the use of lower resolution display devices. Another difficulty encountered was in deciding what format to hold and display information, bearing in mind that the PC-based system would have the ability to graphically overlay multiple data sets. A simple vector format was chosen, with each map being optimally designed on an individual basis, but with account being taken of design conflicts between the most likely combinations of maps. Recognition of PC display limitations led to the introduction of a zoom facility, and this was later enhanced to automatically cope with a series of different scale data sets such as bathymetric contours and coastlines.

The PC system has been shown or distributed to many interested parties, both in the UK and abroad, with the result that MAFF, the Department of Agriculture (Scotland), the Nature Conservancy Council and the Royal Institute of Chartered Surveyors are collaborating in the operational phase of the project.

6.2 Phase 2: Operational System

While the PC-based system was under development, work was undertaken to develop methods of cataloguing a wide range of data at a variety of scales. It soon became apparent that a set of fixed scales would be the best way of reconciling different data sets, and initially base scales of 1:1M, 1:250,000 and 1:50,000 were adopted, since these relate to many land-oriented topographic data sets. This also fitted in with the coastal region interests of NCC and NERC, and provides a future link to land-based GIS.

One of the most difficult decisions encountered with the operational system was the choice of projection system. Because the MAFF atlas was drawn entirely in the Mercator projection this was used in the demonstrator system. However, to comply with large scale UK-based data and to provide general flexibility a simple latitude/longitude system was adopted.

The operational system is based on a Laser-Scan Laboratories mapping system running on a dedicated DEC VAXstation 3100 computer at the NERC Proudman Oceanographic Laboratory, where the BODC databanks are held on an IBM mainframe computer. A similar mapping system is in use at NUTIS, on which the developmental side of the project has been carried out.

6.3 Phase 3: GIS Functionality

The current development phase of the project is concerned with the introduction of GIS technology to the cataloguing element. This has involved the use of pcARC/INFO in the development of a menu-driven demonstrator system, based on the original PC demonstrator. The pcARC/INFO system allows the full range of GIS tools to be applied to the data held in the demonstrator, with the result that better and more flexible query facilities have been implemented. However, in common with most commercial GIS this system cannot cope very well with information possessing a depth or time dimension, such as salinity and tem-

perature. The effective handling and portrayal of such data sets must therefore await the development of suitable new data structures and tools.

7. CONCLUSIONS

This study has shown that there is widespread interest in a digital atlas-based marine information system for the UK.

The establishment of such a UK marine atlas project is proceeding along an evolutionary, staged path for two reasons. Firstly, in view of the extremely disparate nature of marine data and the manner in which it is held, the effort which would be required to put it into a single information system in one go is too great at present. By adopting this approach the problem of gathering sufficient resources at the outset can be overcome, since only those resources necessary to complete each stage are required. Secondly, the technical problems of dealing with the multi-dimensional property of marine information can be deferred until such time that new data structures for handling such data and also new techniques for portraying it as effectively as possible can be developed.

Bibliography

GREEN, N.P., 1987: Teach yourself geographical information systems. The design, creation and use of demonstrators and tutors. *International Journal of Geographic Information Systems,* 1, pp. 279-290

LEE, A.J. and RAMSTER, J.W. (compilers), 1981: *Atlas of the Seas Around the British Isles.* (London: Ministry of Agriculture Fisheries and Food).

MORRIS, B., 1987: Carto-net: a cartographic information retrieval system. British Library Research Paper No. 33.

HMSO, 1987: *Handling Geographic Information.* (London: Her Majesty's Stationery Office).

RHIND, D.W., 1987: Recent developments in geographic information systems in the United Kingdom. *International Journal of Geographic Information Systems,* 1, pp. 229-241.

RHIND, D.W. and GREEN, N.P., 1988: Design of a geographic information system for a heterogeneous community. Natural Environment Research Council Geographic Information System Workshop, Keyworth.

SOWTON, M.S. and HAYWOOD, P., 1986: National standards for the transfer of digital map data. *Proceedings Auto-Carto London,* September 1986, pp. 298-311.

WAUGH, T.C. and HEALEY, R.D., 1987: The GEOVIEW design: a relational database approach to geographical data handling. *International Journal of Geographic Information Systems,* 1, pp. 101-118.