# Hypermedia For Prototyping and System Integration In Information Systems Development


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# Abstract

This thesis investigates information systems development with special regard to the area of Geographical Information Systems. It addresses the area through the investigation of the software life-cycle development model and its augmentation by the use of prototyping. Observations are made on empirical experiments conducted to assess the usefulness of the new techniques of hypertext and hypermedia and their suitability within this field of study.

This investigation is complemented by a case study, the Norfolk and Suffolk Broads Authority. The Norfolk and Suffolk Broads are designated by statute with similar status to the National Parks of Great Britain, and are managed by the Norfolk and Suffolk Broads Authority. Through cooperation with the Norfolk and Suffolk Broads Authority, a prototype information system was created. This system makes use of geographical data from the Broads Authority. The development stages of this system were used to conduct experiments for this thesis.

The tools and techniques used for the development of this system are described. These include a hypertext tool called FIELD (Fully Integrated Environment for Layered Development) which has been especially designed for the complete storage of all information for each stage throughout this development. The use of this tool and hypertext for the development of the geographically based information system for the Norfolk and Suffolk Broads Authority are discussed.

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# Chapter 1 Introduction

## 1.1 Information Systems

Information systems analysis, design and implementation has progressed through the last 20 years. Great evolutionary strides have been made in the practices which are now recognised as the software development life cycle. Such techniques now bring this discipline to the verge of a new age of information systems development. As with many areas of interest there is much debate concerning the precise definition of an information system. An information system has been defined as follows:

> "An information system, therefore, is designed to transform data into information and make it available to decision makers in a timely fashion. There are many components of an information system. These are simply parts that can be identified........ - hardware, software, data, and finally people" (Mandell 1987).

The process of information systems development is in many cases iterative and is best illustrated in the software life-cycle model (Diagram 1.1). This shows that there are several points at which feedback from any point in production can flow to another part. Thus the developer could return to the systems analyst for clarification of a system specification, and so on.

Diagram 1.1 indicates several stages: definitional; developmental and implementational. The definition stage can be sub-divided into 3 areas: requirements analysis; specification; and systems design (Davis and Olson 1987). During this stage the analyst is trying to assess the user requirements. From these the analyst is able to create a specification from which the developer can successfully produce a system. This process can take several iterations until the user, analyst and developer are able to communicate effectively in order for a successful product to be created (Boehm 1976, Agresti 1986).

Much time and effort has been invested in devising better ways of creating software specifications through the process of specialised methodologies (Avison and Fitzgerald 1988). There are a large number of methods which use approaches that range from data flow diagrams, entity-relationship models, to more practical methods such as prototyping. However since the 1970's, during the period when Royce and others (Royce 1970, Boehm 1976) began to develop methodologies for systems analysis and design, there has been an ever growing debate about the appropriateness of these methods (this is further discussed in chapter 2). Design methodologies and the information systems produced by them have been criticised for their inherent limitations which render these systems open to a high level of failure. Several problems are apparent. These can be sub divided into three areas: firstly those relating to the time elements of development; secondly, those where there is a direct causal relationship between the defects of the information system and the methodology used; and finally those where mis-implementation and low confidence cause product failure (Avison and Fitzgerald 1988, Davis and Olson 1987, Pressman 1987). These three areas are discussed in more detail in the following paragraphs.

Time delay is an important factor in the development of information systems. There are two major problems which can be directly attributed to time delays. These are cost and the functional usefulness of the delivered system. The extra costs of delays can exceed the budget of an information system considerably (Pressman 1987). As well as this penalty, there is also the danger that the functional requirements of the system may no longer match those of the organisation, as their objectives have evolved and changed. This gives rise to a delivered system that only has limited functionality and low flexibility for the organisation and hence the need for further program 'fixes' to allow the system to function with a reasonable level of success (Land 1987).

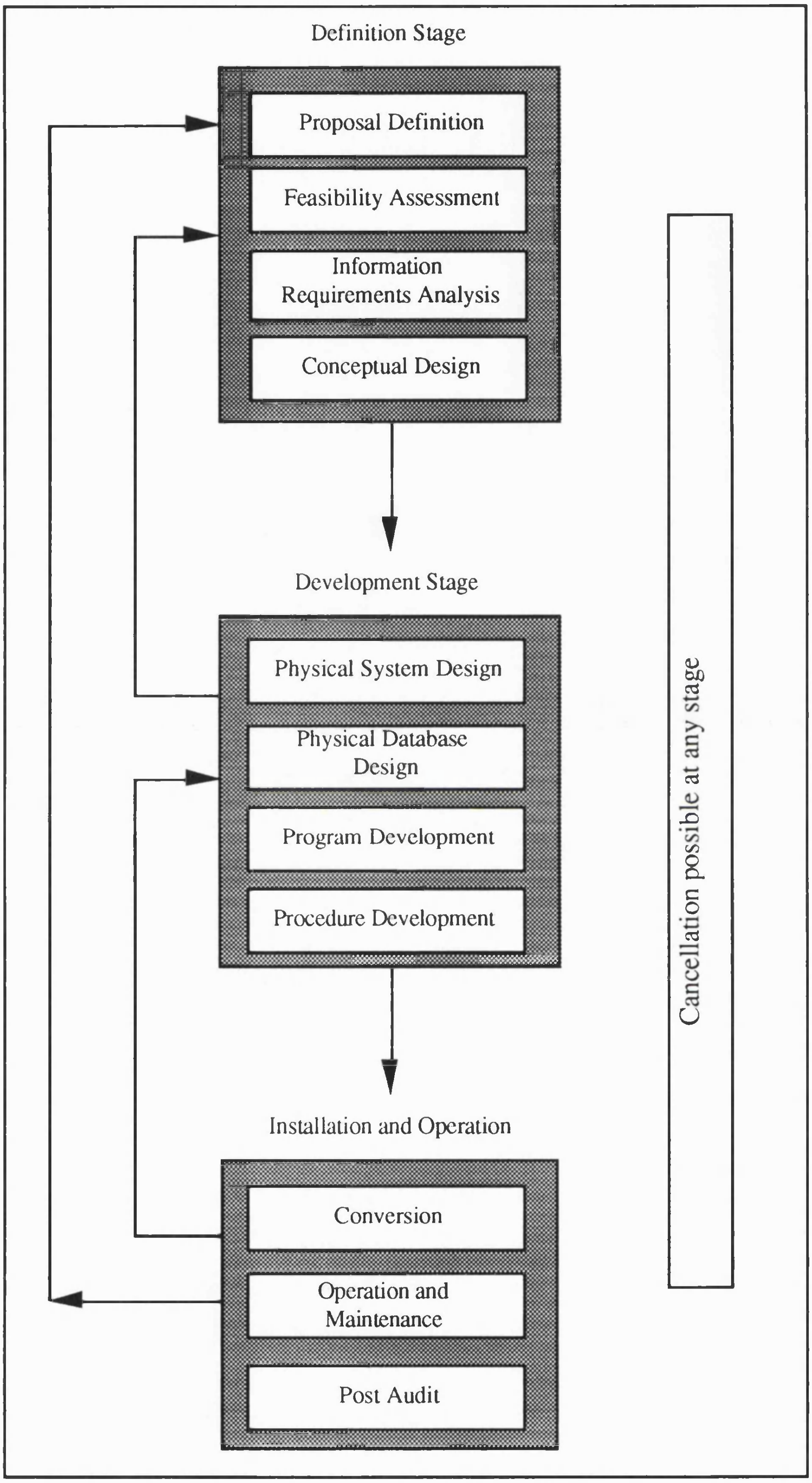



**Diagram 1.1 Information System Development Life-Cycle (Davis and Olson 1987)**

From the causal point of view, there are several factors which may affect the design and implementation of information systems. These fall into three categories: misinformation; misinterpretation; and omission (Avison and Fitzgerald 1988, Pressman 1987). Several important factors relate to information systems, as perceived by the non specialist user. In many instances there is a general fear of computers and the generic term "information systems" and it is also possible that this "fear" extends to those people commissioning new information systems. Regardless of the intent of the systems analyst, this may make the user feel nervous or intimidated (Mumford 1983) and incorrect information may be passed from the user to the analyst. The information received by the analyst may be partially or wholly incorrect so that the design and creation of the system may be compromised (Avison and Fitzgerald 1988). Valusek and Fryback (1987) categorize these factors into three main areas: obstacles within; amongst; and between. Obstacles within suggest that users are limited by their own cognition and judgement of the situation. Obstacles amongst users are found where conflicts in preliminary information from different users are identified. Finally Obstacles between users and analysts are found where communication is hampered by the lack of a common framework.

Ciborra (1987) states that much of the understanding of information systems within organisations focuses on human computer interaction and exchange of information rather than on the individual decision making process. In this light it is possible that the systems analyst may misunderstand the requirements of the users. This could be the result of either incorrect information being given to the systems analyst or by error on the part of the analyst. If the latter is the case this may be for a number of reasons, ranging from lack of interest to insufficient time spent with the user (Avison and Fitzgerald 1988, Mumford 1983). Finally, information system development may be compromised by the user and or/the analyst omitting part of the requirements during the requirements analysis stage. If misunderstandings or omissions occur during the requirements analysis stage of the process then the design and implementation of the system may be compromised from the outset. This can result in time delays and a possible rewrite of the system (Avison and Fitzgerald 1988).

Finally, it is possible that during the coding stages of the systems development the system may be poorly implemented. Employing inefficient methods of creating the system may render some features inoperative, thereby stopping the system from functioning according to its original design. Although the employment of inefficient methods is a primary cause of system failure, there is also a more fundamental cause. This is poor coding. The major problem caused by poor coding is that the code will be inefficient and the resultant system slow. Because of these obstacles the user is inhibited from using the system to the full. This inefficiency may in turn give rise to a low initial use and confidence in the new system and therefore it will be less likely to succeed regardless of later improvements. As a direct result of the inefficiency of these systems it is probable that the organisation will suffer (Avison and Fitzgerald 1988, Pressman 1987).

Given the myriad of problems which can befall the development of an information system, it is desirable to find appropriate methods to attempt to alleviate eventual shortcomings. An area of approach for designing information systems relevant to this research is that of prototyping, that is of creating a dummy system to elicit from the user the nature of the systems requirement (Hekmatpour and Ince 1986, Davis and Olson 1987). These methods can be extremely useful in providing information to aid systems development and are good mechanisms for allowing the user greater involvement in the development process (Hekmatpour and Ince 1986, Davis and Olson 1987). A discussion of the advantages and disadvantages of prototyping as a development tool is appropriate given the nature of this thesis (outlined in section 1.5) and its emphasis on practical information systems development techniques. This discussion is pursued below.

Prototyping is the term given to a group of practical methods for the design and development of information systems which attempt to comply closely with the ideas of the user. These methods give the systems analyst a good understanding of the user's requirements through the structure of the developed prototype system (Pressman 1987). A prototype is iteratively modified until it complies closely with the user's actual requirements. This system is then analysed, formally specified and implemented. The user is able to participate in the design of the system and therefore misunderstandings can be reduced before the system is fully developed (Avison and Fitzgerald 1988, Hekmatpour and Ince 1986). In the context of information systems there is much discussion within the field of prototyping (Hekmatpour and Ince 1986), and this is pursued further in chapter 2.

Although there are many positive features of prototyping this does not imply that there are no problems concerning the design and use of prototypes. These can be classified as: inefficient systems; incomplete functionality; temporally based problems and finally general mis-implementation (Avison and Fitzgerald 1988). Due to the iterative nature by which these prototypes are constructed there is a tendency for these systems to become inefficient. It is also possible that these inefficiencies may be transferred to the final system (Pressman 1987). Since prototype systems are designed in an incremental manner, it is possible that functionally the system may be incomplete. Finally there is a tendency for each new system to be developed to deal with a direct problem. This leads to a tendency for new systems to be poorly integrated with core systems (Avison and Fitzgerald 1988).

The iterative nature of prototyping may also cause time delays. This in turn may lead to problems of user dissatisfaction with the lack of progress. These frustrations may be expressed as a lack of interest in further refinements and insistence that the prototype, not a full system, be implemented immediately it is agreed upon. This, through its poor construction, may lead to a lack of confidence in the delivered product (Pressman 1987).

There has been much negative discussion concerning the implementation of systems developed as prototypes due to poor code and construction being transferred into the final system. These are problems created by the use of development approaches for ease rather than for the robustness of the system (Avison and Fitzgerald 1988).

Despite these shortcomings prototyping remains one of the most powerful methods of information systems development. However, with the increasing concern over high levels of system failures, it appears prudent to search for solutions to its deficiencies. It is recognised that there are many other processes of analysis, design and implementation of information systems, but on inspection many faults may be found within all of these methods. In the search for solutions to these problems, the use of relatively new environments such as hypertext and hypermedia may offer a way forward for systems development in the future. Hypertext and hypermedia are discussed next in section 1.2. It is the intention of this thesis to investigate the potential of these environments to aid in the development of information systems. For the purpose of demonstrating this potential, a case study of the Norfolk and Suffolk Broads Authority will be used (see section 1.3). Section 1.4 discusses the objectives of the research described in this thesis followed by the thesis structure and research method in section 1.5 and 1.6 respectively. Section 1.7 concludes this chapter.

## 1.2 Hypertext: A Different Approach

Hypertext is the storage of information in a non-linear fashion. It is claimed that hypertext allows the user to store information in a manner analogous to the way in which the human mind works, i.e., by association (Jong 1988, Tsai 1988). These systems impose very few constraints on the way in which the user may access and store information. Along with these capabilities, the user can make associations or links between 'chunks' of information. This linking facility allows users to move freely between chunks of information, in a manner which best suits their purpose, whether this need is of a structured or browsing nature (Conklin 1987).

Much empirical work has been carried out in connection with the structure in which these hypertext systems can be created (Halasz and Schwatz 1990). In some ways these structures can be likened to an expert systems shell. The designer of an expert system encodes rules and information. The user of a hypertext system encodes the nodes and the information which is placed within the node and the linkages (although this may also be carried out automatically). In both cases, once information has been encoded, some form of inference or movement engine is invoked to carry out administration and interrogation.

### 1.2.1 History

The majority of hypertext inventions and developments can be traced to four people. These are: Vannevar Bush; Douglas Engelbart; Ted Nelson; and Randal Trigg. In 1945 Vannevar Bush wrote the first article on hypertext "As We May Think" (Bush 1945). In this article he outlined his idea of having a complete literary system for accessing all literature by machine. This system was called Memex. His system was designed before the invention of the digital computer and was intended to operate using microfilm and photocells.

Some eighteen years later Douglas Engelbart, whilst researching at the Stanford Research Institute (SRI), was influenced by Bush's ideas and wrote "A Conceptual Framework for the Augmentation of Man's Intellect" (Engelbart 1963). His ideas were eventually to lead to the design of NLS (oN Line System) and to several pieces of hardware including the mouse (Conklin 1987, Engelbart 1963, Jong 1988).

At the same time as Engelbart was developing his ideas of NLS, Ted Nelson was also developing ideas about augmentation. It was indeed Nelson who coined the term "hypertext" and it is his thinking and writing which are the most extravagant of the early work in this field (Conklin 1987). His idea was to create a system which had an emphasis on creating a unified literary environment on a global scale (the Xanadu System). (Nelson 1981, Conklin 1987).

The final part of the history of hypertext was brought about by Randal Trigg. He wrote the first Ph. D thesis on hypertext, describing his TextNet system (Trigg 1983). After finishing his thesis Trigg joined Xerox PARC and was one of the principal architects of the Xerox NoteCards System.

It has been only over the past few years that there has been a sudden increase in the uptake and use of ideas such as hypertext for the storage of documentation in a much richer structure than the conventional "flat files" and "directory hierarchies" (Conklin 1987). It is only more recently, since 1986, that these ideas have reached the eyes and ears of the general public. There are several reasons for this. First, there has been a phenomenal increase in the power of computers at vastly reduced prices which are within the reach of the general public. These machines are capable of supporting hypertext ideas. Second, general computing has now progressed far beyond the rigidity and formalism of the bespoke program. People now want a richer structure in which to store other forms of information which are not already provided. People want to use these much richer structures for browsing as well as to store and access information.

The most prevalent literature so far has been written on the use of these systems for the integration of online information systems in illogical as well as logical manners. These systems began to be developed by people like Ted Nelson who was frustrated by the structures within which people were supposed to work. Since the 1960's a myriad of systems have been developed which meet the above needs.

Wide public interest was first aroused during 1987 with the introduction of the first HyperCard system from Apple Computers Inc. Although this system is not a full implementation of hypertext, it can be placed in the chronology of computer history as one of the systems which brought the ideas of hypertext into the public eye. Since that time interest within this field has grown and the general area for research and development has increased exponentially.

It has been recognised that the use of hypertext has already influenced the development of software. This has been most notable in the design of human computer interaction and the personal usability of software (Doland 1989). The speed at which these prototypes can be created means that the final product can also be produced in a far shorter period and at a reduced cost. This reduction occurs because the system is closer to the user requirements.

### 1.2.2 Structure of Hypertext

The basic theoretical structure of hypertext is a network of nodes stored within the computer with links between each of the nodes providing an interconnected whole. The nodes are the areas where information is stored, with each node being linked to as many other nodes as necessary. The user can look at a node and follow a trend of thought by traversing the system to look at different chunks of information which have been linked together. This permits the users to benefit from the richness of the structure that hypertext can create. Many more areas of information which were not ideally suited to more conventional means of information storage can now be fruitfully accessed by hypertextual means so making the dreams of Vannevar Bush a reality (Bush 1945, Conklin 1987, Jong 1988, Tsai 1988).

### 1.2.3 Hypermedia

Because the area of non-sequential text linking has been thoroughly developed and because computing power and connectivity have increased to such a degree, (i.e. the ability to network machines together to provide conferencing facilities and linking machines to other peripheral devices to allow information to flow from one form of media to another), it was only a matter of time before hypertext expanded to include different forms of media. These facilities allow the incorporation of any form of information storage from sound and pictures, information on CD-ROM, laser disks and image and text scanners. These systems enable the user to access information from all sources and store it in an enormous data structure. The potential for such tools as these has already been seen in the sphere of computer aided learning (Allinson and Hammond 1990). The potential of this tool for use in the general working place is also apparent.

The extension of hypertext from the non-linear storage of information to incorporate all media of communication and sources of information, means that it has enormous potential which is only just beginning to be explored. To aid the discussion on the relevance of information systems development through the medium of hypertext and hypermedia a case study will be used to illustrate the relevant gains to be made from these environments. The case study is the Norfolk and Suffolk Broads Authority and is briefly discussed below.

## 1.3 The Case Study

The information system environment chosen for research in this thesis is the management of important environmentally sensitive areas. The particular area of application of this study is the Broads Authority, the Norfolk and Suffolk Broads. This has been chosen for a number of reasons. First, it is an environmentally sensitive area. Second, this area has recently been designated a similar status to a National Park. The Norfolk and Suffolk Broads Act (HMSO 1988) gave the Authority powers and set out its statutory responsibilities. Third, the Broads Authority has limited in-house computing experience. Fourth, the Broads Authority is legally responsible for four activities, the policies for which may be in conflict to some extent. These activities are tourism, planning, environment and navigation.

The diversity of the information handled by the Broads Authority, the newness and extra responsibilities of this Authority plus its inherent lack of a substantial computer base or computer experience makes it an appropriate case study for this thesis. The obligations of the Broads Authority require the coordination of information from each functional area. This may best be served by using an integrated information system which is capable of supporting the full range of the Broads Authority's responsibilities.

The responsibility of the Broads Authority is to oversee the land and water uses within the Broads Area. According to the Norfolk and Suffolk Broads Act (HMSO 1988) there are several criteria which the Broads Authority must fulfil. In particular the Broads Authority must pay attention to the conservation and enhancement of the natural beauty of the Broads Area; promote the enjoyment of the Broads; protect the interests of navigation and continue with the planning functions of the local authority. The Authority must also protect the local interests and needs of agriculture, forestry and the inhabitants and users of the waterways (HMSO 1988).

Arising from the Broads Authority functions there are many forms of information which are flowing through the Broads Authority. This information may be used individually and in conjunction with other information sources. Any information system provided must make allowance for these factors in its design. This information ranges from facts and figures about water quality and levels of phosphates within the Broads to pay-roll information for the Broads Authority staff. Each of these administrative roles create different types of information all of which must be stored within one system. The magnitude of the problem can be seen. Any information system must allow the Broads

Authority to handle this information in an integrated manner to enable the overall management of the Broads Area in a sympathetic and efficient manner. This in itself provides an immensely complex management task, both to store this information in a logical but also useful manner, and also to ensure that the system can cope with the management ideals and goals of the Broads Authority.

Given these complex management issues, it is likely that there will be conflicts of interest. These bring forward more managerial problems for the Authority. One of the more obvious conflicts is that of the conservation of natural beauty versus general public enjoyment. There is a need, therefore, for an information system that is capable of aiding the Broads Authority management over both the short (public pleasure) and the long (conservation) terms. It is possible to provide individual software packages that would be able to cope with each of the individual needs of the Authority, but it is questionable whether this approach would help the overall cohesion of the Authority and its ability to manage as it moves forward through the 1990's. The Broads Management needs would best be served by an integrated management system. The development of such a complex information system may be improved by the use of hypertext.

The use of hypertext to develop this type of information system has not been reported on before. It is the intention of this thesis to design and implement a prototype system and thereby investigate its ability to cope efficiently with the information management needs of the Broads Authority. Hence inferences about the appropriateness of these ideas and their implementation in general application will be drawn.

In this first chapter only preliminary information has been given about the Broads Authority. More detail will be given in Chapter 4.

## 1.4 Objectives of the Thesis

This thesis examines mechanisms that may improve the development of information systems, particularly analysis and design. The information systems considered are limited to those which are computer based.

This thesis looks at ways in which systems analysis and design, through the medium of prototyping, can be further developed and made more effective, thereby reducing the amount of time and effort needed to structure the relevant information for the design of these systems. In particular, the environments of hypertext and hypermedia are examined to determine their potential. The particular application area of Geographic Information Systems (GIS) is taken since it has many features common to information systems, with complex additional features such as spatial analysis.

To accomplish these objectives, a case study is employed to illustrate the use of these tools in a particularly complex and real GIS environment. The results of this are reported. The case study adopted for this particular problem is the Norfolk and Suffolk Broads Authority. Since the approaches of hypertext and hypermedia are investigated to ascertain the usefulness of these tools within this framework, this thesis also investigates areas related to this topic. These include: information systems; hypertext and hypermedia; and where these relate to the case study and Geographical Information Systems (GIS).

It is anticipated that the use of hypertext may allow a more rapid turn-around of information systems. It may allow the development of a flexible tool which may facilitate the systems analysts and programmers getting closer to the true user requirements and the functionality of the systems. Hence the traditional costs of rewriting - in time, confidence and money-may be lowered considerably. In addition to this, greater understanding may lead to a lower failure rate of information systems.

## 1.5 Structure of the Thesis

The aim of this thesis is to look into mechanisms to aid the development of information systems using the flexible properties of hypertext and hypermedia in conjunction with a case study of the Broads Authority. Information Systems, hypertext, hypermedia and environmental management are discussed in the following chapters. Chapter 2 discusses the ideas and development issues of IS and hypertext. Chapter 3 discusses Geographic Information Systems. Chapter 4 discusses the case study, the Broads Authority and its information needs in broad terms. Chapter 5 describes and discusses the analysis and specification of an information system for the Broads Authority using Hypertext. Chapter 6 describes the design and implementation of the prototype information system, giving a description of progress, development of the system, its problems and advantages and its broader methodological implications. Chapter 7 summarises the previous six chapters and draws conclusions from them.

## 1.6 Research Methods

Several methods of observation and development are used. First, this thesis gives a review of the current thinking in the fields of information systems development, hypertext and hypermedia.

Second, a practical method of data collection is used. The majority of the data for the case study is dealt with empirically. A considerable amount of time was spent actually working with the Broads Authority. This allowed first hand insight into the structure and information flows within the organisation. This is combined with an assessment of the structure of the organisation, covering the theory of how decisions and information should flow and the reality of how information is actually passed from person to person to decision maker. From the data collected a prototype information system has been created that is capable of serving the needs of the Broads Authority and may possibly in the longer term serve other similar organisations. From this development, inferences to general systems analysis and information systems are drawn shedding light on the problems of information systems development.

Within the context of the prototype development it is recognised that no specific method currently exists which is able to cope with the fuzziness of information which is being handled or the hypertext mechanisms which are being used to handle it. The resolution of this problem and the results of the case study are discussed in chapter 4. Therefore the creation of a mechanism or set of guide-lines attempts to meet this thesis' objectives.

## 1.7 Conclusions

It is the aim of this thesis to inquire into mechanisms which may aid the development of information systems through the medium of prototyping. As described above there are several shortfalls to these types of methods and it is hoped that by the use of hypertext and hypermedia it may be possible to alleviate these problems. To illustrate this inquiry this thesis describes the design and implementation of a prototype information system for the case study of the Norfolk and Suffolk Broads Authority. The results of this inquiry are discussed.

# Chapter 2 Information Systems and Hypertext

## 2.1 Information Systems

This chapter discusses the potential problems of the development of information systems. It endeavours to present some approaches that attempt to tackle these problems. These approaches and solutions are then discussed in the light of alternatives that may provide useful contributions to this debate.

The history of information systems development stems from the mid 1950's. At that time development was carried out in an ad hoc manner. Most applications were small and few were used in the private, commercial sector of the economy. When the application of software began to infiltrate the business sector pressure grew for new approaches because the development of software projects was costly, the projects frequently arrived late and were often over budget, inefficiently coded and accompanied by poor if not outdated documentation. Much of the blame for this was placed on poor specification.

As previously stated in Chapter 1 much time and effort has been put into designing better ways of creating software specifications, enabling sufficient planning during the development of information systems. According to Avison and Fitzgerald (1988) there has been a growing appreciation of that part of systems development that concerns analysis and design and therefore of the role of the systems analyst as well as that of the programmer. There has been a realisation that as organisations are growing in size and complexity, it is desirable to move away from one-off solutions to a particular problem and towards a more integrated information system.

At present there is no agreed correct method for the design and development of information systems. In many ways each method has differing objectives. Although they all aim to record accurately the requirements of the information systems, the techniques used to accomplish this recording highlight important features and problem areas early in the development process. By using information systems development methodologies it is possible to produce information systems which are well documented, easy to maintain and cost effective within an appropriate time scale.

The most well known of the information systems development methodologies is the conventional software development life cycle. Detailed descriptions of this can be found in Boehm (1976) and Agresti (1986). The method is broken down into six stages: Feasibility study; System investigation; System analysis; System design; Implementation; Review and Maintenance.

The feasibility study looks at the existing system, probably manual, and recommends a solution. A management decision is made using this study as its basis. Once a successful decision has been reached a detailed fact finding systems investigation begins. This phase investigates the functional requirements of the existing system and any constraints that must be considered. The main techniques employed in this phase are: observation, interviewing, questionnaires and searching. A fuller description of these techniques can be found in Avison and Fitzgerald (1988).

On completion of data collection the systems analysis phase begins. This phase analyses the present methods of working and the current system. The systems design phase encompasses the design and documentation of the system. It is at this stage that any emerging facts may lead to modification of the system design. At this point the information system is implemented. During this phase all program coding is completed and tested as far as possible. This is an important aspect as failure can cause a lack of confidence in the system. The system is then put into operation. Throughout the development process there are likely to be reviews of the system to ensure that the requirements and development cost targets are being met.

This conventional system analysis methodology has many features to commend it. It has been well tried and tested. The use of documentation standards help to ensure that specifications are complete and that they are communicated to systems development staff, the users in the respective department and the computer operations staff. It also ensures that these people are trained to use the system. Following this methodology also helps to prevent missed cut-over dates (the date when the system is due to become operational) and unexpectedly high costs.

There are several criticisms of the conventional approach. The resultant systems may fail to meet the needs of management and therefore will not fulfil the full purposes for which they were originally designed. The system design may be considered unambitious since this approach has been applied only to the design problem in hand. Sometimes these systems may be incomplete because the software has not been developed fully. This may mean that the future prospects of the system have not been planned for in the implementation of the present system. These methods may lead to instability with the system not being robust enough for the job in hand. The system may be inflexible since the information system has been designed for a specific purpose and it may not be possible to alter the uses of the system. There may be problems with documentation; it is likely in some instances that documentation for developed systems may be poor. As a direct result of this there may be a high maintenance workload for the systems' programmers which in turn leads to an application backlog. These problems may lead to user dissatisfaction which may in turn cause the failure of the system.

It is widely agreed that there is no panacea that will solve the criticisms listed above. There are, however, some developmental approaches that may be beneficial. The ideals of the systems theory and planning approaches, systems analysis and software engineering have been well discussed and documented by many authors (Avison and Fitzgerald 1988 and Senn 1985). It is not proposed to discuss them further here because this thesis concentrates on a particular approach to improve the situation. Further discussion of development techniques or strategies will be limited to participative and prototyping techniques.

## 2.2 Participation and Prototyping

### 2.2.1 Participation

In conventional systems analysis methodologies, the importance of user involvement is stressed frequently. However, it is the computer professional who more often makes the real decisions and drives the development process. Systems analysts are trained in, and knowledgeable of, the technological and economic aspects of computer applications but far more rarely in the human aspects that are at least as important. The systems analyst may be happy with the system when it is implemented. However this is of little significance if the users are not satisfied with the product. It is well documented that end users have frequently been resentful of the little part that they have played in the development of a new system while it is recognised that top management often do little more than pay lip-service to these computing methods (Mumford 1983).

Reactions against a new computer system may stem from several factors some of which maybe largely historical. Participative approaches involving the end users of the new system can do much to overcome the problems and concerns that may generate negative attitudes. The proponents of participation would argue that attitudes to the relationship between the analyst and users need to be modified if future computer applications are going to succeed. It is often said that the users may regard the computer department as having too much power and control over other departments through the use of technology. It is also often noted that poor communications between people in the organisation may be related to the use of computer jargon. It is recognised that training and education for both users and computer people can address this and avoid this cultural clash.

Somehow these barriers have to be broken down if computer applications are really going to succeed. One way to do this is to involve those people who are to be affected by the new computer system. This is discussed in greater detail in Mumford (1983).

The advocates of the participation approach recommend a working environment where the analysts and users cooperate as a team. Although the technologist might be more expert in computing matters, the user has knowledge of the application area and it can be argued that the latter is the more important. Where the users and technologists work closely, it is less likely that there will be misunderstandings that might result in a badly designed system. The user will also know how the new system operates when it is implemented. Therefore it is probable that there will be fewer problems with the new system. It is likely that this will increase commitment to the information system when operational and increase the likelihood of its success (Avison and Fitzgerald 1988).

In the participative approach the role of the computer analyst is that of facilitator, advising on the possibilities from which the user chooses. This movement can be aided by application packages that the users can try out and subsequently select from (Mumford 1983). A further option is to develop a prototype. This is discussed in the following section.

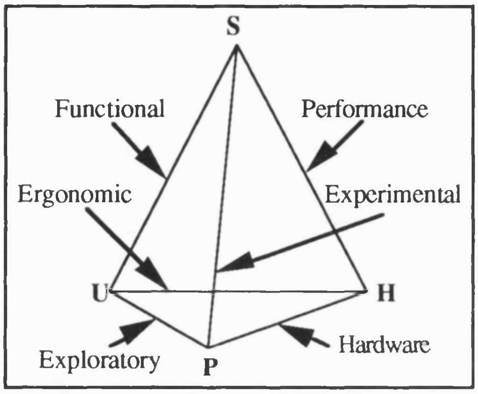
### 2.2.2 Prototyping

As stated previously in section 1.1, much time and effort has been put into better ways of creating software specifications. One of these mechanisms is prototyping. Prototyping is common in other areas such as engineering, where before production can occur, it is imperative that the design has been tested thoroughly. Within the area of information systems development, the rapid development of systems can assist the user and analyst to express and attain knowledge about each others, ideas of the system. In addition to its contribution to design, prototyping can therefore be seen as a much improved form of systems investigation and analysis. It is particularly useful where the application area is not well defined and where there is a requirement to assess the impact of the proposed system. This technique is also useful where user participation needs to be encouraged and where avoidance of user rejection is critical.

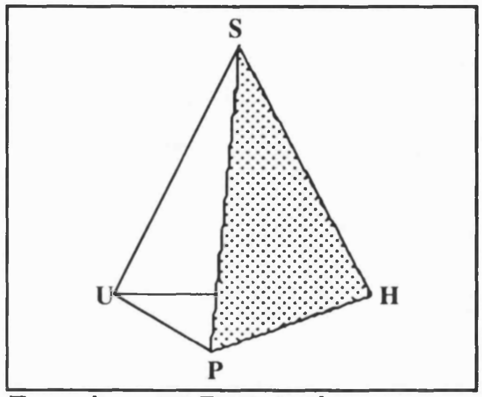
Prototyping can be described in many ways and can be used for many differing purposes. Mayhew and Dearnley (1987) developed a taxonomy by extending the classifications of Floyd (1984) and Law (1985). This classification is called the PUSH pyramid classification. This pyramid describes the relationship between the following players in the prototyping scenarios: the prototyper (P); the user (U); the software (S) and the hardware (H). Each component interacts with all other components and can therefore be displayed diagrammatically as a pyramid (Diagram 2.1). It is the relationship between these elements within the pyramid that gives an insight into the different levels of prototyping illustrated in diagram 2.1, i.e.: Exploratory; Experimental; Organisational. These are discussed below.

Experimental prototyping gives the opportunity to determine the adequacy of a proposed solution to a particular problem. The essential components of this are the prototyper, the software and the hardware (Diagram 2.1). It can be seen as a mechanism for testing the feasibility and acceptability of proposed hardware and software solutions. Within this context, experimental prototyping is also constructed to validate some elements of software design. This is represented by the PS edge of the pyramid. Performance interaction between the software and hardware is represented by the edge SH and is the central concern for judgement of a prototype's effectiveness.

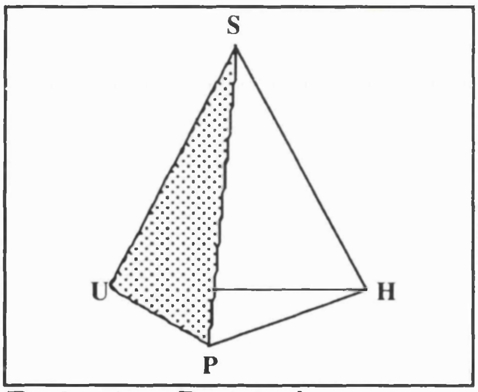
Organisational prototypes are often used to target the environment in order to clarify the wider system requirements and implications. The major participants within this class of prototyping are the user, the software and the hardware (Diagram 2.1). The aims of this are twofold: firstly, to ensure that the user requirements will be met and secondly, to clarify the needs of the surrounding organisation. The prototype may concentrate on the interaction between the user and the hardware represented by the line UH or alternately it may concentrate on the interaction between the user and the software (US) edge.



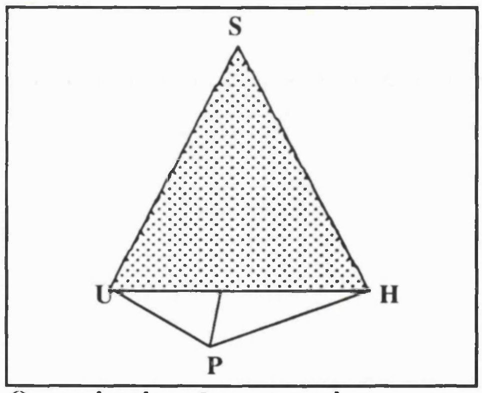

**PUSH Pyramid**




**Experimental Prototyping**




**Exploratory Prototyping**




**Organisational prototyping**

**Diagram 2.1 The PUSH Classification (Mayhew and Dearnley 1987)**

Within the category of exploratory work, prototyping is often seen to be helpful in the elicitation and validation of user requirements. The prototyping stage is seen as a catalyst for encouraging the user to participate creatively. It is seen as an aid to communication during development because the system is designed through user/analyst interaction. Exploratory prototyping can be described as prototyping the specification. Predominantly this involves the prototyper, the user and software components (Diagram 2.1). In this thesis the approach used is most accurately described by the exploratory prototyping category from the PUSH classification (Mayhew and Dearnley 1987).

Prototyping can be more than just another tool available to the analyst. It can be used as a basis for a methodology of systems development in the organisation. The methodology may have an analysis phase that is designed to understand the existing system and suggest the functional requirements of an alternative system. This may lead to a prototyping phase to construct a working model for the users to evaluate. This may then lead to a full evaluation phase where any modifications to the model are recognised and implemented. After this there may be a set of design and development phases to allow the finalization of the target system using the prototype as a part of the specification.

Many prototypes are intended to be discarded. This is because they are not designed to be used as operational systems since there are likely to be several disadvantages in using them. These disadvantages fall into several categories and in some ways mirror the criticisms of the conventional life-cycle methodology. Prototypes are often incomplete as they only perform some of the overall tasks. As the implementation of a series of prototypes occurs, often little or no attention is paid to documentation. These systems therefore are often very poorly documented and are often unsuitable for integration with other operational systems since during the completion of new prototypes several fixes are included. It is likely that these will be machine specific and thus the portability of the prototype from machine to machine is lost. Finally the performance of these systems is criticised in several ways. The systems are inefficient often due to the rapidity at which they were developed. It is plausible that the coding is not highly efficient and therefore the system will be slow. Moreover, due to the nature of the prototype it is likely that it will lack security features and be incapable of operating with the load capacity needed for the system. Finally these systems are criticised for their inadequacy and are often designed for one type of user only. It is possible that those involved in the development may represent a small number of those who are involved in the data and information processing (Avison and Fitzgerald 1987, Galliers 1987).

Prototypes are most often used as development tools, and as learning vehicles. They may lack many features that are essential in an operational system. This needs to be stressed to the users who may expect the target system to be developed at the same time as the prototype. In information systems development the value gained from prototyping is undoubtedly high. The criticisms against prototyping might be considered a major obstruction to their more widespread use. The introduction of the ideas of hypertext may alleviate these problems and hence the possibilities of this technology and its use within information system development are described below in the next section.

## 2.3 Hypertext

Hypertext originates from ideas concerning computer based information storage. The concepts of information storage have been applied successfully for many years, but, in the last few years as computers have increased in speed and memory, it has become possible to be more ambitious. Some of these more adventurous forms support the capability to store information in a non-linear manner. It is these that have been called Hypertext (Shneiderman and Kearsley 1989).

> "Hypertext, or non-sequential writing with free user movement along links, is a simple and obvious idea. It is merely the electronification of literary connections as we already know them." (Nelson 1987)

Hypertext allows the user to store information in a manner analogous to the way in which the human mind works i.e. by association (Bush 1945). These systems impose very few constraints on the way in which the user stores information. Along with the ability to store information it also allows the user to link chunks of information together (Oren 1987). In Diagram 2.2 below, assume that the reader starts by reading the piece of text marked A. Instead of following a single route through the document, this hypertext node has three options for the reader: B, D, or E. If route B is taken then the reader has two further options to go to either E or C and so on. Hypertext presents several different options to readers and the individual reader determines which route is followed at each point. Therefore there are a number of alternatives for readers to explore rather than a single stream of information.

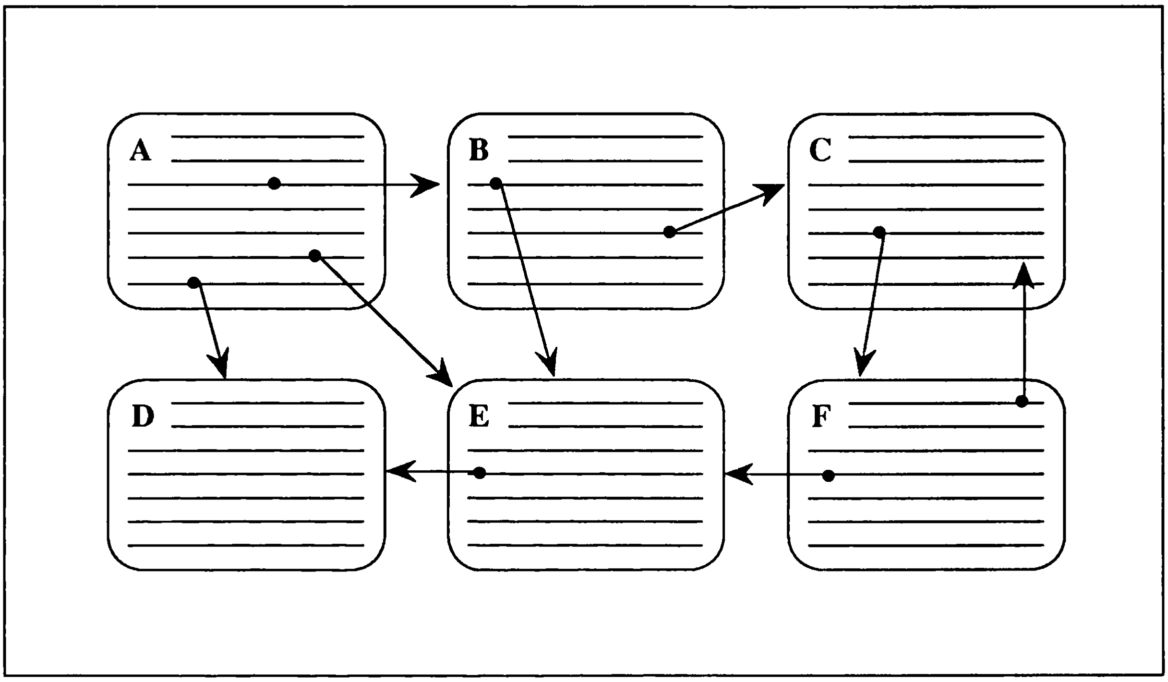



**Diagram 2.2 A Graphical Example of Hypertext**

In this instance hypertext is taken to mean a form of non-linear storage that is accessible by computer technology rather than a paper-based medium. Diagram 2.2 illustrates two important features of computer based hypertext: nodes and links. Each of the boxes (A-F) represents the computer screens or windows within computer screens. Each of these contain chunks of text or other media. These chunk holders are called nodes (this is discussed in section 2.5). Within each node there can be one or more pointers to other nodes within the hypertext system. These pointers are called links (see section 2.5). They are designed to provide pathways to join or link items together. These may be links of association to extra information or to whatever the author of the hypertext system wishes. There is no finite limit to the number of links, more can be added at any time throughout and after the development of the system, although this usually will depend on the context of the node (Nielsen 1990, Conklin 1987). These hypertexts allow the evolution of node/link networks. These networks are often referred to as webs.

Since the popular advent of hypertext there have been many different and some unusable definitions of a hypertext system. A hypertext system is a storage mechanism within which information is stored as nodes. It is also a navigation mechanism that handles the linking and other exploratory mechanisms (Nielsen 1990). Further, it is a user interface mechanism that handles the interaction between the system and the user (to be explained in section 2.4). There are also some features that characterise these systems as opposed to other types of programs. It has been stipulated that any hypertext should have a graphical view finder. Any hypertext system will form a network of nodes and links but in most current systems that network is only represented inside the computer (Conklin 1987, Zellweger 1989). At any given time the user only sees the current node and links leading out from that node. It is therefore up to the user's imagination to picture how the entire network is structured. Hypertext system developers such as Halasz (1988) emphasise the need to have a dynamic display feature to show the structure of the web that has been built. Such facilities are not usually included within systems of this type because it is difficult to represent all the dimensions of large systems on a conventional computer screen. Some systems have compromised by only showing the local neighbourhood of the current node being interrogated. It is also recommended that systems such as these should be able to nest nodes within nodes and be able to support a hierarchical structure (Conklin 1987, Halasz 1987).

### 2.3.1 Hypermedia: Multimedia Hypertext

The traditional definition of hypertext implies that it is a system for dealing with plain text. Technological advances have been such that many current systems now include the possibility for working with graphics and various other media. The word 'hypermedia' is often used in place of hypertext to illustrate the difference. However, these two terms are often used interchangeably. It may also be noted that hypertext is considered to be a more intuitive technique for supporting multimedia interfaces since it is based on the interlinking of nodes that contain different media. Typical media in hypermedia nodes are text, graphics, video and sound. The area of hypermedia is further discussed in Sherman et al (1990), Puttren and Guimeraes (1990) and Ogawa et al (1990).

### 2.3.2 A Comparison between Hypertext and Other Packages

It is true that hypertext has some similarities to databases. There is a need for some form of database underlying a hypertext system to store and retrieve the text and other media contained within the nodes. From the perspective of the user, however, hypertext is fundamentally different from traditional databases. For example, a normal database has an extremely regular structure often defined by a high-level data definition language. All the data follows this single structure, so that all records have the same fields for attribute. A hypertext information base lacks a central definition and no regular structure. Some nodes will be very extensive, with much information, and others relatively sparse. Linkages may also be made to indicate many different relationships as well as other information. Other links are also put in because of the semantic nature of the relationship of the data held within the two nodes linked (Schütt and Streitz 1990).

Similarly hypertext systems are likened to out-liner programs. Out-liners are normally used to construct the outlines of reports or presentations in a hierarchical manner. They are similar to hypertext in that they connect units of text in a user-defined format. However, that format is typically restricted to a hierarchy. Sections can only be viewed as having downward or local pointers to sections and subsections. For example, a chapter heading in an out-liner cannot have a pointer to a subsection in another chapter even though that subsection may be very relevant to its topic (Neilsen 1990).

A multi-windowed system is often categorised as hypertext but technically this is also incorrect. In fact, some hypertext systems, like HyperCard (Apple Computers Inc), and KMS (Akscyn et al 1987) do not make use of windowing. A traditional multi-window editor may allow the user to move among several units of information and compare them on the screen but the users themselves must physically access these extra windows. The basic concept of hypertext implies that the computer locates and presents the information for the user.

A mixture of text and graphics is not enough in itself for a hypermedia system. Many multimedia systems are based mostly on displaying various film clips to a passive user who does not navigate an information space. Only when the user interactively takes control of a set of dynamic links among units of information does a system become hypertext (Sherman et al 1990). One type of multimedia system that is often confused with hypermedia is interactive video. Again, it is possible to show interactive video inputs in a hypermedia interface to good effect, but many so-called interactive video systems are not really interactive enough to classify as hypermedia. The real issue is the extent to which the user is allowed to determine the activities of the system. Many interactive video systems reduce the user to the role of a passive television viewer who is only allowed to select the video clips from menus. The user has no way to interact with the video clip once it starts playing. The granularity of the interaction is too coarse to provide the user with the feeling of being in control and able to explore an information space (Conklin 1987, Zellweger 1989).

## 2.4 The Architecture of Hypertext Systems

There are three levels of a hypertext system as shown in diagram 2.3: presentation level - user interface; Hypertext Abstraction Machine (HAM) level - nodes and links; database level - storage, shared data and network access (Campbell and Goodman 1987). The basic concept of a hypertext system is described in the following sections.

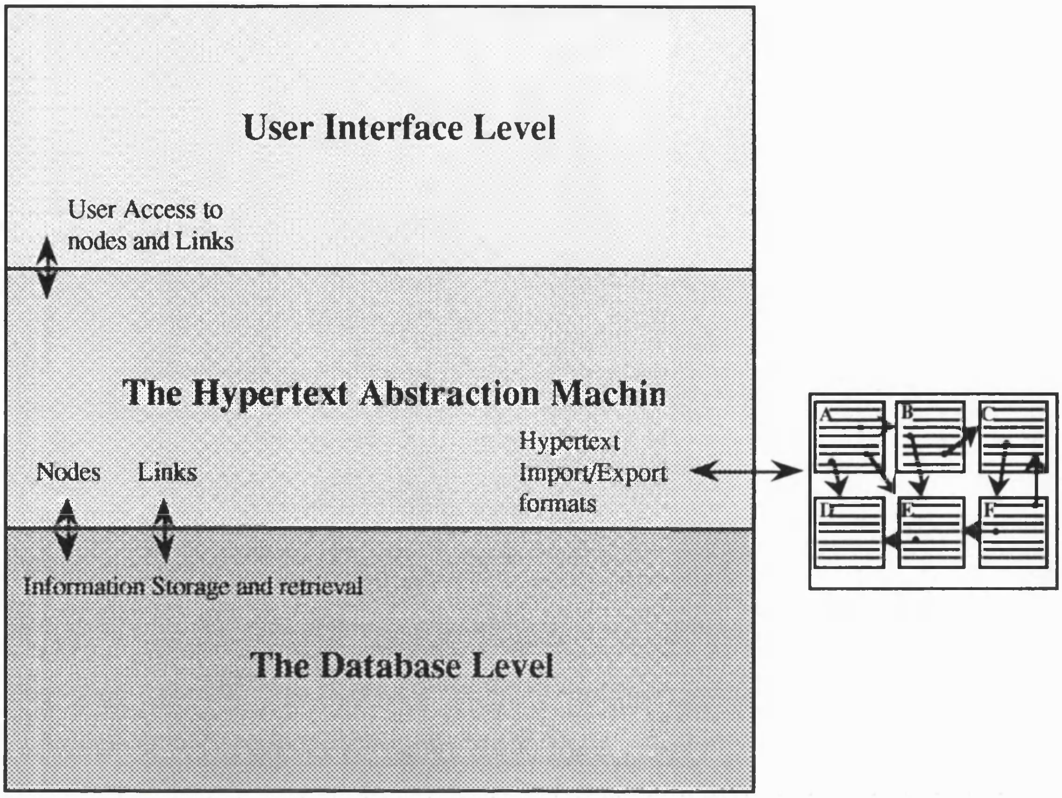



**Diagram 2.3 The Theoretical Levels of Hypertext Architecture (Campbell and Goodman 1987, Halasz and Schwatz 1990)**

### 2.4.1 The Database Level

As with many types of database, those relating to hypertext are machine dependent (see Appendix 1). The database level is at the bottom of the three-level model and deals with all the traditional issues of information storage that do not really have anything specifically to do with hypertext. According to Schütt and Streitz (1990), the creation of the database layer is important because it simultaneously defines the database and the data model which is application independent along with the development of a query language with respect to this data model. It is often necessary to store large amounts of information on various computer storage devices such as hard or optical disks and it may be necessary to keep some of the information stored on remote servers accessed through a network. No matter how or where the information is stored it should be possible to retrieve a specified small chunk in a short period of time. Furthermore, this database level should be able to handle other traditional database issues such as multi-user access to the information or security considerations. Ultimately it will be a function of the database level to enforce the access controls which may be defined at the upper levels of the architecture.

Within the database specification, hypertext nodes and links are data objects with no particular meaning. Each of these forms a unit that only one user can modify at any time and that takes up so many bits of storage space. In reality, it may be advantageous for the database level to have more information about its data objects to enable it to provide a fast response time and manage storage space efficiently (Neilsen 1990).

### 2.4.2 The Hypertext Abstract Machine (HAM) Level

The Hypertext Abstract Machine is the second level of this model. It is situated between the database and the user-interface levels. This central level is where the hypertext system determines the basic nature of its nodes and links. Practically as well as theoretically it is here where all relations between these units are maintained. The HAM has the programmed knowledge of the form of the nodes and their attributed links.

The HAM is able to recognise the forms of nodes and links and interpret their related attributes. There is a basic need to allow the import and export of data freely to and from all sources of raw data or other hypertexts systems. As mentioned above the database level of hypertext tends to be machine dependent. Similarly the User System Interface for each hypertext will be application dependent. Therefore, both of these levels are unsuitable for the development of standardised import-export formats.

Import/export of hypertext is more complex than that of the traditional information system. Hypertext interchange also requires the transfer of linking information. The possibilities of transferring basic links (e.g. from point 'a' to point 'b' links) are simple to comprehend. However major problems are now being encountered with more complex linking (Campbell and Goodman 1987). Where linking is either bidirectional or complex in nature it is increasingly more difficult to transfer such information from one hypertext format to another.

Hypertext interchange formats were initially developed through informal meetings of the Dexter Group that consisted of many designers of early hypertext systems (Halasz and Schwatz 1990). Further development now continues through the more formal activities of the U.S. National Institute of Standards and Technology. Hypertext interchange formats are, however, still a major research area within the field of hypertext (Nielsen 1990).

### 2.4.3 The User Interface Level

The user-interface level deals with the presentation of the information in the Hypertext Abstract Machine including issues such as the commands that should be made available to the user, how to show nodes and links and whether to include overview diagrams. Many of the decisions relating to these issues are decided by a mixture of the flexibility of the Hypertext Abstract Machine and the user-interface designer (Campbell and Goodman 1987). Therefore the user interface may display differing levels of information depending on the skill of the individual user, for example less information for a novice and gradually increasing for more experienced users.

Within the user-interface there may also be several display modes such as data entry and retrieval. The distinction between these activities is a major question for designers. Secondly there are questions about how linkages may be displayed. There are many different designs that can be used, for example Guide (Brown 1987a) changes its cursor style to indicate links, while NoteCards (Halasz 1988) indicate links by changing the representation of the text or icon by a differing shading or line pattern. These user-interface decisions must be made whilst considering the likely data-forms that are to be displayed. The style of the user-interface will also be dependent on the number of link types required and finally whether the hypertext system will support colour (Shneiderman 1987, Walker 1987).

## 2.5 Components of a Hypertext System

### 2.5.1 Nodes

Nodes are the fundamental units of hypertext (Halasz and Schwatz 1990). However, there is no general agreement as to what constitutes a "node". There are two main categories, the main distinction being between frame-based systems and window-based systems.

Frames take up a specific amount of space on the computer screen regardless of the amount of information they contain. Typical examples of these are KMS frames (Akscyn et al 1988) and HyperCard cards (Apple Computer Inc) (further information is given in Appendix 2). Often the size of the frame is defined as the size of the computer screen although that determination may not hold for all systems. The frame has a fixed size and thus the user may have to use several frames to display a given amount of information. The advantage of frames is that all user navigation takes place using whatever hypertext mechanisms are provided by the system. The user is not burdened with having to search the unexposed areas of each node in order to navigate fully as the system navigation takes them to the actual point required, not the just the node entry point (Neilsen 1990).

In contrast, window-based systems require the user to scroll in order to get the desired part of the node displayed in the window. As the system needs only to display a part of the node through the window at any given time, the node may be as large as needed and the need for the distribution of text over several nodes is eliminated. Guide and Intermedia are typical window-based systems (Brown 1987b, Meyrowitz 1986).

The windows may be of different sizes depending on the importance and nature of information within them. This may prove to be advantageous in the design and display of these windows within the User System Interface. These windows, however, have the disadvantage that the designer has no control over how the node will appear when the user accesses it since they can be scrolled in many directions.

There also some systems that incorporate both windows and frames into their design. For example, HyperCard is mostly frame-based but also allows the possibility of having scrolling text fields as part of a card. 'Hyperties' (Shneiderman 1987) uses a full-screen display without scrolling but permits the users to page back and forth through a sequence of screens in cases where the node is too big to fit on a single screen (Kreitzberg and Shneiderman 1988, Neilsen 1990).

Most current hypertext systems provide fixed information in the nodes as written by the original author. In computational hypertext systems like KMS and HyperCard (with embedded programming languages) or NoteCards (Halasz 1988) (with an interface to a programming language), it is possible to have computed nodes generated for the reader. For example a node may be capable of importing data and completing calculations for investigation for examples.

### 2.5.2 Links

Links are the other fundamental units of hypertext. They are almost always anchored at their departure points to provide the user with some explicit object to activate to follow the links. Most often, this anchoring takes the form of "embedded menus" where part of the primary text or graphics does double duty as being both information in itself and the link anchor. It is also possible to have the hypertext anchors listed as separate menus. (However, it is considered that this reduces the "hypertext feel" of the design.) The result of activating the anchor is to follow the link to its destination node (Conklin 1987, Neilsen 1990).

Almost all current hypertext systems are limited to providing uni-directional links. This means that the system can show the users the links that have the current node as their departure point but not the ones that have it as their arrival point. Hewett (1987) advocated the use of bi-directional links in hypertext. This means that the system should also be able to display a list of incoming links. From a computing point of view this is a trivial task but it is rarely implemented.

A hypertext link connects two nodes and is normally directed in the sense that it points from one node (called the anchor node) to another node (the destination node). Hypertext links are frequently associated with specific parts of the nodes that they connect with rather than with the nodes as a whole (Diagram 2.3 on page 37). Links can be made general or specific to the extent of relating to a relevant word.

Most links are explicit in the sense that they have been defined by somebody as connecting the departure node with the destination node. Some systems also provide "implicit" links, which are not defined but follow from various properties of the information. For example, an automatic glossary look-up is possible when using the application Intermedia (Meyrowitz 1986). It provides a link from any word in any Intermedia document to the definition of that word in the dictionary. However, it would be inefficient to have to store all these links explicitly. Only when the user requests the definition of a word does the system need to find the implicit destination for the link.

A hypertext link has two ends. Even if a link is not bi-directional there may still be a need to anchor it explicitly at the destination node. Most frame-based hypertext systems only have links that point to an entire node, but where the destination node is large it may be an advantage for the user to have the system point out the relevant information more precisely. In general, a hypertext should be designed so that it is able to tell the user why the destination for a link is an interesting place to jump to by relating it to the point of departure and following a set of conventions for the "rhetoric of arrival" (Landow 1987).

In addition to standard links connecting two nodes, some hypertext systems also have super-links to connect several nodes. This is where a single anchor is a gateway to several destinations. There are several mechanisms for displaying these super-links. The two simplest options are either to show a menu of the links or to go to all the destinations at the same time. For example Intermedia uses the menu option and allows the user to choose only a single destination. This obviously will be dependent on the node architecture of the system. Users of NoteCards can implement a "fat link" type that simultaneously opens windows on the screen for all the destination nodes (Trigg and Irish 1987).

An alternative would be for the system to choose for the user in some way. The choice could be based on the system's model of the user's needs or some other estimate of the best destination or it could simply be random. The latter choice is not recommended (Landow 1987).

Link anchors present special problems for layered hypertext architectures. Principal links belong at the hypertext abstract machine (HAM) level but the location of the anchor in the node is dependent on the storage structure of the node media. In a text-only node, an anchor position can be described as a sub-string whereas an anchor in a film clip needs both sub-string information and a graphic location. Therefore the actual anchoring of the link cannot be handled by the hypertext abstract machine. The Dexter model defines an explicit interface between the hypertext abstract machine and the database level as a potential solution to this problem. Anchors become indirect pointers and the anchoring interface provides a translation between anchor identifiers in the hypertext abstraction machine and actual anchor values in the node data (Halasz and Schwatz 1990).

Annotation has also been singled out for comment by several authors. These are a special type of link that allows the author to place a link to a small additional amount of information. By analogy they are quite similar to footnotes in traditional text and can be implemented for example as mouse controlled pop-up windows. However the most interesting use of annotations in hypertext is for the users. Many hypertext systems allow users to add new links to the primary material but not to change the original node and link structure. Users can employ these facilities to customize the information space for their needs (Neilsen 1990, Meyrowitz 1986).

There is much debate about whether or not to make anchors especially prominent within the node context. It is generally agreed that this must be related to the percentage of the information within a node that serves as link anchors. Shneiderman and Kearsley (1989) have stated that where up to 10% of the nodes are anchors then it is beneficial to emphasise the anchors. However as this percentage increases in more anchor rich hypertexts it is better to remove any special emphasis from the anchors.

There are several different ways of indicating anchor points rather than having them on the screen. Most current hypertext systems have plain links which are just connections between nodes. The advantage of that approach is its simplicity for both the author and the reader. The link appears transparent to the user and navigation can be achieved by a mouse click or similar action (Brown 1987a).

Alternatively, a link can be tagged with a keyword or semantic attribute such as the name of the creator or the date it was created. These tags allow the complexity of hypertext to be reduced through filter queries e.g. to show only links created after a certain date or by a certain person. Links can also be typed to distinguish between different forms of relationship between nodes. Trigg (1983) presented an elaborate taxonomy of 75 different link types including abstraction, simplification, refutation and data.

### 2.5.3 Hypertext Engines

Most of the hypertext systems commercially available or under development are really engines that can display many different hypertext documents. Other hypertext systems are built specifically to display a single document and can therefore provide a much richer interaction with the content of that document. Hypertext engines have the advantage that they provide a user-interface common to many documents. Users who already know how to access one system can immediately start exploring a new document written in the same system.

Some hypertext system such as Guide and Hyperties are truly plain engines. The author includes text and graphics and the system manages the data. The author does not have to make any user-interface decisions except for a few low-level details such as text format. Other hypertext engines allow the hypertext designer to customize the user-interface to a document within a certain framework. HyperCard is a prime example of such a system. It allows the designer to change the location of fields and add background graphics. Even so the designer is constrained by the basic HyperCard framework of being a frame-based system with individually fixed size monochrome cards. There are certain user-interface facilities available in a kind of construction kit for the designer, but it is not possible to add new interaction techniques (Sherman et al 1990, Puttren and Guimaraes 1990).

## 2.6 Applications of Hypertext

Hypertext is not suitable for all applications. To determine whether an application is suited to hypertext, Shneiderman and Kearsley (1989) proposed three golden rules for hypertext.

i) A large body of information is organized into numerous fragments.

ii) The fragments relate to each other.

iii) The user needs only a small fraction at any time.

This is further extended by Nielsen (1990) who states:

> "do not use hypertext if the application requires the user to be away from the computer".

These differing types of hypertext applications are summarised in Appendix 2; those most relevant to this thesis are discussed in the following section.

### 2.6.1 Software Engineering

During the software development life-cycle a large number of specification and implementation documents are produced and hypertext has great potential for providing links between them. It is therefore possible to create links between relevant parts of a document, for example a requirements document, to enhance understanding (Garg and Scacchi 1987). It is also possible to use hypertext in a less life-cycle oriented approach by including facilities in structure-oriented editors for program code. For example, it is possible to click on a variable to see its definition and associated comments or to link from a procedure call to opening a window with the text of the procedure. The Smalltalk Browser links related pieces of code together in a manner similar to this.

Since much of the software engineering process is spent on designing systems rather than coding there is interest in specialized tools to support the design phase of the life-cycle. Software design is usually a collaborative process involving many people. The participants in the design process argue about these issues by suggesting positions (ways to resolve the issue) and arguments for and against those positions within a hypertext system. The gIBIS system has been used for this purpose very effectively (Conklin 1987).

### 2.6.2 Operating Systems

Current personal computers are fundamentally based on a file paradigm where the user manipulates discrete (but large) units of information as files. Each file can be typically found only in a single location in the file system and it is typically best suited for use by a single application program.

This model had a good fit with early personal computers which were rather small and limited in many ways. They operated on limited data types (often numbers and text). Each user attempted only a small number of applications because they were difficult to learn and the file storage was limited by the capacity of small hard disks. Modern personal computers are intended for multimedia data. They support sufficiently user-friendly interfaces to allow users to learn and attempt many different applications. Furthermore, these machines are often connected to large storage media either directly or by network and have to access a large number of files. Hypertext has the potential to revolutionize the user-interface of personal computers bringing closer the possibility of a task-integrated working environment (Neilsen 1989). Further examples of applications of Hypertext are given in Appendix 2.

Most current systems organise files in a hierarchy and require the user to navigate through multiple levels of subdirectories to reach individual files. It is not surprising that users often have difficulty locating stored information and are aided only by limited searching abilities. These facilities are primitive compared to the navigational facilities offered by some hypertext systems. It would be possible to extend future operating systems with a system-based hypertext service. Preliminary research has resulted in the Sun Link Service (Pearl 1989). This extension would allow different applications to link transparently to information generated by other applications and stored elsewhere. Within such systems users would only need to make initial connections between items. After this the system is able to switch from one to another seamlessly. This would avoid the need to drop into the operating system to carry out searching tasks. Users could concentrate on their tasks while allowing the computer to integrate its applications and data to fit those tasks.

These new interesting mechanisms of integration have enormous potential for software development and operating systems. There is also the potential to use these systems as prototyping tools. It is ideas concerning hypertext that are of the most interest within the context of this thesis and its investigation of information system prototyping and integration.

## 2.7 Conclusions

This chapter has discussed the development of information systems and its problems. The methods of prototyping appear to offer facilities to improve the elicitation and validation of system specifications. They provide mechanisms for testing new products and for extending existing organisational systems. Through these iterative processes prototyping offers opportunities for greater commitment to the new system through user involvement, as well as achieving system specifications that are closer to the true user requirements than would be possible through traditional systems analysis.

As described in sections 1.1 and 2.2.2, prototyping is often criticised because of the extra development time that these methods take, the incompleteness from which these systems suffer and the inefficient nature by which they operate given the rapidity with which these are developed. For these reasons they are mainly used as learning vehicles, and the emphasis of these methods must now rest on the speed in which prototypes can be developed and the amount of information that can be gleaned through these methods.

Hypertext may potentially facilitate prototyping by giving the prototyper an environment in which to collect both the information and to build the prototype. As can be seen by the work of Fletton (1990), program documentation is already carried out in a retrospective manner. It is postulated that hypertext may be exploited throughout the whole prototyping and information systems development process.

Before testing these assumptions on the Norfolk and Suffolk Broads Authority Case Study in chapter 4, the topic of Geographic Information Systems (GIS) is introduced in chapter 3, so that the general natural of these systems and their particular complexities are understood.

# Chapter 3 Geographical Information Systems

## 3.1 Geographical Information Systems

This chapter describes Geographical Information Systems (GIS). It discusses the traditions of GIS, and the individual functions and components that comprise a GIS. This chapter will briefly describe the criteria that are employed during the design and implementation of GIS. The spatial analysis techniques and the applications to which they are applied are also discussed.

These systems were first developed during the 1960's starting with the Canada Geographical Information System. Despite previous technical limitations, it has been clearly recognised that certain types of map analysis and inventory, particularly overlays and measurement of area, can be carried out much more efficiently by computer than by hand. This idea of automated map analysis remains a key justification of GIS (Griffiths and Lynch 1987). The evolution of these systems into that which are now recognised as GIS has taken place because of the technical and analytical skills of interested parties. This has come about because of the interest of cartographers, surveyors and photogrammetrists, spatial analysts and geographers. They recognise GIS as a mechanism for efficient mapping, larger and better spatial data storage and analysis (Tomlinson 1990).

The growth in GIS has caused much interest over the past few years. The first publication of the International Journal of GIS was in 1987 and included a review of spatial data handling (Chorley 1987). In the light of the continuous reduction in computer costs it is easy to postulate that there is likely to be growth in this area. The development of GIS packages for personal computers and workstations has brought the cost of GIS within the grasp of both the private and public sectors. With the emergence of these systems and the technological platforms on which they are based it is necessary to define GIS in terms of its technical and actual potential.

GIS is a branch of information systems. It deals with the analysis and storage of geographically distributed or spatial data using computer systems. The term 'Geographic' is used to mean spatial phenomena. A GIS is, therefore, a software package that contains a unified set of tools and concepts for handling and displaying spatial data. As with other software packages, GIS can be applied in many different spheres with different aims and abilities as well as running on different hardware platforms (Butler 1988).

These systems provide many benefits in both the short and long term. GIS have the ability to provide access quickly and easily to large volumes of data. Such systems can also provide more flexible forms of output such as maps, graphs and summary statistics that can be tailored to individual requirements. GIS also facilitates analysis for long term strategic planning, for example, the US Bureau of Census. The use of GIS allows the analysis of spatial data in ways that previously were inconceivable because of the amount of manual effort needed. The data in a GIS can be thought of as a representative model of the real world. These data can be accessed, transformed and manipulated interactively in a GIS. Such data can, therefore, serve as a test bed for studying new trends. For example, for analysing the results of the trends, or of anticipating the possible results of a planning decision. These are discussed further in the following section.

It is necessary to define geographical information and the technical details that are commonly associated with Geographical Information Systems. Geographical information is defined by Chorley (1987) as:

> "Information which can be related to specific locations on the earth."

Geographical information is most commonly thought of as having three basic characteristics. Firstly, that there is an actual phenomenon or characteristic, such as a variable, its classification, value or name. Secondly, that it has a spatial location, for example, the location within the geographic space where it resides. Finally, that the data has a temporal dimension (Dangermond 1990a). (Spatial data is further discussed in section 3.2). Locational data may also have attributes assigned to it. Within the GIS data system, therefore, there are three data elements of locational and non-locational (attribute) data and time (Dangermond 1990a, Peuquet 1990).

Geographic information, or spatial data, can be considered as the main functional component in the study of GIS. There are several differing definitions of GIS. These have appeared because of the different terms by which these systems are known, for example, 'geo-based information systems', 'natural resource information systems' and 'spatial information systems' (Clarke 1986). This has lead to the definition of GIS by its particular function. For example, Smith et al (1987) define GIS as:

> "A database system in which most of the data are spatially indexed, and upon which a set of procedures operates in order to answer queries about spatial entities in the database."

Whereas Ozemoy et al (1981) describe GIS as:

> "An automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation and display of geographically located data"

It is helpful to have a global definition of Geographical Information Systems. Clarke's (1986) definition is widely accepted as a good universal definition. He describes GIS as:

> "Computer-assisted systems for the capture, storage, retrieval, analysis and display of spatial data".

Clarke (1986) has outlined several elements that GIS must incorporate. A GIS must hold a large body of data that have spatial properties. Secondly, a GIS should not consist of a series of stand-alone exploratory programs but should be a complete application. Thirdly it should have a common set of sub-components that perform functions necessary for the system. These sub-components fall into five categories: Data Input, Maintenance, Retrieval, Manipulation and Output. These are discussed in the five sections 3.2 - 3.6 below.

Two distinct classes of GIS may be distinguished. The first class uses map-based data (particularly in vector format) and finds applications in, for example, engineering, boundary analysis and thematic representations. The second class uses image-based data (particularly in raster format) and finds applications in image analysis and remote sensing. Griffiths and Lynch (1987) add two further categories to this classification. These are the traditional manual GIS and expert, knowledge-based systems. Most research so far has involved GIS based on map-type data (Smith et al 1987). This thesis discusses the categories of vector and raster based GIS only.

## 3.2 Data for Input to a GIS

Geographical Information is often obtained in a variety of formats. These include graphic data, non-spatial information from both printed and digital files, as well as digital spatial data types such as remotely-sensed data, for example, LANDSAT or SPOT satellite remote sensing images. These data require manual or automated pre-processing before encoding. There is no single method of entering spatial data. There are several mutually compatible methods that can be used alone or in combination. The choice of which method to use is based on the application, the available budget and the type of data being input. The method of data input used is also dependent on the structure of the GIS database and whether the data is to be handled in raster or vector format.

During data acquisition, relevant information for each data type should be obtained which as far as possible, describes the accuracy, precision, currency and spatial characteristics of data (Smith et al 1987). There are a variety of pre-processing procedures and these are described in the following paragraphs. With vector data the source of data is envisaged as points, lines or areas (see Diagram 3.1). If the data is to be encoded manually, the coordinates of the data are obtained from the reference grid already on the map or from a reference to a graticule or overlay grid. They can then be simply typed into a file or input into a program (Burrough 1986).

Raster data is input in a different manner. All points, lines and areas are envisaged as sets of cells. Factors such as the size of the grid squares and the method of encoding may be decided by the individual (Dangermond 1990a). Each cell must be separately recorded and entered. The storage of this type of grid data may be completed manually or by using run-length codes. Run-length codes can save considerable time during the data encoding process. These make use of the fact that many adjacent cells have the same value. Consequently it is only necessary to enter the data for each row, or run, specifying a cell range and a value (Burrough 1986).

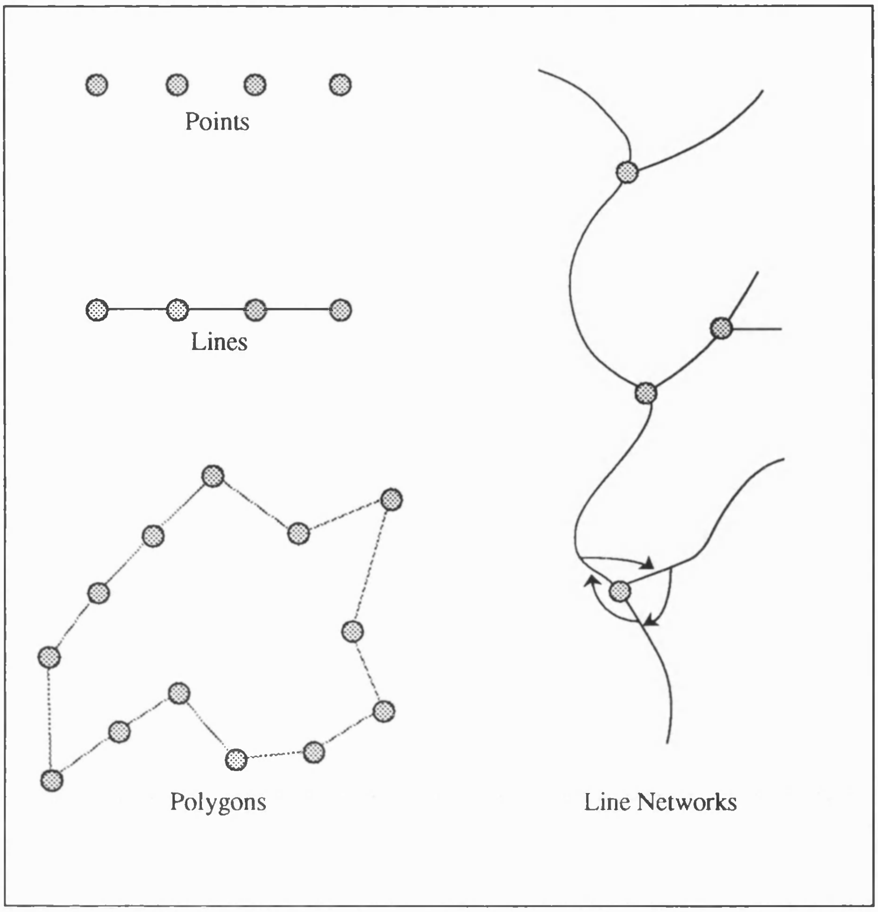



**Diagram 3.1 Vector Data: Points, Lines and Polygons**

One important method of encoding vector data is to use a digitizer. Digitising automates the process of manual recording of vector coordinates. A digitizer is an electronic or electromagnetic device consisting of a tablet upon which the map or document is placed. These machines function by either using an electrical-orthogonal fine-wired grid or electrical-wave phase. Both kinds of digitizers can be supplied in formats up to $3m^2$. The coordinates of a point on the surface of the digitizer are sent to the computer by a hand-held magnetic pen. This is a simple device called a 'puck'. The puck consists of a coil embedded in plastic with an accurately located window with cross-hairs. The coordinates of a point are digitized by placing the cross-hairs over it and pressing a control button on the puck. A fuller discussion of digitizing may be found in Dangermond (1990a).

There are also several forms of automated scanning procedures. These tools are available to scan both raster and vector images. Raster scanners are fairly common and rely on low-powered laser technology to create the pixel image from the original. It is possible to convert images that are created by raster scanning into vectors. There is also technology available to vector scan images, but vector scanners are more complex. The process involves the production of a transparent copy of the map to be digitized. This is then projected onto a screen in front of the operator. Using a light cursor, the operator guides a laser beam to the start of a line. The laser then follows the line until it arrives at a junction or back at the start point. This is repeated for all lines to create the final image (Howman and Woodsford 1978).

The inclusion of non-spatial attributes may be carried out quite simply by typing the data values with a common identifier into the spatial data file. Therefore although attribute and spatial data are encoded separately, they can be linked within the GIS database. Vector data that has already been encoded may be simply linked as the digitizing process allocates individual codes to each data entity. Raster data is more difficult to link. At present there are no methods to identify uniquely raster data and automatically associate it with a geographical entity. The attachment of unique identifiers must be completed manually.

Where data (both spatial and attribute) is received in machine readable form it is possible that the data will be either input straight into the GIS or it may have to undergo some format conversion. This could mean that the data is either vector or raster, or that the data does not conform to the input regulations of the GIS software. The format of the data must therefore be transformed into the correct pattern for the system. Once the data is in the correct format for use by the system the appropriate level of spatial data resolution must be created. This can mean that the spatial data points must either be reconstructed or generalised from other spatial data units. The reconstruction of these data points may be carried out by the amalgamation of data from higher and lower levels of abstraction of the data for the spatial area needed. Further details on spatial data manipulation are given in section 3.5.

As with all data entry there is a possibility of encoding errors within the data entry part of the system. Spatial and attribute data is often input manually, a time consuming, repetitive task and it is likely that errors may be present within such data sets. However, the encoding of these data points can be checked both manually and by error detection processes within the GIS. Where errors are found it is normally possible to edit the data to rectify the problem. A fuller description of error detection and editing can be found in Chrisman (1990).

The data can either be stored as points, lines or polygons (see Diagram 3.1 on page 55). For different types of analysis it may be beneficial to merge points into lines and lines into polygons. This merging procedure may also be carried out when spatial data is input into the system as part of the format conversion. Polygons, which were originally digitised separately, may be input together to form a single map. Since it is possible that lines which are common to both polygons may have been digitised differently these edges may be mismatched. To overcome this and to remove any mismatches, an edge-matching data management technique is used. These are discussed in section 3.5.

Throughout these processes the spatial data units are registered within the system so that the use of these units as objects and layers can be more easily completed. The spatial data handling side of the GIS completes all the above tasks.

## 3.3 Data Management

Data management allows a database to be used through a combination of hardware and software facilities and operations. A GIS should include integrated database management software designed to support multiple users and multiple databases. With the increased use of micro-computers has come the ability to use individual personal computer-based GIS over a network attached to a centralised database (Whitehead and Hershey 1991).

The data management of GIS must also allow for the efficient storage, retrieval and update of spatial data. Within the machine many different data structures may be used as well as simple files. The most commonly used of these structures are the hierarchical, network and relational database structures. These structures are shown in diagram 3.2a - d (Burrough 1986).

Due to the nature of spatial data, large amounts of storage space are often occupied. It must be possible to access these data sets in a timely fashion for analyses. The data management of the system must be able to store the information in ways that are both storage and access time efficient. Finally, due to the changing nature of GIS, data management must also be able to accommodate updating and editing of spatial and non-spatial data. This may usually help to eliminate redundant data. Thus, information may be stored at the most detailed spatial level to allow the access to all levels of spatial detail. The security and integrity of the data must always be ensured. The manager therefore must be able to support several of these functions to ensure the safe running of the GIS (Burrough 1986).

Data management is governed by the type of data being stored. Diagram 3.2 a - d below illustrates the data structures that are most commonly used in GIS. Where the data have a one - to - many relationship, hierarchical methods provide quick access to the data. These systems assume that each part of the hierarchy can be reached using a set of discriminating criteria that fully describes the data structure. These systems of data storage have the advantage that they are easy to understand, update and expand.

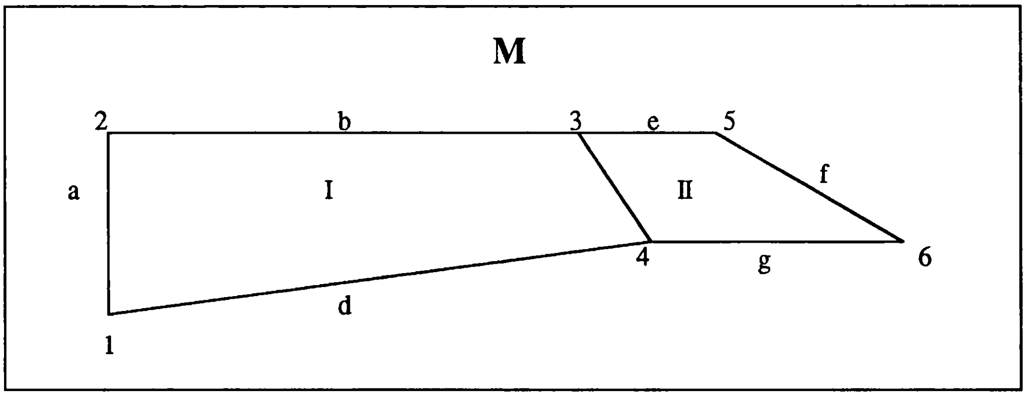



**Diagram 3.2a A Schematic Map (M), showing two polygons (Burrough 1986)**

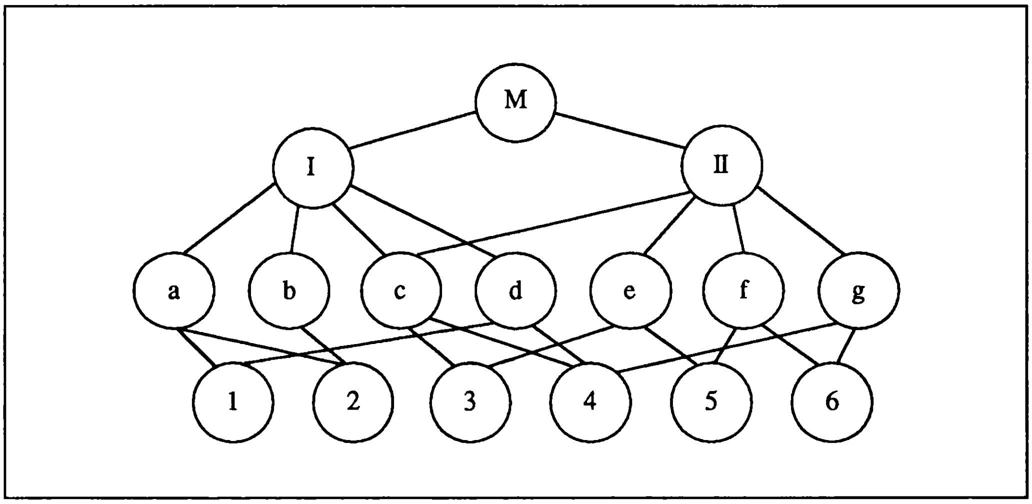



**Diagram 3.2b The Network Linkages within the Polygons of Map (M) (Burrough 1986)**

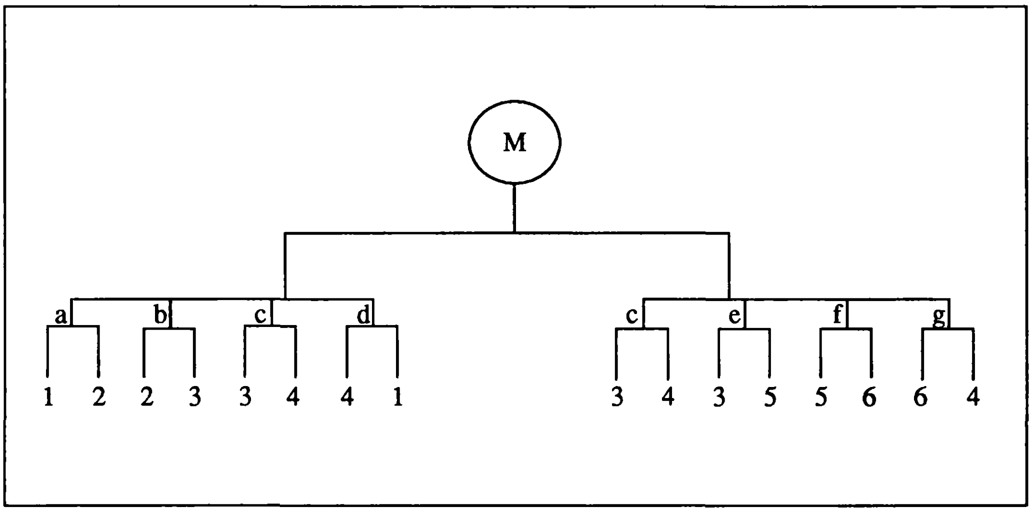



**Diagram 3.2c** **The Hierarchical Data Structures of a GIS (Burrough 1986)**

| | | | |
|---|---|---|---|
| I | a | 1 | 2 |
| I | b | 2 | 3 |
| I | c | 3 | 4 |
| I | d | 4 | 1 |
| II | e | 3 | 5 |
| II | f | 5 | 6 |
| II | g | 6 | 4 |
| II | c | 4 | 3 |

*Line Descriptions*

| | | |
|---|---|---|
| M | I | II |

*Map Description*

| | | | | |
|---|---|---|---|---|
| I | a | b | c | d |
| II | c | e | f | g |

*Polygon Description*

**Diagram 3.2d** **The Relational Data Structures for GIS (Burrough 1986)**

Data access to key attributes is simple but it is more difficult to access associated attributes. Hierarchical systems are good for data retrieval if the structure of all possible queries is already known. This provides limitations when using spatial data. An associated problem with hierarchical structured databases is that they have large index files that must be maintained and certain attributes may be repeated often. This causes redundancy (Peuquet 1990, Date 1976).

Network systems make some inroads into solving this problem. In hierarchical systems, travel within the database is restricted to paths up and down. In many situations much more rapid linkage is required, particularly in data structures for graphic features where adjacent items in a map or figure need to be linked. Network systems are very useful when the relations or linkages can be specified before. They avoid data redundancy and make good use of the available data. They have the disadvantage that the database is enlarged by the overhead of these pointers which in complex systems can be substantial (Burrough 1986).

The relational database structure in its simplest form stores no pointers and has no hierarchy. Instead, the data are stored in simple records. These are known as tuples. These tuples contain an ordered set of attribute values that are grouped together into two-dimensional tables. These are known as relations. Each table or relation is usually a separate file. The pointer or key structures are replaced by identification codes that are used as unique keys to identify the records in each file. Relational databases have the advantage that the structure is very flexible. They have the disadvantage that many operations involve sequential searches through the files to find the required data (Peuquet 1990, Date 1976).

There are several data structures that must be outlined. These can be subdivided into raster and vector data structures. The simplest raster structures consist of an array of grid cells or pixels. Each grid cell is referenced by row and column number and it contains a number representing a value of the attribute being mapped. Raster representation assumes that the geographical space can be treated as though it is a flat Cartesian surface. Each pixel is then by implication associated with a square parcel of land. The resolution, or scale of the raster data is then the relation between the cell size in the database and the size of the cell on the ground.

As each cell in a two-dimensional array can only hold one number, different attributes must be represented by separate sets of Cartesian arrays. These are known as overlays. The idea of overlays is realised by attaching two-dimensional arrays. This results in a three-dimensional structure. The vector representation of an object is an attempt to represent the object as exactly as possible. The coordinate space is assumed to be continuous which allows all positions and lengths to be defined precisely. Methods of storing vector data tend to use implicit relations that allow the data to be stored in minimum space. Such data can be stored in points, lines, networks and polygons. Points are defined by their X,Y coordinate pair and its related information. Line entities are defined as linear features built up from straight line segments made up of two or more coordinates. The simplest line requires the storage of a start point and an end point plus a record indicating the display symbol to be used. Simple lines and chains carry no inherent spatial information about connectivity such as might be required for a drainage network.

To build a network of lines that can be traced by the computer, it is necessary to include 'pointers' into the data structure. The pointer structure is built by the nodes. The nodes carry pointers to the lines and carry data records indicating the angle at which each chain joins the node and thereby defining the topology of the network. Areas or regions of polygons can be represented in various ways in a vector database. Each polygon has a unique shape, perimeter and area. The aim of a polygon data structure is to be able to describe the topological properties of area. This is so that the associated properties of these basic spatial building blocks can be displayed and manipulated as thematic map data. Geographical analyses require the data structure to be able to record the neighbours of each polygon in the same way that the stream network requires connectivity. Polygons need not all be at the same level or digitised to the same level of accuracy.

Vector database structures may also contain layers similar to the raster database structures. In principle the number of layers that can be created is unlimited. However, limitation is imposed by the amount of hardware storage space. For data manipulation, the type of data being stored, and the amount and the detail that is to be stored, are important. It is important to select the correct database model for implementation. Therefore for the successful retrieval and manipulation of data from GIS databases it is important that these factors be considered.

## 3.4 Data Retrieval

Data retrieval involves the basic extraction, query and Boolean manipulation of information contained in an organised GIS. These retrieval functions can be categorised into: browsing; windowing, query window generation; multiple map sheet spatial querying; Boolean attribute retrieval and statistical summary (see Diagram 3.3).

Browsing consists of using a computer monitor to browse through the graphic and non-graphic data files associated with various maps and groupings of maps. Windowing relies on the ability of the user to specify windows either by X,Y coordinate or by textual information. Spatial database management typically calls for the organisation of map sheets into some form of modular relational structure which creates the illusion to the user that a continuous map is contained within the computer (See Diagram 3.3).

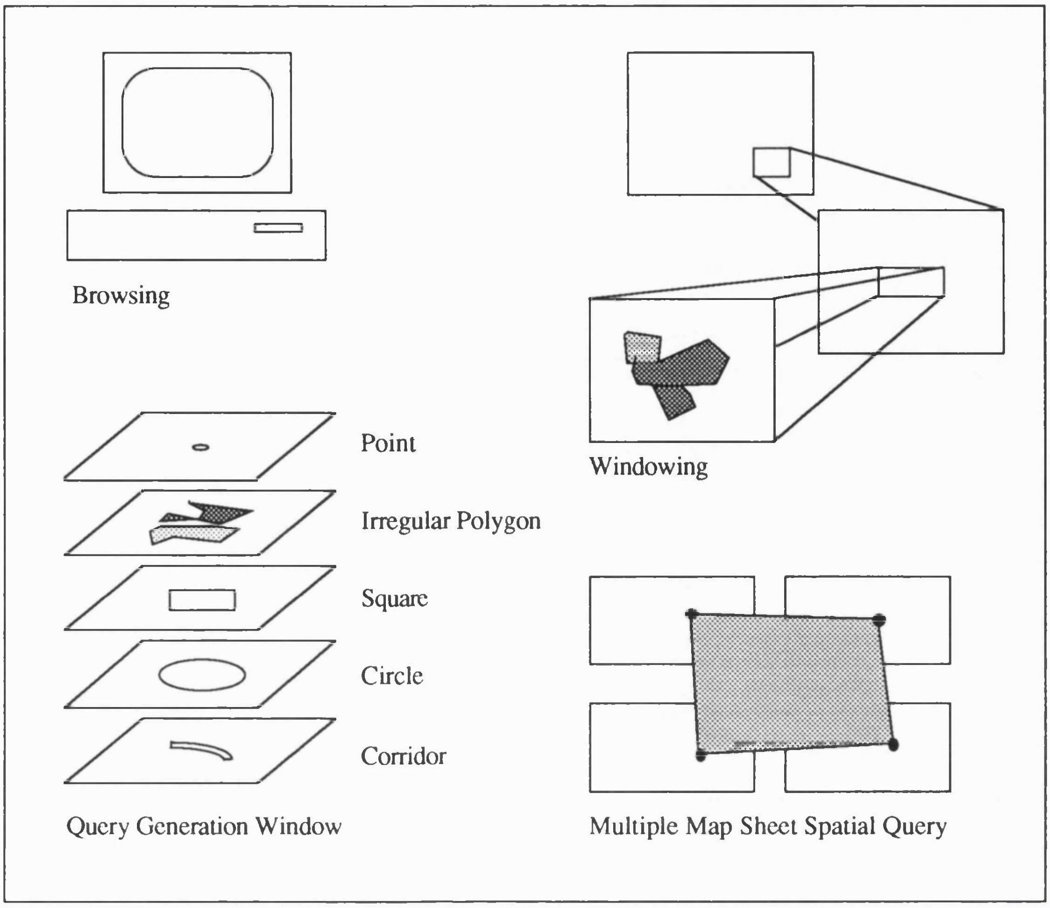



**Diagram 3.3 Data Retrieval Techniques (Dangermond 1990a)**

Query window generation involves the ability to generate points of irregular shaped polygons, squares, circles and corridors for interactively overlaying with data planes contained within the geographic file. These windows are typically used to perform spatial retrieval of spatial data from various map layers that coincide in the space with these generated query windows. Where this is carried out over several map sheets it is called multiple map sheet spatial querying. The data retrieval software, therefore, must have the ability to create a polygon across several map layers (see Diagram 3.3). Finally, the retrieval of attributes involves the specification of Boolean criteria for extraction of information based on non-graphic attribute data. The production of statistical summaries of data attributes is also possible.

## 3.5 Data Manipulation

Most modern GIS include complete sets of functions for entering, storing and retrieving spatially indexed information. The methods of analysis that are usually included in standard GIS are often based on Boolean operations on the attributes of spatial entities. These operations are carried out on all spatial entities and are used to compute various statistics or to create new spatial data, for example, isomorphic buffer zones. In raster systems the analysis methods often include options for "Cartographic Algebra" such as addition and subtraction of layers, computation of slopes and aspect, sun intensity and filtering.

Users often wish to re-classify attribute data and carry out analysis that entails the aggregation of that data into different spatial levels. Often the user may wish to present data in different projections and these might entail geometric operations such as the rotation, translation and scaling of coordinates. These may also entail the conversion of geographic coordinates to specific map projections, rectification, registration and removal of distortion. Within these types of analysis the user may wish to locate the centres or centroids of polygons and areas. He or she may also wish to allocate values to lines (Smith et al 1987). Data manipulation operations typically needed by users and found in many GIS are described in the following sub-sections 3.5.1 - 3.5.6.

### 3.5.1 Map Generalization

As shown in diagram 3.4, map generalization is a series of techniques that allows maps to be created at the correct level of detail for the display scale required. There are four basic types of map generalization: line coordinate thinning; dropline; edge-matching; and polygon thinning. These tools are most frequently used when map scales are changed. Line coordinate thinning is a technique for reducing the number of coordinate pairs that define a given line. The technique of dropline is used where a polygon boundary that separates two polygons of similar characteristics can be deleted. The remaining line segments of the two polygons are then joined to form a new polygon unit.

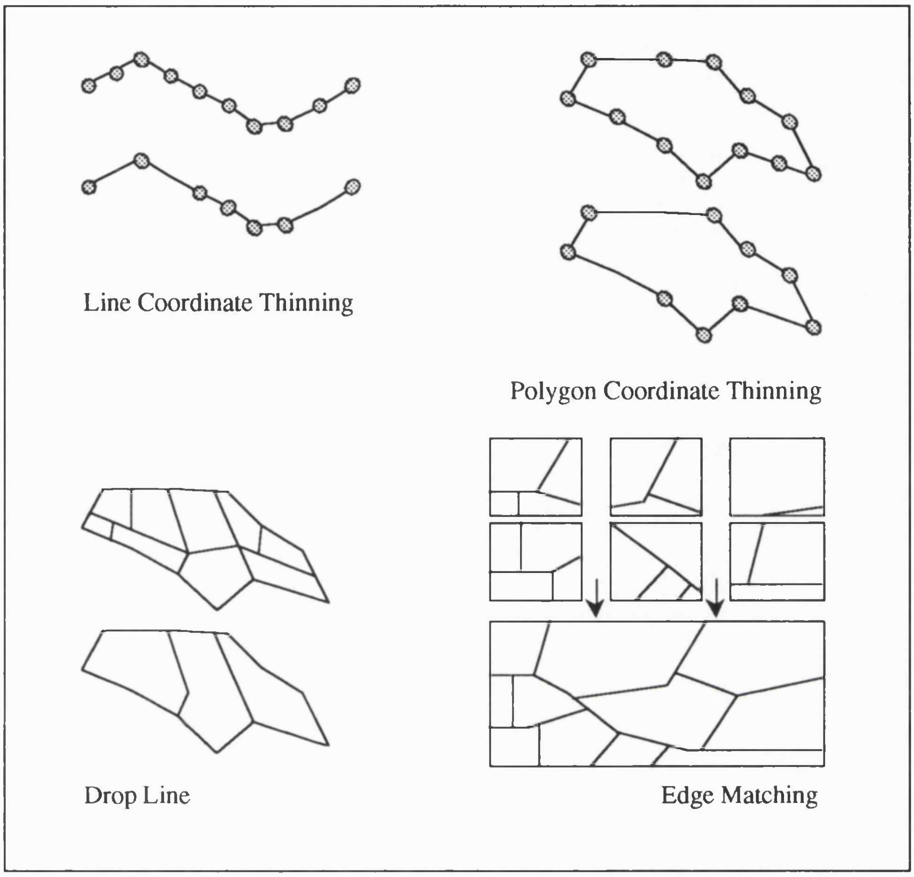



**Diagram 3.4 Illustrations of Map Generalization Techniques (Dangermond 1990a)**

Edge-matching is a series of procedures for bringing together a number of map sheets and compositing them into one continuous map. There are several problems that can occur during this process. These problems occur when joining lines and polygons from adjacent maps together. Further difficulties are encountered when lines that separate polygons having the same characteristics are dissolved or dropped. Although automated techniques are available for this process, basic errors made on the cartographic manuscripts input into the systems often make clean edge-matching difficult to achieve.

### 3.5.2 Map Abstraction

The technique of map abstraction is closely associated with map generalisation, but it involves five different techniques (see diagram 3.5). These are the calculation of centroids, automatic contouring, proximal mapping, reclassification, and finally conversion to grid.

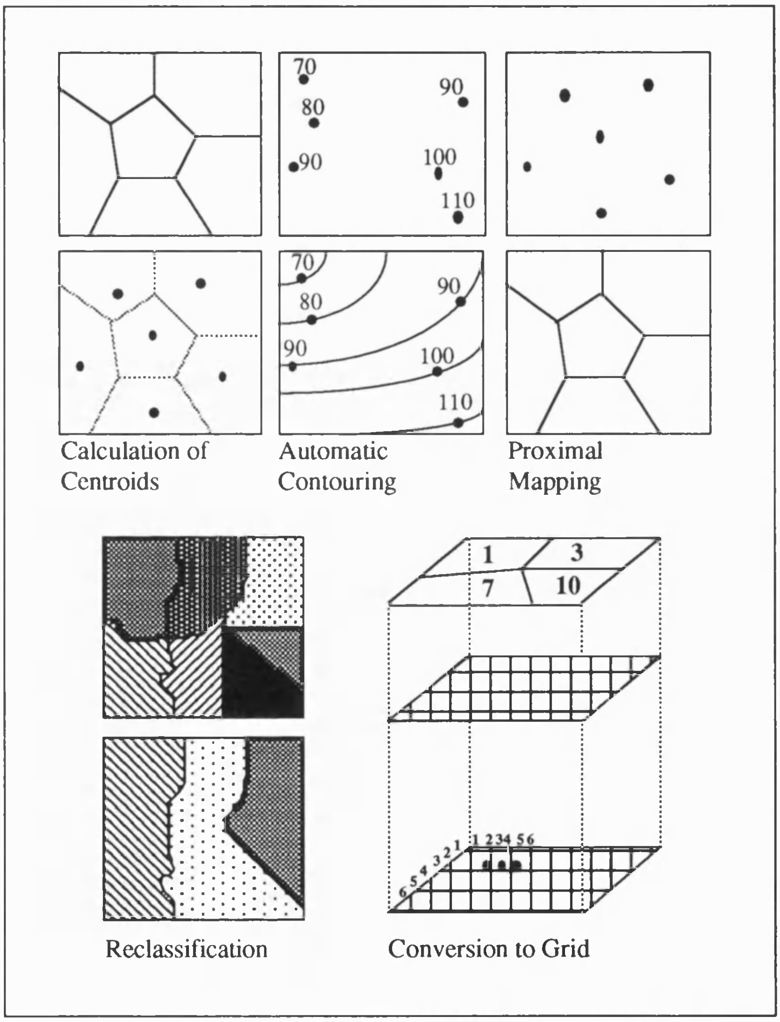



**Diagram 3.5 Techniques of Map Abstraction (Dangermond 1990a)**

The calculation of centroids involves the computation of either the mathematical or visual centre of the polygon. The technique of automatic contouring allows the threading of lines, which represent equal value, through randomly spaced data. For example contours are often used on maps to represent height above sea level. Proximal mapping is carried out by the calculation of Thiessen or Voronoi polygons. This technique calculates the mid-points between each pair of coordinate points mapped, and draws polygons based on these calculations (Peuquet 1990). Map abstraction often involves the reclassification of polygons. This reclassification allocates a new value to a polygon to show a different perspective on a map. The final technique of map abstraction is x,y coordinate location data conversion. This technique is used to convert data from either remotely sensed sources or different map projections to a uniform grid. (Dangermond 1990a)

### 3.5.3 Map Sheet Manipulation

Map sheet manipulations are carried out where digitally encoded maps require changes. These features are illustrated in Diagram 3.6. These techniques manipulate the X,Y coordinates for a given map sheet. The most commonly used of these techniques are: scale changes; distortion removal; projection changes; coordinate rotation and translation.

Scale changes involve the use of map generalisation tools in connection with an actual scale modification. Distortion Removal is carried out by both linear transformation and discriminatory stretching (this is often called rubber sheeting). Projection changes allow any digitally encoded map to be converted to any other type of grid coordinate system or projection. Finally coordinate rotation and translation are functions that involve the alteration of the coordinate sets either through their rotation or shifting to match correctly overlapping or sets of adjacent coordinates.

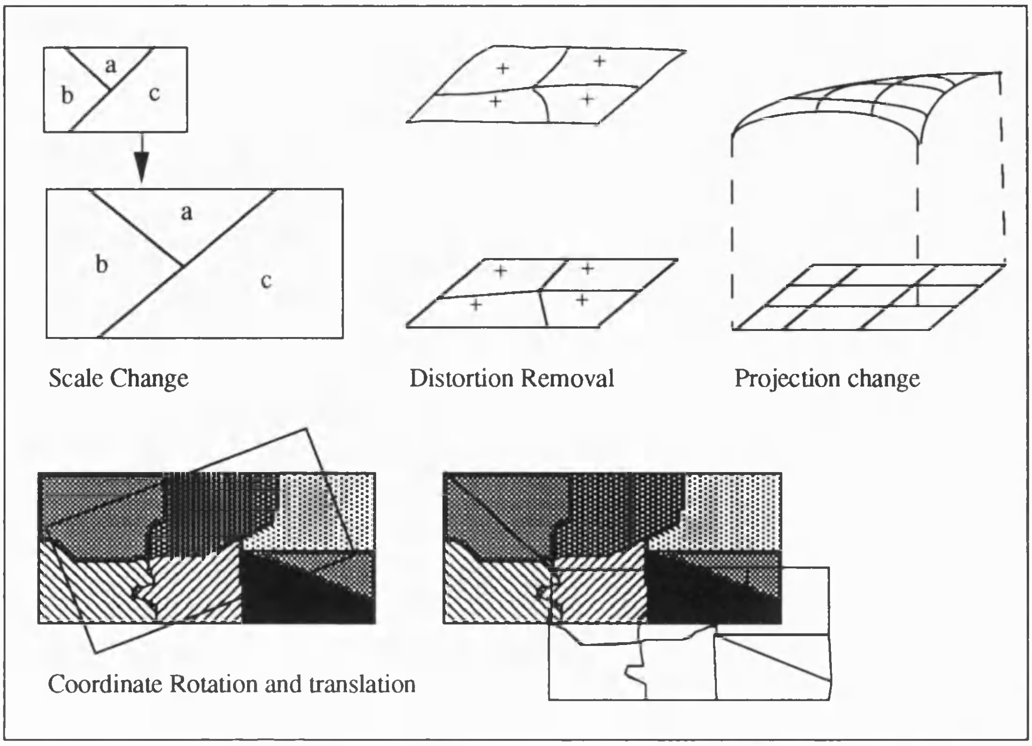



**Diagram 3.6 Map Sheet Manipulation Techniques (Dangermond 1990a)**

### 3.5.4 Buffer Generation

Buffer generation involves the creation of new polygons from points, lines, and polygon features within the database (see Diagram 3.7). Circular as well as square buffers can be calculated, from a given point or series of points. Similarly with a string of points both narrow and broad buffers can be calculated and in cases where these line buffers overlap, new polygons can be formed. Polygons can be generated both around the exterior perimeter of an existing polygon and also within the interior of a polygon. This results in a dual set of polygons measuring horizontal distance relationships relative to a given geographic element.

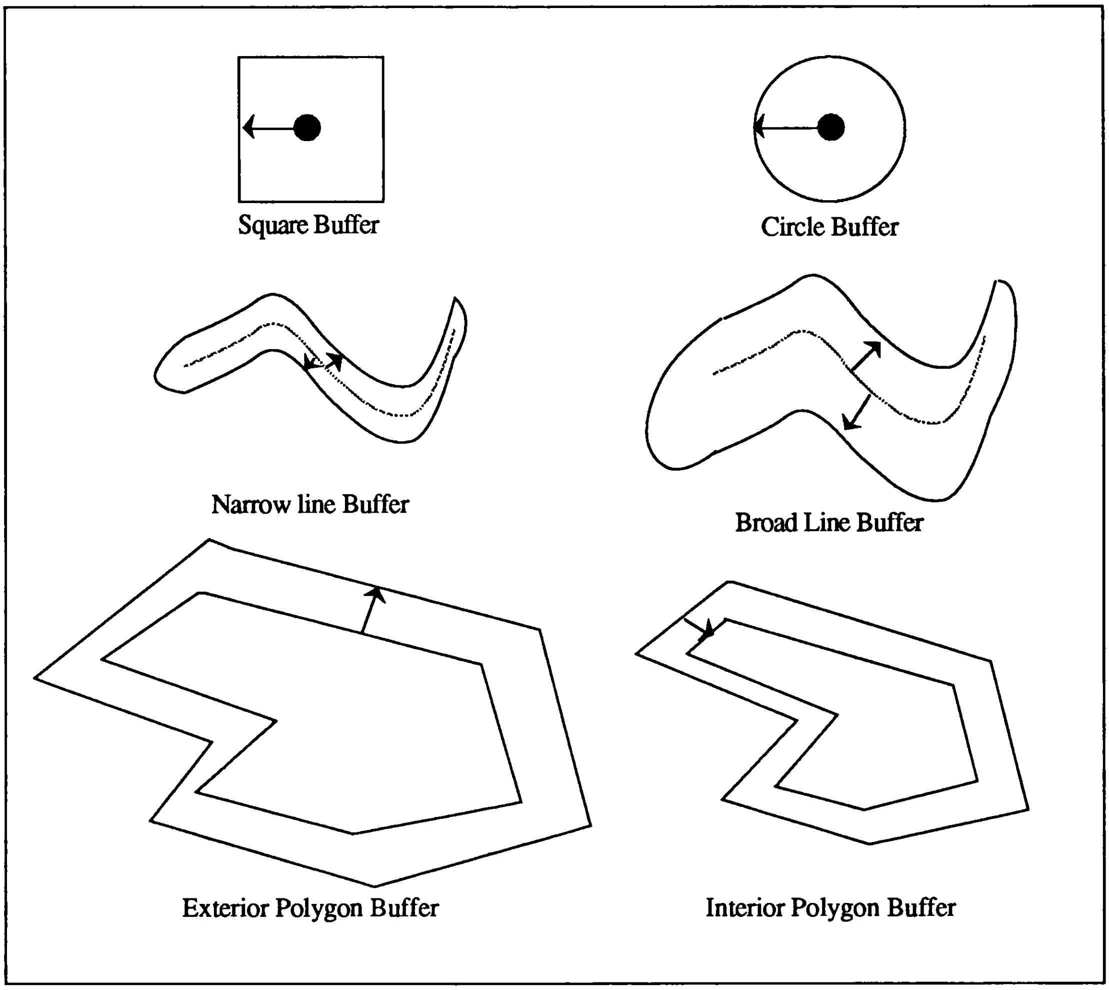



**Diagram 3.7 Buffering Techniques (Dangermond 1990a)**

### 3.5.5 Polygon Overlay and Dissolve Techniques

Polygon overlay and dissolve techniques involve the compositing or extracting of multiple maps to create a new data set. These techniques can be broken down into three main techniques. These are: polygon overlays; map dissolve; and finally map overlay for area calculation. For polygon overlay a new data set is created containing new polygons created from the intersection of the boundaries of the separate polygon layers. Besides creating new polygons based on the overlay of multiple layers, these polygons are assigned multiple attributes. The mathematical overlay of these maps is performed for the area and measurement as well as multiple attribute modeling. Map dissolve functions involve the converse of polygon overlaying. It is the ability to extract from a multiple attribute polygon file a single attribute, both by attribute description as well as locational definition. A second type of polygon overlay is typically performed when the areas for a given data layer need to be calculated and summarized within a second layer of polygons. The resulting output is the summary of statistics. Such statistical analysis can include histogramming or frequency counts, regression, correlations and cross-tabulation, and file generation to interface with a standard statistical package (Knapp 1978).

### 3.5.6 Measurement

The four most common types of measurement tasks involve points, lines, polygon and volumes. The two most typical measurement activities associated with points are the display of a given set of points and the enumeration of the total number of points falling within a polygon. Line measurements also take two basic forms. These are the measurement from point-to-point and the measurement along a curvilinear line. Measurement of areas consists of the measurement of the area of and the perimeter of polygon areas. Finally, volume involves the measurement that is performed either through a cross-section technique or through overlays or multiple surfaces (Green et al 1985).

## 3.6 Data Display

A GIS should include software for the display of maps, graphs and tabular information in a variety of output media. Software should exist for the production of maps that depict the spatial or aerial abstraction of various objects and phenomena. The choice of which type of mapping is to be used depends upon several factors relating to the nature of the data and the use to which the map will be put (Green et al 1985).

The components of a geographical information system are divided into software and hardware. Whilst the software and hardware for data input and manipulation have been described in the previous sections it is important to outline the variety of output devices and styles. Output from a GIS can take many forms and does not simply occur after the analysis. Whilst the user is interrogating the database the results from these queries can be output to the screen or (VDU) in several forms, for example, text, statistical summary and graphics. Output can also be processed through several other output routes. Display media includes both hard copy materials and hardware devices for the production of temporary and permanent graphics. Hardware devices for output displays include line printers, electrostatic printers and plotters, ink jet plotters, cathode ray tubes, colour fill recorders and computer output microfilm devices (Butler 1988, Smith et al 1987). Most GIS will support the more usual forms of information system output such as laser and dot matrix printers. Data must also be exportable in electronic format (Burrough 1986).

## 3.7 GIS Design and Implementation

Based on recent research concerning the design and implementation of GIS, it can be inferred that any GIS should incorporate several design and implementation principles. Although in a separate sub-division of the field of computer science and information systems, GIS is still part of the computer science and information systems disciplines. The systematic application of techniques and approaches developed in a variety of other sub-fields of computer science can be applied to this problem. Thus main-stream integrated approaches and procedures such as those developed in computer vision, image understanding, digital cartography and remote sensing may play a beneficial role in the development of GIS. It is recognised that the use of interdisciplinary tools and experience may prove beneficial within this context (Smith et al 1987).

Research also suggests that there are several general requirements that should be satisfied in the design and implementation of most GIS. Initially there must be an ability to handle large, multi-layered, heterogeneous databases of spatially indexed data. This is a necessary requirement so that the user is able to access information in a timely and efficient manner. The users must also have the ability to query the database about the existence, location and properties of a wide range of spatial objects. The efficiency of this querying part of the system is paramount in allowing the user to exploit the system in real time and therefore permit the system to be fully interactive (Smith et al 1987).

The application of efficient and versatile searching and processing algorithms is desirable to allow the maximum gain of information from the minimum amount of effort. Therefore during the design of a GIS the ability to incorporate these procedures into the system allows the system to be sufficiently configurable to accommodate a variety of specific users and needs.

The use of a GIS to satisfy the needs of a given user is called an application. Most GIS applications involve some form of geographical or spatial analysis. There has been a movement away from the application of GIS technology for simple map overlay and comparison towards more complex spatial analyses. GIS systems are now employed to trace containment movement though the environment, to predict crop yields, to follow financial flows and to automate mapping and the management of facilities.

Currently most users involved in geographical analyses require maps as output. Along with significant national and local requirements for thematic products, the business community has definite requirements for thematic mapping. In particular, private businesses that supply information derived from remotely-sensed data have found that almost all their clients' requirements are cartographic in nature (Burrough 1986).

An important principle relating to the design and implementation of GIS involves the integration of approaches and procedures developed in a variety of disciplines that are related to GIS. These disciplines include computer vision, image understanding and digital cartography. There are two reasons for this integration. Firstly, these disciplines all study the same basic problem of recognising and reasoning about spatial objects implicitly encoded in spatially-indexed data sets. Since their evolution has been somewhat independent, research on GIS would benefit from the integration of approaches and procedures developed in these other disciplines. Secondly, there has been a recent and growing realisation that it is often of practical necessity to merge image datasets such as a LANDSAT remotely sensed images, with more traditional datasets of GIS such as digitized maps and vectorized representations of map features. Computer vision and image understanding have developed techniques that will allow the integration of such capabilities into GIS. Such systems must be able to integrate both raster and vector-based approaches to spatial data analyses (Ballard and Brown 1982, Jackson 1985).

The integration of map and image data within a single system is currently the focus of work at several research centres. The main thrust of current work in this integration has involved the use of both hierarchical data structures and knowledge-based approaches to search and analysis.

## 3.8 Conclusions

There has been a significant increase in the generation of spatially-indexed data from a large variety of sources leading to huge volumes of data for storage retrieval and analysis. Similarly the demand for GIS to handle such volumes of data in a large variety of decision-making situations has also begun to increase dramatically.

Given these trends, it is important that the design, implementation and use of GIS be placed on a more systematic and scientific basis than has generally been the case until now. Such a basis involves the application of the theory and the techniques of several sub-fields of computer science and information systems and the integration of techniques developed in computer vision and image processing in the design and implementation of GIS. In particular there is still a great deal of investigation to be undertaken concerning appropriate data structures and computational procedures for the storage, retrieval and analysis of spatially-referenced data in large scale GIS.

In this chapter GIS have been seen to encompass a set of basic components. These components are: The mechanisms of spatial data entry and management; those mechanisms of data retrieval and the procedures employed to manipulate this spatial data entry and management; and finally the output and display of such data. It has been seen that the major element that distinguishes a Geographic Information System from a more traditional information system is that all the data are spatially indexed to a point in the Earth's surface. Secondly, that the mechanisms of input, for example, digitizing, and output through plotters, mean that these systems encompass more than a traditional Information System. Therefore, the particular needs of a GIS can be described by the following. A GIS must be able to handle large multi-layered databases of spatially indexed data. Access to data within a GIS must occur in a timely fashion. The query of the system must be efficient to allow the individual user to inquire about the existence and properties of a wide range of spatial objects. Since the primary source of output from GIS are maps there is a need for a high quality output device, for example, a plotter and efficient built in programs (drivers) to "drive" the device.

This chapter has outlined the nature of GIS, their generally relationships to information systems, and their particular differences. The next chapter describes the particular GIS case study which forms the basis for the empirical research of chapters 5 and 6. Clearly, the general nature of GIS makes GIS development at least as difficult as that for any information system. Hence the prototyping theme of this thesis. The particular spatial characteristics of GIS also point to a hypertext medium as a natural development environment.

# Chapter 4 The Broads Authority

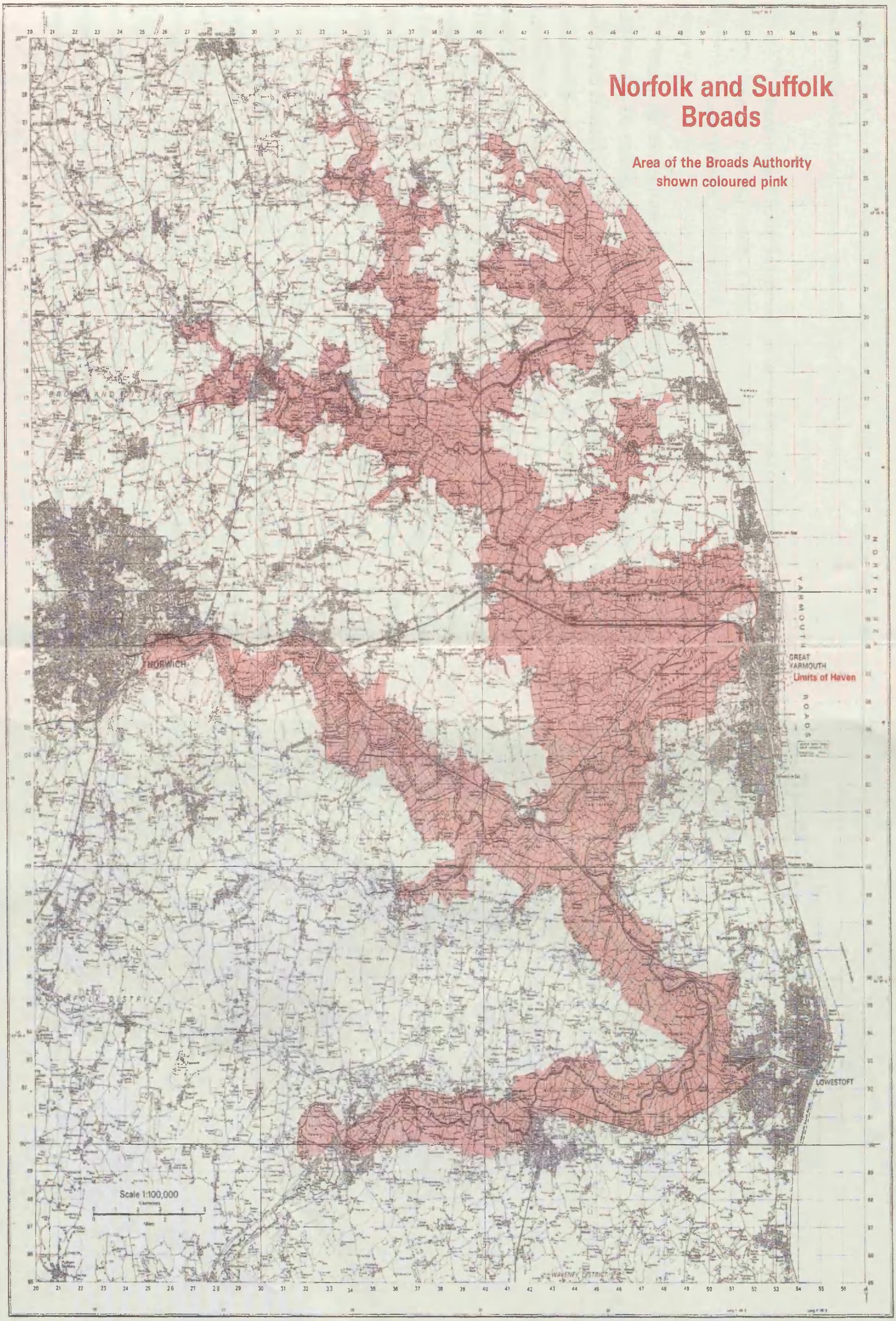
## 4.1 Introduction

The Area of the Norfolk and Suffolk Broads in East Anglia is unique in its environmental and ecological characteristics. It has been classified as an Environmentally Sensitive Area (ESA) by the Dept of Environment. It contains areas variously designated by the Countryside Commission and the Nature Conservancy Council. It is managed by a statutory body, having a status similar to that of the National Parks authorities, which was established in 1989 by the Norfolk and Suffolk Broads Act (HMSO 1988). This statutory Body was created out of an existing organisation, the Broads Authority, and has retained this title. The terms Norfolk Broads, Broads and Broadland are all in common usage to describe this area. They are used within this chapter interchangeably and are syonymous with the executive area specified under the 1988 Act (HMSO 1988) (see map 4.1). This chapter describes the Broads Authority as used for a case study in this thesis and includes: background information and historical aspects of the Authority; its present obligations under the Norfolk and Suffolk Broads Act (HMSO 1988); and the management problems and information needs of the Authority. These aspects will be described in terms both of the Broadland region and the administrative structure of the Broads Authority.

## 4.2 Background

Geographically the Broads extends over the lower valleys of the Rivers Waveney, Yare and Bure, together with the two tributaries of the Bure, the Ant and the Thurne. These rivers and their tributaries drain 3600 $km^2$ - an area equivalent to two thirds of Norfolk and much of Northern Suffolk. The low lying land in these valleys consists of shallow lakes (the broads), rivers and drainage systems (dykes), fens (undrained marsh),

Map 4.1 A Map of the Norfolk and Suffolk Broads
(Ordnance Survey 1986)




Department of the Environment Cartographic Services November 1986 Base map reproduced from the Ordnance Survey map woodland and drained marshlands (Broads Authority 1987). It is renowned for its individual beauty:

> "Reed-fringed rivers and Broads, its gentle farmed contours, its brick, flint and thatched buildings and its wide horizons and skies." (Broads Authority 1987)

Within the Broads there are several, often competing interests for land and water use. There is the farming community who depend for their living on the fertile (grade 1 and 2) land present in the Broads. Secondly, there is a recreational aspect to the Broads. Broadland provides opportunities for fishing, sailing, walking and tourism. This supports a large tourist and other related industries, such as boat building. Thirdly, for many people the Broads harbours ecosystems where diverse meadow and dyke flora and fauna can be observed. Finally, the Broadland area is a populated area with a thriving economy. The population, although valuing the surroundings and environment as adding to their quality of life, must also consider their personal economic prosperity. For the Broads Authority this means the reconciliation of these competing uses in a way that is compatible with the management policies that the Authority seeks to pursue.

### 4.2.1 Environmental Importance

The Broadland area is largely the product of past cultural and economic exploitation of the land and waterways. In recent years many features of this traditional management have declined and disappeared. With the change in agricultural practice and the economy of the region many of the features of the more traditional farming management have disappeared. It is because of this decline and other factors, such as the increase in river water pollutants, that the Broads have deteriorated (see section 4.2.3). The fens are notable for their reed and sedge beds and also grazing marshes which support important populations of rare birds (e.g. Marsh Harrier, Bittern and Reed Warbler). The dykes contain over one hundred species of freshwater aquatic plants as well as rich invertebrate populations. These areas are now in serious danger (Broads Authority 1987).

The Broads area is a wetland of considerable significance. Within the area there are three national nature reserves: at Bure Marshes (456 hectares (ha)), Hickling Broad (1380 ha) and Ludham Marshes (69 ha). Both Bure Marshes and Hickling Broad are recognised to be two of the thirteen wetlands which are internationally important for nature conservation. In addition there are 24 sites of special scientific interest (SSSI) covering 880 ha, with another 156 ha that are proposed to be scheduled as SSSI by the Nature Conservancy Council.

The Broads is not a series of isolated habitats: it is an integrated landscape within which its wildlife features produce a peculiar distinctiveness. It is because of the combination of nature conservation and its landscape character that the Broads is considered a national asset.

### 4.2.2 Economic and Recreational Importance

The economy of Broadland is very much based around farming, tourism and light industry. Agricultural land occupies a substantial part of the Broads Area and the management of this land plays a fundamental role in influencing the character of the area. Modern agricultural practices are very different from traditional approaches. Since the environment is such an significant part of all other aspects of the Broadland economy it is important for the Broads area to retain key elements of its ecology and landscape. Recent changes in government policy have made it possible for some farmers to retain their established agricultural practices by means of a subsidy. In this way, it is possible to protect the environment without disadvantaging the farming industry.

The maintenance of traditional farming and management practices help to protect the wildlife and landscape characteristics of the Broads. These combined with the many historic features of the Broads area, for example, St. Bennetts Abbey, provide interest for tourists who visit the Broads. The close proximity of the Broads to Norwich and to the major coastal resorts of Great Yarmouth and Lowestoft makes it a popular destination for day-trippers as well as longer-stay visitors. The primary attractions are the rivers and Broads, together with opportunities for a wide range of leisure activities including motor-boating, sailing, rowing and fishing. The Norfolk boat-building industry is also of international importance, constructing craft for the national and international markets as well as for local use. The thousands of holiday makers who hire pleasure craft boost the local economy through their riverside spending. The tourist industry that has been developed around these activities is an important part of the local economy employing people to build, maintain and service boats of many kinds.

Heavy industry within this area is limited to a few primary extraction sites and processing plants and the introduction of new heavy industry into this area is now discouraged. Light industry, however, supporting the tourist, boat-building and farming industries as well as producing goods for the national and international market is encouraged to improve the overall economic base of the region.

### 4.2.3 Environmental Change and Economic Consequences

It is widely maintained that the future survival of this area lies in the combination of conservation and development. Careful planning is aimed at producing no conflict between these but one factor is of overwhelming importance. If mistakes are made and these fragile ecosystems disrupted, it may take many years and high levels of investment to restore the balance. Since the health of the ecosystem is a vital part of the economy, careful planning judgements must be made.

Over the past 45 years the Broads has undergone many environmental changes, mostly to the detriment of the area. Moreover, experimental restoration projects are costly and time consuming (Broads Authority 1990). The main features of the Broads decline are as follows. There has been a wholesale loss of the Broads special habitat, which has caused a most notable decline in the variety of water plants in the rivers and the Broads. The impoverishment of fenland plant communities is the result of neglect and the alteration of water regimes where fens have been converted to drained arable agriculture, which was encouraged by the EEC agricultural grant initiatives. The effects of boat wash, uncontrolled moorings and anglers have caused the progressive erosion of the river banks and protective flood walls. River bank erosion is accelerated by the exposure of the vulnerable river margins caused by the decline of protective reed buffers. This loss of the fringing reed growth is in part due to the enrichment of the water by nutrients discharged from sewage treatment works and as a result of modern intensive agricultural practices. Reed loss is also caused by wash from speeding boats.

These changes place both an environmental and economic burden on the economy of the area. It is already proving costly to maintain the Broads ecosystems as they are, whilst restorative costs are increasing (Broads Authority 1990). If the forces of ecological simplification are not halted, the cost of repairing floodwalls, piling eroded river banks and protecting key habitats will accelerate exponentially. The alternative is to let the Broads deteriorate. This will have devastating consequences for the boating and tourist industries as well as for the environmentalists, the marsh farmers and local inhabitants of the area. A scientifically-based programme of restorative investment for the Broads is in the interests of everybody. Investment in the restoration of the Broads is necessary to stop deterioration.

The management of such a programme is the responsibility of the Broads Authority. The Authority was created in April 1988 with wide-ranging powers and an ability to plan in the long term for a necessary restorative program. This will be further discussed in sections 4.4.

### 4.2.4 Physical Formation of the Broads

The Broads are man-made. They are the result of medieval peat digging. Large pits were excavated by the inhabitants for fuel and to provide energy for the prospering cathedral city of Norwich. Most of the pits were about 4 metres deep although some deeper workings did take place, for example at Fritton Lake.

In the fourteenth century the sea level gradually began to rise and the pits flooded. Peat diggings then became uneconomic and were abandoned. These flooded pits are the present Broads. Some working of the peat did continue into the nineteenth century. These were shallow workings which were subsequently flooded and are now known as turf ponds, as for example at Barton Turf.

Natural processes have gradually infilled these shallow lakes with dead vegetation and sediment. Little is known of the original size of each of the Broads although estimates at the time of the Tithe maps in the 1840's give a total area of approximately 1200 hectares. The Authority's aerial photographic survey in 1980 showed an existing area of little over 600 hectares indicating that half the area of the Broads has been reclaimed by natural processes (Broads Authority 1987).

The Broads can be divided into two main categories:

(i) Main valley Broads - those that lie in the main river valleys and are usually connected by cuts or dykes to the river, for example, Cockshoot and Ranworth Broads.

(ii) Side valley Broads - those that lie in side valleys and although connected to the rivers by streams are not directly influenced by river water, for example Alderfen and Upton.

## 4.3 History and Background of the Broads Authority

Following the Dower Report, the Hobhouse Committee (Dower 1945, Hobhouse 1947) proposed twelve national parks for England and Wales: Broadland was one. Only 10 national parks were finally created but Broadland was not included. There was, however, concern that Broadland should have some form of special status to aid planning, and the idea of a Broads Joint Advisory Planning Committee emerged from a Broads Conference in 1949 and was formally constituted in 1950. The county, borough and rural district councils provided 23 of the 34 members of the Committee, the rest being made up of water, navigation, boating, farming and naturalists' interests. This Committee's structure and ethos was based on the Town and Country Planning Act 1949. It was considered as a coordinating mechanism for reviewing planning applications in order to control development. It did not operate using criteria based either on scientific or environmental protection principles. It had no plan or set of policies on which to base specific judgments and it exercised no powers over planning authorities, except the influence of persuasion. This was an ineffectual method for managing the Broads but it reflected the mood of the times. Planning control was the primary consideration. At that time environmental science had not been established as a discipline, the Natural Conservancy Council was in its infancy and inter-organisational co-ordination on a systematic and effective basis had never been tried anywhere in the country.

It has been argued that the formation of the Broads Joint Advisory Committee probably helped to accelerate the deterioration of the Broads (O'Riordan 1991). By prompting a policy of village expansion, planners and district council public health officers positively encouraged the construction of sewage treatment works instead of septic tanks and soakways. The eutrophication that has been such a dominant feature of the ecological decline of the Broads since the 1950's was inadvertently fostered by the very organisation designed to safeguard the environmental quality of the region. This pattern of counter productive good intent continued through to the middle 1970's.

In 1958 the Committee of Enquiry into Inland Waterways (Ministry of Transport 1958) recommended that the Broadland area should be given special recreation status and that it should be administered by a reconstituted body, the Great Yarmouth Port and Haven Commissioners. Throughout the history of the Broads, navigation interests have always been paramount and in this case proved to be no exception. This situation was a compromise as the Joint Advisory Committee was adamant that the area should not be made a National Park. In the early 1960's Broadland was seen as simply not appropriate for membership of the National Park "club" and this was confirmed in 1961 when the Broads Sub-committee of the Standing Committee on National Parks rejected designation as a National Park. The area was regarded as inaccessible by foot, as well as having enormous difficulties for securing public access over so many private land holdings. The growth of commuter populations in Broadland villages meant, for the National Park visionaries, too little space and too many complicated and possibly controversial planning decisions regarding amenity and public access. They felt that the local planning authorities would not show the same sympathy to the needs of the wilderness and freedom to roam that was characteristic of the upland parks. There was also enormous local opposition to the National Park idea from a wide cross-section of local public opinion. This was partially induced by a belief that National Park status would result in a loss of local autonomy to external domination by either the existing National Parks Commission or eventually by central government.

In 1965 following a Consultative Document in 1963, the Report on Broadland was published by the Nature Conservancy Council (Nature Conservancy Council 1963, 1965). This was the output of a working group of planners, ecologists, water managers, boat owners, landowners, naturalists and local government members who considered the state of scientific evidence on the changing character of Broadland. Unusually for a nature conservation report, the panel also considered possible administrative reforms needed to put the area to right. The study pointed out clearly that the Broads were becoming shallower, that fens were slowly becoming drier and susceptible to willow and alder tree invasion and that the ecological tendency in Broadland favours Carr woodland. The group committed itself firmly to a future of fen and marsh management that would maintain an ecologically healthy Broadland through the principles of sound nature conservation. This meant that Broadland was committed to something akin to a return to the ecological status-quo of the mid-nineteenth century at least for the major fen areas. It was also recognised that this would involve significantly larger numbers of trained people and larger amounts of money than had been available before.

It was not apparent that the working group as a whole recognised this dilemma. A minority favoured the establishment of a single management authority that was separated from the local authority machinery and had a commitment to recreation on both land and water and to nature conservation. This group also believed that the new agency should be vested with the necessary financial resources and should be required to prepare a long-term strategic plan. It called for a unified perspective on land and water management that rested on a solid foundation of scientific discovery and aimed to protect the rich wetland ecosystems. This management was to be based within a framework of government that would be sympathetic to the safeguarding of the environment.

As a compromise, a consortium of local interests was suggested, combining the local authorities, the water authority (the then East Suffolk and Norfolk River Authority) and the navigation body (the Great Yarmouth Port and Haven Commissioners). In 1966 the Broads Consortium Committee was established to improve liaison between planning, water management and navigation.

In 1970 the then Chief Planning Officer of Norfolk, R.E. Maxwell, argued that a single executive agency should have control over both planning and navigation. This was rejected. An alternative proposal that the navigation function of the Broads and rivers should be taken out of the hands of the Rivers Committee of the Great Yarmouth Port and Haven Commissioners and vested in the River Authority was put forward but was also disregarded. The Broads Consortium Committee completed its task of producing a form of strategic plan and published its report "The Broadland Study and Plan" (Broads Consortium Committee 1971). This was the first composite official review of Broadland's needs. It was primarily a planning analysis with little attention given to environmental matters. The Great Yarmouth Port and Haven Commissioners (1971) submitted a minority report seeking to retain their control over all aspects of navigation. In 1971 the Consortium disbanded leaving the three authorities to manage the steady deterioration of the ecological health of the Broads.

### 4.3.1 The First Broads Authority

The trigger to the formation of a more unified body was the publication of a report by Mason and Bryant (1975). This showed that only 6 out of the 28 broads surveyed were in even a modest state of ecological health. What was particularly disturbing was the evidence of very rapid eutrophication since the publication of the "Report on Broadland" (Nature Conservancy Council 1965) ten years previously. The Norfolk Naturalists Trust, being a major landowner in the region, lobbied hard for a much tougher conservation regime. This was supported by the Countryside Commission (1977), and the Nature Conservancy Council (1977) who initiated a major programme of research at the University of East Anglia.

With the backing of the Countryside Commission (Countryside Commission 1977) the Norfolk Branch of the Association of District Authorities proposed a Joint Committee, to be established under section 101 and 102 of the 1972 Local Government Act, that would serve as a locally dominated version of a National Park Authority. This body, known as the Broads Authority, was subsequently formed in 1978 (Countryside Commission 1979) and was formally inaugurated on 1 April 1979. It was essentially a joint standing committee of the two county Councils and the six district councils, to which two members from the Great Yarmouth Port and Haven Commissioners and two members of the Anglian Water Authority (formed in 1974 under the 1973 Water Act) were co-opted. In addition the Countryside Commission was invited to nominate three members to reflect national interests in Broadland management (Countryside Commission 1983). The co-optive status of these seven individuals was reinstated at every annual meeting when the local government members voted to invite their presence.

The creation of the Broads Authority was a major step forward but its structure and financing was unsatisfactory. The Authority had delegated powers granted to it by the local authorities over all local government matters including planning and development control, litter and recreation management. The county council also ceded some minor powers over highways and footpath maintenance. The essential support services of planning, property, legal and financial management were handled by quasi-voluntary co-operative arrangements between the various responsible officers in local government departments and the Broads Authority.

The co-operative arrangements worked particularly well in planning matters where the district council officers handled much of the paperwork. The Authority's Planning Committee consisted for the most part of the chairmen or vice-chairmen of the local planning committees. The Authority's planning adviser was seconded from the Norfolk County Council's planning staff. Similar arrangements, involving the commissioning of local authority officers for specialised advice on legal matters, property deals and management agreements, highway and conservation issues were also efficient and good humoured.

One of the greatest achievements of the Broads Authority was the production of a comprehensive management plan. The final version appeared in 1987 only a year before the Authority ceased to exist (Broads Authority 1987). The process of preparing this non-statutory but highly influential document involved widespread consultation, the establishment of three panels on ecology, landscape and recreation and an enormous amount of scientific research. The Authority published ten scientific reports, produced many unpublished reports and invested some 25% of its total budget in scientific research. These panels provided interested parties with direct access to the Authority's policy making machinery. The Authority in many ways acted as a catalyst to enable grant aided bodies to collaborate.

The Authority also established a series of local environmental improvement schemes, notably on public staithes, to help make riverside areas where people congregate more accessible and scenically attractive. It built and staffed four public information centres at strategic points throughout the area and ran several publicised events aimed at attracting public interest in the area and its natural beauty. It collaborated with private enterprises to promote conservation values and to stimulate environmental education, notably by purchasing 180 hectares (ha) of prime marshland and fen at How Hill, near Ludham, to help create the How Hill Education Centre.

Possibly its most remarkable achievement was to encourage the change in Government Policy over agriculture and environmental protection. It did this in 1985 by stimulating the idea of Environmentally Sensitive Areas (ESAs). These designations, formally incorporated in the Agricultural Act of 1986, permitted the Ministry for Agriculture, Fisheries and Food (MAFF) to offer payments to land occupiers in compensation for retaining practices that enhance the scenic amenity and nature conservation values of key landscapes in the UK. In 1987 the whole of the Broads executive area (the area covered by the Broads Authority) was designated as an ESA. Within the Broads ESA participating farmers received £125 per ha per annum (tier 1) for accepting restrictions on farming practices that aim to maintain the nature conservation value of their marshes and dykes. Payments of £200 per ha per annum (tier 2) may be made where the land is of particularly high conservation value or the farmer agrees to manage his land to enhance its ecological interest.

About 12400 ha of marshland have been covered by agreements (O'Riordan 1991) including 90% of the eligible grazing marsh. About a third of this land is covered by tier 2 agreements and the remainder by tier 1. Over 80% of farmers have voluntarily participated and the conservation status of about one quarter of the eligible land has been upgraded either by raising the water table and/or by special dyke management. Through these designations of tier 1 and 2 about 400 ha of arable land have already been returned to grass. The scheme therefore has enabled a collective sense of goodwill and concern about the Broadland environment to develop.

The Broads Authority is unique in the "National Park" community in enjoying ESA status throughout its entire area. It is also unusual to have such a high proportion of landowners adopting the more conservation-orientated management regime. This means that the Authority pays very little for conservation-based management agreements (about £5000 per year compared with over £100,000 annually in Dartmoor and the Peak District National Parks (O'Riordan 1991). Clearly a powerful precedent has been set for central government agricultural money being spent to further a National Park's interest.

Although a cost effective solution was produced, during the whole of its ten years of existence the Broads Authority staff never exceeded 25 (less than the planning department alone of most major national parks). The Broads Authority was never in a secure position. Its financing was based on the support of local authorities any one of which could leave the arrangement at any time. The dependency on participating member contributions and on Countryside Commission grant aid meant much lobbying and paperwork. The Authority survived by good will but it could never guarantee that it would be able to invest in the necessary remedial measures over a long planning period.

### 4.3.2 The New Broads Authority

Despite these achievements, the first Broads Authority was in many respects ineffectual. It had no power over water matters, drainage or navigation. It was not notified of any changes affecting the landscape that fell outside the Planning Acts unless landowners did so voluntarily. It was unable to allocate resources on long term budgetary plans for restoration and it was also subject to political accountability through the membership of its Committee.

In 1984 the Countryside Commission launched a bid for a special statutory authority with powers over navigation and 75% grant aid from the Treasury on a continuing basis. The Government then supported a Public Act that created the new Norfolk and Suffolk Broads Authority with a reformulated membership and budget in April 1989.

The new Authority consists of 35 members of whom two are co-opted from navigation interests via the Authority's Navigation Committee and 18 are appointed by local authorities, with 12 of these coming from the six district councils. The Countryside Commission nominates two members, the Nature Conservancy Council one member, the National Rivers Authority one member, and part of the Great Yarmouth Port and Haven Commissioner (now confined to the Port of Great Yarmouth) two members. The Secretary of State for the Environment appoints nine members two of whom must represent farming interests and three boating interests.

From empirical observation this body of people has already established itself as a cohesive group. The expected conflict between navigation and conservation interests has not so far materialised. Indeed, the Authority's Navigation Committee is proposing tough speed restrictions and boat-user educational material designed to reduce boat wash damage even further. Work is already under way to rewrite the "Broads Plan" (Broads Authority 1987) as is required by the legislation, based on sustainable economics. The Authority is now discussing with the National Rivers Authority common guide-lines for river quality objectives and for the financing of flood protection measures. This will commit long term investment in sewage treatment, mud pumping, biomanipulation of fish and aquatic flora restoration for the future.

The major problems facing the new Authority lie in government financing policy and in the sheer scientific difficulty of knowing how to manipulate a degraded ecosystem into a steady state.

On the matter of financing, the Authority still cannot guarantee a roll-over budget from year to year, nor sufficient money from the Treasury to meet its genuine needs. In addition, other authorities, such as the National Rivers Authority, responsible for land drainage, cannot borrow beyond very narrow limits. Therefore capital investment in flood wall protection, reed bed regeneration and washlands cannot be undertaken on a systematic long term basis.

Similarly agricultural policy is also in a state of flux. There may not be sufficient funding to ensure that all current participatory farmers remain in the ESA after the five years of the initial commitment ends in 1992. Extra "top-up" money for farm conservation investment may not be sufficient to encourage those farmers, whose real income is falling, to spend money on farm conservation measures. Local authorities are also financially "squeezed" and may be unable to provide the funding for flood protection that is necessary for Broadland.

Meanwhile the mechanism for restoration is still far from being resolved. It is possible that only a few of the smaller broads can be fully restored with clear water and even then constant surveillance will be necessary. Fen management requires much labour, and funds for labour supported Community Programmes that employed the equivalent of 40 people per year, are no longer available. Volunteer armies will still be desperately required but they cannot do the job alone. A Broadland Conservation Task Force which is as much an agency as it is a labour unit has been established by the Broads Authority. This is funded by the Authority but works on an enterprise basis. This is an efficient and encouraging arrangement, although more will be needed if the fens, which are one of the most critical habitats in conservation terms, are to be substantially restored.

The return to the new economics of the green age and to some form of European interest have added a new interesting dimension to the National Park status in the 1990s. It is possible that the kind of environmental service economics started by the old Broads Authority in 1985 will be swept up in the changing Treasury and Department of Environment thinking, that is currently at an early stage. The Authority will have to prove its case by developing a sustainable economic audit in its new plan. This will have to show that investment in flood protection and nutrient removal now, will save enormous amounts of expenditure in future years that would be needed to remedy the environmental damage that would otherwise occur (O'Riordan 1991).

## 4.4 The Functions and Responsibilities of the Broads Authority

The commitment of the present government to the creation of a special statutory authority, which assumed office in April 1989, shows an important step forward in the comprehensive management of the Broads. The Authority has wide ranging powers and an ability to plan long term investments and embark upon vital experimental projects.

The Broads Authority Management Plan and Strategy is based upon four guiding principles:

> "(1) Broads restoration involves people, not just ecosystems: action must be based on consensus, informed support and competent advice.
>
> (2) Ecology and economy fuse into unity through the application of the principle of sustainable development: sustainable development means applying environmental science laws to programmes of economic investment and ensuring that decision making organisations are geared to that relationship.
>
> (3) Scientific understanding of fundamental environmental processes is an essential prerequisite to planned investment.
>
> (4) Where the necessary scientific knowledge cannot provide an answer, carefully monitored experiments can indicate how best to proceed." (Broads Authority 1987)

This section describes the legal obligations of the Broads Authority under the Norfolk and Suffolk Broads Act (HMSO 1988). In addition to the employees of the Broads Authority the Act makes provision for a committee of 35 members (see Section 4.3.2). These 35 members make up the statutory Broads Authority, and the committee is the major decision making body for the Broads Authority.

### 4.4.1 The General Functions of the Broads Authority

Section 2 of the Act (HMSO 1988) provides that the Authority's general duty will be to manage the Broads for the purpose of: "Conserving and enhancing the natural beauty of the Broads; Promoting the enjoyment of the Broads by the Public; and protecting the interests of navigation."

In discharging its functions the Authority must have regard to:

> " (a) The national importance of the Broads as an area of natural beauty and one which affords opportunities for open air recreation;
> (b) The desirability of protecting the natural resources of the Broads from damage;
> (c) The needs of agriculture and forestry and the economic and social interests of those who live or work in the Broads."
> (Broads Authority 1989)

Within the provisions of the Act the Broads Authority also has certain powers, which fall into four categories: Planning; Recreation; Conservation; Navigation. These categories are discussed in sections 4.5.1 - 4.5.4 below, with administration discussed in section 4.5.5.

### 4.4.2 Management Issues for the Broads Authority

The Norfolk and Suffolk Broads Act (HMSO 1988) provides for a division of the managerial tasks which the Authority is legally obliged to carry out. These generally fall into five areas: Planning; Recreation; Conservation; Navigation; and Internal Management. There are many potentially conflicting issues that the Broads Authority may have to contend with while carrying out its duties. These are discussed in sections below. This is due to the integrated management regime which the Broads Authority has adopted. However, this management system is very much dependent on goodwill and the information collected by the Authority from the public, the registration of applications for planning and water-borne vessel licence registration. It is recognisable that there is also more specialised information gathering from the conservation and recreation side of the Broads Authority which also play their part in the overall management of the Broadland Region. It is necessary to discuss the information requirements of the Broads Authority so that the Authority can carry out their Brief most efficiently, and section 4.5 below covers this.

Within its management Brief the Authority has powers to make byelaws. These byelaws can relate to land owned or supervised by the Broads Authority, or to land on which it has public right of access or if the land is common land. The purpose of these byelaws is to restrict public activities to those that do not damage the land and to ensure that any activity does not interfere with another person's enjoyment of the land.

The Authority also has the power to make byelaws for the good management of the waterways, the conservation of their natural beauty and amenities and for the promotion of their use for recreation purposes.

> "Specific byelaw making include: the speed of vessels, the enforcement of Safety provisions; the prevention of pollution or excess noise on vessels; and finally the regulation of the provision and use of the moorings."(Broads Authority 1989)

So the information needs are quite considerable as the Broads Authority needs to keep records of the byelaws created and of offences committed on these lands.

### 4.4.3 The Committee Structure of the Broads Authority

The Broads Authority is governed by a series of committees which report to the Broads Authority Committee. Each of the departments, with the except of the Information and Interpretation and the Administration Departments of the Broads

Authority, has a committee bearing the same name (see Diagram 4.1). To each of these committees representatives of all interested parties are elected. When controversial or new decisions must be taken these committees must be consulted and their views either acted upon or considered when drawing up plans or documentation. In certain instances there are consultative panels which provide advice for certain departments. Any decisions arrived at must be reported to the governing committee, the Broads Authority Committee. Similarly, where decisions can not be reached, the case may be taken to the Broads Authority Committee for their judgement. Where agreement is not forthcoming these may be taken before the Secretary of State.

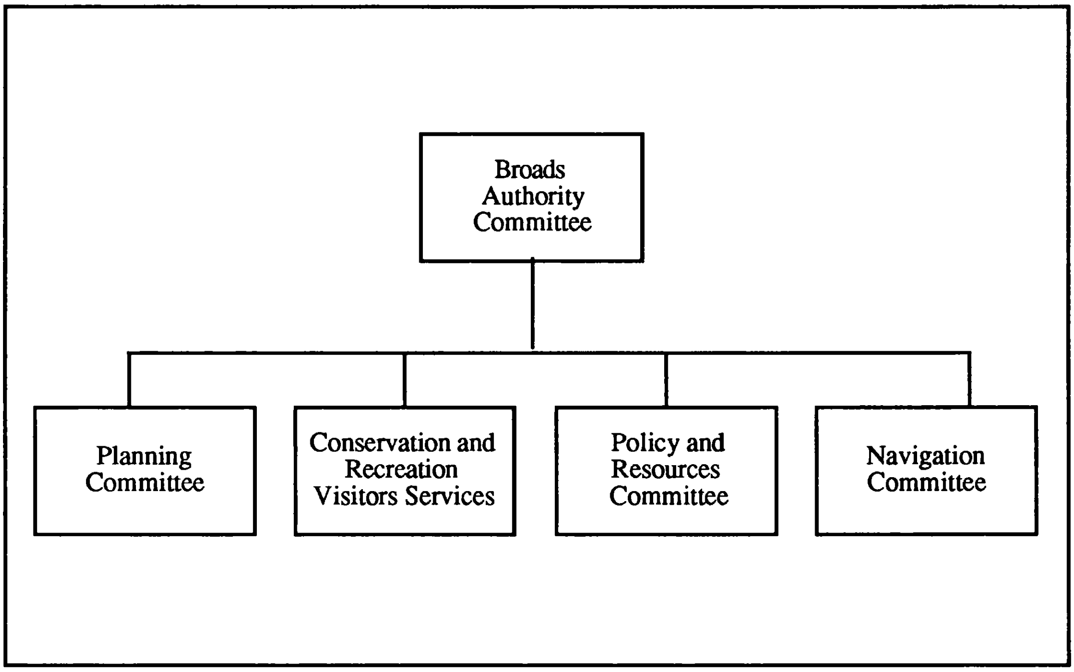



**Diagram 4.1 The Committee Structure of the Broads Authority**

### 4.4.4 Interactions within the Broads Authority Organisation

There are 35 full time employees working for the Broads Authority. Diagram 4.2 shows the internal organisation of the Broads Authority. Although there is a formalised management structure, it is evident from first hand experience gained during this investigation that the Authority functions in a very informal manner, in which much of the formal hierarchy is by-passed. There is evidence of much interdepartmental co-operation which is positively encouraged by the Authority. The general cohesion of the Authority is reinforced by a general meeting of all officers bi-weekly or more frequently when necessary. It is postulated that this internal cohesion generally aids the overall management of the Broads region.

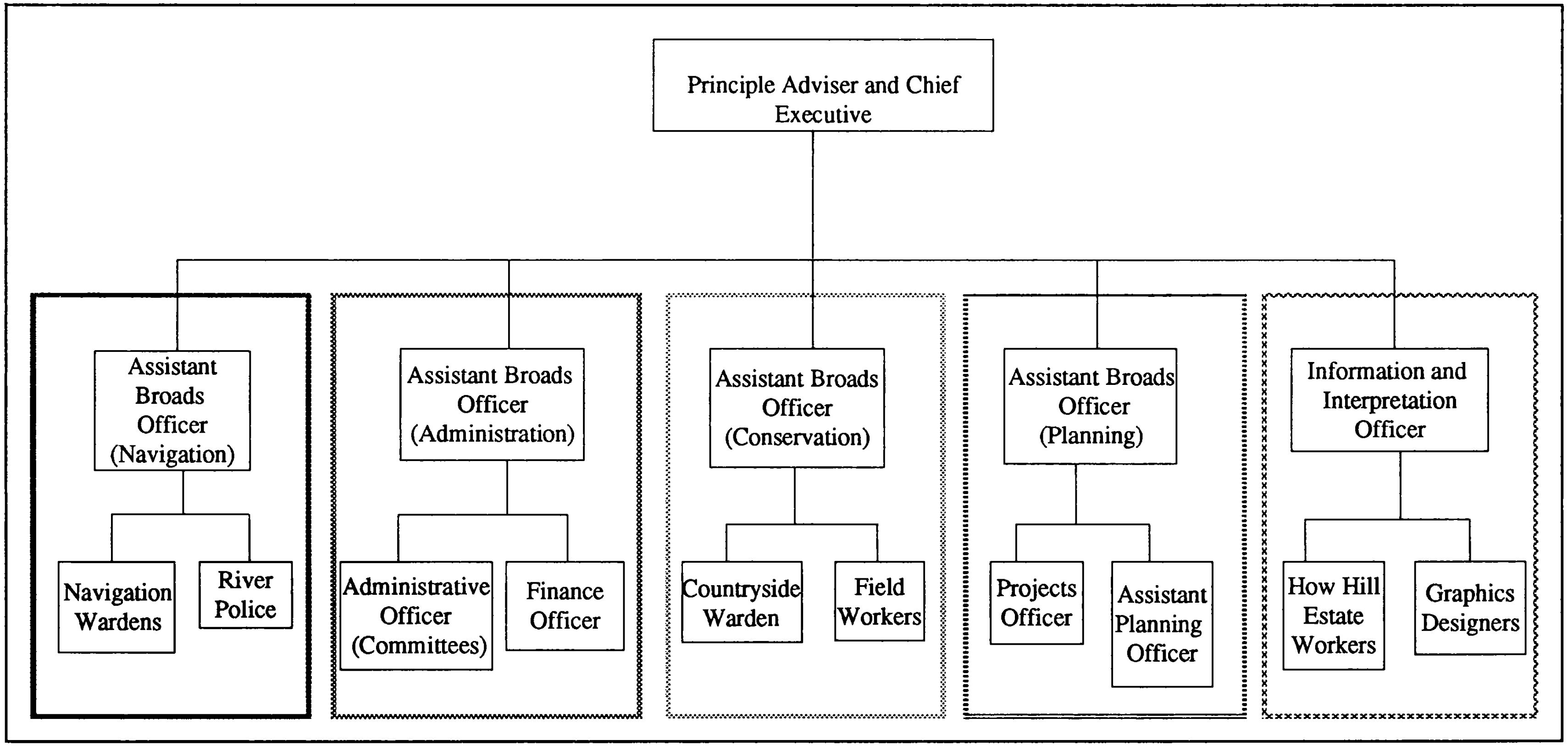



**Diagram 4.2 The Internal Organisation of the Broads Authority**

## 4.5 The Internal Structure of the Broads Authority

For the good management of the Broads Executive Area, the Broads Authority has several activities and functions which it needs to maintain and increase information flows into the organisation. This section discusses the Broads Authority's duties under the provisions of the Norfolk and Suffolk Broads Act (HMSO 1988) and the information needs associated with them. To satisfy the terms of the Act the Broads Authority must at minimum cover its five major functions. The Broads Authority however, also carries out many activities that are not within their Brief but which are intended to promote the Broadland region. These activities and projects create goodwill between the local population and the Authority. To this end, section 4.5.1 below describes the function of the Planning Department, section 4.5.2 describes those features relating to the recreational side of the Broads, section 4.5.3 describes those relating to the Conservation Department of the Broads area, section 4.5.4 looks at this in relation to the Navigation Department of the Broads, section 4.5.5 discusses the internal Administration Department of the Broads Authority.

### 4.5.1 The Planning Department

The Norfolk and Suffolk Broads Act outlines the following duties for the Planning Authority. A fuller description of these functions and provisions for planning is found in schedule 3 of the Act (HMSO 1988). This states that the Authority is the sole District Planning Authority for the Broadland area. It is therefore the Authority that:-

(a) Determines planning applications (apart from those relating to mineral extraction and waste disposal which will be decided by the relevant County Council);

(b) Takes planning enforcement action;

(c) Prepares local plans;

(d) Controls advertisements;

(e) Protects listed buildings;

(f) Takes action in respect of "Planning Act" conservation areas.

The Authority however shares with the local authorities existing powers relating to the control of:-

(a) Tree planting and tree preservation;

(b) Historic buildings;

(c) Ancient monuments;

(d) Derelict land;

(e) Litter.

Finally the Authority also has the power to undertake conservation or restoration work in respect of a building or vessel in the Broads and to make grants or loans to other bodies for that purpose.

As the sole planning authority for the area of the Broads, the Planning Department is assumes the planning powers from the six local authorities within the area. All the local authorities forward planning applications for this area to the Planning Department. Compared with the Local Authorities, the Planning Department of the Broads Authority has stricter criteria for planning control in the Broadland region. Thus the quality of the environment may be maintained and possibly improved. Routine non-controversial applications are normally processed by the Broads Authority Planning Department. Where planning applications are of a less than routine nature or where the application is likely to be controversial the application must be presented to the Planning Committee for its judgement. Further to these requirements the Planning Department must notify other departments and where necessary their committees within the authority where planning permission is likely to affect their activities. Most often the Planning Authority must contact the Navigation and Conservation departments within the authority. In certain controversial cases where no decision can be reached at the Planning Committee the applications may be considered by the full Broads Authority Committee.

The planning policy of the Broads Authority is based upon planning regulations used by local government and therefore is legally binding once planning permission has been granted. Where a planning application is refused the applicant may re-apply for planning permission after twelve months, so that the application may be reconsidered. Planning permission is often granted only on condition that certain criteria are fulfilled. These criteria range from a change in the building materials to be used to fit in with the local area, to a change in the style of the building or development being planned. Where the application is not granted the applicant may appeal to the Secretary of State who will make a decision for all people concerned in the matter.

The Planning Department and Committee have several criteria on which planning decisions are made. These fall into two guide-line areas: the right activity for the area, and the appropriate building style and materials for the project. To carry out such a decision making process the Planning Department needs to have information on the following: the planning application itself; the area that the application will affect; any other issues, for example information from other Departments that may affect the decision (such as conservation). Therefore the decision making process is highly influenced by the information available .

Although the primary concern of the Planning Department is the process of determining planning applications, it has several other responsibilities. These are discussed below, and fall into the categories of further development controls and additional powers which it shares with each local authority. With regard to the first category, the Department is required to: carry out enforcement action; control advertisements; and protect listed buildings. Additionally, in conjunction with the local authority, it may: serve tree planting and preservation orders; and preserve ancient monuments and historic buildings. It may also place orders for the use of derelict land and the preservation of common land.

### 4.5.2 Information and Interpretation Department

Recreation is handled by a section of the Broads Authority called the Information and Interpretation Department which reports to its respective committee. The department is responsible for the public relations of the Broads Authority and for the provision of information about the Norfolk and Suffolk Broads. Its brief comes directly from a section of the Norfolk and Suffolk Broads Act (HMSO 1988) which states that:

> "It shall be the general duty of the Authority to manage the Broads for the purposes of:
>
> (a) .......
>
> (b) Promoting the enjoyment of the Broads by the public."

and

> "In discharging its functions, the Authority shall have regard to:
>
> (a) The national importance of the Broads as an area of natural beauty and one which affords opportunities for open-air recreation."
>
> (HMSO 1988)

The land-based recreational powers of the Authority are also contained in schedule 3 to the Act (HMSO 1988). The Authority shares the following main powers with the local authorities in the area:-

(a) The provision and management of open spaces;

(b) The provision of accommodation, meals, refreshments and toilets;

(c) The provision of camping sites;

(d) The provision of caravan sites;

(e) The provision of country parks;

(f) The provision of study centres and other facilities for learning about the Broads;

(g) The encouragement of tourism;

(h) The creation, diversion, extinguishment, widening and maintenance of footpaths and bridleways;

(i) The protection, maintenance and improvement of staithes;

(j) The protection of common land and village greens.

When any of these functions require planning permission this must be gained from the Broads Authority Planning Department (see section 4.5.1 above).

The publicity of areas within the Broads which are likely to fulfil these recreational requirements must be framed within the criteria of the Act. The Information and Interpretation Department of the Broads Authority therefore coordinates information about the Broads region, making it available to the public. Some information collection for this purpose is informal, for example relying on the good will of the public to inform them of future events.

For the purpose of publicity the Broads Authority produces a leaflet every two months called "Fun in the Broads". In addition the Broads Authority also produces other information packs and long term information about permanent activities and places of interest in the Broads Area. Publications in general are available from the Broads Authority offices, Broads Authority Information Centres, Tourist Information Centres and other interested bodies. The Broads Authority runs four information centres throughout the region. These distribute information about the Broads Area as well as providing an educational service. Many publications about the Broads are available free of charge and provide useful information about the area and places to visit. The Broads

Authority also provides other more detailed material on the region which are priced accordingly.

The Information and Interpretation Department is also responsible for the educational concerns for the Broads Region. It is responsible for projects such as the How Hill residential Study Centre where school children may learn about important aspects of the Broads.

The Information and Interpretation Department has implemented these measures in an integrated and organised manner. Projects which fulfil the Broads criteria are funded through the Broads Authority. These projects are open to the public (e.g., Toad Hole and the Electric Eel). It is the deliberate policy of the Broads Authority Information and Interpretation Department to release information about certain features of the Broads while safeguarding some of the more environmentally sensitive areas.

### 4.5.3 Conservation Department

This section discusses the information needs of the Conservation Department of the Broads Authority. The brief of the Conservation Department of the Broads Authority is wide. The Broads Area has deteriorated badly from a lack of environmental awareness and a laissez-faire approach by local authorities, and there is much restorative work to be done.

This department has the responsibility for grant-aided land improvements, restoration and conservation of the broads, improvement in water quality, and the provision of 'nature resources' for the public and further research. There are several provisions made with regard to conservation. These may be seen more fully in section 3 of the Act (HMSO 1988) and are briefly discussed below.

The Conservation Department is concerned with the monitoring of flora and fauna within the Broads Executive Area. To this end, records of species cover and density are recorded and used as indicators of the Broads health and for planning the conservation and restoration of the Broads Area.

The Authority is able to carry out works or make grants and loans to improve water quality within the region. To this end, Anglian Water Plc must consult the Conservation Department before implementing any proposals that are likely to affect water quality in the Broads. The Department must also be consulted when Anglian Water Plc have received any applications for discharge of trade and sewage effluent into the Broads Executive Area. The monitoring of chemical concentrations is important. In practice the Conservation Department negotiates with the Water Authority (Anglian Water Plc) to restrict the amount of pollutant discharge into the water and where necessary to remove such pollutants from the water before discharge. This information is needed so that preventive as well as restorative measures can be successfully carried out in the Broads.

The Authority presides over a code of practice for carrying out and maintaining drainage works within the Broads, so as to limit the environmental impact of this type of work. Since all new drainage work must be licensed by the Conservation Department, environmental damage can be reduced. If there is any major disagreement between the Conservation Department and anyone carrying out drainage work under this code, arbitration is determined by the Minister of Agriculture, Fisheries and Food.

Section 5 of the Act (HMSO 1988) allows Ministers to make orders controlling the carrying out of specified damaging agricultural operations. These orders are restricted to areas of grazing marsh, reed bed or broadleaved woodlands. Where landowners intend to carry out operations which fall under these categories they must apply to the Authority. If the Authority objects then the proposed operations may be banned for twelve months. Within this time the Broads Authority is allowed to negotiate a management agreement or compulsorily purchase the land. The Authority is able to enter into management agreements for the purposes of conserving or enhancing the natural beauty or amenity value of land in the Broads or for promoting its enjoyment by the public. As well as these specific powers the Authority will be able to provide resources for the appreciation of nature and make byelaws for general management.

As well as these mandatary powers the Conservation Department must also create and maintain a map showing any areas of land within the Broads, the natural beauty of which is particularly important for conservation. The map is to be kept under review.

The Conservation Department supports applications for the restoration and improvement of the ground. This is done by applications for money being presented to the Broads Authority and grants being given to individual projects on their merit. The Conservation Department must keep control of these expenditures and needs information on these to coordinate a coherent grant strategy.

### 4.5.4 Navigation Department

The Navigation Department did not exist within the previous Broads Authority. Its original functions were carried out by the Great Yarmouth Port and Haven Commissioners. These functions were incorporated into the Broads Authority in 1989 as part of the Broads Authority by the Norfolk and Suffolk Broads Act (HMSO 1988).

The Navigation Department has assumed responsibility from the Great Yarmouth Port and Haven Commissioners as the Navigation Authority for all the public waterways in the area of Broads Authority jurisdiction except for Breydon Water, the lower Bure in Great Yarmouth and the lower Waveney to a point just upstream of the Burgh Castle marina. The Authority has to maintain their navigation area to an appropriate standard and take essential steps to improve it.

The Navigation Department has a statutory Navigation Committee comprising thirteen members. Six of these members are appointed from the membership of the Authority (including one of the two members appointed by the Great Yarmouth Port and Haven Commissioners) and the remaining seven are co-opted onto the Committee following consultation with bodies representing navigation interests and users of the Broads waterways.

Section 3 of the Act provides a detailed account of the provisions for navigation made for the Broads Authority (HMSO 1988). The Act provides for the appointment of two Navigation Officers, one for the River Yare and one for the rest of the Broads. The Broads Authority has chosen to appoint only one for the whole area. The Navigation Officer has several specific powers for controlling and directing vessels.

The Act contains a number of provisions for the protection of sea-going freight shipping:

> "(a) In discharging its functions on the Yare the Authority must have particular regard to the interests of sea-going vessels.
> (b) The Authority must provide a communications service to enable such vessels to move between the Yare and the Haven in Great Yarmouth, and also operate patrols along the Yare.
> (c) The Navigation Officer for the Yare must exercise his powers with a view to ensuring the safe passage of sea-going freight vessels and in appropriate circumstances to comply with directions given by the Port and Haven Commissioners' Harbour Master." (HMSO 1988, Broads Authority 1989)

There are provisions for the protection of the Great Yarmouth Port and Haven Commissioners, for example:-

"(a) The Authority must at the commissioners expense carry out dredging works in the Broads which are necessary to prevent a reduction in the flow of water in the Haven at Great Yarmouth.
(b) The Commissioners' consent will be required for dredging works which the Authority proposes to carry out or licence and which might materially affect the flow of water in the Haven."
(HMSO 1988, Broads Authority 1989).

The Authority is given a number of Navigation powers:-

(a) To provide and control moorings.
(b) To control any works or dredging within or adjoining the waterways by licence.
(c) To require the repair of landing places, embankments and private moorings which become a potential danger to users of the Broads waterways.
(d) To remove sunken, stranded and abandoned vessels.
(e) To maintain, improve and dredge the Broads waterways.
(f) To operate a vessel registration service (as the Great Yarmouth Port and Haven Commissioners currently do).
(g) To create new rights of public navigation.
(h) To close parts of the waterways for navigation purposes.
(Broads Authority 1989).

The Navigation Department is obliged to operate a vessel registration service. In conjunction with this, it must collect license fees from all vessel owners. The Department also has the power to levy tolls on users of the Broads waterways. All these fees may be used for Navigation purposes only. The Navigation Department is obliged to balance its navigation budget, although capital expenditure and expenditure incurred in connection with conservation are exempted, because funds for these categories are provided from central government and the local authorities.

The maintenance of the Broads navigation channels is the biggest of the concerns of the Navigation Department of the Broads Authority. It is responsible for the maintenance of the navigation area to Broads Authority standards. It must make provision for protection of sea-going freight shipping and make byelaws for the control of navigation throughout the Broads. There are several functions that it must carry out. It must maintain, improve and dredge Broads waterways so that river traffic are not hindered. The Department must allow such sea-going vessels safe passage from the River Yare to the Haven at Great Yarmouth and must provide police patrols for such duties. The Navigation Department is also responsible for the removal of sunken, stranded and abandoned vessels. Within these maintenance functions the Navigation Department is responsible for overseeing the provision of mooring places within the Broads for vessels. It is responsible for regulating the provision and use of moorings in this area. This is potentially controversial since the provision of additional river or Broad side mooring is now prohibited.

The Navigation Department is responsible for making byelaws. These may control the following problems: damage to land; creation of new rights of public navigation; the control of vessels using the Broads to regulate speed and prevent pollution; excess noise; and to regulate safety precautions. It is also responsible for byelaws for regulation of disturbance.

From this brief description of the functions of the Navigation Department it is clear that its needs are complex. These activities and their information needs are further discussed in chapters 5.

### 4.5.5 Administration

The administration of the Broads Authority must deal with the provisions of all the Broads Authority's water and land based department functions described in sections 4.5.1 to 4.5.5. The functions for which this department is responsible can be classified as follows: personnel; accounting; and coordination of committee meetings, staff meetings and inter departmental coordination meetings. It is also the function of this Department to provide secretarial support and maintain office supplies at working levels. The final role of the Administration department is the resolution of conflict situations, whether these are personal or between departmental interests.

## 4.6 Summary

This chapter has described in detail the history and present position of the Broadland region and the Broads Authority. The legal provisions and observable structure have enabled the information needs of each department within the Authority to be outlined briefly. Chapter 3 introduced the nature of a Geographic Information System as distinct from a general Information System. In this chapter the particular features of the Norfolk and Suffolk Broads Authority have been drawn out. The main distinguishing features of this case study are the diversity of information which must be handled for decision making and the wide range of functions that must be served. Decision making has to be balanced against the constraints of a budget, and current needs against future problems and opportunities.

These features are difficult to handle very easily by the conventional static methods of information system development because of the wide range of data, the diversity of information flows within the Broads Authority and the many different functional levels at which this organisation operates. As described in chapter 2 above, prototyping and hypertext offer particular solutions to some of these problems, in that hypertext allows the storage of a wide range of information types and facilitated dynamic access of this information through its web structure. Therefore by using hypertext as a prototyping environment for such an information system development, the dynamic nature of a hypertext environment may be employed to the fullest advantage in the analysis, specification, design and implementation of a prototype information system. In the next chapter these approaches are applied to the analysis and specification of the case study with a view to developing a prototype system in chapter 6.

# Chapter 5 Analysis and Specification of the Information System

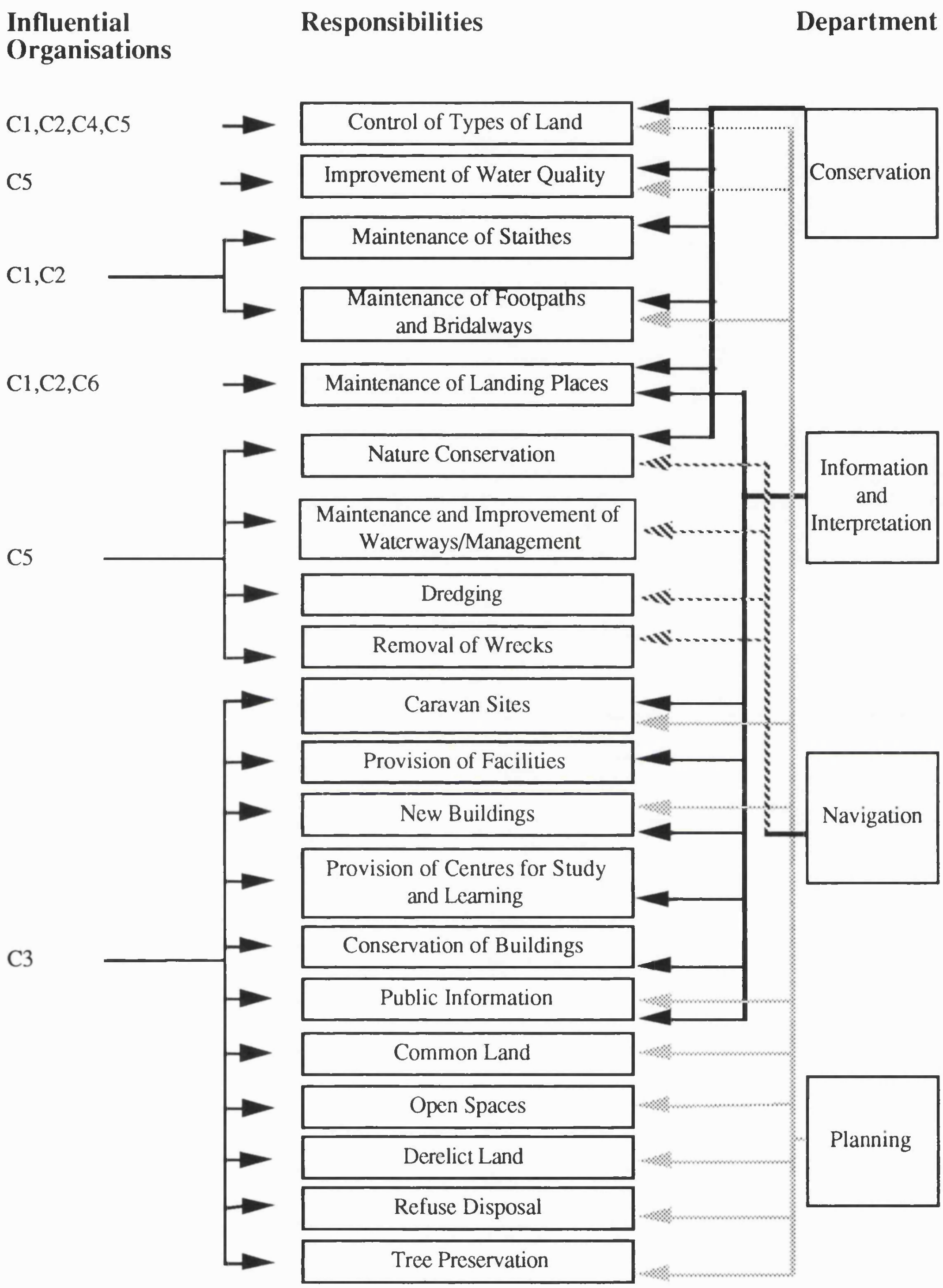
## 5.1 Introduction

This chapter describes the analysis and specification of the Norfolk and Suffolk Broads Authority Information System. It discusses the techniques of data collection and documentation used and examines the existing information system of the Broads Authority. Finally it seeks to outline the information system specifications for the Broads Authority. Throughout this discussion references are made, where necessary, to traditional techniques of specification although emphasis is placed on the use of hypertext to aid these processes of analysis and specification.

## 5.2 Methods of Initial Data Collection

While investigating the Broads Authority for this study, emphasis was placed on informal interviewing, where the observer gained insight into the internal mechanisms by talking informally to members of the organisation. This technique was carried out in parallel with two other requirements gathering techniques, namely observation and documentation review. These three methods are discussed below.

Although the Broads Authority is in the main part without a computer system a small part of their operation is computer based. This part of the system was also studied, see appendix 4. The initial results of these data collection methods are illustrated by diagram 5.1.




Key to Influencial Organisations

C1:- Countryside Commission
C2:- Nature Conservancy Council
C3:- Department of Environment
C4:- MAFF
C5:- Anglian Water plc
C6:- Owners of Land

**Diagram 5.1 The Functions and Responsibilities of the Broads Authority**

### 5.2.1 Informal Interviewing

Whilst observing the day-to-day operations of the Broads Authority, it was possible with key people within the organisation of the Authority. These discussions were broad-ranging and often very detailed. From these it was possible to compile a picture of the day-to-day running of the Authority, typical movements of officers, routines of departments and the aims of the Authority.

### 5.2.2 Observation

This activity entailed watching and monitoring the activities conducted by employees within each department of the Authority. The method of observation was limited in some ways because the observer was obliged to be unobtrusive since the Broads Authority is an extremely busy organisation. Nevertheless observations were enhanced by the cooperation of many Authority members. Since the Broads Authority has a limited computer-based information system, it was necessary to adopt alternative methods of enquiry. Observation and monitoring had a useful additional benefit because it allowed the identification of peaks and troughs in work-loads within particular departments over certain periods of time. Observation confirmed the anticipated pattern of communication within the Authority. Informal channels of communications exist within the Authority and the organisation operates more through a cell structure than through its formal hierarchy. Observation also made it possible to identify key patterns of document access.

### 5.2.3 Document Reviewing

Since the Broads Authority does not have an existing integrated computer-based information system alternative sources of information were found. The documentation, job descriptions, internal and external circulars, committee reports, publicity and promotional material were studied, in an attempt to gain a fuller impression of the system in operation at present.

## 5.3 The Systems Observed

The organisational systems and information flows of the Broads Authority were studied. Diagrams and descriptions were created as a method of attempting to understand the systems. These are outlined below. The descriptions at this stage are a representation of the basic organisational structure and the data and information flows within the Broads Authority and its constituent Departments.

The description of the subject matter for use within a hypertext system does easily lend itself to the sequential written word. Proper understanding is gained by viewing the hypertext system itself. The results of this analysis of the Authority are summarised in 5 subsections, based on the 4 Departments and the Administration of the Authority.

The structure of the Authority can be more easily understood from diagram 5.1 above which outlines the relative positions of each of the Departments within the Authority. The Authority has a very hierarchical formal structure, although, through observation, it has been noted that there are well established mechanisms of informal communication.

The existing structure of the Broads Authority, except the Navigation Department, is paper-based. From a mixture of formal documentation sources and the data collected, the needs and functions of each department were elicited and are set out in sections 5.3.1 to 5.3.5 below.

### 5.3.1 The Planning Department

The Planning Department is responsible for the 'determination' of planning applications within the Broads Authority Executive Area and has influence in those areas that bound this. The activities and the information used in planning application decision making is briefly outlined in the following paragraph.

The Planning Department receives approximately 200 applications for planning permission per month. These are forwarded from the six local authorities within the Broads Executive Area. These forms hold the name and address of the applicant, the location or address and a brief description of the item or task for which permission has been sought. Applications may have additional items of information attached to them. These are usually additional descriptions, maps, sketches, plans and architectural drawings. In addition each application has an individual planning code number. These numbers are allocated to the applications by the local Authorities before they are forwarded to the Broads Authority.

Once received by the Planning Department, each application is checked to make sure that no extra details are needed, and where necessary, a member of the Planning Department may contact the applicant to provide additional information. After this process applications are sorted into those that may be routinely processed by the Planning Officer and those that must be refered to the Planning Committee for decision.

Throughout the application process the Planning Officer uses certain types of information. These are the policy documents of the Broads Authority which relate to planning. Maps of the area are used to ascertain the location, local features, the infrastructure and any zoning information which applies to the area, for example, whether the area is a site of special scientific interest. Where there are zoning influences to be considered the Department must contact the Conservation Department to ask for their advice. Whilst completing this decision making process the Department also uses the Broads Authority and County structure plans.

For routine applications this process may be completed by the the Planning Officer, and the Notification of Decision sent to the applicant. Where the application must be viewed by the Planning Committee, notification of this is sent to the applicant. The Planning Committee meets once a month where applications are viewed and decisions are made. This process uses the information gained by the Planning Officer. The summarized information is presented to the Planning Committee. During this part of the decision making process the Committee may request additional information from the Planning Department and from other Departments and Committees within the Broads Authority. It may also request additional information from the applicant. In unusual cases the Committee may request a site visit by either the Planning Officer, some members of the Committee, the whole committee or, in rare cases, the whole Broads Authority Committee. Under these circumstances arrangements are made by the Broads Authority's Administration Department for the site visit. In such cases the hearing of the application is resheduled until the information has been collected, and where this may mean that the time for the planning decisions may expire, (planning decisions must be made within 6 weeks) appropriate restraining and enforcement action may be taken to stop the applicant carrying out the task for which permission was requested.

Once a decision has been agreed by the Planning Committee in the light of all the evidence, the applicant is notified of the decisions by the Planning Department. In cases where no agreement can be reached the application is refered to the Broads Authority Committee for consideration by the whole of the Broads Authority. If the applicant is unsuccessful then s/he may appeal to the Secretary of State for final judgement. If this course of action is carried out then the Planning Department must prepare a report for the Secretary of State. After this process is completed the planning application is archived at the Broads Authority, and the individual Local Authority is sent notification of the planning decision for their records.

As mentioned in section 4.5.1 above, the Broads Authority Planning Department also has responsibilities to carry out other functions. The Planning Department must identify buildings which are worthy of listed status. It must liaise with the Local Authority for this purpose, whereby it must request the addition of the building and its description to the register. Information generally used for this process are, the address and description of the Building, a map of the area, and the Broads Authority's policies.

There are also certain instances where it is necessary for the Department to take enforcement action. This usually occurs where information is received about an illegal development, or where application for planning permission is made retrospectively, or where planning decisions are delayed. The information used here are the details of the planning violation, its location and address, the people involved in the activity, and the policy documents of the Broads Authority. Enforcement is usually carried out in conjunction with the legal advisers to the Broads Authority, and therefore the case information is passed to the Broads Authority Solicitors.

It is the responsibility of this Department, along with the other departments within the Broads Authority, to develop and revise the structural plan for the Broads Executive Area. The first of these plans was published in 1987 and set out the Broads Authority's policies regarding planning, conservation, navigation and recreation of the Broads Authority. In constructing this plan the Department uses the policies of the Broads Authority and any modifications that may have been made to these through the committee meetings. Ideas and information from interested organisations and people are also taken into consideration during this process. During the Draft stages of this process the document is circulated to the Broads Authority Committee and all interested parties.

This department receives and processes planning applications, but it is also has several other duties that it must perform. Diagrams 5.2 shows the schematic organisational flows of the Planning Department encompassing all duties.

**Planning Department**

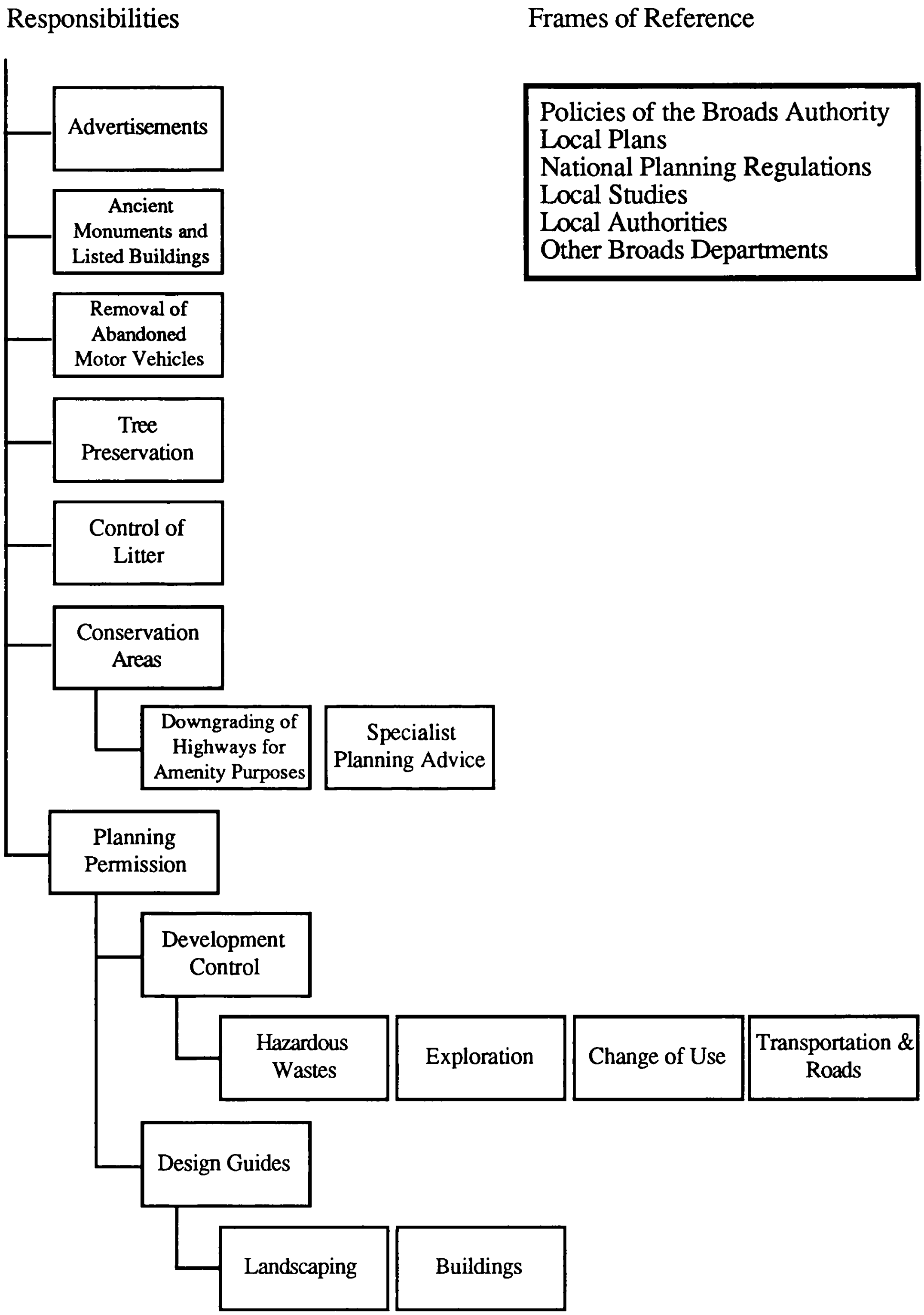



**Diagram 5.2 A Detailed View of the Planning Department**

### 5.3.2 The Information and Interpretation Department

The main functions of the Information and Interpretation Department have been described in section 4.3.2. The activities of the Department and their information needs are described briefly in this section.

The main undertaking of this department is the provision of information to the public. This is carried out by means of publications and by the provision of amenities within the Broads Area.

The publication activities of the Department require the collection and amalgamation of information throughout the Broads Region. Such information is derived from several sources, mainly from the Public. The Department, therefore, relies on the goodwill of the public for much of its information input. From these information sources it produces the publication "Fun in the Broads". The activities within the Department involve the graphic design section of the department as well as the information gathering service. The graphic designers are responsible for the layout and typesetting of the publication and for any graphics or maps which are included within it. This process involves the planning of the layout, and the production of graphics by hand. Once the graphics have been drawn and the layout word processed, the publication is sent to a typesetter within the City of Norwich, the proofs are returned and, on approval, the document is printed. This process is completed for all the publications which are handled by this Department. There are some educational publications known as "fact packs" which are created in conjunction with other departments within the Authority especially the Conservation Department.

The Information and Interpretation Department is also responsible for the provision of information offices, Broads Shops and interpretive sign posting throughout the Broads Executive Area. In many places shops and information offices have been combined to allow visitors the opportunity to purchase items as well as learn more about the Broads.

These shops sell a range of items from confectionery to environmentally friendly detergents. On the information side these points provide information on local attractions and activities, and provide publications about the area and maps. There is also an interpretive side to these offices or shops that allows the visitor to look at the environmental aspects of the Broads from the point of view of pollution and of the wildlife. These centres are administered by the Information and Interpretation Department. The information that they require relates to the information which they provide for display and sale within these shops. The financial side of this is administered by the Broads Authority Administration Department, who administer invoices and purchases and the pay roll of the employees of these enterprises.

The Department also considers applications for grants for the purpose of providing interpretive materials. These projects are considered by the department and its committee for advice and funding. The information required to evaluate these projects are: the name and address of the project applicant and, if different, the location of the project; the nature of the project and the amount of funding sought; the appropriateness of the project and level of funding is decided. Projects which are funded by the Broads Authority are opened to the public, therefore the Department has a role to play in the supervision and erection of notices and displays for public information. Therefore the information needs for these activities are the location, the details of the project, and the update reports for the project.

The information and interpretation department is obliged to give advice and information to all departments and committees which make requests of it. Such information may take several forms; such as formal reports or a written summaries, both of which may be accompanied by graphics. Diagram 5.3 is a schematic representation of the duties and functions of this Department.

**Information and Interpretation Department**

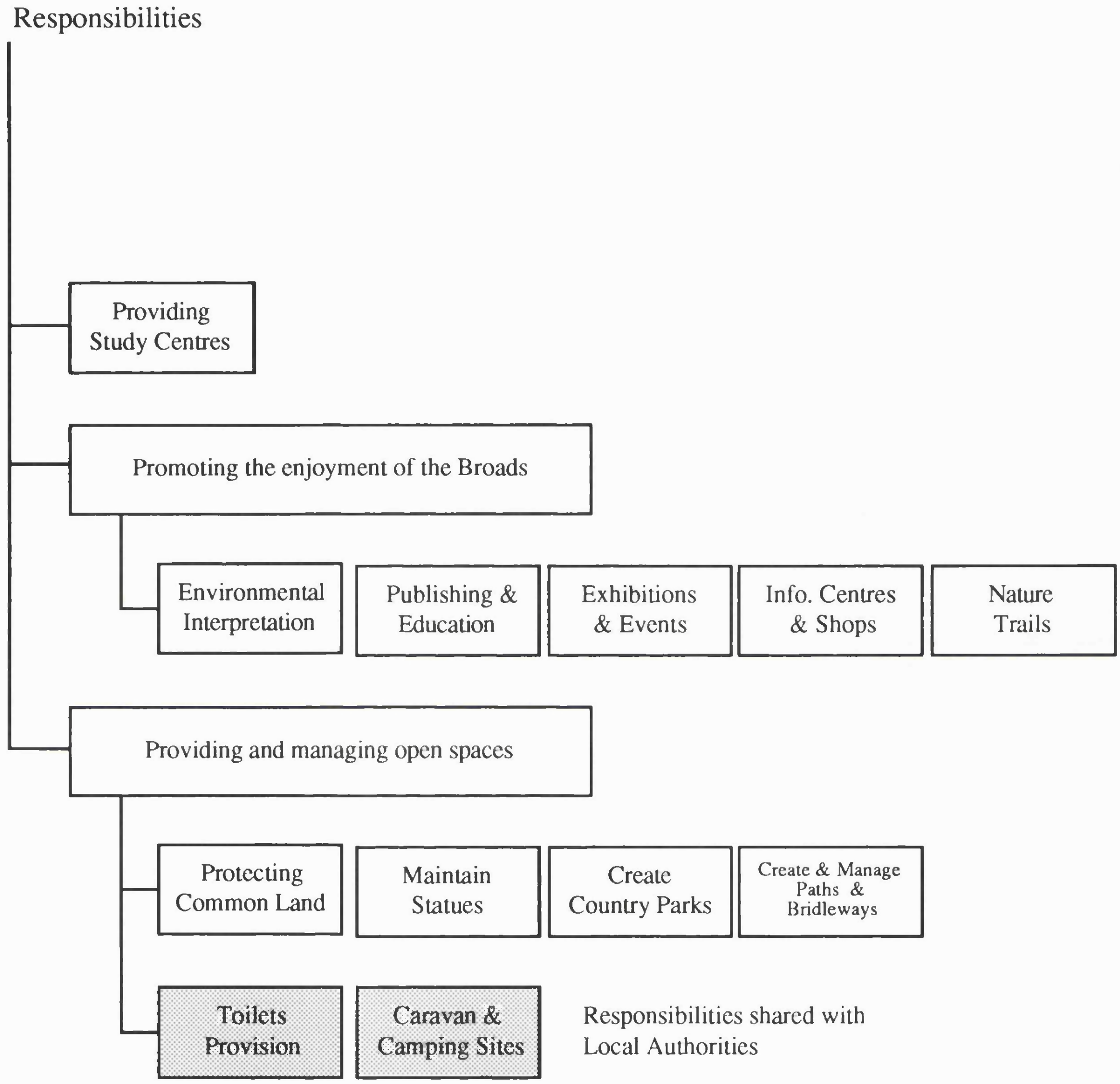



**Diagram 5.3 A Detailed View of the Information and Interpretation Department**

### 5.3.3 The Conservation Department

The Functions of the Conservation Department have been described in section 4.5.3. The activities of the Department and their information requirements are briefly discussed in the following paragraphs.

Monitoring is one of the key activities of the Conservation Department. These monitoring activities concern the levels of pollution, and the diversity of species of flora and fauna within the Broads. Each of these types of monitoring is carried out in a similar manner. Monitoring points are sited throughout the broads for items such as water quality, and are sampled at regular intervals throughout the year. For items such as flora and fauna monitoring is carried out by a field worker visiting each of the Broads and rivers, and physically recording the amount and types of vegetation or the number of a species found throughout the Broads. This data is recorded and used for further conservation and restorative planning. It is also used as a mechanism to measure the success of a restoration project. For example the restoration of Cockshoot Broad now shows higher levels of water plant life than previously recorded.

The Conservation Department is responsible for the implementation of restoration projects. These projects are firstly created by the identification of areas that are in need of restoration or conservation. This may occur as a direct result of the monitoring program conducted by the Conservation Department or by an application from a member of the public for advice and funding. In both instances the projects are considered by the Conservation Committee for their feasibility and, where appropriate, funding will be allocated from the Conservation Department Budget. Where large restorative projects are undertaken over several years by the Broads Authority, updates of the progress of these projects are presented to the Committee. For each project conducted by the Broads Authority, detailed records are kept by the Department. In certain instances there may be the need to apply to other departments for licences and planning permission to allow the completion of the project (e.g., the Cockshoot Broad applied to the Navigation Department and Committee to close the Broad permanently to navigation). Therefore the information generally used during this process is the location of the project, the name and address of the applicant, the type of project, the evidence and justification for the project, an estimate of the cost of the project, and information and advice from the Planning and Navigation Departments and Committees.

Under the conditions of the Norfolk and Suffolk Broads Act (HMSO 1988), Anglian Water Plc must seek the advice of the Department when they wish to issue licenses for the discharge of either trade or industrial effluent within the Broads Authority's Executive Area. Therefore the Department receives information of the location and nature of the discharge. In the Department's deliberations it may consider the water quality of the area, whether the site for discharge is in a sensitive area, and thus whether it is appropriate for the license to be granted. For large projects the application may be taken to the Conservation Committee for their experience and advice. The Department sends its views on the application to Anglian Water Plc, with its recommendations.

Where damaging agricultural activities occur in land that contains broad leaved woodland, grazing marshes or reed beds, the Conservation Department can make orders to ban these activities. Since the landowner must apply to the Conservation Department before carrying out these activities, on receipt of this information the Broads Authority can issue the relevant banning order. Such a ban lasts for 12 months during which time the Department may attempt to reach a management agreement with the landowners.

The Department is allowed to attempt to create management agreements with land owners. These may take the form of applications for ESA designation and practice agreements. The Department is able in extreme conditions to compulsorily purchase land from land owners where no agreement can be reached. The information generally used for these purposes is that of location of the land, the classification of the land type and its environmental importance, the nature of the practices which are at present being used on the land or applied for, records of attempts to create agreement, the final outcome, and whether application is made from compulsory purchase.

The Department is responsible for the introduction and use of a code of practice for drainage within the Broads Authority. Therefore, when drainage organisations apply for drainage licenses, the Conservation Department issues a code of practice along with the license. Where, on inspection, the organisation is breaking the code, then the Conservation Department can order them to complete the work in a different manner. Therefore, the information needed for this activity are, the drainage code of practice, the application for drainage works, the location of the intended works, the type of drainage, whether this location is in a sensitive area, records of the inspection of drainage and any orders that may be issued.

To allow the Conservation Department to complete its work most efficiently, it must maintain a map of the areas of natural beauty which are most important. This is originally created by the use of remotely sensed information gathered by aerial photography. From this data categories of land can be identified and therefore a map completed. The use of this map is highly appropriate throughout most of the work of the Conservation Department.

The Department has an obligation to provide nature resources to the public. In many respects this is completed in conjunction with the Information and Interpretation Department. These provisions allow the public to see the environmental importance of the Broads at first hand. These nature provisions are completed in the form of nature walks and activities such as a trip on the Electric Eel, which is an Edwardian Boat powered by electricity which takes visitors on a silent visit through some of the the reed beds on the River Ant. Such provisions are dealt with on a project basis, the general information needs of which are described above. There is a high level of communication between the Information and Interpretation and Conservation Departments, both to plan the level of access to these resources and the explanation which is to be shown to the visitor. In conjunction with the provision of these resources the Department may make bye-laws to restrain the publics' activities with respect to litter, public nuisance or where damage is being inflicted on the land.

Finally the Conservation Department has a duty to advise the other departments of the Broads Authority and all interested committees of facts that might influence their respective decision-making. Therefore the major organisational and system flows of this department are centred around the monitoring of ecological data, report generation for other departments and committees, and finally project information. (See diagram 5.4.)

## Conservation Department

Responsibilities

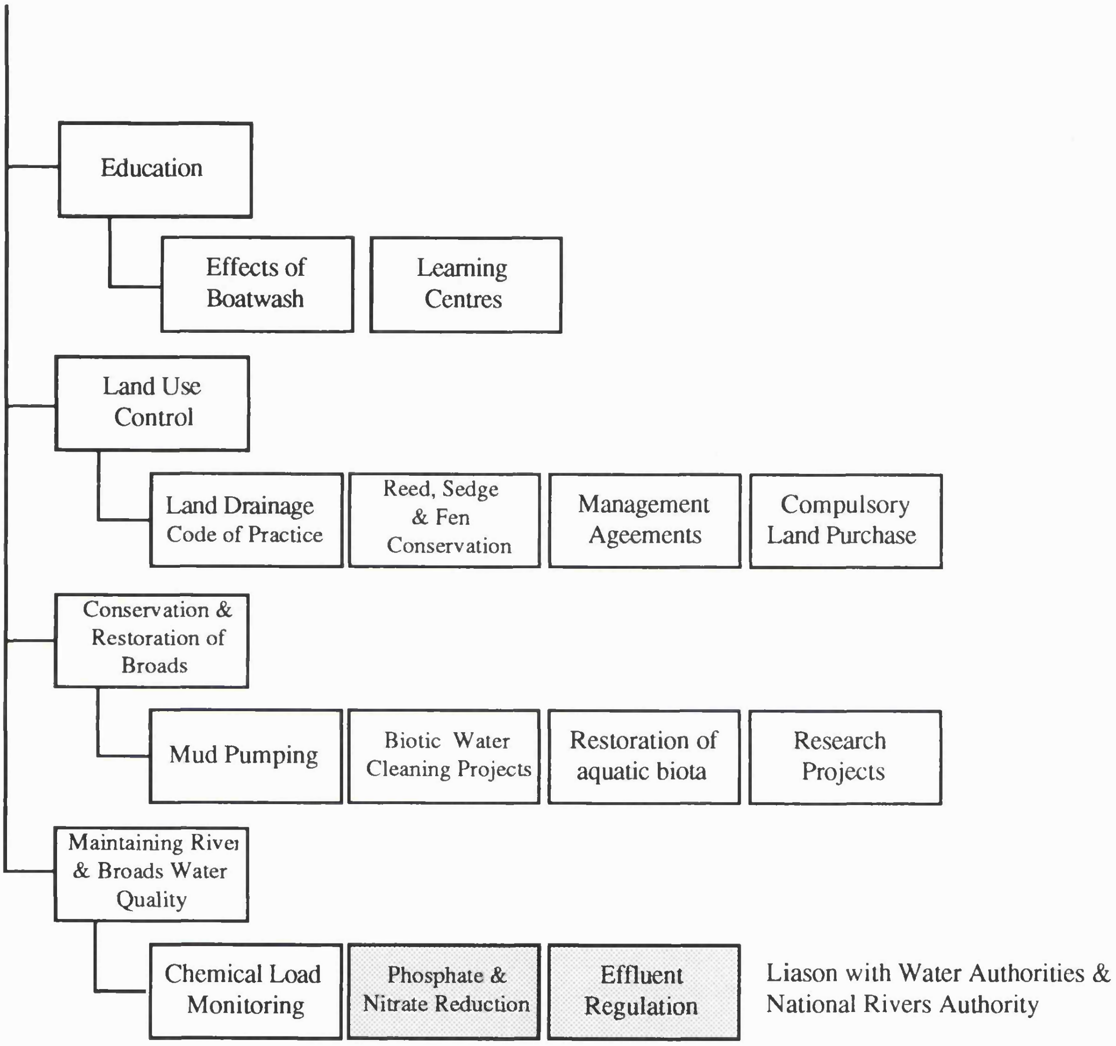



**Diagram 5.4 A Detailed View of the Conservation Department**

### 5.3.4 The Navigation Department

The main functions of the Broads Authority Navigation Department have been outlined in section 4.5.3. These activities and the information that is needed to complete these tasks is discussed in the following paragraphs.

The Department is responsible for the maintenance, improvement and dredging of the Broads waterways. These duties must be completed to a standard which is approved by the Department and that will allow sea-going vessels unhindered access to the Broads through the River Yare. There are several activities which are associated with this maintenance. These are: the regular checking of the depth of channels; the identification of areas that have reached the minimum depth for safety; the application for dredging and restrictive navigation access licenses, advertising of the commencement of works, and finally the completion of the work.

The channel depths are measured regularly at low tide. These are then compared with the agreed minimum depth that is considered safe for navigation. Where these measurements begin to get close to the minimum depth these areas are notified to the Navigation Department. The Norfolk and Suffolk Broads Act (HMSO 1988), states that the Navigation Department must issue licenses for all dredging works which are carried out on the Broads waterways. The Act also states that where any work may restrict navigation access, then an advertisement announcing these details must be posted in the local newspaper and sent to the Great Yarmouth Port and Haven Commissioners. In both these respects, the Navigation Department is responsible for the issue of the works license and advertisement. For this the Department needs information regarding the location of the dredging works, duration time of the works, where necessary how long the channel is likely to be blocked, and the name and address of the dredging contractors. Once the work has been completed a member of the Navigation Department inspects the dredging and reports back to the Department. Once a satisfactory report on the workings is received by the Department, payment is authorised.

Further to these functions the Navigation Department also has the responsibility to maintain and repair landing places, embankments and private moorings which may become dangerous. This information is received by the Department either from the river police or from the Public. In order to carry out the maintenance of these places the Department needs to know the location, the type of landing place, its function and whether it is private or public. If the landing place is privately owned the Navigation Department attempts to request the land owner to complete the repair. If they are unwilling, then the Department has the power under the Act to carry out such repair work in the interest of public safety. Again the Department must issue a works license and advertisements where such work may interfere with the navigation of the area. For this work the department needs the location of the dangerous point, the type of point that it is, (e.g. landing place, embankment or private mooring), the extent of the damage and an estimate of the cost to repair.

In the interests of safety the Department must also remove all vessels that have been sunk or abandoned. Where the vessel is not an immediate danger to navigation then in the first instance the Department will attempt to contact the owner of the vessel using the vessel registration painted on the vessel. The Department will request the immediate removal of the vessel. If there is no compliance with this request the Navigation Department will remove the vessel themselves. If the vessel is an immediate danger to navigation then the Department will remove the vessel first and then contact the owners afterwards. Where vessel extraction is not possible for several days then avoidance barrages and lights are placed around the vessel. To complete this task the Department needs to know the name and registration number of the vessel, the type of the vessel, whether the vessel is sunk or abandoned and whether it is able to be towed. Each of these will affect the severity of the task which has to be undertaken.

To enable the smooth operation of the Broads Navigation and to provide the funding for much of the Broads Navigation Department, the Department operates a vessel registration service. This is currently the only computerised part of the Broads Authority except word processing. This database holds the registration details of all vessels in the Broads Executive Area and charges a license fee to each owner proportional to the size and type of vessel owned. The information currently held in this database is shown in Appendix 4, but can be summarised in the following manner: owner's name and address; the vessel's name; registration number and type; the type of engine or sail craft; when it was first registered; where it is usually moored; and fee payment details. This database also holds details of the number of previous convictions and whether the owners have removed the vessel from the Broads.

As well as charging license fees the Department also charges tolls for access to the Broads Area. These are mainly charged to sea-going vessels which are escorted from the River Yare to the Haven at Great Yarmouth. For this purpose the Department relies on the services of the Great Yarmouth Port and Haven Commissioners to collect the tolls. The tolls and details are sent to the Department. These details include the name and registration and size details of the vessel, the cargo, the length of stay in the Broads system and the returning date to the Haven.

The final activity of the Department is that of attempting to secure new rights of access for the public to private navigation areas. In completing these tasks the Department identifies the areas that it would like access right to. It makes a request to the landowner for access. The landowner either grants or denies access. If the access is denied then no further action is taken. If the landowner grants access then an agreement is drawn up between the Broads Authority and the land owner.

**Navigation Department**

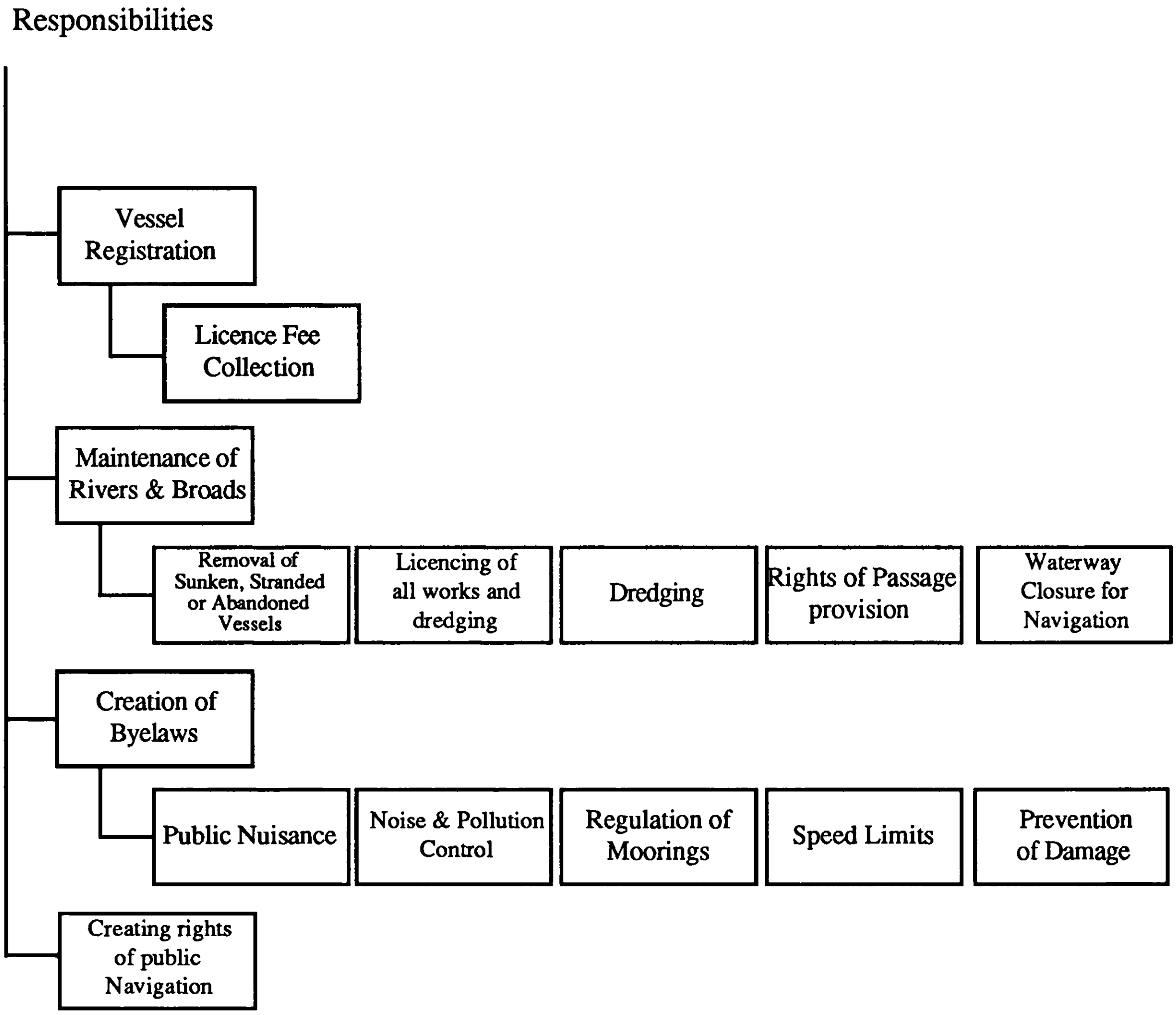



**Diagram 5.5 A Detailed View of the Navigation Department**

### 5.3.5 Administration

The functions of this department have been described in section 4.5.5. This section describes the activities and information needs of this department. Although the nature of this department is administrative, like all departments within the Authority it is necessary for the Administration Department to provide information to all the relevant committees and departments on request. A member from the Administration Department is obliged to attend all the meetings of the Broads Authority committees.

It is the duty of the Authority's Administration Department to ensure the smooth running of the Authority. Within this remit this Department must administer items such as the payment of staff and the maintenance of staff information and records. Pay roll is currently undertaken by Norfolk County Council but it is envisaged that it will be taken over by the Administration Department of the Broads Authority. To complete this activity the department will need the following information; the name and address of the employee; the name and address of the bank or building society account; the employee's national insurance number; the salary level of the employee; and any tax/national insurance exemptions which apply to that person. With the following information the Tax, National Insurance, union and pension contributions and resulting salary may be calculated. These are then paid into the relevant bank account and notification sent to the employee. Where the employee has no bank account the employee is paid in cash and notification is issued at the same time as payment.

Staff information and records are presently handled by the Administrative Officer of the Broads Authority and are securely stored within the Broads Authority. The information handled here relates to the personal details of the Broads Authority employees. These are the name and address of the employee, their national insurance number, title and job description for which they are employed, their work reports and records, health records and recorded level of fitness for work, and number of days taken on sick leave. Within these reports are stored any disciplinary cautions or warnings which may be given with regard to the behaviour or working standard of any member of staff.

This department also handles items such as inventory supplies, (e.g., paper and working materials), which have to be maintained at reasonable levels, as do building and maintenance items. The information required for these are the type of supplies, the supplier and the Broads Authority's order numbers, and the name and address of the supplier. Once the supplier has delivered the materials, authorisation for the invoice to be paid is made and this payment is processed. The information needed for this activity to be completed is the order number, the invoice, the name and address of the supplier, the amount to be paid and the account name and number from which the payments may be made.

This Department also organises the distribution of incoming mail (e.g. planning applications) and other secretarial activity. These other activities include word processing and the filing of communication documents. Secretarial support is administered centrally through this Department, as is the completion of document filing. There are, however, some documents which are stored by department. These are mainly concerned with the Planning Department. This in itself means that the central filing system must be efficiently categorised. The Administration also maintains a small library of key references and useful texts for use by the Broads Authority staff.

## 5.4 Data Flow and Organisation Diagraming

During the investigation of the Broads Authority's organisation, data flow diagraming (DeMarco 1978) was used as a tool to aid the analysis. The nature of data flow diagraming and the methods employed in this context are discussed briefly in the following sections.

### 5.4.1 Data Diagraming

Data Diagraming is a technique which allows the analyst to gain pictorial insight into the way that data and information flows through an organisation. Data Flow Diagrams consist of four components: Data Flows, Processes, Data Stores and Terminators, and these are represented in diagram 5.10. Data Flows trace the flow of data through a system. Processes show the procedures and transformation points of data. Data Stores represent logical files or databases. Terminators show the origin and ultimate recipient of data, and are respectfully often called sources and sinks (Martin and McClure 1985, DeMarco 1978).

Since the flows of information within an organisation are often very complex, it is necessary to create data flow diagrams at different levels. This is done by creating layers of diagrams, where each successive layer provides a more detailed view than the last. Each of the processes in a data flow diagram may have a corresponding full data diagram at a lower level. For example, the process 1.3 in diagram 5.8, is expanded in diagram 5.9.

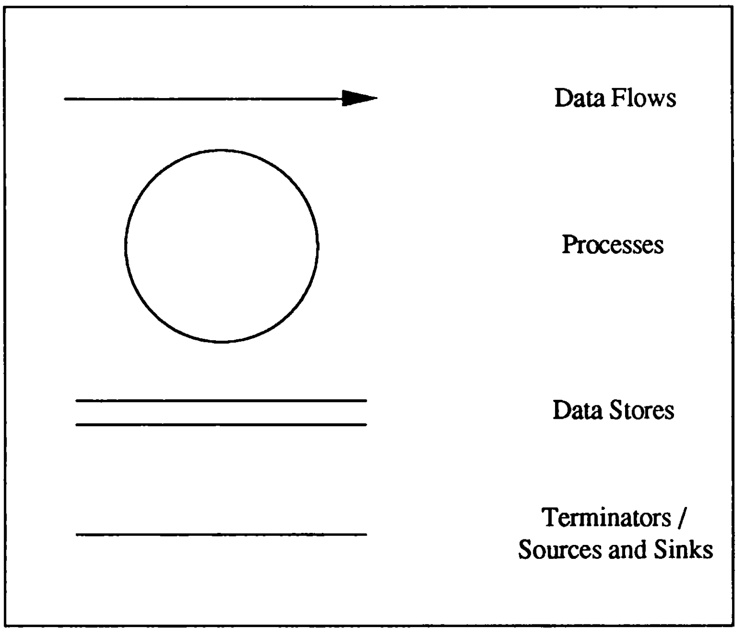



**Diagram 5.7 The Components of a Data Diagram**

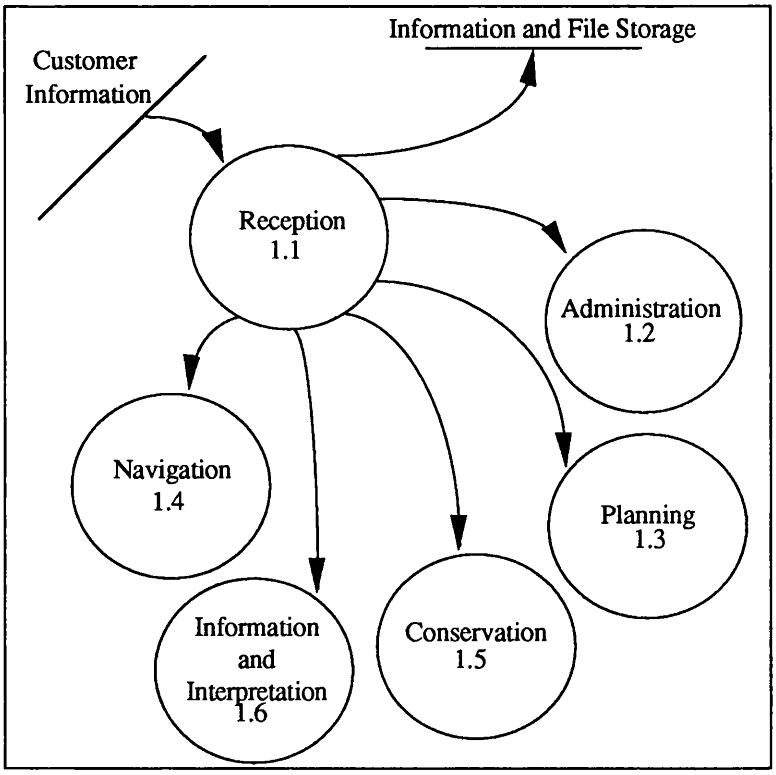



**Diagram 5.8 The Top Level Data Flow Diagram of the Broads Authority**

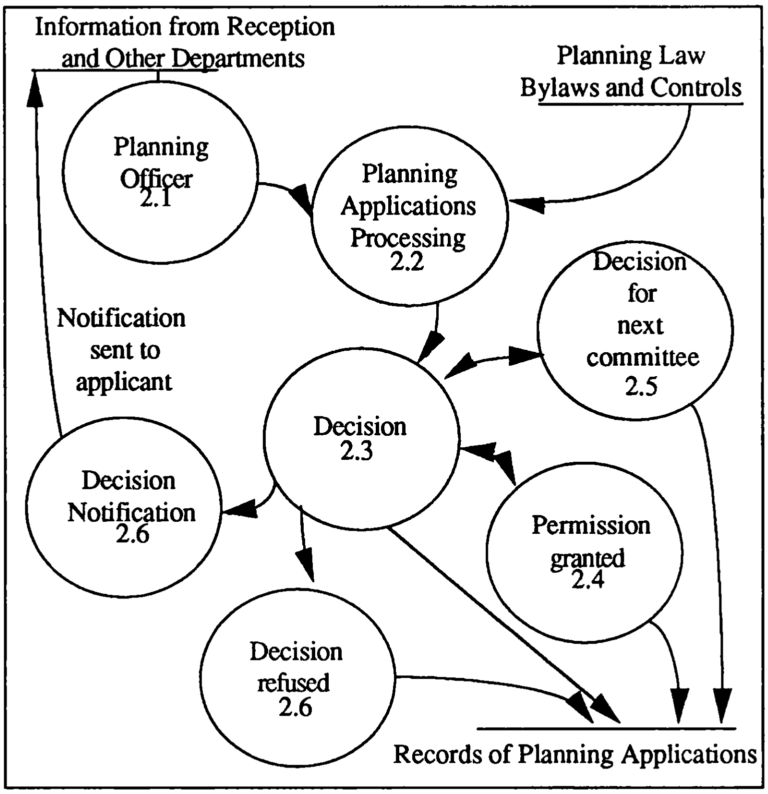



**Diagram 5.9** **A Second Level Data Flow Diagram of the Broads Authority**

### 5.4.2 Data Diagraming Using Hypertext

Within a complex organisation, it is possible that this diagraming technique may result in large multiple levelled, highly complex diagram sets. Because of the large number of these diagrams, their utility can be reduced by an inability to handle them sensibly. This problem was recognised and a solution sought. A solution was found through the development of a hypertext diagraming environment, and this is discussed below.

Throughout the process of data acquisition a data diagraming system was used. Software for this was created using the hypertext package HyperCard. The development of this tool was done for two reasons: firstly for effectively storing the diagrams manageably; and secondly to provide additional facilities to enrich the observed diagrams.

This system consists of work space, palettes containing diagraming components, linking facilities and additional text processing. The system aids the analyst by allowing the storage of diagrams levels. These facilities offer the ability to create diagrams with the minimum of drawing time. This is possible because individual components of the diagram can be copied and pasted into the diagram work space from the system's in-built palettes.

The Data Flow Diagraming Techniques of DeMarco (1978) and Gane and Sarson (1979) were used. Certain minor modifications were made to the method to allow for the use of hypertext links and text processing. Data stores, especially the database aspects of the system, are represented using Chen's (1976) entity-relationship database diagraming notation. The components of this notation were also included within the palettes of the system.

Moreover, the system allows the ability to enrich the diagrams by creating links between chunks of information, to link processes with their lower level diagrams. This function itself enables the analyst to gain more from the diagrams purely by the ease of access. Therefore hypertext aids one of the major problems of data diagraming.

The developed system also provides enrichment of the data collected. This is provided by the ability to add pop-up text fields throughout the system. These allow the analyst to attach notes wherever s/he feels that additional information is warranted. Examples of these system diagrams can be seen in Appendix 4.

In many ways the development of this tool can be seen to take Fletton's (1990) ideas of retrospective software documentation one stage further (backwards). This is facilitated since the system provides the basis for self documentation during the development of the system. Therefore as well as providing a tool for enhancing the productivity of data diagraming, a second aspect of self documentation is also provided by this system.

A versatile on-line tool was developed to aid the analysis of the Broads Authority's Organisation. Further to these achievements the values of this system were not forgotten during the further stages of the specification and design of the Broads Authority Information System Prototype. The diagraming System was extended to allow it to be used during these stages. This system and the specification of the Broads Authority Information System are described in section 5.5 below.

## 5.5 Specification of the Broads Authority Information System

This section describes the specification of the Broads Authority Information System. Whist completing this stage of the development, specification methods and on-line information storage tools were used. Again the description of the subject matter for use within a hypertext system does easily lend itself to the sequential written word. A fuller understanding is gained by viewing the hypertext system itself.

Specification is the translation of the informal user requirements into an unambiguous form so it is understandable by the information systems development team. For the Broads Authority Information System the specification is translated from the data captured in the data flow diagrams using Structured English. Structured English is a reduced vocabulary set of the English Language, where all words that create ambiguity are removed. The system is then described using this vocabulary (DeMarco 1978).

The objective of this specification stage was to derive a specification for the Broads Authority. At this point the questions concerning hardware specification were ignored. It was hoped that this specification stage lay the foundations for an integrated solution in the design stages of the development of this Information System. To aid this specification stage, the data diagraming system was extended for use throughout this stage of the information system development.

The diagraming system, described in section 5.4 above, was extended to incorporate a specification styled interface. The abilities to link and annotate this interface were implemented as before. This diagraming and specification system was used throughout the specification of the information system to aid the storage of the specification and documentation of the resulting information system.

For discussion purposes the specification has been divided into five main topics, each of which covers a department of the Broads Authority. These topics cover, Conservation, Navigation, Planning, Information and Interpretation, and finally Administration. The specifications for each of these departments are described in the following sections 5.5.1 to 5.5.5, although a further details of the specification are shown in Appendix 4.

### 5.5.1 The Software Requirements of the Planning Department

Section 5.3.1 above describes the activities and the information needs of the Planning Department. This section describes the software requirements that are necessary to successfully support these activities. These requirements must completely encompass the planning application processing function. To do this, applications and extra information which relate to them must be stored electronically. For some applications it is recognised that there will be items of information that will be difficult to store in this manner and therefore within this system there must be a mechanism for locating information which is stored externally. It is probable that it will be necessary to keep and store the original planning application, and it is logical that other such materials, for example technical drawing, may be stored similarly. The planning applications and details relating to these features should be stored within a data retrieval mechanism similar to a database. Further to the storage of the applications, additional information is often used in the decision making process (e.g., the Broads Authority policies, and the area and town structure plans). The information system is likely to be more successful if the user is able to access all documentation on-line. Therefore, the system should at least include summaries of these policy documents, if not the whole items, or references to where the physical document may be located. It is recognised that the Planning Officers will be well served if they are able to access an on-line set of maps for purposes of showing location, infrastructure and zoning. Within this section, therefore, there will be the need to have some interrogative techniques. For example, the planner may wish to overlay the zoning maps with the ordnance survey plan bases.

The user must be able to access the details of the planning application and relevant details about planning regulations, Broads policies and other relevant information in forms such as maps. Where enforcement action is necessary it is appropriate that on-line records of these activities are also kept. For enforcement on existing planning applications or where planning permission is sought retrospectively, pointers can be included in the records of the application to the enforcement records where further details can be encoded. Where enforcement is necessary for illegal activities these may be directly encoded into the enforcement records.

The listed buildings register is also a part of the Planning Department duties. Although local authorities must keep a complete list, it is practically necessary for the Broads Authority Planning Department to also maintain a register of these properties, for reference during the consideration of planning applications. An on-line storage mechanism is also appropriate here.

Finally the Planning Department is responsible for the development and update of the structure plan for the Broads Authority's Executive Area. The detail of these plans and ideas for future developments may be stored on-line within a discussion section of the system. During the creation and modification of these plans, a hypertext discussion board may be a good mechanism from members interaction and full information storage. Members of the whole Broads Authority are able to include their comments about the proposals. Once this stage in the discussion of the plans is completed the whole plan may be held on-line for use by the Broads Authority. Similarly a hypertext can be considered as a good mechanism for users to access the final plans. The user then can navigate directly to the specific section of the text which needs to be viewed.

It has been seen in sections 5.3.1 and 4.5.1 that the Planning Department reports to a committee bearing the same name. It is necessary for the records of this Department's Committee to be stored on-line. These must be stored in a manner which is accessible to the Planning Department and to the Administration Department, whose duty it is to provide the agendas and the minutes of the proceedings.

Throughout the discussion of this Department it is clear that there is a need to build in interdepartmental communications. It is recognised that the close community and informal practices of the Broads Authority will be duplicated by the development of interdepartmental communications, but if the Broads Authority is likely to grow in size and nature, a formal communications system should be included. Further to this interdepartmental record, a look up mechanism should be implemented. This will enable an individual user in one department to search for record entries in any of the other departments so that the whole information may be assimilated for reference and decision making.

### 5.5.2 The Software Requirements of the Information and Interpretation Department

The activities and information needs of the Information and Interpretation Department have been briefly described above in section 5.3.2. This section describes the software requirements of the Information and Interpretation Department.

One of the primary obligations of the Information and Interpretation Department is that of publication. It would be most useful to the Department to have its own document processing system to allow complete control over graphics, layout and final typesetting of the documents. In conjunction with this document processing system the use of a compatible high quality graphics capability is necessary to make full use of this system.

The Department like those of Conservation, Navigation and Planning may make use of a map based system to determine the location of projects and information sign posts to be elicited.

Finally the Department needs a form of flexible on-line record storage for the storage of project information and information connected with the activities within the Broads Executive Area. Such an on-line system could be used in conjunction with a mapping system to add greater value to the information obtained.

### 5.5.3 The Software Needs of the Conservation Department

The main functions of the Conservation Department have been outlined in section 5.3.3. This section describes the software requirements that are necessary to successfully support these activities. Since the work of the Conservation Department is so diverse it is necessary to address the requirements that best suit the Department needs.

Throughout the whole of the Department's work there is a definite need to use maps. The Department must create its own map of the area and within every activity that it carries out it is possible to see where the use of this and other map information could prove to be very useful. Therefore the Department of Conservation would benefit greatly from the use of map-based information interrogation throughout the whole of its practices.

The Department also keeps several types of records, which range from applications for drainage works licences to the storage of project data and reports. Each of these types of information needs to be handled by this information system. It is thought that some form of flexible on-line storage mechanism would be most appropriate for this type of problem. Thereby the details and information for each type of record may be held within the software structure.

Therefore the software functions of the Broads Authority may be completed by the use of a map based interrogative tool, and a flexible records storage system.

### 5.5.4 The Software Requirements of the Navigation Department

The activities carried out and the information used by the Navigation Department have been outlined in sections 4.5.4 and 5.3.4. This section describes the software functions which must be incorporated into an information system to enable the efficient running of this Department. These software functions are divided into two sections: those that relate to the registration of vessels and their management within the Broads; and those that relate to the physical maintenance and management of the Broads waterways.

Vessel management may be most usefully managed by using a database. At present vessel registration is stored by means of a database. It is felt that this should be extended to allow information such as the removal of obstructive vessels (sunken and abandoned) and charges made for this purpose. The existing database features are depicted in appendix 5.

The physical management and maintenance of the Broads is a very complex problem, as described in section 5.3.4. There are several procedures which must be followed whenever any maintenance must be completed. The features of maintenance are all in the first instance map based, therefore this section of the information system must have a map based element to allow the Department to plan the necessary licenses and other items routinely carried out in connection with these problems.

Although severely curtailed by the policies of the Broads Authority, the Navigation Department has responsibilities to make sure that all mooring provisions are located in places where they are not a hindrance to navigation, and that these are not in areas where there are high densities of other mooring places. The provision and the subsequent maintenance of mooring places may be aided by the use of a map based interface, with accompanying text information records. The user will therefore be able to see the level of mooring provisions within the area and from this allow the update and management of the mooring provisions. An underlying text information storage will enable the user to access data as well as viewing these maps.

These map features may also be used to enable the maintenance of the Broads Region. In the same way that the maps may show the location of moorings, they may also display the licensing of works and maintenance. This may allow the coordination of works enabling the minimisation of disruption to certain areas. It is possible that these features may be augmented by the use of a mechanism for storing records attached to these areas. By coordinating management, the application and issue of works licenses and notices for the closure or the restriction of these waterways may be automatically generated from the initial records of the maintenance problem.

Such a map-base section may also allow for the storage of accurate records for items such as bye-law provisions and traffic speed limits throughout the Broads Waterways, thus enabling the policing of these bye-laws by the river police.

Therefore the software functions for the Navigation Department comprise a pure database and a map-based information system. The database mechanism would be used for the routine management and administration of the vessels. The use of the second set of management tools enables the effective overall management of the Broads Waterways and the automation of many features. The design and implementation of these features are discussed in chapter 6.

### 5.5.5 Software Functions for the Administration of the Broads Authority

It is important that the needs of administration must also be integrated. To a certain extent this is a more traditional problem in that the system can provide more administrative functions at a more fundamental administrative level than the other functions. These functions are more fundamental to the running of the Authority than the management roles the system performs.

The functions of Administration are as follows: financial spread sheets and balance sheets for accounting and audit; and stock control of vital commodities that the authority uses, for example, stationary, photographic, field working equipment and similar items. For these purposes a simple stock-control system is needed. It is also necessary to note the word processing needs of the Broads Authority. At present word processing is only carried out by secretarial staff and within the designed system there is a need for compatible centralised word processing and printing facilities. Since it is seen that these functions are vitally important to the development of the Broads Authority IS, these functions have been specified.

### 5.5.6 The Overall Specification for the Broads Authority Information System

Throughout the specification of the departments' functions, (except the Administration Department), it has been noted that there is a need to have a form of geographical referencing of locations of projects and therefore there is also a need for a mapping system. This has been specified. This facility will allow the Authority the ability to see in map form, the location of, for example, a project, or planning application or mooring point.

It also became apparent that the ability of the system to allow the inclusion of additional annotation information fields that provide additional comments and documentation about an item, for example, a project, would also be useful. This was also specified.

A specialised Geographic Information System (GIS), therefore, was considered to be beneficial to the Broads Authority. A GIS certainly possesses the capabilities to use map-based information and there is a functional ability to access data in many ways. It is also possible for these systems to access and keep records for items attached to particular spatial references. Therefore information can be stored and referenced by postcode or by other indicators. It is interesting, however, that GIS, although having the functionality of databases that can access data in a spatially referenced manner, are unlikely to be able to allow for the diverse range of information stored within each field for each data item. Depending on the region and the item in question there may be as little as a few lines on an item or as much as twenty pages. It is unlikely that a conventional database, with inherent rigid structures, will be able to handle this range. It is postulated that hypertext may be able to provide augmentation for such facilities and provide links to other important information about the region. For example, when the Planning Department wishes to assess a planning application within an area of the Broads, the relevant data may be retrieved from the system, a map appear next to the data and extra links may show that there is additional important information about the area in the Conservation Department. The planning application can then be considered in the light of the new information. This is advantageous for both departments and the aims of the Broads Authority, as well as providing a safety net to eliminate the embarrassment of a wrong decision.

## 5.6 Critique

Within each of the stages of data collection, documentation, data diagraming and specification there have been many questions and criticisms that could have been considered. These are included within this section.

The methods of data collection used during the study of the Broads Authority's organisation have been described in section 5.2. They are summarised as informal interviewing, observation and document reviewing. It is recognised that each of these techniques has its limitations. Informal interviewing allows access to the normal working practices within the organisation. However this technique may lead to some of the less usual practices being omitted and in some ways may give a distorted view since some people with differing tasks may not be interviewed. General observation suffers not only from these problems but also from the observer only being allowed to see selected aspects of the organisation that is under scrutiny. In this light it is advantageous for the third method of document review to be used. Here all the full mechanisms by which the organisation is intended to be run may be formally reviewed by the analyst. It must, however, be recognised that the formal system may not be used by the employees in its specified manner at all times.

The use of each of these techniques is justified as they individually provide information and insights into the system and together provide a comprehensive view of the organisation. It is recognised that there is some overlap between each of the data collection techniques but this is considered advantageous rather than redundant. The overlap allows for cross-checking of information from different sources and therefore enables a more complete study to be carried out. It is noted that these forms of data collection individually will not be able to cover completely the whole organisation. The use of the three methods together however may facilitate the collection of data on most of the organisation's functions.

Throughout the analysis of the Broads Authority all observations were documented. Much of the initial data collection was completed and recorded in notebooks for further study during this research. Once the initial data collection had been made, it was documented and stored within a hypertext system (see sections 5.4 and 5.5). The main organisational parts of the system were described pictorially and extra annotation provided for each individual section of these diagrams.

This form of diagram documentation can be criticised as it is a summary of the information within the documentation stage. This may result in the loss of some of the detail. It is possible within the documentation stage that oversimplification of the data may occur, although the prudent use of annotation fields may have prevented much of this loss. This simplification may cause major problems during the specification and design stages of the system's development. To prevent further data loss, the use of the linkage mechanism was extended to link between the diagraming and specification layers within the system developed to contain this information. This method, as well as providing a mechanism for documentation and information trapping, also provided a data hiding mechanism by allowing pop-up text fields and inter-diagram and level linking.

During this first stage several questions had to be answered. These ranged from the type of graphics to be used in the display of the diagrams, the method of including text within the system, the methods of linking from item to item in the document system, and finally how to handle the growing size of the document stacks.

With regard to the diagram graphics, two options were considered in the first instance. These were either to use button icon objects or to use HyperCard's graphics. The simplest solution would have been to use button objects, it was found however that it is not possible to display icons at the correct screen scale to be useful for this inquiry. The second solution to the use graphics to display these diagrams was devised. It became apparent that the amount of time it took to draw these diagrams using these graphics was unreasonable. To solve this problem a range of palettes were created. The idea of these palettes was to hold all the components of data and system diagrams in both button icon objects and graphics format, so that the user has the choice. The use of these palettes is facilitated by copying and pasting the graphics required onto the work space. By doing this, diagraming was made more efficient.

The chosen method for showing text was that of the HyperCard text field. The advantages of this are that these fields can be displayed and removed from the screen at the request of the user. There was, however, one problem that was encountered. This is that these text fields can only hold a maximum of 32K of information. The solution employed for this problem was that of duplicate fields. The user requests more writing space and the system creates another text field related to the first. Although this is not an optimal solution to the problem it is an efficient temporary solution.

The mechanism of linking individual items together within these documents allows extra functionality and information to be built into the system. The appropriate mechanisms to complete this linking process are always available within hypertext systems. At this point it seemed efficient to develop a mechanism that allows the user to avoid having to use the hypertext systems that are hidden in every button. This was done by use of a specially created link facility, which creates a link anchor and prompts the user to set its destination by going to that destination.

Finally there appeared to be a problem that these documents are to be storage inefficient. It is recognised that part of this problem is caused by using bit-mapped images, which are storage intensive. This problem was kept to a minimum. By the inclusion of a compacting routine in each document which compresses each document as it is stored.

## 5.7 Conclusions

In this chapter hypertext has been used for the analysis and specification of the Norfolk and Suffolk Broads Authority case study. We have observed that hypertext has fulfilled the following assertions made concerning its contribution in this area. Throughout the data collection phase of this study hypertext was used as the vital information storage mechanism. This storage mechanism was used for data diagrams. As well as data diagraming the system also includes comment text and system diagrams within it. By using this system it was felt that the consistency of document input and storage aided the consistency of the data collection process. So the consistency and the completeness of the information collected was better established. The visual nature of the hypertext system, as well as the information storage structure, added to a greater understanding of the problem, and therefore a clearer, technically valid specification.

However, the following difficulties were also encountered whilst attempting to make the documentation system as simple to use as possible. These problems concern graphics, the size of documentation documents, text input fields and item to item hypertext linking.

Whilst engaged in using hypertext in this case study the following innovative methods were employed. To facilitate inter-documentation linking a special linking facility has been created. In an attempt to save time in the particularly laborious task of creating the diagraming graphics, graphically based palettes containing documentation diagram components were constructed. Each individual component can be copied and pasted into the document diagram. To avoid a large increase in document size, an automatic compacting routine was encoded into all projects. This means that as any document is closed the hypertext system automatically compacts the document to its smallest dimensions. It is unfortunate that this hypertext environment, HyperCard, is only able to hold a maximum of 32 K in a text field. The documentation system avoids this problem by the user requesting further writing space and another field being attached to the same pop-up button. Finally, to make the user's job of using this system as simple as possible, the system has been programmed to open the HyperCard development toolbox automatically so that the user can select tools at will without any extra learning burden.

This chapter has described the analysis and specification stages of the development of the Norfolk and Suffolk Broads Authority Geographic Information System. Chapter 6 describes the design and implementation of this system.

# Chapter 6 The Development of The Broads Authority Prototype

## 6.1 Introduction

This chapter describes the design and development of a prototype information system for the Broads Authority. It attempts to look into the use of the development media hypertext and through this experiment gauge its effectiveness as a prototyping mechanism. It is intended that the design and implementation of the prototype will be completely documented and analysed for comment in this chapter and chapter 7.

## 6.2 Software Used for the Implementation

During this stage of rapid prototyping the appropriate software tools had to be selected. The choice of software was initially constrained to those implemented on the Macintosh hardware platform. This choice was made as more software products in this field have been developed for the Macintosh and it is generally considered that this is a superior development platform in this field. A short-list of 4 packages was drawn up, these being SuperCard, HyperCard, Intermedia and Plus. HyperCard was selected for the purposes of these experiments. There were several reasons for this choice. Firstly Intermedia is unable to support a programming language, a critical criterion for these experiments. From the remaining choice, HyperCard was chosen because of the greater availability of documentation, both proprietorial and third party, and the availability of reusable code in terms of stackware (proprietorial and third party systems). HyperCard was also considered the most robust package and the best common denominator since both SuperCard and Plus are able to convert HyperCard Stacks to their own format.

The software for use within this project is HyperCard 2.0 which is a recently released version of this object based hypertext system. It is the most well established hypermedia system so far developed. It offers hypermedia linking, large screen format, colour and a static frame metaphor for the node interface. Several descriptions of this software can be found in the relevant literature (Williams 1987, Gardner and Paul 1991) but it is sufficient to say that HyperCard is a frame-based hypertext system. A brief description is given below.

HyperCard is made up of stacks which contain cards, and these contain fields and buttons. In conventional computing terms stacks can be broadly likened to files; cards and backgrounds to records; and fields and buttons to objects within each record. All the items listed above are objects and it is possible to place programmed codes behind each of these to perform a series of functions. These functions are supported by messages passing through the whole system from buttons and fields, to cards, to stacks and backgrounds and finally to the home stack (see Diagram 6.1 below). The Home Stack is a very important part of the HyperCard system. It administers all the "housekeeping" for the system and acts as a final message handler. It is to the Home Stack that messages that fail to activate a message handler are passed to the HyperCard Program system for error handling. The Home Stack also deals with the storage of path names and other administration. The Home Stack is often used as the top class of the inheritance structure. It is here that much of the system code is stored for this system development.

HyperCard has an English-like programming language called HyperTalk. It is with this language that all the objects of HyperCard are programmed and through this that much of the functionality of HyperCard is achieved. HyperTalk is a very basic programming language. It has 46 commands, 6 control structures, 58 properties, 11 constants, 49 functions and 21 operators. The language is extensible by the addition of external

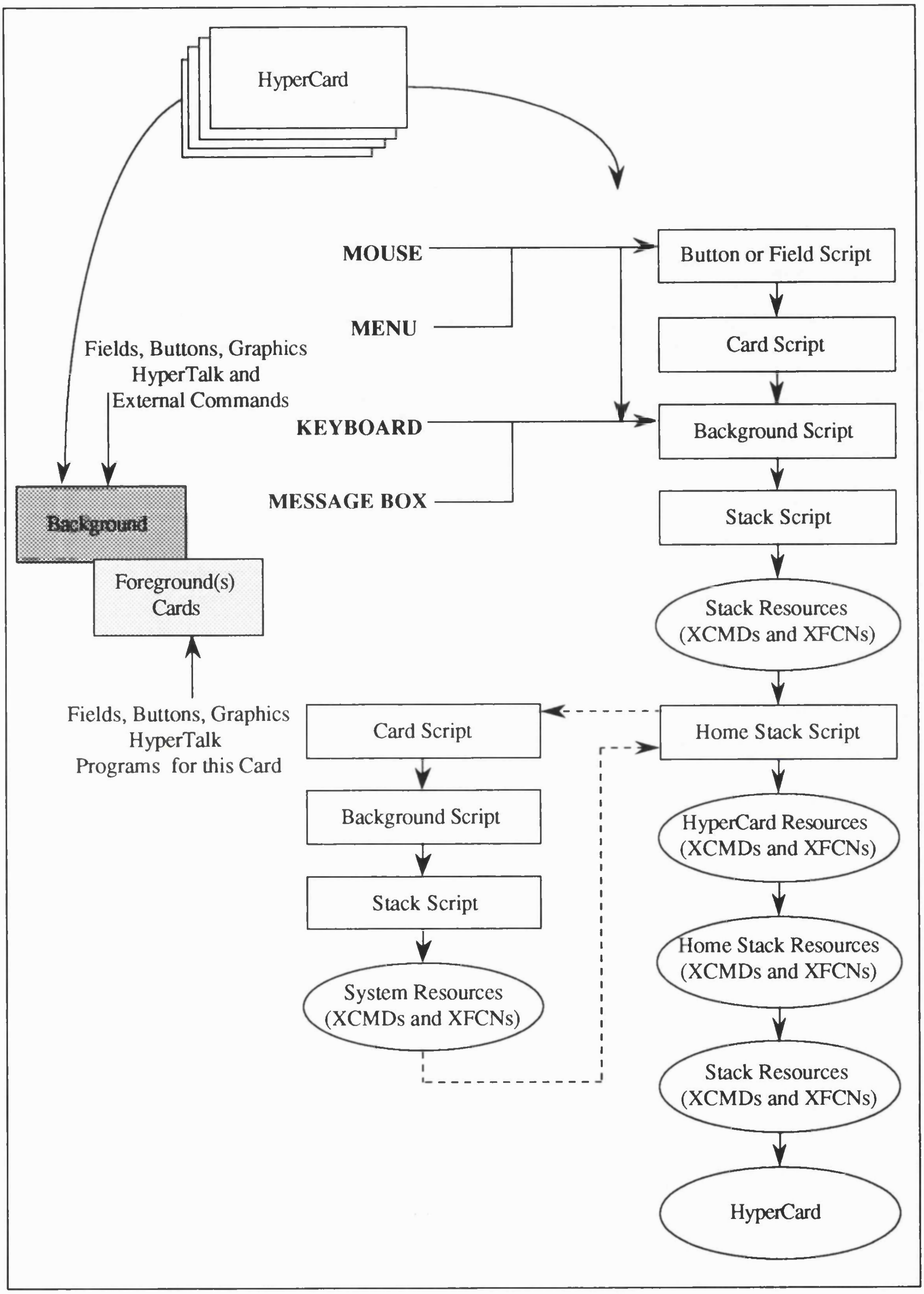



**Diagram 6.1 The Structure of HyperCard (Poole 1988)**

commands or functions (XCMDS and XFNS) that can be written in either Pascal or C. These external software items can perform the extra functions that the initial functionality lacks. This extensibility of language has become a regular feature of hypertext development environments. This is all summarised in Diagram 6.1 above, which shows all the detailed levels, hierarchies and inheritance structures within the application.

The limitations of HyperCard are again well documented and a full discussion of these shortcomings can be found in Conklin (1987) and Gardner and Paul (1991). HyperCard is not a full hypertext implementation. Although HyperCard has nodes and links and has a standard hierarchy of objects ranging from the Home Stack to buttons and fields, it does not have a general mechanism for hierarchically structuring cards. Stacks cannot be nested, which in effect makes the hierarchy only one layer deep. There is no standard text formatting in the sense that link anchors from text to other node points are not an inherent design feature. There is also no graphical browser for showing the local or global arrangements of cards within the webs. This means that the user is unable to gain a general picture of the system or to use the advantages that these facilities would offer. The lack of these features prevents HyperCard from having the status of a true hypertext, but from a prototype development point of view it does not detract greatly from the functionality of the system.

## 6.3 Design Specification for the Prototype

The specifications discussed in chapter 5 were incorporated into the design of the prototype system. The specifications were translated into drawings and commands that were implementable with the prototyping software used. At present there do not appear to be any robust methods for designing information systems within hypertext systems. The design guidelines of Riley (1990) and Shaffer (1987) were used. Riley (1990) details guidelines for user system interface design and Shaffer (1987) details guidelines for stack development. From these sources of information a design method was devised.

To this end the user system interface is discussed in section 6.3.1 and the overall structure of the system is discussed in section 6.3.2. The implementation of the prototype is described in section 6.4. It is worth reiterating that the description of the subject matter for use with a hypertext system does not easily lend itself to the sequential written word. Proper understanding is gained by viewing the system itself.

### 6.3.1 User Interface

The design of the user interface was carried out using the guidelines of Riley (1990). The interface was designed to provide functionality with the lowest possible learning overhead to the user. The mechanisms by which the user may interact with the system reflect this factor. The use of a command line interface was disregarded in favour of a command palette, pop-up menus and buttons. The mechanism of a palette of commands was designed (see diagram 6.2). Such palettes are becoming a standard in user system interface design. It is defined in terms of a tear-off menu which may be placed anywhere on the screen. The commands on this palette are those which are used often. These are depicted as icons and words. This palette is always available. The use of such a palette is beneficial to the design in terms of reduced code duplication. The functions defined for the palette are: move to the previous hierarchical section; move to the previous screen; move to the next screen; open the mapping section; open a help facility; move to the top of the hierarchy; search the database and finally quit the system. This palette will be refered to as the navigation palette throughout the rest of this thesis.

Pop-up menus are employed in certain instances where the user must make a choice from several options. This allows the user to make choices simply avoiding screen clutter. Buttons are appropriately placed throughout the system were additional (one-off) features and functions are necessary.

Riley (1990) outlines basic guidelines for the layout of screens, (e.g., for the placement of text, dialogue boxes and graphics). This design was carried out in the following manner. The screen layouts were planned according to these rules. The actual depiction of the screen layout is shown in diagram 6.2. The pictorial view of the screen layout shows that the interface is divided into three sections diagonally with command characters placed in the bottom right hand and top left hand corners. The command features are permanent throughout the system and may be accessed at any time.

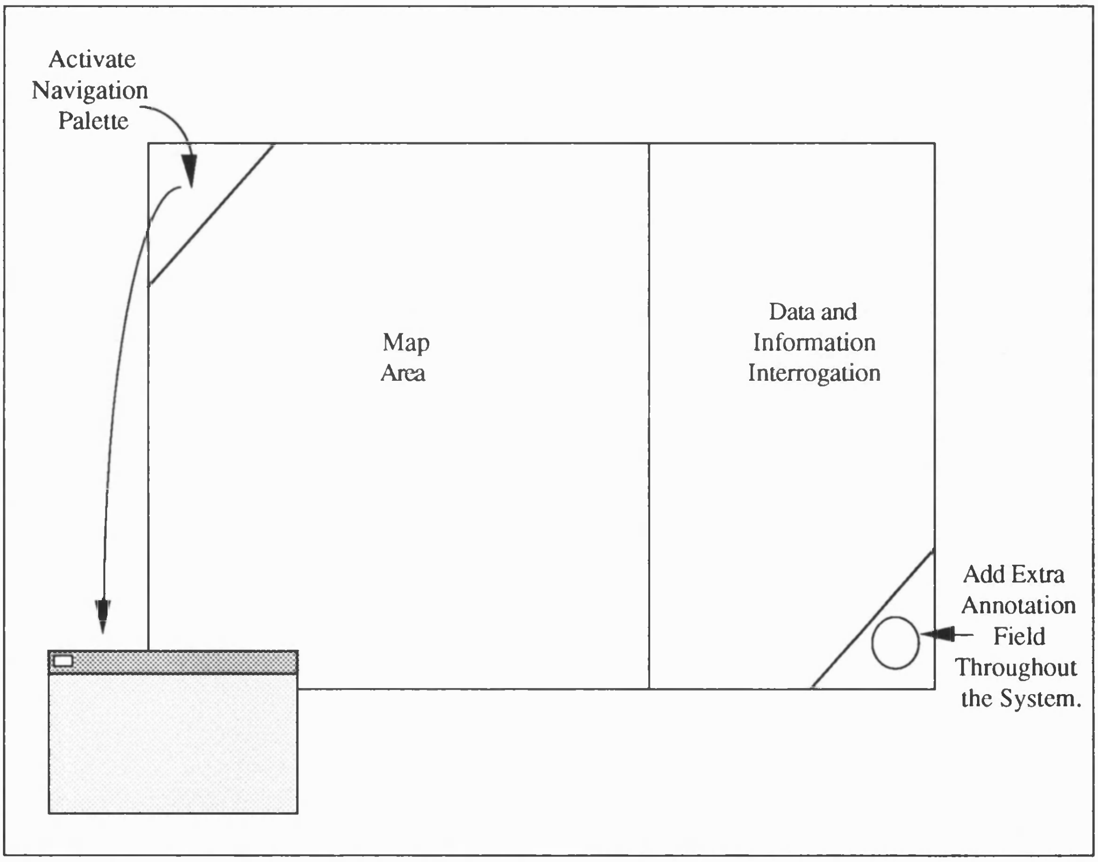



**Diagram 6.2 The Basic Design of the User System Interface**

The first decision within this stage of design was the choice of screen size. The size of the monitor on the machine used to develop the system was chosen to be the most functionally suitable for the end use of the system. The size of an Apple Macintosh II standard colour monitor is 440 by 640 pixels (this does not, however, entirely preclude the use of smaller monitors for running the system, as the rest of the node may be viewed by using view/selection panels). The use of this standard sized monitor also provides a good basis for portability of the final product to other systems (see diagram 6.3 below).

Secondly, HyperCard is able to support windowing, and because of the greater functionality that is afforded, windows were implemented. It was decided to use a range of window sizes, each compatible with the function of that part of the system. It was decided that the maximum size of these windows should match the size of the Apple Macintosh Computer Screen, that is 640 by 400 pixels. With the exception of the navigation palette, a minimum window size of 512 by 342 pixels was also set (the size of an Apple Macintosh Plus Screen). For this prototype system it was felt that functionality would be greatly reduced below the size of an Apple Macintosh Plus Screen.

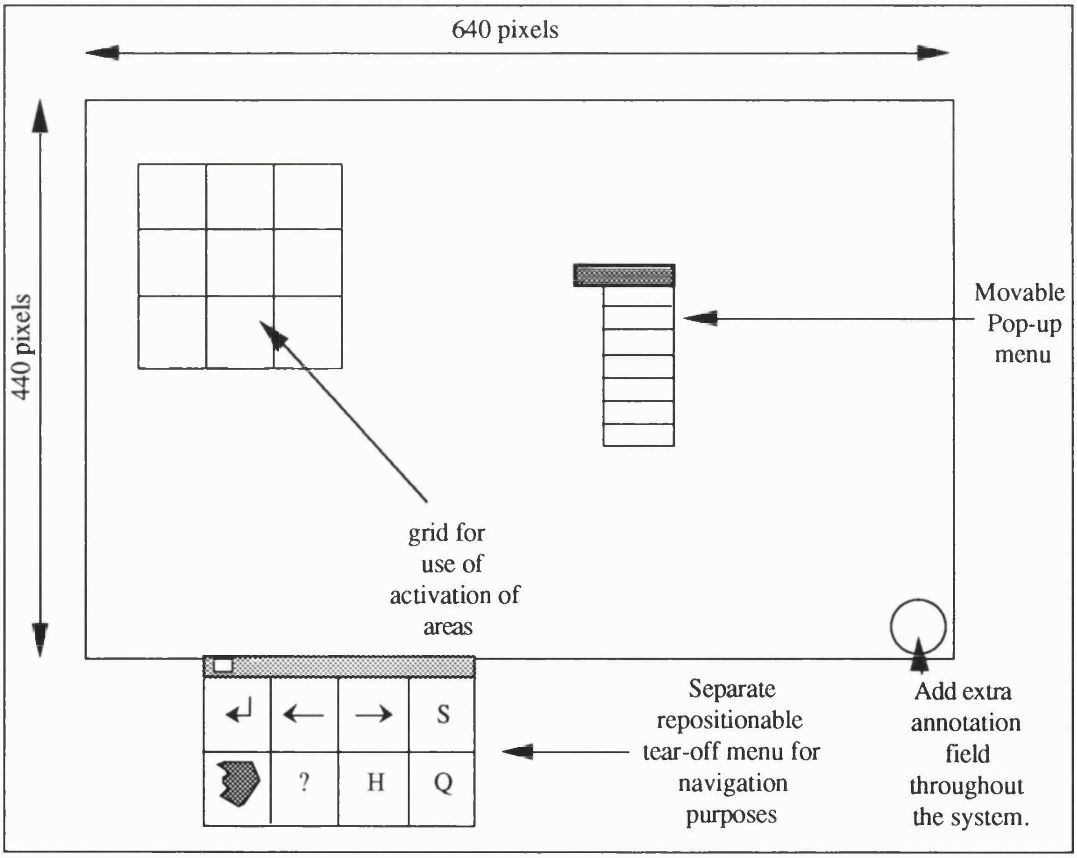



**Diagram 6.3 The Planned Navigation Tools**

Finally, the use of a special type of link known at this stage as the annotation link is available for use. This gives the Broads Authority the ability to attach extra information fields throughout the system to give additional detail about areas of the Broads and special regulations that refer to that feature. The ability to create personal annotation facility is also planned. These features are constant throughout the system (see Diagram 6.3 above).

### 6.3.2 Overall Structure

The process of structural design is broken down firstly into functional requirements and then by technical components.

The observed everyday functions of each department identified in the data diagrams have been included in the design of the Broads Authority Information System. The common components of these departmental needs were extracted and used as the principal design template. It is recognised that this template is not sufficient for the needs of each department of the Broads Authority. Additional features for individual departments were also prepared. The designs of these departmental systems are described in the following paragraphs and in diagram 6.4.

Functional support for common facilities for word processing, database access, spread sheets and graphics were designed so that the system is extensible and able to access directly commercial software packages. These facilities are available throughout the system.

The final facilities which are common to most departments are the reliance on interrogation of maps of the Broads Authority's Executive Area and the adjacent areas of the surrounding boundaries. There are several design points that must be noted. Firstly, the use of maps is both for visual and data interrogation. The system must be able to show the maps clearly and at the correct scale. The user must be able to click on the screen map at any point and go to the next more detailed map. The resolution of the maps was designed to ensure access to the highly detailed maps. The user must also be able to interrogate the database that is attached to these maps in a logical manner and accordingly the location of the maps must be referenced in the database. Thus the user interrogating a map will also be able to access, intelligently, any data related to any location or area of the Broads.

In common with many conventional paper maps and GIS it is not possible to store a complete seamless map within this prototype. The mapping section therefore controls maps by using a tiling mechanism. The map is segmented and displayed as individual pieces of a mosaic. Navigation around this section of the system is controlled by command keys and buttons. From these, the real location can be derived and the correct map displayed.

It was recognised that problems would occur at the boundaries of map tiles. It is possible that locations that physically appear at the edge of map sheets could be difficult to access. This problem is well recognised from the experiences of the maps of the Doomsday System. The coarseness of interaction and a lack of overlapping of the map sheets can cause the locations on the edges of maps to be difficult to interrogate in a useful manner. This prototype includes an element of duplication for 10 mm (an area up to 0.5 km in width, depending on the map scale) around the edge of each map sheet. This means that each map at the same level will store 10 mm of the surrounding edge of the map sheets on all sides of it. The incorporation of map overlapping inevitably involves a degree of redundancy. To maintain the functionality of the system, however, it is necessary to incorporate this into the design. The choice of 10 mm gives the user the ability to see clearly where locations are.

HyperCard is a raster based software package, therefore all maps included within this system must be scanned raster images. Spatial data in vector format (e.g. Ordnance

Survey digital outlines) may be appropriate at a later stage of development, but for this prototype all spatial referenced data is displayed solely in raster format.

Individual departments all have functional requirements which are different, for example, the Administration Department is the only department which needs access to accounting software. Therefore, where necessary, additional functions are included for each department.

The technical requirements were planned to take maximum advantage of HyperCard's Object features (see section 6.2 above). A modular design was adopted which takes advantage of these message handling capabilities. Since messages may be "passed" through the object hierarchy it is logical to attach all common features handling code to the Home Stack, which occupies the highest class position. The number of backgrounds was also minimised in order to limit the number of classes within the prototype.

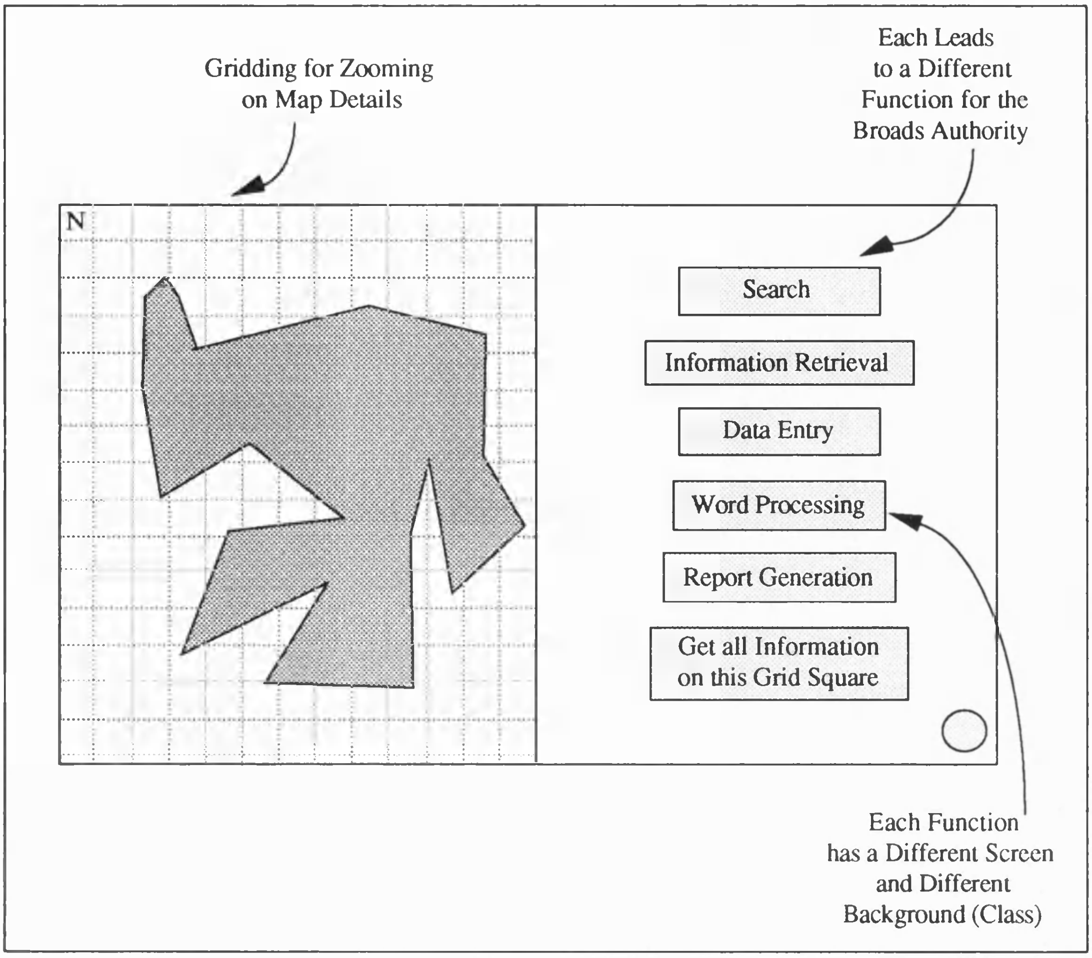



**Diagram 6.4 The Basic Needs of the User System Interface**

Within the hypertext system the hypertext file handling structure requires no outside handling. Where specific file handling functions of the system are designed to import and export data and to write command or data files for the system, these file handling capabilities have been included. File handling with regard to other commercial applications software allows the user to open a specified document by name from within the system or by indirect access once the program has been activated. This design, therefore, takes full advantage of the features of hypertext systems considered in chapter 2 above.

## 6.4 The Prototype

To explore the effectiveness of this hypertext system for the ideas of rapid prototyping, a partial prototype Information System for the Broads Authority was developed. The implementation was carried out in the following manner. Firstly the basic web structure was developed. This involved the construction of stacks, cards and the navigation (movement) system. Secondly all common functions were encoded into the Home Stack and departments. Finally all specialist functions were encoded. These functions and facilities are discussed further in the following sections.

### 6.4.1 Aspects of System Design

The prototype system has been created as close to the initial design as possible. There have however been some small modifications made to accommodate the removal of errors and to aid the efficiency of the system. These changes include the modularisation of the map section into a stand alone section which is accessible by all departments. This change was made to reduce redundancy within the system. Secondly the use of a pull-down menu is implemented constantly throughout the system. This menu enables annotation, the access to the navigation palette and find facilities which were originally located as buttons on cards. By placing these in a pull-down menu, this aids the efficiently of the system, the consistency of the interface and reduces redundancy. For ease of construction and maintenance a modular development approach has been employed. For this reason all departments and major features are individual modules, or in this instance, stacks. The system is described in terms of its user system interface, navigation or interaction and functionality.

The user system interface was implemented in a manner functionally similar to the planned interface. There were two variations to this interface. These were that constant buttons such as annotation, palette access and find facilities were moved to a pull-down menu. Secondly, departments were given different background patterns so that the parts of the system could be recognised.

The system navigation has been implemented in 3 complementing ways. These are the navigation palette, buttons and windows. The navigation palette provides basic interaction facilities. It allows the user to proceed to the next or previous sequential screens. It also allows the user to step up through the hierarchy of the system to the previous system section. The palette also allows access to the mapping and database sections of the systems. It also provides fast access to the introductory screen of the Broads Information System. Finally the palette provides a mechanism to quit the system completely. During this stage it was recognised that the specification and execution of this palette design had to be clear to avoid poor user interaction with the system.

The second navigation technique is that of buttons. The function of buttons is to carry out actions which are only needed in either one section or one card. These are therefore included as and when necessary throughout the system.

Finally since the system is based on a windowing environment, this further aids the user. Sections are opened in individual windows. Therefore, if the user wishes to go back to a previous section, s/he simply clicks on the required window.

### 6.4.2 Features of the System

The functionality of the system is divided into departmental functions, maps, a database, and annotation.

It must be noted that access to each department is completed by correctly entering the password for that department. Functions which are common to all departments have been included in two ways. Access to the mapping and database sections of the system have been included under the navigation palette mechanism. As described above this mechanism allows the user to select an item from the palette that is to be opened. Further features such as access to word processing, spreadsheets and graphics packages may be gained by use of the Broads Authority pull-down menu. This menu accesses all software packages without the user having to have knowledge about the underlying operating system. On the selection of a package, the system prompts the user for the name of the file or whether it is a new file, either of which is subsequently opened.

The map module of this system has the functionality of allowing the access and display of data at three levels. The navigation mechanism for this section, its advantages and disadvantages are discussed in sections 6.4.3 and 6.4.4.

The database system used for this experiment is Oracle for the Macintosh (Oracle Corporation). The database is accessed through a proprietorial HyperCard front-end, which has been modified to integrate into this information system. Oracle is a relational database and operates by using a query language called SQL (Structured Query Language). The HyperCard front-end uses a modified version called HyperSQL. Therefore the interrogation of the database within this information system is controlled by the HyperSQL language. The database created for this information system can, therefore, be tailored to suit the Broads Authority. Data stored within the database can be exported so that the map module or other software packages may display the coordinate data.

As mentioned in section 6.3, the system is further enhanced by giving the user the ability to annotate the system with text. This provision is enabled by the user selecting public annotation from the Broads Authority Menu. This function provides a pop-up text field which may be dragged to any point on the screen. The existence of the text field is marked by a special button. This button opens and closes the pop-up text field. Such text fields can be viewed by anybody and are called public annotations.

The system also includes a feature for individual annotations, when an individual selects this option, the system provides a password protected small note pad for the user to write comments on. These note pads provide the ability to use text and graphics. Links can be made between these comments and the particular sections of the system that they refer to.

Within each of the departmental sections there are points where information can be included and linked with other pieces of information to gain a complete image of the features of a particular problem. These features are made available within the individual sectors of the departments. Although there is the need for confidentiality, it is also recognised that there is also the need for cross-departmental cooperation. This cooperation can be enhanced by the making of links within these departments' texts on certain issues. For example, where there is a planning application that involves an SSSI, it may be useful to cross-reference the data held by the other departments to provide insight into the true nature of the problem.

This section has discussed systems features in broad detail. The next section looks in more detail at the geographic features of this information system.

### 6.4.3 Mapping and GIS Functionality

The development of geographically-based information interrogation tools was constrained in two main areas. These were, firstly, by the types of tools which are considered appropriate for the Broads Authority and secondly, by some technical problems which are discussed later in section 6.4.4. Each of these constraints has limited the number of features that the developed system contains.

The map module of the system is based on the Ordnance Survey maps of the Broads Authority's Executive Area. There are three levels of maps stored within the system. These are accessed by use of the mouse: if the command-key is held down the user may access a more detailed map; if the option-key is held down, then the user can access a less detailed map; if a mouse click is used by itself, then the user can explore surrounding map sheets at the same level. This is done by clicking on the side of the map that the user wishes to explore next. (Note: the command and option keys are specialised keyboard keys found on all Apple Macintosh Computers).

The medium for map display used in this system was bit-mapped images. There are many advantages and disadvantages of using these, and these are discussed below in section 6.4.4. Map images are displayed on the background of each card. These images were scanned from Ordnance Survey maps using a package called HyperScan (Apple Computers Inc). Data to be shown on these cards is then displayed in the foreground.

Geo-referencing for the area of Norfolk and Suffolk is based on grid referencing and postcodes which have been assigned grid references. This referencing system operates by taking the the grid coordinates and generating a small dot that appears on the screen map at the point at which the information relates to the map. During the interrogation of these points the coordinates can be mapped onto the relevant scale map to show the distribution of the data. Further functionality is encoded into this system giving it the functionality of being able to display the prepared polygons and line data. This data is displayed in a similar manner to the way in which point data is displayed on the screen. Geo-referencing is the key to this GIS's functionality and aids the maximum utility of the system to be gained.

The GIS functions of this information system enable the user to produce new maps from the originals by overlaying an existing map with a data or map plane. These maps and planes may be held as polygon or raster units. The system devised for the Broads Authority holds all information in graphical representation in raster format. The overlays in this instance may be prepared as a painting operation on the computer screen.

The system also handles the calculation of lengths, which is carried out by a conversion from screen point to point. If the road bends, then the length of the road must be measured in sections to take account of this. The calculation of road lengths within this system is carried out in this way because of the functionality of the software environment used to create this Information System. It is not possible to create and measure vectors within this software, as all images are handled in raster format. A grid-to-grid measurement can be created. The limitations of this are discussed in section 6.4.4.

### 6.4.4 System Limitations

This system is a prototype and in no way is it intended to be a fully constructed system. As with the development of any prototype system it has its limitations. There have been several changes to the specification where mistakes have been rectified. These limitations fall into several categories: screen and image problems and the resolution of the software screen.

During the development of the map module there were several problems, mainly connected with the inclusion of graphics into the system. The intended method of graphics inclusion was to be high quality colour graphics, in Macintosh terminology "PICT2" files. HyperCard only supports colour graphics through external-commands which have been written to complete this task. These graphics can be displayed into HyperCard, but it is not possible to superimpose HyperCard paint layers on top of these images. Therefore it was impossible to use this method of graphics display. A substitute was found. These were bit-mapped images. The quality of the images is poor and makes the use of the system harder. But by using these maps the functionality of the system can be fulfilled more fully than by using "PICT2" images.

The development of this prototype encountered several problems connected with the screen resolution controlled by HyperCard. Many products support a high screen resolution but HyperCard limits the screen resolution to 72 pixels per inch, which therefore make image handling difficult and calculations based on screen coordinates inaccurate.

Further limitations of the system lie in the problem of the software used for the design of this prototype. This relates to the images handled and the calculations in maps and on the analysis side of the system that are carried out in a raster format. All the map images within the system calculate their grid coordinates and other functions from the resolution of the pixel level of the data stored. Where calculations and analysis are solely dependent on the pixel level of the data the accuracy of the analysis is governed by the coarseness of the data available. There is an enforced low level of data display accuracy as coordinates must be displayed to the nearest pixel. Thus the calculations of buffering and corridoring, as well as area and length are likely to incur minor measurement errors which may be higher than normally tolerated in such circumstances.

## 6.5 Methodological Implications

From the point of view of the design and implementation of system prototypes using these environments, there have been several lesson learnt. These point to ways in which these systems must be enhanced in order to be able to handle these implementation problems well. These systems must be able to handle high resolution graphics, and they must also support high level screen resolution. The range of objects available in hypertext should also include graphics to enhance the functionality of these systems.

Numerous criticisms of the methods used in information systems development prototyping have been made. These have made it difficult to condone this approach to systems design. It is possible that with the ideas developed in chapter 5 and this chapter using hypertext there may be a radical improvement in the time savings for the design and implementation of software systems. With the ideas of hypertext and development environments there are large time savings to be made within the development life-cycle process. There are also the added advantages of the extra capabilities that these types of systems are able to contribute to the notation and information enrichment of the data available to the information system user. With the introduction of hypertext there is also the incentive to encourage the user to express his/her wishes about the system and for the user to gain the maximum benefit from the new system.

Compared to the traditional software development life cycle, it is possible to see that there are likely to be great advantages from these methods. The use of these processes can assist in the creation of better documentation of the systems developed. This was done in three stages. As described in Chapter 5 the stages of system development, data flow diagraming and specification can be created and stored within a hypertext web in the system. This allows all users accessing the system to have a complete working and constantly updateable model of the system that is being designed. This is useful where the system is being designed by many people who may at different times all need access to different aspects. Having an on-line system available for all the designers to see will allow the consistency of design and annotation structures within the designed system to be more rigourously enforced. Secondly, with a complete understanding of the data and information flows of the system there is a much greater insight into system documentation, and thus the ability to produce good rigourously designed system documentation before and during the implementation is greatly enhanced. From this it is possible to see that these systems may provide the basis for self documentation.

## 6.6 Conclusions

This chapter has described how hypertext has been used for the design and implementation of a partial Broads Authority prototype information system. We have observed that hypertext has fulfilled the following assertions made concerning its contribution in this area. The creation of a multi-layered hypertext document storage facility to aid the storage of information connected with this project, from data flow diagrams to system implementation documentation. Secondly, the design of the information system and the storage of its pre-implementational documentation. Thirdly, the implementation of the prototype information system has been carried out using hypertext as its implementation medium.

Despite these problems using HyperCard in this manner, throughout the development of this prototype it was necessary to repeatedly refocus the development towards the issue that this experiment was only to produce a prototype. The versatility of hypertext systems may allow the developer the luxury of creating a fully operational information system within this environment. It is important to state that the implemented prototype is an example of what might be considered as a Fully Integrated Environment for Layered Development (FIELD) approach to Information Systems Development. The analysis to implementation stages are combined within the one environment, and explicitly linked in that the various layers, analysis, specification, design and implementation are logically connected. Not only does this assist in understanding what, how and why the system functions but it means that subsequent adaptation is no longer sub-divided in an unnatural way to the previous steps. The full power of the FIELD concept is amply demonstrated in the case study prototype.

The following problems were, however, encountered. The resolution of raster map image storage was considered to be inappropriate for the detail of visual interrogation and analysis at which the system was designed to operate. Secondly, the nature of HyperCard's display was considered to be critical in the limitation of the number of functions which could be included in this section of the system. The final problem that was encountered was that of the screen resolution. Since all coordinates are displayed in screen coordinates which have been converted from Ordnance Survey, the resolution of the screen becomes vital. In some of the larger scale maps the accuracy of the map analysis is much lower than is acceptable.

Whilst engaged in using hypertext in this prototype development, the following innovative methods were employed. In the case of the quality of the maps it was considered prudent to employ the use of bit-mapped images instead of high resolution graphics in the background of cards and allow a transparent card to act as a layer on top of it. On this layer all the raster graphics and analysis can be completed. It is unfortunate that the nature of the display of HyperCard is limited by the resolution of the screen. It was possible to limit the inaccuracy of these systems where possible by displaying data at the correct scale in terms of maps and data.

This chapter has described the design and implementation of the Norfolk and Suffolk Broads Authority information system prototype. It illustrates the versatility of hypertext within this field and shows its potential for future developments in software engineering. The implications that these new tools will have for the development of future software will be discussed in Chapter 7.

# Chapter 7 Summary and Conclusions

## 7.1 Summary

This chapter summarises the results and findings of this thesis. It draws out the major conclusions and discusses their relevance to information systems development. Finally it looks to the future and discusses possible trends within the fields of software development and hypertext.

As outlined in Chapter 1 this thesis has aimed to explore and experiment with information system development prototyping through the medium of hypertext. It has used the Norfolk and Suffolk Broads Authority and the development of Geographic Information Systems to suit their needs as a case study. In this context Chapter 1 provided an introductory overview to this thesis area. Chapter 2 provided a detailed overview of hypertext and hypermedia. Chapter 3 provided a detailed description of Geographic Information Systems both in terms of their technical details and potential applications. Chapter 4 described the Norfolk and Suffolk Broads Authority, its history and functions. Chapter 5 described the systems analysis and documentation of the Norfolk and Suffolk Broads Authority Information System. Chapter 6 described the design and implementation of the prototype Norfolk and Suffolk Broads Authority Information System and discussed the methodological implications of these experiments for information system development.

## 7.2 Conclusions

This thesis has discussed hypertext, Geographic Information Systems and information system development. It has examined information systems development. It has also examined mechanisms which offer substantial improvements to these techniques, especially prototyping. It has addressed a case study, the Norfolk and Suffolk Broads

Authority and with respect to the geographical nature of this case study the area of Geographic Information Systems is also addressed.

The main contributions to research in information system development are as follows. Hypertext can be successfully employed in the field of information systems prototyping. Moreover, hypertext can be usefully employed throughout the whole information systems development process. As well as a software development tool, extra benefits can be obtained from its use, by using hypertext as the development environment it may also be further possible to extend the use of hypertext to include the final fully operation information system. These benefits are namely in the fields of system analysis, documentation and data diagraming.

The mechanisms that have been outlined throughout this thesis allows the process of systems dynamics to be seen more clearly, so leading to a greater understanding of the system observed. This facilitates the inclusion of further organisational information flows more effectively by using the web techniques. Greater understanding of the systems dynamics and organisation as a whole may be gathered and thus a closer fit to the final needs of the organisation may be created.

Such techniques provide the developer with the ability to build a prototype. Moreover the developer is able to build a model of what s/he thinks represent the dynamic systems of the organisation. The developer may continue to experiment with the model created by the prototype until s/he is satisfied that the model represents closely the system observed. Such facilities may allow the creation of an information system which is closer to the users' requirements, and through these will allow the developer to alter the final system more effectively by using the model of the system.

Through the development stages of these models an information system prototype may be useful to improve the efficiency by providing management information regarding the structure of the organisation, the flows of information and control. Such information may be invaluable when reorganisation is proposed.

This research demonstrates that systems analysis and documentation can be efficiently enhanced by using hypertext technology. This aids the understanding and the consistent documentation of an existing information system or process. These systems store the documentation in one place and in a consistent format. Since the whole system may be documented using this technology, this facilitates annotation and allows information linkages to be performed. This enables extra contextual information to be included within the system. Hypertext systems enable the complete diagraming of a potential information system. Hence it is possible to include more hidden information in each diagram. For example it is possible to store each process in a diagram and to store a detailed description of the actual features that are proposed for the process.

The use of a documenting system during the development of this prototype has demonstrated the creation of linkages and therefore relationships to the original systems analysis and specification. In general when using such capabilities, more of the systems analyst's original reasoning for data and systems design can be traced back to the system that was originally observed. This is useful in two ways. Firstly, it improves the overall design of information systems since all the diagrams are present within the system. Thus the analyst can refer easily to the correct part of the diagram and, as a result of this continuity, fewer errors will appear in the final system. Secondly, because of the nature of the environment, these systems free up analysts time once the system goes to the coding stage. For example, this may occur when a programmer discovers a problem. The system may be used as a first stage problem solver thus allowing the analyst to be called upon only at a secondary stage. Considerable time savings may occur both in terms of the project and of the individual analysts' time.

For documentation support, hypertext is a valuable tool for the software developers tool-box. Its benefits do not however stop there. Hypertext environments such as HyperCard have their place in the development of prototypes. The prototypes developed for this thesis were those connected with software documentation systems and the development of a prototype information system for the Norfolk and Suffolk Broads Authority. Chapters 5 and 6 have described in detail the systems analysis, design and implementation of this system. In terms of its proficiency of development the critical development time was remarkably small, approximately 2 months. The inclusion of a proprietorial database allied with the more fluid data handling of hypertext is beneficial. The development of geographic data handling proved to be straight forward. Although the implementation of a GIS is not a mainstream problem in terms of information systems development, it is an extremely difficult and worthy test for such an experiment.

The development of an information system for the Norfolk and Suffolk Broads Authority proved to be a successful experiment in the development of information systems using hypertext technology. That it has to date been impractical to return to the Broads Authority to ascertain their feedback about the system prototype design and its appropriateness to their working practices. It is foreseen that their future participation and comments will be included in further design and implementation iterations of this prototype development and its completion and documentation. The development of this prototype information system reflects the benefits of techniques in information systems development and may be considered as an extension to the software development life-cycle.

The main contribution of this research has been in the development of the Fully Integrated Environment for Layered Development (FIELD) concept. It has been shown in the development of this system that the FIELD concept can be implemented successfully, and that its contributions to enhance development speeds, reliability, understanding and knowledge sharing are extensive. As well as storing and linking the analysis, specification, design and implementation layers in one environment, the FIELD approach to information systems development also encourages the addition of new aids. Inter-layer linking provides the ability to follow changes to the system through to all layers in the environment. Hence, for any particular design attribute, proposed modifications can be investigated by pursuing the attribute linkages.

## 7.3 Future Work

The future of hypertext software development is promising. The future of applications of hypermedia in software development is categorised by the widespread adoption of these techniques in software development and the development and adoption of hypermedia to enrich information systems once developed with its abilities to provide new features.

It is interesting to imagine future research within this area. There are three main strands of research which are brought forward by this thesis. These are: the further testing of the FIELD concept; the assessment of the potential for creating a complete information system within a hypermedia environment, and finally investigation into the appropriateness of the inclusion of hypermedia aspects within a traditionally created information system.

The FIELD concept has been implemented as a prototype. It will be necessary to implement a complete robust version of this development tool to enable further work to be completed. This concept must be further tested to evaluate fully its usefulness as a development aid throughout the sphere of information systems development. It is postulated that in the fullness of time such development tools will provide utility throughout information systems development.

As mentioned in Chapter 6, the potential for information systems development within a hypermedia environment is very clear. The use of hypermedia as an overall operating system which enables the seamless control of multiple media sources must be investigated. In addition to this the potential for information systems development within a hypermedia environment is recognised. It is imperative that further research into this area must be carried out to ascertain the full viability and the additional benefits over traditional approaches that might be offered by such environments. Further to this it would be interesting to see how traditionally developed information system may benefit from the inclusion of hypermedia facilities. It is postulated that from these humble beginnings great benefits may follow.

The benefits from these areas will provide "food for thought" for the software production industry. FIELD is a very positive mechanism to ensure stability of design mechanisms. It is predicted that the world of software development will embrace the technology of hypertext throughout the complete design and implementation of information systems. It is plausible to expect that the stages of information systems development may be considerably enhanced by the constant use of hypermedia. Errors caused by incomplete changes in the design of the information system may be kept to a minimum through use of the FIELD concept, additional benefits may be gained through hypertext environments being used as additional features within information systems or as developments environments.

# Appendix 1 Hypertext Packages

The majority of hypertext system use work-stations or personal computers as their hardware platform. Therefore the description of hypertext packages will be based around these platforms. Work-stations on which most of the early hypertext system were based on work-stations such as Sun, Symbolics and Xerox Lisp machines (see Table A1.1 below). Personal computers such as IBM and Macintosh machines have been the preferred platform for many of the more recent developments within the sphere of hypermedia. Packages for all the above mention hardware platforms and their features are summarised in Table A1.1.

There are some clarifications which must be made to the definitions of each of the columns of Table A1.1. These are:

| | |
|---|---|
| Hierarchy | Specific hierarchical structures supported. |
| Graph-based | System support for non-hierarchical (cross-reference) links. |
| Link Types | Linking ability to have categories. |
| Attributes | Ability to support user-designated attribute/value pairs in association with nodes or links. |
| Paths | Ability to support for many links to be strung together into a persistent object. |
| Versions | Ability to support more that one version for nodes and Links. |
| Procedural attachment | Support for arbitrary executible procedures to be attached to events at nodes and links. |
| String search | Ability to support hypertext searches for strings. |
| Text editor | Type of editor supported for creating and modifying the contents of nodes. |
| Concurrent multi-users | Ability to support several users editing the same hyper-document at the same time. |

| | |
|---|---|
| Pictures or Graphics | Ability to support pictorial or graphical information in addition to text. |
| Graphical browser | Support for a browser which graphically represents the nodes and links in hyper-documents. |
| Platform | The hardware platforms on which these systems are commercially available. |

The data for Table A1.1 below is mainly taken from Conklin (1987), but has been augmented for the purposes of this thesis. This table dose not include some of the more recent systems which purport to be hypertext systems, as these systems are found not to incorporate many of the desired features for hypertext systems.

| | Hierarchy | Graph based | Link Types | Attributes | Paths | Version | Procedural Attach-ment | Keyword or String Search | Text Editor | Concurrent Multi-Users | Pictures or Graphics | Graphical Browser | Platform |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boxer | Yes | Yes | Fixed[1] | No[1] | No | No | Yes | Yes | Emacs | No | Yes | Yes | * |
| CREF | Yes | Yes | Yes | No | No | By link | No | Yes | Zmacs | No | Yes | No | * |
| Emacs INFO | Yes | No | No | No | No | No | No | No | Emacs | No | No | No | * |
| IBIS | Yes | Yes | Yes | No | No | By Link | No | No | Basic Text editor | Yes | No | No | Apple Sun |
| Intermedia | Yes | Yes | Yes | Yes | No[2] | No | No[2] | Yes | Custom | Yes | Yes | Yes | IBM 2250 |
| KMS | Multiple | Yes | Fixed | No | No[1] | Yes | Yes | Yes | wysiwyg | Yes | Yes | No | * |
| Neptune | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Custom | Yes | Yes | Yes | Unix |
| NLS/ Augment | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Small-Talk80 editor | Yes | Yes | Yes | * |
| NoteCards | Multiple | Yes | Yes | Nodes | No | No | Yes | Yes | Interlisp | Yes | Yes | Yes | Xerox Sun |
| Outline Processors | Yes | No | No | No | No | No | No | Yes | Sun View | Yes | Yes | Yes | * |
| Plane-Text | Unix File sys. | Yes | No | No | No | No | No | Unix/ grep | Sun View | Yes | Yes | Yes | * |
| Symbolics Document Examiner | Yes | Yes | No | No | Yes | No | No | Yes | None | No | No | No | * |
| SynView | Yes | No | No | No | No | No | No | No | Line ed/ Unix | No | No | No | * |
| TextNet | Multiple | Yes | Yes | Yes | Yes | No | No | Keywd | Any | No | No | No | IBM |
| Hyperties | No | Yes | No | No | No | No | No | No[2] | Basic Text editor | No | Yes | No | IBM |
| WE | Yes | Yes | No | Fixed | No[2] | No[2] | No[2] | No | Small-talk editor | No[2] | Yes | Yes | * |
| Xandau | No | Yes | Yes | Yes | Yes | Yes | No | No | Any | No | Yes | No | Sun |
| ZOG | Yes | No | No | No | No | No | Yes | Full Text | *. | Yes | No | No | |

**Table A1.1 Hypertext Systems and their Features**

# Appendix 2 Applications of Hypertext

Within the area of hypertext there are several overlapping spheres where hypertext can be and is applied in the modern world. This appendix outlines briefly the types of hypertexts and their applications.

## 2.1 Computer Applications

Hypertext can be used to prototype the user interface for other computer programs because most initial prototyping consists of linking together screen designs and presenting them to the user in an order determined by simple user actions. Extremely simple prototypes can be constructed in any hypertext system by linking together screen designs in an appropriate order. As the prototyping work advances beyond the story-board stage, the need for more application functionality increases, but computational hypertext systems with access to a programming language can be efficiently used in many cases. For example HyperCard has been frequently used for this purpose.

## 2.2 On-line Documentation

On-line documentation may be the most natural of all hypertext application; it was the purpose of the first real world hypertext application, the symbolic Document Examiner.

It is often the case that users do not read computer manuals. When they do it is usually because they have encountered some difficulty. Given this situation they often find that the manual has been borrowed or lost. This situation does not apply with an on-line manual. Since use of these manuals will most likely relate to individual problems such systems require good retrieval mechanisms. Hypertext is the obvious method for helping users in this situation. Many recent software packages have been delivered with on-line manuals or on-line help systems in hypertext form. These types of hypertext are often subdivided into User Assistance Hypertexts and Dictionary References.

Where users need more assistance than a manual can provide it is useful to note that hypertext provides a mechanism for integrating several forms of user assistance, including introductory tutorials, on-line help systems and error messages. In an integrated user-assistance facility based on hypertext, it may be possible for the user to link from an error message to the location in the help system that gives further assistance on the problem. Similarly if the user's difficulty was not the error situation in general but a single incomprehensible word in the message, it may be possible to link from that word to the location in the on-line manual where it was defined. If the user needs further assistance than could be provided by the help system or the manual, it may be possible to link further, to the appropriate location in the tutorial component, to get a computer aided instruction lesson.

Dictionaries and reference Hypertexts provide an extension of the manual system can be seen in the development of dictionaries and reference books. Several dictionaries and large reference works have been converted from a traditional paper format to a hypertext format.

Systems such as the DRUID (Dynamic Rules for User Interface Design) and IBM's Navitext SAM have in general only begun to experiment with these ideas and as yet have not produced any comparable data.

## 2.3 Software Engineering

As mentioned in Section 2.6 of chapter 2 there are a large number of specification and implementation documents have been produced. There is a great potential of the use of Hypertext within this field to provide links between each of these individual documents. It would be possible to start from a requirements document and link to that part of the design specification that meets a given requirement in a similar manner to FIELD. It could then be linked from the design specification to the actual code to see how that design is implemented or the links could be followed in the reverse direction, starting from the source code to see what customer requirements lay behind a certain code element.

To benefit fully from this form of hypertext linking among the various documents in the software life-cycle, a development organisation would need to follow a software engineering methodology supported by an integrated set of computerized tools in a complete CASE (Computer Aided Software Engineering) environment. A system which fits this type of pattern is the Dynamic Design project at tektronix which supports version control for various reports, documents, and code objects by using the Neptune hypertext abstract machine.

It is also possible to use hypertext in a less life-cycle oriented approach by including facilities in structure-oriented editors for program code. For example it is possible to click on a variable to get to see its definition associated comments or to link from a procedure call to opening a window with the text of the procedure. The Smalltalk Browser links related pieces of code together in a manner similar to this.

Since much of the software engineering process is spent on designing systems rather than coding, there is interest in specialized tools to support the design phase of the life-cycle. gIBIS (graphical Issue Based Information System) from MCC (Microelectronics and Computer Technology Corporation) is intended as a design journal, which aims to capture the rationale for software design.Since software design is usually a collaborative process involving many people gIBIS is a multi-user hypertext system. It is based on a theoretical model of the design process as a conversation among "Stake-holders" who bring their respective expertise and viewpoints to bear on a number of design issues. The participants in the design process argue about these issues. The participants in the design process argue about these issues by suggesting positions (ways to resolve the issue) and arguments for and against those positions. All of this is represented in a hypertext structure.

### 2.3.1 Operating Systems

Hypertext has the potential for revolutionizing the user interface of personal computers, so bringing closer the possibility of a task-integrated working environment. Current personal computers are fundamentally based on a file paradigm, where the user manipulates discrete (but large) units of information in the form of files. Each file can be found typically only in a single location in the file system and it is typically best suited for use by a single application program.

Most current file systems organise files in a hierarchy and require the user to navigate through multiple levels of subdirectories to reach individual files. It is not surprising that users often have difficulty locating stored information and are aided only by limited searching abilities. These facilities are primitive compared to the navigational facilities offered by some hypertext systems. It would be possible to extend future operating systems with a system-based hypertext service and preliminary research has resulted in the Sun Link Service (Pearl 1989). This extension would allow different applications to link transparently to information generated by other applications and stored elsewhere. Within such systems users would only need to make initial connections once between items: after this the system is able to switch from one to another seamlessly. This would avoid the need to use the operating system to carry out searching tasks Users therefore could concentrate on their tasks, while allowing the computer to integrate its applications and data to fit those tasks.

## 2.4 Auditing

Auditing is another natural application for hypertext because it is based on relating information from various sources and checking for consistency. The audit task includes gathering and producing large numbers of documents and linking them together to substantiate the accuracy of the information they contain. From this process large amounts of information are distiled into a single financial statement, so links are needed between the conclusions and the source data. It is possible to scan original documents from the client and it might conceivably be possible in the future to link directly into the client's own computer system. Furthermore, the audit of an international company involves a large audit team distributed over several countries. There are therefore several advantages in using various forms of computer support such as electronic mail and hypertext links among documents produced in different areas of the world.

## 2.5 Trade Shows and Advertising

Many kinds of advertising and communication to customers can be improved by hypertext. At present hypertext has only a novelty value which can be seen as an advantage in some types of advertising.

Hypertext can also be used to provide information about an entire trade show and help people find those exhibitors that would interest them; this has been successfully done at the Mac World Show (London Feb 1990).

In the long term, the novelty value of hypertext will disappear and one will have to rely on the intrinsic advantages of hypertext in an advertising context. One of these advantages is the general ability of hypertext to provide access to large amounts of information but to show the user only those small parts that interest him or her. This property of hypertext is important for applications like product catalogues. A hypertext product catalogue can reduce the complexity of choosing among a large number of options by showing only those that are relevant for the individual customer. It can also offer help in placing the order and might even place it by an on-line mechanism.

Hypertext advertising can also benefit from other properties of computer medium. For example Buick have released their car catalogue in hypertext form for several years and now includes driving simulations and other games to attract attention. In a hypertext form for comparative advertising, the screen allows the user to compare these cars with several competing alternatives. Users can click on the one other car they might consider buying instead and then see a detailed comparison. A printed catalogue might have had to compare all the cars in a single confusing table.

## 2.6 Idea Organisation and Brain-Storm Support

Some enthusiasts claim that hypertext is the most natural way to organise human ideas because its semantic network-like structure matches the human brain. It is also recognised that although difficulties still exist with hypertext, it is still more appropriate than the linear text format used by word processors.

As hypertext allows the coordinating of many disparate pieces of text it can be used to organise the ideas of groups of people. Besides allowing regular multi-author support, hypertext can also help coordinate ideas by its basic capability by having any user add new annotations and links to any node. Hypertext can also enhance collaboration taking place via electronic mail or computer conferences. For example the Team WorkStation (Nippon Telegraph and Telephone Corporation) allows several users to interact with the same multimedia work-space at the same time, although at present many computer conferencing systems use asynchronous changes. Hypertext links connect a message both forwards and backwards in time with all those other messages in the same stream of comments.

## 2.7 Journalism

In addition to the long term possibility of having newspapers and television news in an integrated system, it is also possible to use hypertext in the current way of conducting journalistic research. Much of this work is the gathering of information and facts and the writing of articles. Hypertext mechanisms are very good for this type of organisation problem.

For the collection of information it would also be possible to use large hypertext collections of previously published news material. Newspapers like the New York Times already provide information services with on-line access to databases with "old news", but the information is currently not in hypertext form.

## 2.8 Educational Applications

Many of the applications outlined above have an educational slant. However there have been many hypertext systems produced specifically for educational use. Hypertext is well suited for open learning applications where the student is allowed freedom of action and encouragement to take the initiative (Gardner and Paul 1991). An example of one specialized educational hypertext is the Palenque system from Bank Street College of Education (Wilson 1988). The purpose of the system is to teach Mexican archaeology to children aged between 8 - 14 by letting them take a tour of the Palenque ruins. The system is implemented in DVI (Digital Video Interactive) on a CD-ROM and allows surrogate travel among the ruins in a practical application of methods pioneered by the MIT Aspen Movie Map Project.

A different kind of educational use of hypertext is to support the teachers side of the process. John Leggett (Texas A&M University) experimented with hypertext support for teachers as a part of a course he taught on hypertext. Students were asked to turn in their assignments on the KMS hypertext system at the University, they were graded and annotated on the system and then returned by use of the multi-user system, the system also included a cross-reference from one student to another so that students could see how they had done against the rest of the class.

### 2.8.1 Museums

A special case of educational hypertext is the museum information system since most people do not go the museums specifically to study. It is impossible to present museum-goers with all the relevant information about the exhibitions in a printed form. It is however difficult to known the extent of a hypertext information space is actually an advantage in this application.

There is always the underlying problem that museum systems require a : "walk-up-and-use" usability in the sense that users will not be willing to go through a special initial period of training to be able to use the system. The need to pull the Museum-goer into the hypertext information space also impels the use of attractive initial displays. Simple systems like Hyperties without difficult navigational options are very suitable for this application.

## 2.9 Entertainment and Leisure

Hypertext provides several opportunities for pure enjoyment. Unfortunately there has been little research conducted in this area, but there have still been some pioneering research as well as a few commercial examples.

### 2.9.1 Tourist guides

Tourist information achieve a good match with Shneiderman's "Golden Rules" of hypertext since tourists typically want to read only a small part of the information available about a given city or country. Furthermore the information can be reasonably easily divided into nodes for each attraction, tourist service, historical era or geographical location. The problem with traditional tourist guides is that they need to structure all this information according to a single principle whereas the tourist has multiple varying needs.

Most tourist guides structure their information according to the type of information and have separate chapters on hotels, restaurants, shopping and museums and sights. Although some systems use geographical location as their design metaphor.

An example of the former type of system is Glasgow Online, (Baird and Percieval 1989). It is a hypertext tourist guide that combines the best of both types of guide. The front screen of the system has the traditional subject-oriented view of the city and allows the user to find, say, a hotel in a certain price range. From the description of the hotel, the user can jump to a map of Glasgow with a highlighted icon for the chosen hotel. The user can then click on other icons in the neighbourhood to see what other facilities are nearby.

### 2.9.2 Libraries

Some library applications are for the retrieval of technical or scientific information and are very similar to the application for dictionaries and information retrieval techniques. Libraries need to include electronic publication links of hypertext if they want to keep up with modern technology. In the future, a "library" might well be a computer network service rather than a building.

### 2.9.3 Interactive Fiction

There is very little to be gained from converting traditional forms of fiction to the on-line medium. It is only when new forms of fiction are invented that benefit will be derived from putting them into hypertext. The reader needs to be able to interact with the fictional universe instead of just turning the pages (Neilsen 1990).

One possibility for on-line fiction would be the shared universe type of story that has recently become popular in the science fiction genre. The basic idea is that several authors write stories set in the same fictional universe with the same general background and many of the same characters. One could potentially collect several hundred such stories together in a hypertext on a single CD-ROM and let readers pursue the type of plot and character each of them found interesting.

It is also possible to have interactive fiction in works by a single author (Howell 1990). There are several examples of this, the most famous being that of the Manhole a non-verbal interactive fiction for all ages. It contains 753 nodes and takes up 23 megabytes on a CD-ROM. It takes place in a fantasy world. This world is displayed to the user in a first-person perspective, graphically showing what you would actually see if you were positioned at the current location in the world and users move through the world by clicking on the place they want to go to. It should be noted that the Manhole is not completely non-verbal but contains messages from various characters to the user. These messages are printed on the screen in a cartoon-like speech-bubbles and are also read out loud by the system.

With this diversity in the nature and the use of hypertext systems it becomes very easy to see the great range of potential that these systems will have in the future.

## Appendix 3 The Broads Authority's Policies

This appendix holds a summarised copy of the Broads Authority's Policies (Broads 1987).

### Policy 1 Broads Research Advisory Panel

The Authority will continue to co-ordinate and analyse existing and future research through the Broads Research advisory Panel.

### Policy 2 Protecting Broads that Retain Important Aquatic Life

In the Broads that retain important plant and animal life the Authority will seek to ensure that water quality and plant life are regularly monitored, and that discharges of nutrient-rich waters are not allowed to reduce the quality of the water.

### Policy 3 Discharge of Ochre into Sensitive Waterways

The Authority will oppose drainage schemes which will or may lead to discharge of significant amounts of Ochre and/or acidity into the Broads, rivers and drainage systems which contain important plant and animal life.

### Policy 4 Reduction of Ochre

The Authority will encourage the water Authority, drainage authorities and individual landowners to implement schemes to reduce the level and extent of ochre discharge which is pumped into the Broads waterways.

### Policy 5 Protecting the Margins of the Upper Thurne Broads

The Authority, in conjunction with other agencies, will investigate various techniques for protecting the margins of the Upper Thurne Broads from damage and disturbance by boats.

### Policy 6 Voluntary 'Wildlife Zones' on Upper Thurne Broads

Whilst recognising the importance of the Upper Thurne Broads for boating the Authority will consider the need for limited voluntary zoning, to ensure that certain birds are not seriously disturbed.

**Policy 7 Boating Facilities on the Upper Thurne**

No further development of facilities for boating of any kind will normally be permitted in the area of the Upper Thurne Broads, including Potter Heigham and all areas upstream of the old Bridge.

**Policy 8 Water Quality Improvements - River Ant**

The Authority will ask the water Authority to continue its phosphate removal operations on the River Ant and, in conjunction with other agencies, will carry out other works to encourage aquatic plant recolonisation of Barton Broad.

**Policy 9 Water Quality Improvements -River Bure**

The Authority will seek the continuation of phosphate removal on the River Bure and when improvements are evident from the first phase, will ask the water Authority to start a programme of phosphate reduction on the lower Bure.

**Policy 10 Recolonisation of Plants in the River Bure and its Broads**

Once the water quality of the Bure has improved, the Authority, in conjunction with other species, will carry out work to encourage aquatic plant recolonisation of the Bure Valley Broads, rivers and river banks.

**Policy 11 Nutrient Budgets - River Waveney and Yare**

The Authority will request the water Authority to prepare nutrient budgets for the Rivers Waveney and Yare, to determine the feasibility of water quality improvements.

**Policy 12 Weed Cutting**

The Authority will liaise with the navigation Authority on weed cutting programmes in the Broads in accord with ecological conditions and conservation advise.

**Policy 13 General Water Quality**

The Authority will ask the water Authority to:

1) Ensure that the general quality of effluent from sewage treatment worked is maintained at a level which is adequate to protect the aquatic environment and

2) Carry out a review of water quality objectives in the Broads in consultation with the Broads Authority.

**Policy 14 River flows and Ground Water Levels**

The Authority will ask the water Authority to consult them on minimum acceptable river flows and ground water levels for the Broads and its river catchments.

**Policy 15 Lead Poisoning in Swans**

The Authority will investigate alternative measures to reduced the severity of lead poisoning in swans.

**Policy 16 Natural Bank Protection**

The Authority investigate methods of re-establishing natural bank protection.

**Policy 17 Environmentally Acceptable Artificial Bank Protection**

The Authority will investigate more environmentally acceptable forms of artificial bank protection.

**Policy 18 Dredging Techniques**

The Authority will investigate, with the navigation Authority, the impact of different dredging techniques to ensure that those used do not adversely affect bank stability and aquatic flora an fauna.

**Policy 19 Provision of Anglers' Stagings**

The Authority will encourage the provision of anglers' staging in appropriate locations, to prevent damage to sensitive river banks.

**Policy 20 Provision of Temporary Mooring Facilities**

The Authority will encourage the provision of alternative temporary moorings in areas where bank erosion, caused by mooring against unprotected banks, is a serious problem.

**Policy 21 Speed Limits**

The Authority will ask the navigation Authority to undertake a complete review of speed limits and to consider the revision of bye-laws in general, with a view to reducing erosion of boat speed and wash.

**Policy 22 Monitoring of Bank Erosion**

The Authority, in conjunction with the water Authority and navigation Authority, will initiate a programmed of regular monitoring of bank erosion throughout the river system.

**Policy 23 Wash Free Zones**

The Authority, in conjunction with the navigation Authority will investigate the practicality and effectiveness of establishing wash-free zones as a methods of reducing river bank erosion.

**Policy 24 Research into Hull Design**

The Authority will:

1) support investigation of possible design approaches to produce low-wash hulls for the future, and

2) Considered, in conjunction with the navigation Authority, ways of encouraging hire operators and other boat users to use low wash hulls.

**Policy 25 Control of Motor Craft Numbers**

1) The Authority will allow no further development that would permit any increase in numbers of motor hire craft on the rivers. Further development of existing boat-yards will only be permitted when the number of boats operated from that yard is limited by a legal agreement under section 52 of the town and country Planing Act.

2) Further development of permanent moorings for private motor craft will not be permitted.

**Policy 26 Conversion of Boat-Yards to Other Uses**

The Authority will normally permit the conversion of boat-yards to other waterside uses. Where such uses are not feasible, the development of holiday accommodation or tourist facilities may be permitted.

**Policy 27 Removal of Sediment from the Broads**

The Authority will support the removal of sediment from Broads of conservation or recreation importance which re threatened by silting up.

**Policy 28 Management of the Fens**

The Authority will encourage the management of open fen areas for conservation,by:

1) Providing advice and management assistance and coordinating volunteer employment scheme labour;

2)supporting initiatives aimed at stimulating the market for the products of fen management;

3)Providing specialist equipment for fen management.

**Policy 29 Acquisition of Fens**

Where advice and management assistance are not sufficient to ensure the retention of important fen areas the Authority will seek to purchase or lease the area, either by itself or by providing financial assistance to an appropriate agency.

**Policy 30 Rehabilitation of Reed and Sedge Beds**

The Authority will encourage the rehabilitation of reed and sedge beds for commercial exploitation.

**Policy 31 Bore Hole Water Abstraction**

The Authority will request the water Authority to refuse any applications of bore hole or other abstraction likely to affect adversely the water supply to fen areas of ecological importance.

**Policy 32 Drainage of Fens**

The Authority will oppose the drainage of any area of fen recognised as being of conservation value. It will also oppose the drainage of adjacent marshes, where this is likely to affect adversely the water supply of an important fen. Where appropriate, the Authority will seek to safeguard the site by a management agreement or by purchase.

**Policy 33 Management of Carr Woodland**

The Authority will provide assistance with the management of Carr Woodland of landscapes and conservation importance.

**Policy 34 Development of Fens and Carr Woodland**

The Authority will not permit development which would directly or indirectly affect fens and carr woodland of conservation importance.

**Policy 35 Pollution of Marsh Dyke Systems**

The Authority will encourage farmers to provide suitable waste disposal facilities for silage effluent and livestock slurries and to practise appropriate care when spreading on the marshes. Where necessary the Broads Authority will request the water authorities to take the appropriate legal action to prevent the discharge of slurry into the dyke systems.

**Policy 36 Management of Marsh Dykes**

The Authority will encourage farmers and landowners to manage their dykes by methods that will enhance their wildlife value.

**Policy 37 Creation of Small Washlands**

In selected locations the possibility will be investigated of creating flooded areas on the marsh in the winter months to enhance their bird life potential.

**Policy 38 Environmental Safeguarding Arrangements for Marshlands**

The Authority will, in view of designation of its area as an Environmentally Sensitive Area, discuss with all relevant agencies the most appropriate form of support for permanent livestock to ensure continued maintenance of features of environmental importance in the grazing marshes.

**Policy 39 Wildlife and Countryside Act 1981 Management Agreements**

The Authority will object to farm capital improvement grant applications which are likely to result in changes that will adversely affect environmentally important grazing marshes. The Authority will seek to safeguard such areas by management agreements or other appropriate mechanisms.

**Policy 40 Land Acquisition**

The Authority in conjunction with voluntary conservation groups and other interested agencies, identify environmentally important marshes and assist id their purchase, or where appropriate, purchase land directly itself.

**Policy 41 Safeguarding Environmentally Important Areas**

The Authority will seek last resort powers for the Broads, through Landscape Conservation orders, to be used to prevent damage to important sites where negotiations have failed. Until these orders are available for use the Authority will use Article 4 where necessary.

**Policy 42 Land Drainage and Flood Protection**

The Authority will seek to establish an agreement with the Ministry of Agriculture, the water Authority and the drainage authorities, which provides for future investment in land drainage and flood protection that is compatible with the environmental importance of the grazing marshes.

**Policy 43 New Landscapes**

In areas where the traditional landscape character has been lost the Authority will encourage the development of an attractive new landscape, based on traditional features.

**Policy 44 Preservation of Windpumps**

The Authority will continue its programme of preserving the existing remains of wind pumps in the Broads area by providing assistance to private owners and historic trusts.

**Policy 45 Restoration of Windpumps**

The Authority will continue to support the full restoration and future maintenance os selected windpumps by offering assistance to private owners and historic trusts.

**Policy 46 Conversion of Windpumps to Other Uses**

The Authority will only encourage the conversion of windpumps to other uses where this will involve preservation of the original form of the building and restoration of authentic features. The Authority will not permit the windpumps identified in its programme for restoration to be converted to other uses.

**Policy 47 Woodland Management and Planting**

The Authority will support and encourage the management and replanting of woodlands on valley sides and also promote new planting of small areas to restore some of the tree cover lost by hedgerow clearance.

**Policy 48 Development on the Marshes**

The Authority will not generally permit development on the open marshes or on adjacent sites where it will be visually intrusive. Where development is essential for agricultural purposes locations on the valley sides will usually be preferred.

**Policy 49 Control of Agricultural Buildings**

The Authority will seek designation of its executive area under the town and Country planning act (landscape Areas Special Development Order) as a means of influencing development of agricultural buildings.

**Policy 50 Overhead Power Lines**

The Authority will normally oppose proposals to erect overhead power lines through are of grade 1 and 2 landscape and other areas of attractive landscape where they would be intrusive, and will encourage the undergrounding of these lines wherever possible. The Authority will also press Eastern Electricity to review its current networking in the Broads area with a view to removing any lines not in use and unlikely to be required in the future.

**Policy 51 Building Preservation Notices**

Where a building considered to be of historic or special interest to the Broads area is threatened by unsympathetic changes or demolition, the Authority will protect it by service of a Building Preservation Notice.

**Policy 52 Grant Aid for Restoration of Historic Buildings**

The Authority will provide grant aid, where appropriate, towards the repair and restoration of buildings of historic or other special interest.

**Policy 53 Assistance to Historic Buildings Trusts**

The Broads Authority will encourage and assist the Historic Buildings Trusts to restore buildings within the Broads area.

**Policy 54 Alternative Uses for Historic Buildings**

The Authority will generally permit the change of use and alteration of redundant historic buildings provided that this is compatible with the character and setting of the building and retains the features of historic interest.

**Policy 55 Designation of Conservation Areas**

The Authority, in conjunction with the local authorities, will review the settlements in the Broads and, where appropriate, designate further conservation areas.

**Policy 56 Enhancement of Conservation Areas**

The Authority, in conjunction with local authorities and local residents, will seek to enhance the character and appearance of the conservation areas in the Broads.

**Policy 57 Conservation of Ancient Monument and Archaeological Sites**

The Authority will assist in the conservation of ancient monuments and archaeological sites in the Broads area and will not normally permit development which would be detrimental to these important historic features. The Authority will, where appropriate, support archeological excavations.

**Policy 58 Design Guidance**

The Authority will provide detailed guidance on the design of buildings in the Broads context, both through published material and advice.

**Policy 59 Control of Design**

The Authority will only permit new and replacement building in the area which are well designed, with form character, materials and colour appropriate to their settings.

**Policy 60 Local Plan Studies**

The Authority will review each of the settlements in the Broads area to determine which approach is appropriate to its future planning and management. The Authority, in conjunction with the District councils, will carry out special studies or local plans of Broads settlements where necessary.

**Policy 61 Environment Improvement Schemes**

The Authority Will initiate schemes to improve the visual appearance of Broads settlements and developed areas.

**Policy 62 Development in Riverside Areas**

The Authority will normally only permit new riverside development within existing centres.

**Policy 63 Clearance of Unattractive Riverside Development**

The Authority will seek to achieve the removal of unattractive and intrusive development in riverside areas.

**Policy 64 Off-River Overnight Moorings**

The Authority will ask the navigation Authority to ensure that any new overnight mooring are, wherever possible, located in off-river cuts or mooring basins.

**Policy 65 Mooring at Bridges for Sailing Craft**

The Authority will support the navigation Authority in their Policy of seeking to provide areas of moorings, reserved for sailing craft at Wroxham and Potter Heigham bridges.

**Policy 66 Conditions Relating to New Bridge Construction**

Where new bridges are proposed, the Authority will support the navigation Authority in their Policy of requesting that the highway Authority:

1) Provides moorings on both sides of any new bridge for sailing craft to lower their masts.

2) Construct the bridge with sufficient clearance to allow passage for present Broads motor craft.

**Policy 67 Improved Temporary Mooring Facilities**

The Authority will encourage the Navigation Authority and others, to increase the number of short-stay moorings at the riverside centres, particularly off-river facilities.

**Policy 68 By-pass Channels**

The Authority, in conjunction with the navigation Authority, will investigate the feasibility of by-pass channels to reduce congestion in heavily-used riverside area.

**Policy 69 Development for Sailing Uses**

The Authority will normally permit development relating to sailing on the main Broads rivers, except the middle and lower reaches of the river Bure, the lower reached of the River Ant and the Upper reaches of the River Thurne, upstream of the old Potter Heigham Bridge.

**Policy 70 Use of the Broads Not Open to Public Navigation**

The Authority will examine the potential of the Broads not open to public navigation for certain types of boating use, taking into account the environmental sensitivity of these Broads and the interest of existing recreation users.

**Policy 71 Mineral Workings**

The Authority will consider applications for mineral workings in selected Broads sites, with a view to creation of new Broads, subject to the following conditions:

1) That sites correspond with the appropriate county's structure plan or other mineral policies.

2)That the areas would not result in the loss of good quality agricultural land (grades 1, 2, and upper 3).

3) That the areas involved are not of nature conservation or landscape importance.

4) That satisfactory access can be provided to an adequate highway and that the traffic generated would not be materially harmful to the environment.

5) The Effective measures can be taken to reduce visual and noise disturbance to nearby residential areas.

**Policy 72 Water Recreation Liaison Panel**

The Authority will examine the opportunities for overcoming problems between different water user groups through the water recreation liaison panel.

**Policy 73 Zoning**

The Authority will undertake a detailed examination of the possibilities for zoning certain areas of the Broads for different water activities.

**Policy 74 Use of Isolated Lakes and Waterspaces**

The Authority will encourage the use of isolated lakes and waterspaces throughout the counties of Norfolk and Suffolk for water recreation uses.

**Policy 75 Board-Sailing**

The Authority will encourage local sailing clubs to integrate board-sailing into their organised activities.

**Policy 76 Mooring Provision at Norwich and Great Yarmouth**

The Authority will encourage the Norwich city council, great Yarmouth Borough Council and the navigation Authority to increase provision of moorings and related facilities in Norwich and Great Yarmouth.

**Policy 77 Overnight Mooring at Boat-Yards**

The Authority will encourage improvements in the appearance and facilities in boat-yards so as to encourage greater use of their moorings for overnight and other temporary mooring use.

**Policy 78 Access for Land-Based Visitors**

The Authority will seek to improve car parking and other visitor facilities at riverside access points in the middle Bure area.

**Policy 79 Access to Upper Yare**

The Authority will consider what improvements in capacity can be made to each of the existing access points in the Upper River Bure.

**Policy 80 Informal Recreational Use - Restored Gravel Pits**

The Authority will encourage the local Authority responsible to make some provision for informal recreation facilities within restoration schemes for gravel workings.

**Policy 81 Local Study of Hickling**

The Authority will continue to initiate and implement measures to resolve the problems at Hickling in close cooperation with all concerned.

**Policy 82 Access - Trinity Broads**

The Authority will negotiate with the riparian owners with a view to implementing the informal access proposals identified in the Trinity Broads Study.

**Policy 83 General Access Improved**

The Authority will seek to improve the management and layout of riverside areas throughout the Broads in a way which maintains the natural character of the area as far as possible.

**Policy 84 Circular Footpath Routes**

The Authority will establish and maintain a network of circular footpath routes in the Broads Area.

**Policy 85 Public Toilets**

The Authority, in conjunction with the District Councils, will seek to provide public toilets at popular riverside locations and to improve toilet facilities for the disabled within the Brads area.

**Policy 86 Litter and Refuse Collection Services**

The Authority will ask each district council to review its litter and refuse collection services in the Broads area with the objective of ensuring that frequency of collection is adequate.

**Policy 87 Investigation of Litter Problems**

The Authority, in conjunction with the District Councils, will investigate ways of overcoming litter problems throughout the Broads.

**Policy 88 Development of Commercial Facilities**

The Authority will favourably consider the development and redevelopment of commercial facilities within recognised commercial areas, provided that these developments enhance the appearance of the area concerned and are compatible with planning criteria.

**Policy 89 New Permanent Holiday Accommodation**

The Authority will only permit new holiday accommodation where:

1) The proposals are within or adjacent to exiting areas of development and are of a scale that is acceptable in relation to the size of the existing development.

2) There are adequate mains services and suitable road access.

3) The site does not involve the use of high grade agricultural land.

4) The development does not affect areas of landscape or ecological significance.

5) The development proposed is of a high quality of design sympathetic with it Broads Setting.

**Policy 90 Landscaping Holiday Sites**

The Authority will seek improvements in the appearance of areas of holiday accommodation and may offer grants for approved landscaping schemes.

**Policy 91 Permanent Static Caravan Sites**

No new permanent static caravan sites or extensions to existing sites will normally by permitted.

**Policy 92 Touring Caravan and Camping Sites**

The Authority will favourably consider proposals for small scale touring caravan and camping sites provided that:

1) The sites considered are well landscaped.

2) The sites do not affect or intrude on areas of landscape or ecological importance.

3) The sites have adequate mains services and suitable road access.

**Policy 93 Houseboats**

No further houseboats will normally be permitted in the Broads.

**Policy 94 Holiday Accommodation - Occupancy Conditions**

Where new permanent holiday accommodation is permitted in locations considered inappropriate for permanent housing, the use f that accommodation will be restricted to holiday uses only, by a specific condition.

**Policy 95 Leisure Plots**

The Authority will oppose the sub-division and change of land for the creation leisure plots.

**Policy 96 Integrate Information and Interpretation Programme**

The Authority will adopt an integrated approach to the provision of information and interpretation using varied and imaginative media.

**Policy 97 Expansion and Co-ordination of Information and Interpretation Services**

The Authority will seek to encourage an expansion of information and interpretation either by involvement or by providing assistance and co-ordinating the activities of other organisation.

**Policy 98 The Design and Presentation of Information and Interpretation Services**

The Authority will encourage a high standard of design and presentation in information and interpretation and will offer financial assistance, where appropriate, to those providing these services. The Authority will also advise on the planning, design, construction and management of information and interpretation services.

**Policy 99 Broads Information Centres and Points**

The Authority will establish Information Centres or Points at various key locations throughout the Broads.

**Policy 100 Networking the Broads Information Centres**

The Authority will work closely with the East Anglian Tourist Boar and where appropriate will seek inclusion of the Broads Information Centres in the National network of Tourist Information Centres.

**Policy 101 Addition Information and Interpretation Services**

The Authority will extend the provision of information and interpretation through it warden service and will investigate the potential of other outlets.

**Policy 102 Tourist Information Signs**

The Authority will work with the navigation and highways authorities and the Tourism Board to provide tourist information signs which are helpful and appropriate to the Broads environment.

**Policy 103 Public Relations and Consultation**

The Authority will encourage public interest in its work and will set out to inform and consult local people and visitors about its policies and the implementation of those policies.

**Policy 104 Environment Education**

The Authority will encourage the use of the Broads area as a resource for environmental education.

# Appendix 4 Example screens from the FIELD System

This appendix shows example screens from the document storage system refered to in this thesis as FIELD. For continuity all screens are taken from one department, the Administration Department. Each screen shows a different aspect of the Administration problem while being complemented by the relevant specifications.

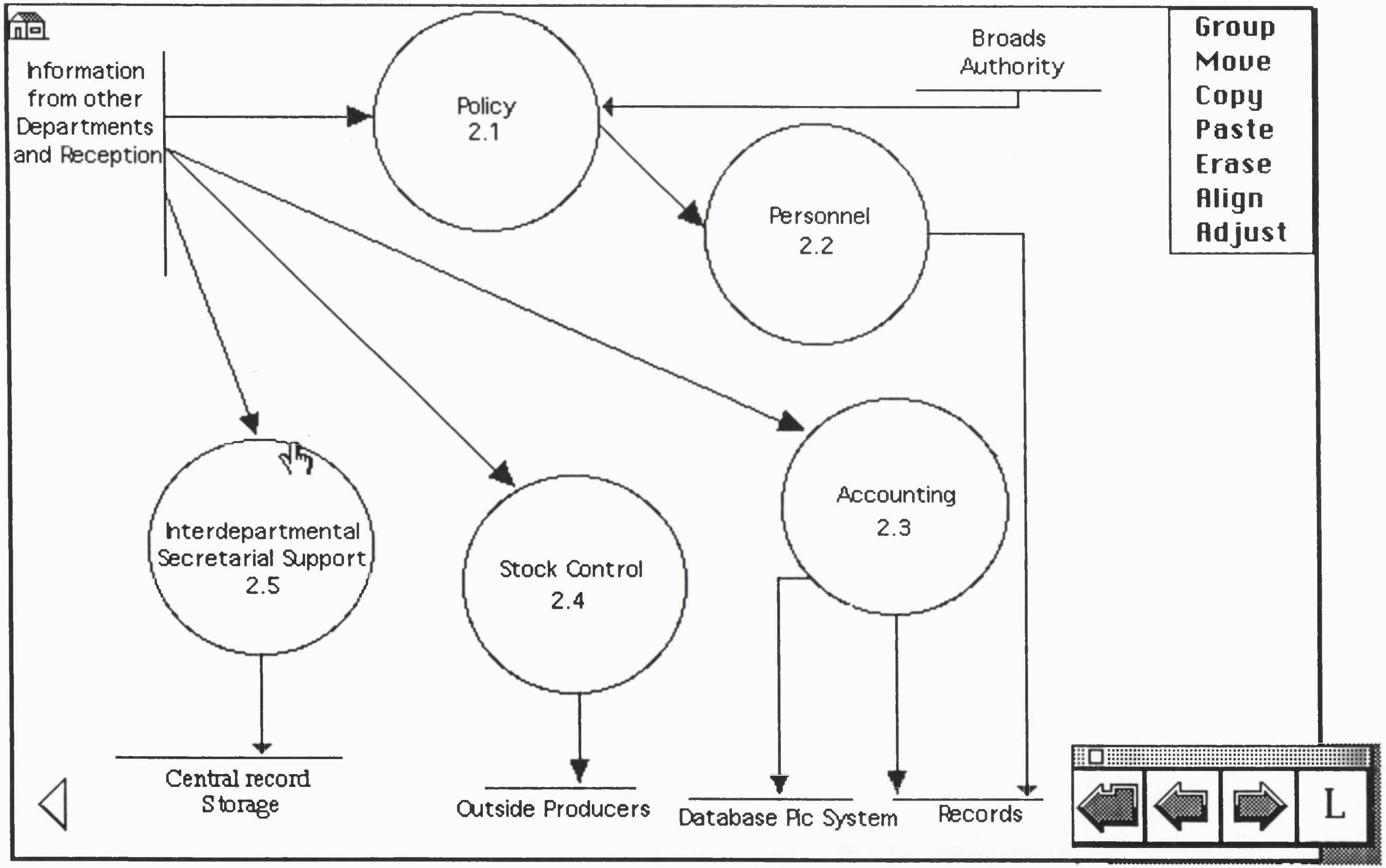



Diagram A4.1 A Second Level Data Diagram from the Administration Department.

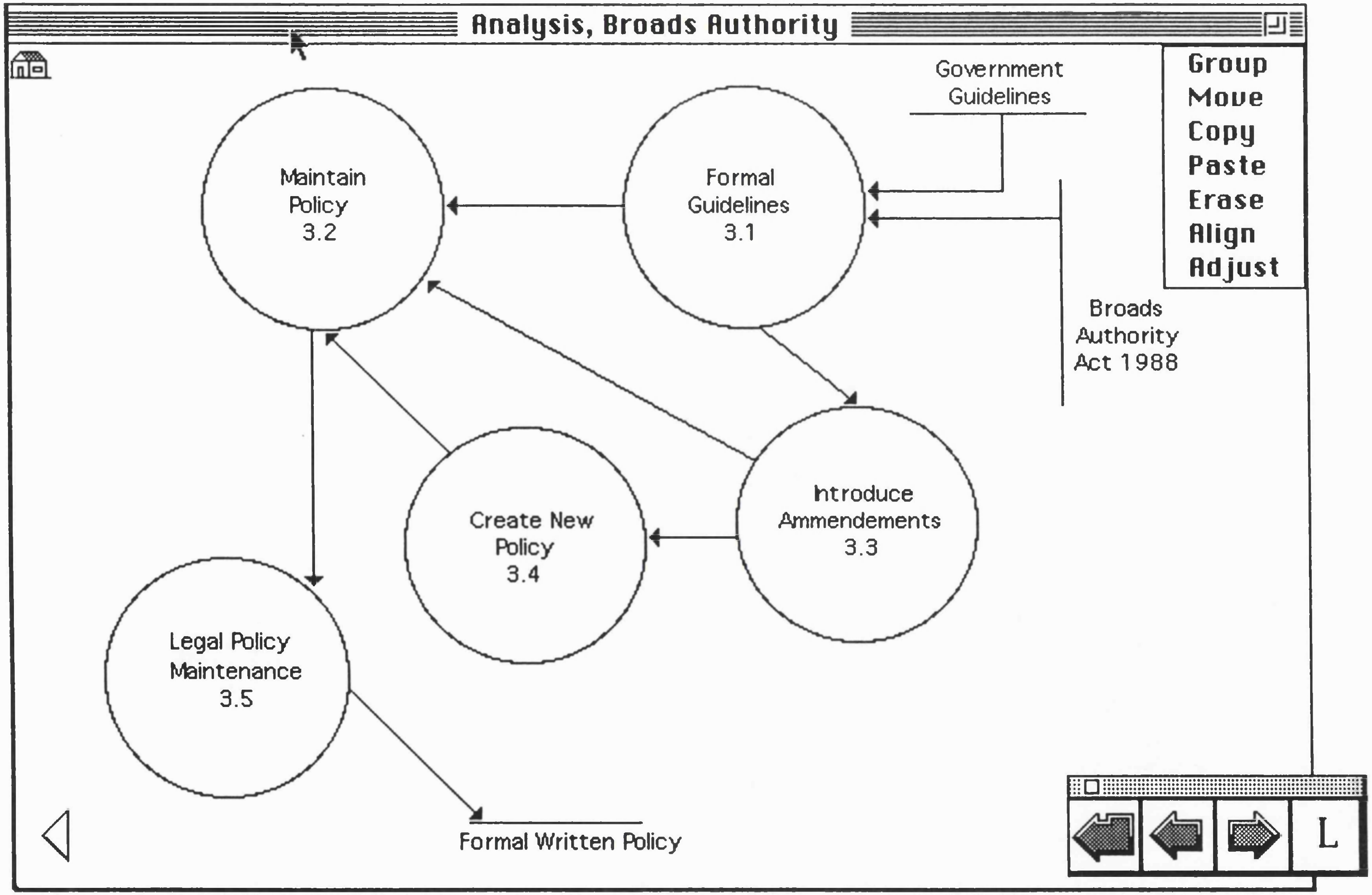



Diagram A4.2 A Third Level Data Diagram from the Administration Department.

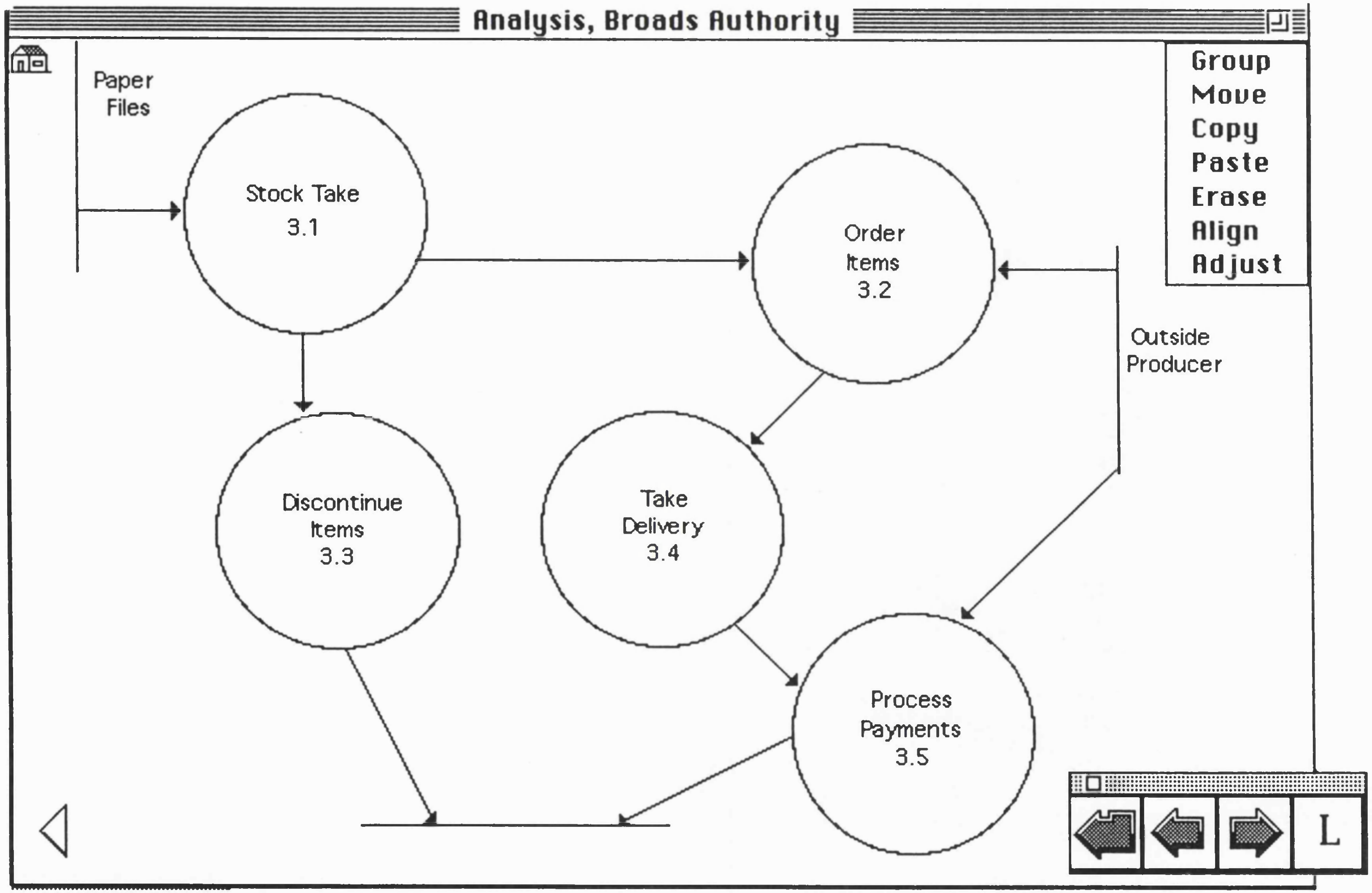



Diagram A4.3 A Third Level Data Diagram from the Administration Department.

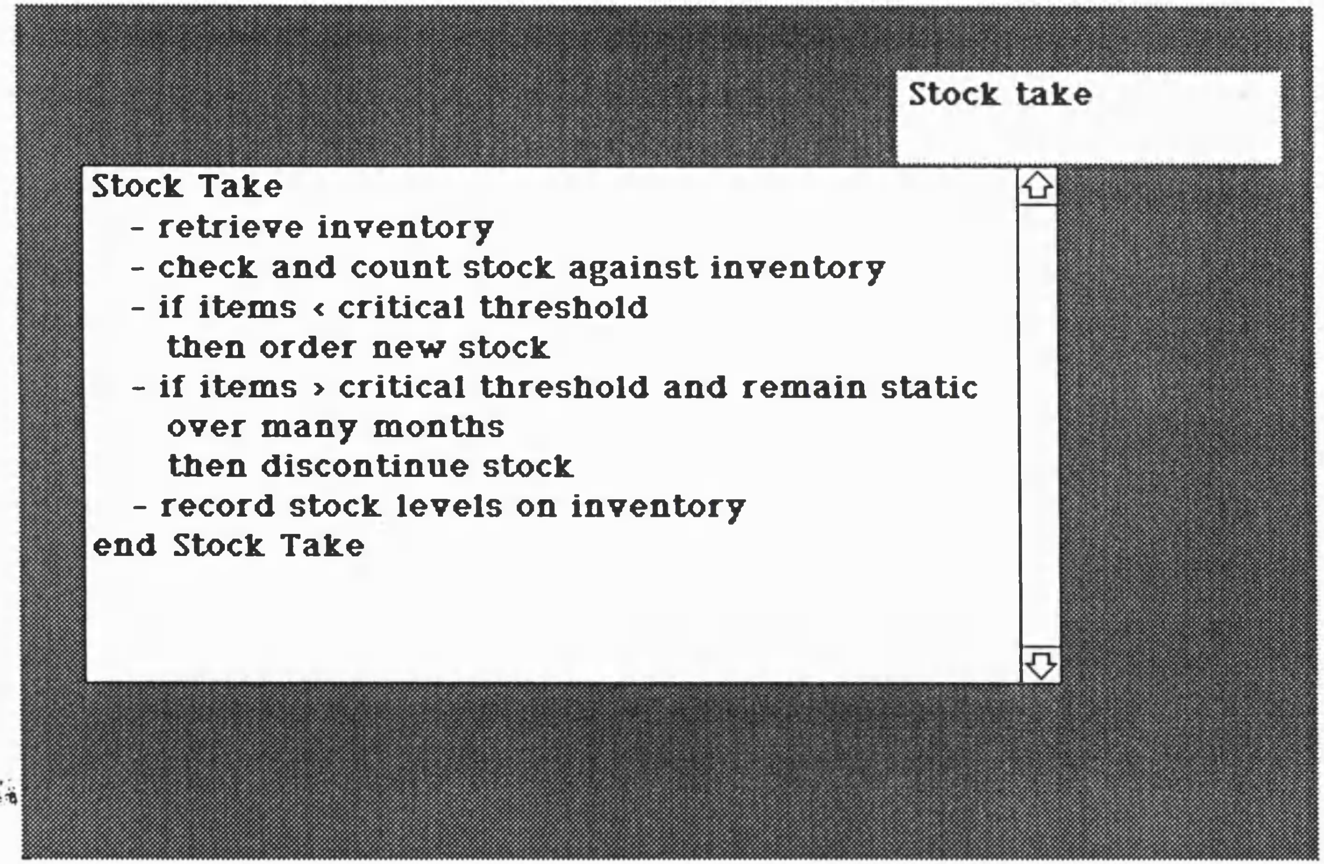



Diagram A4.4 A Process Specification of the Administration Department.

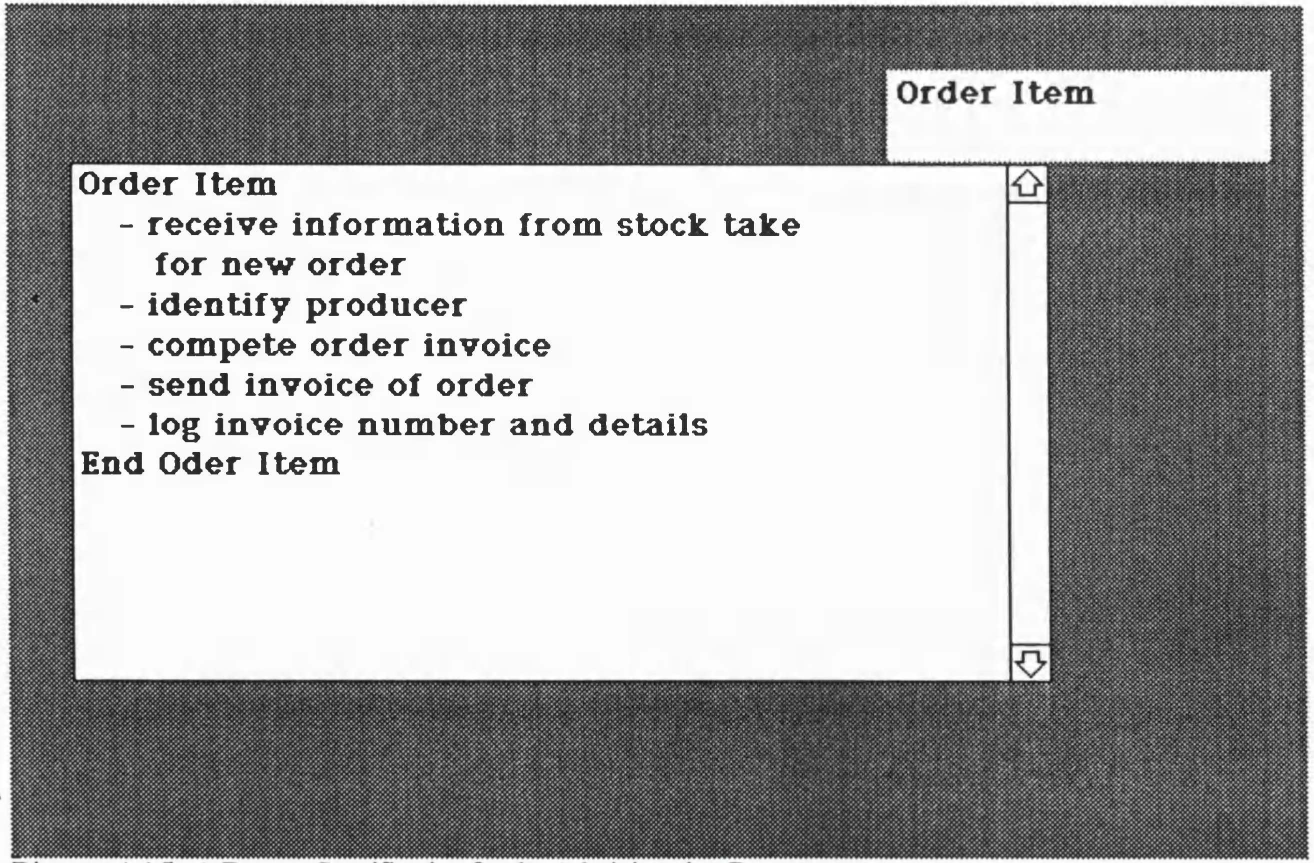



Diagram A4.5 A Process Specification for the Administration Department.

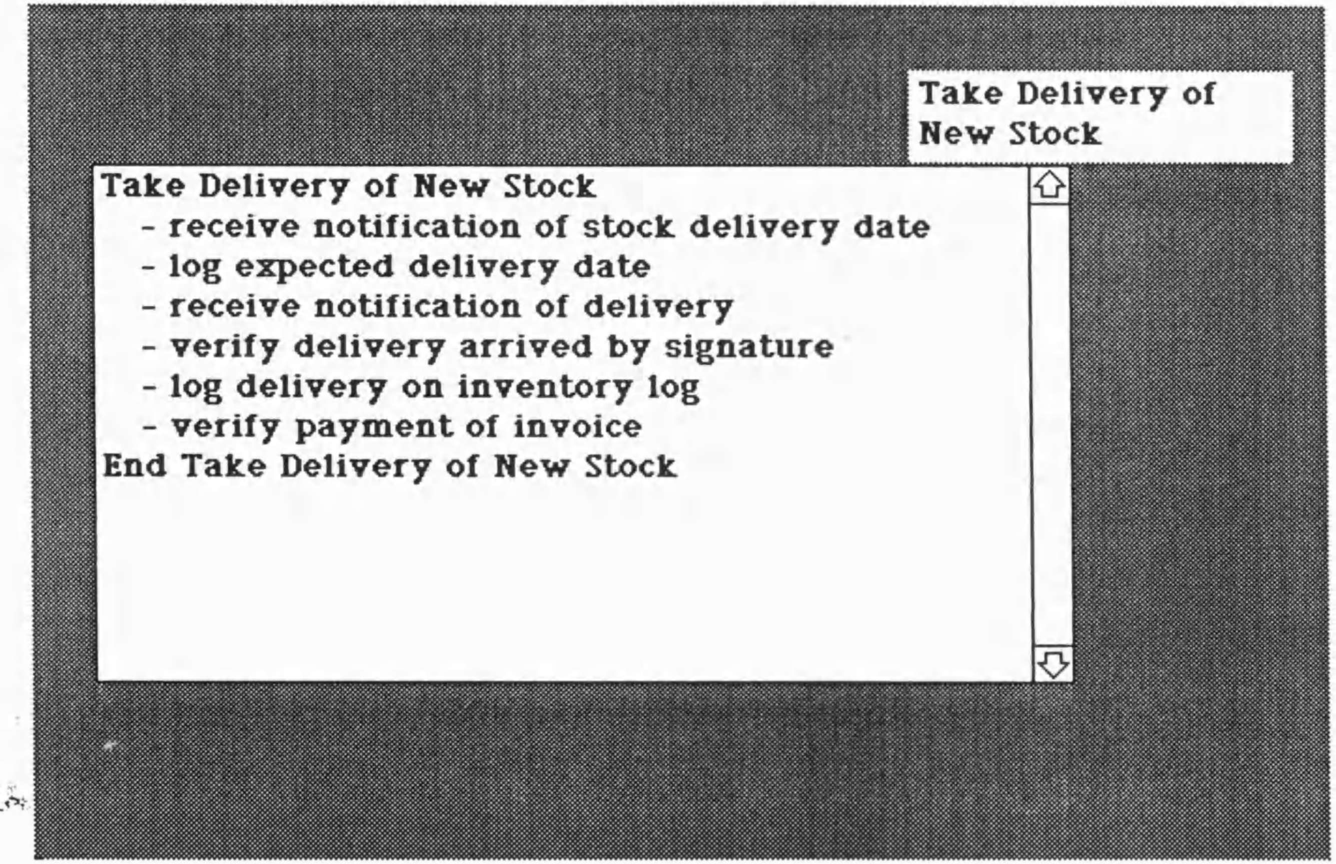



Diagram A4.6 A Process Specification for the Administration Department.

## Appendix 5 Entity-Relationship Diagram for the Navigation Department

The Norfolk and Suffolk Broads Authority Navigation Database at exists in electronic format. The structure of this database is shown in diagram A5.1. The notation used in this diagram is derived from Chen (1976) and Martin and McMclure (1985).

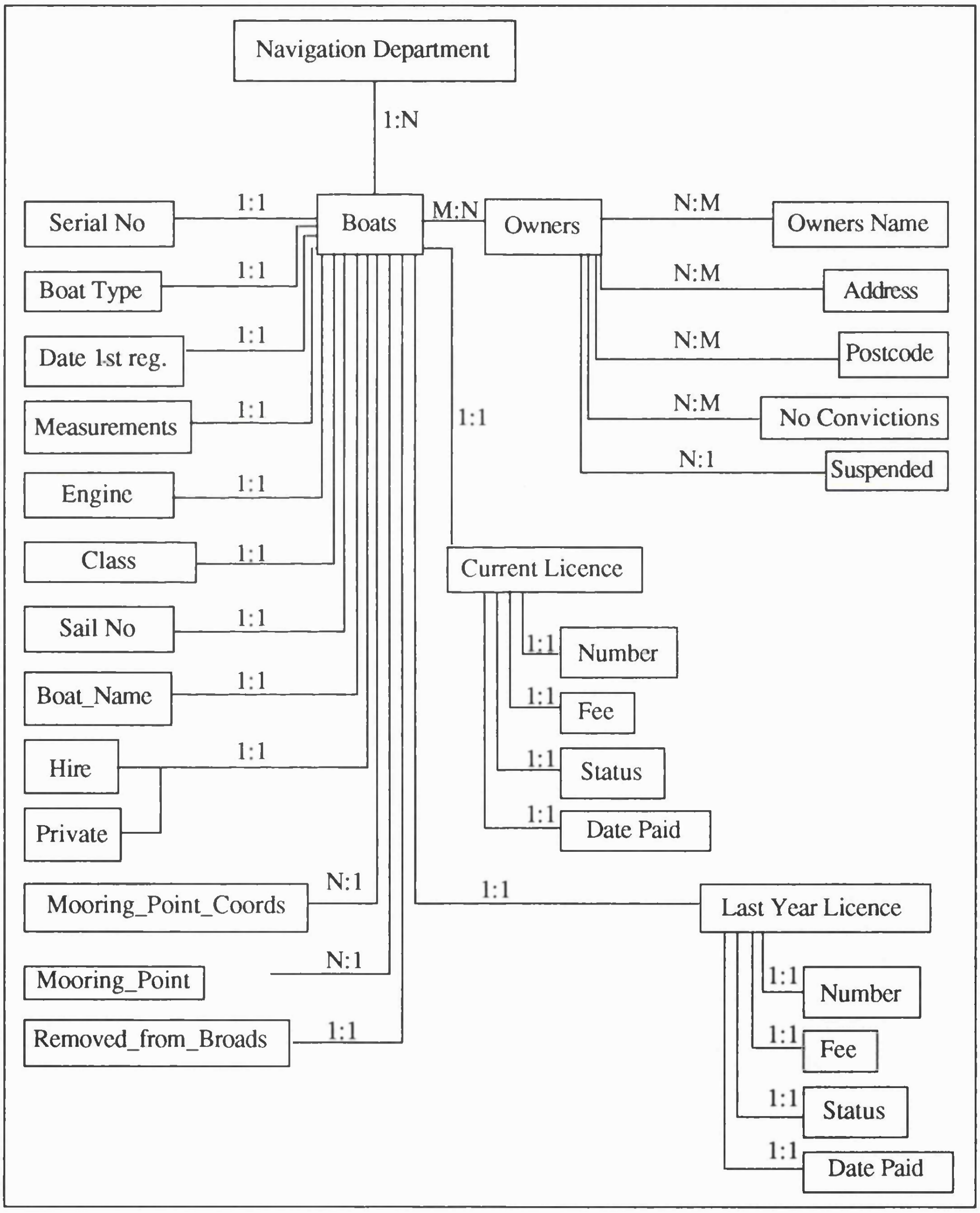



**Diagram A5.1 The Structure of the Navigation Vessel Registration Database.**

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