15 GIS in a landscape archaeology context

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This paper is concerned with the role of a geographic information system (GIS) within the North West Wetlands Survey, a long–term landscape archaeology project aimed at the identification of wetland sites and landscapes under threat and in need of management action. The project also aims to provide a sound archaeological basis for explanations concerning prehistoric settlement in and around wetland areas within its environmental framework. The GIS, whose implementation is at an early stage, is seen as central to the fulfilment of these broad project goals and the basis for long–term action to preserve the region's archaeological and paleaoecological resource.

15.1 THE NORTH WEST WETLANDS SURVEY

It has long been apparent that wetlands, with their unique qualities of preservation at both the site and landscape scale, have a pivotal role to play in the elucidation of patterns of past human behaviour. Since the work on the Swiss lake villages, the Danish bog burials and the so–called "lake villages" of Somerset, England, there has been a great deal of interest in wetlands, although until recent years, much of this has been on a piecemeal basis. In the last 20 years, however, English Heritage, the statutory body for the preservation and management of the archaeological heritage in England, and its predecessor, the Department of the Environment, have been involved in archaeological projects designed to investigate the wetlands of England systematically. These have, particularly since 1945, been under great threat from a variety of agencies including drainage and commercial peat extraction. It was appreciated that work in wetlands cannot be approached in a piecemeal fashion and systematic and structured procedures are required to achieve a well–developed set of objectives.

Initially this work was concentrated in the Somerset Levels in South–west England and, between 1978 and 1988, the East Anglian Fens, where the Fenland Project investigated multi–period settlement in a complex coastal and riverine environment of silts and peat. The next development of this process was the establishment in 1987 of the North West Wetlands Survey to examine, in detail, the lowland peat of North–west England (Figure 15.1). Work has focused on this particular type of environment, defined on ecological and hydromorphological criteria, as it is under the greatest threat and it allows the project to focus on the formulation of both fieldwork and management strategies for a specific type of environment. The term "lowland peat" includes basin, valley, flood plain and raised mire peats (Middleton & Wells 1990).

This work is a part of the wider survey activities of the Lancaster University Archaeological Unit which undertakes many high–quality excavations and survey projects principally in North–west England.

15.1.1 The scope of the project

The survey area covers the administrative counties of Cumbria, Lancashire, Merseyside, Greater Manchester, Cheshire, Shropshire and Staffordshire. Topographically, the northern part of the area comprises a lowland plain that varies from 1 km to 20 km in width merging, in the south, with the Cheshire/Shropshire Plain. The underlying geology is largely glacial in origin with the predominant deposits being of boulder clay with lesser amounts of fluvio–glacial gravels and coastal wind–blown sands. The majority of the peat deposits have formed within folds in the boulder clay landscape varying in size from small basin mires a few metres wide but, in some cases, many metres deep, to the large raised mires of the Solway Plain, the Fylde and the Mersey Basin.

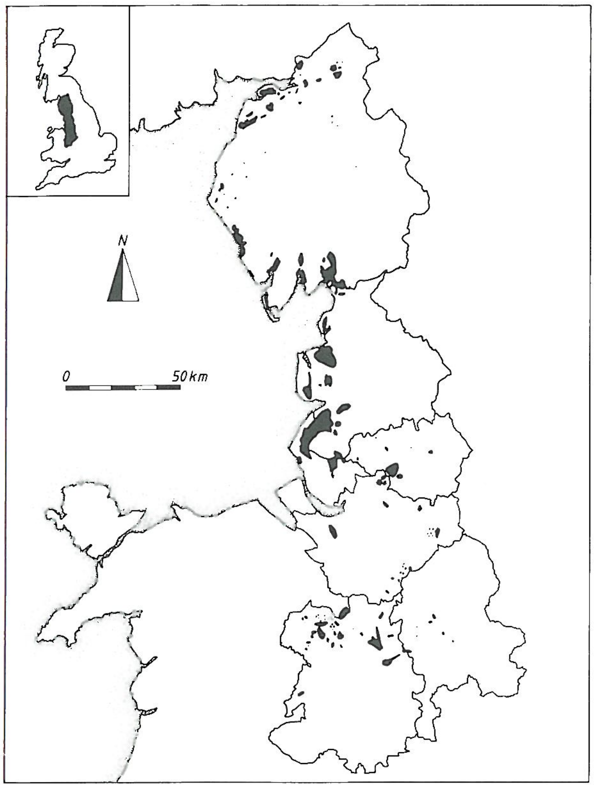

Figure 15.1: The distribution of lowland peat in North–west England.

15.1.2 Project structure

The North West Wetlands Survey has three major phases:

15.1.2.1 Initiation

This involved a desk–based assessment of the distribution of peat and the extant archaeological evidence. It was published in 1988 as *Peat and the Past* (Howard–Davis *et al.* 1988) which gave an indication of the extensive archaeological remains that have been found in wetlands in North–west England, both as sites and stray finds, but which had never seen any modern, systematic fieldwork to place them in a meaningful context.

15.1.2.2 Identification

This stage was established as a result of the initiation phase which not only hinted at the extensive archaeological deposits which remained undiscovered, but also, in common with similar deposits throughout the British Isles, the great threat that the peat deposits are under from a variety of agencies. The appropriate response to this was a systematic, eight–year fieldwork programme covering all known peat deposits in the survey area. The work has concentrated on the discovery of new sites and the re–evaluation of the old, using non–destructive methods. This has involved large–scale fieldwalking backed–up by aerial photography (Figure 15.2), selective geophysical survey and sondage. Work has been underway for two years since 1990 and will be completed in 1998.

15.1.2.3 Management

This phase will follow on the results of phase 2 and steps will be taken to manage actively the archaeological deposits located by the survey. In some cases sites may not be preserved *in situ* for a variety of reasons including poor existing preservation of organic materials. In these cases the aim will be "preservation by record" and the site will be excavated either whole or in part. Due to the finite nature of the archaeological resource, however, the preferred option is "preservation *in situ*" where possible with the full backing of local people keen to see their archaeological heritage preserved.

15.1.3 Problem identification

It was apparent during the research design stage of the "identification" phase that a number of problems would need to be solved if the project was to achieve its objectives. The aim was to keep costs to a minimum and to try and integrate as many of the solutions as possible. The problems were grouped under three headings: *Archive and management*, *Problem solving* and *Publication*.

15.1.3.1 Archive and management

In the identification phase the archive procedures, in terms of both storage and recovery, are crucial to the success of the management phase and any succeeding action. Similarly, the current interest in wetlands from several perspectives represented by different agencies, may involve the need to incorporate new types of information within the archive. An example of this may be the integration of ecological data for the regeneration of peat bogs from English Nature who are concerned with the ecological aspects of conservation. As a result, archiving procedures have had a high priority in the design of this project and, at an early stage, it was apparent that a flexible system would be needed which could combine many strands of data from a variety of sources keyed to a 1:10,000 map base which forms the basis of all field recording.

The principal source of data is, obviously, the result of the archaeological and palaeoecological survey which are recorded in the following formats:

1) *Site and landscape data recorded on 1:10,000 maps.* This is the principal form of recording for land-

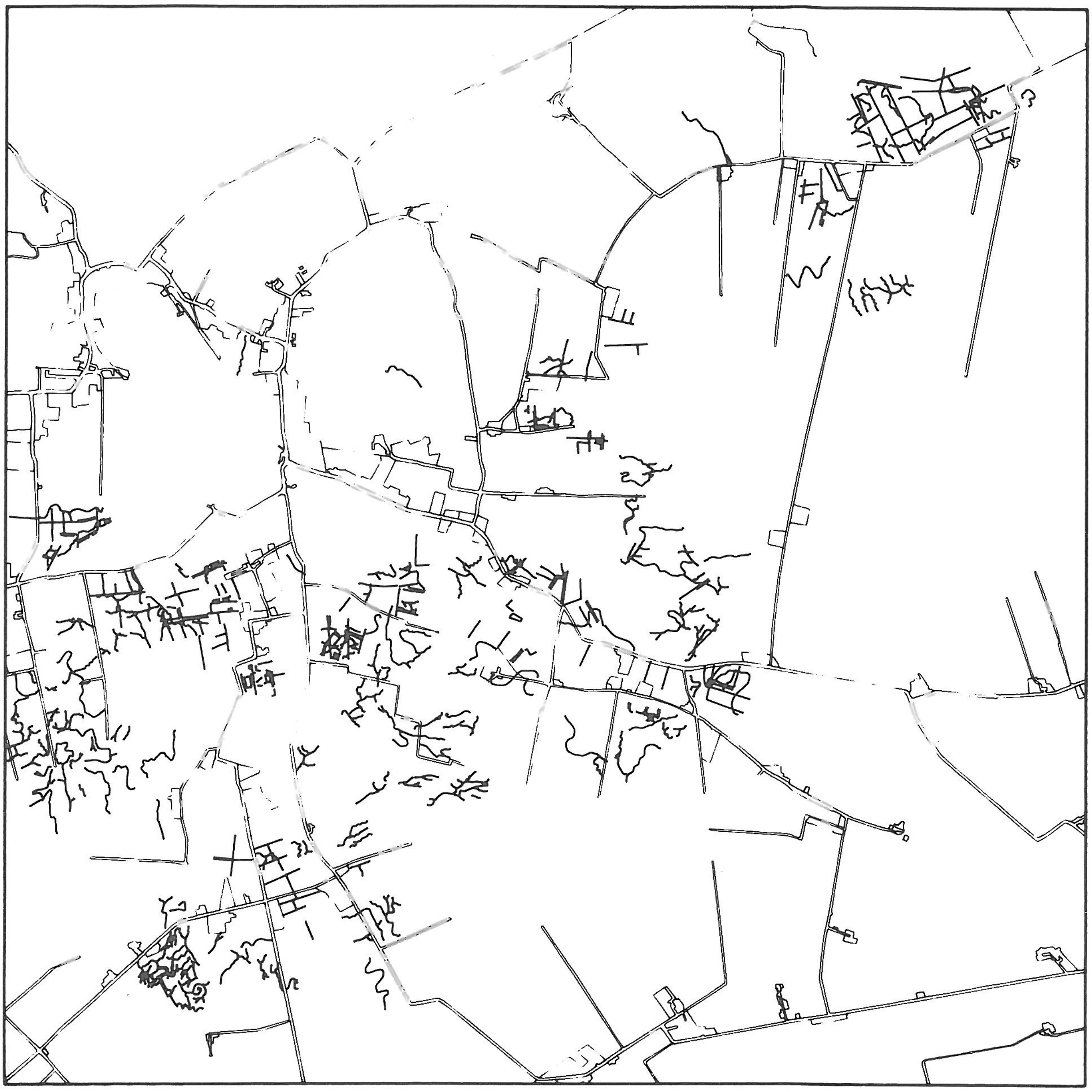

Figure 15.2: A sample of the initial survey area in Lancashire showing features plotted from aerial photography on a simplified base map.

scape features such as site location, estimated peat depth, modern land–use and archaeological visibility in areas of fieldwalking. This data, which is recorded on map extracts in the field, is transcribed onto overlays for a standard 1:10,000 map. Included in this category are data relating to aerial photography in the survey areas which is also output at the same scale.

2) *Site record sheets.* Standard forms recording site attributes such as location, nature of material discovered, topography, etc., as well as forms recording inspection data gathered from sites visited in the course of developments in peat areas, which record peat depth and stratigraphy as well as archaeological features.
3) *Pollen and macrofossil data sheets.* Recording the counts for different taxa at macro and micro scales of plant remains analysis. These can both be the detailed records of a specific coring point or may relate to data gathered during the rapid stratigraphic analysis of large areas of peat. This data has a temporal element with the C–14 dating of the principal palaeoecological sequences, to which the rapid transect data is related.

4) *Site specific records*. Where excavation has been undertaken, the site records, comprising plans, sections and the written site archive, will also be included.
5) *Other Information*. This includes data from old maps which shed light on the modern landscape, and factors affecting archaeological visibility. Also included here is the pre–existing archaeological data for the region that was compiled in the first, "Initiation" phase of the survey.

An archival system was required which permitted these several "layers" of data to be combined on a 1:10,000 map base such that data concerning site and landscape management can be retrieved in any form or scale required. Similarly there will be a requirement for data to be output for storage in local Sites and Monuments Records (the county–based records of all known archaeological sites) in a variety of formats to suit local needs. Data input and output may also be required for use by other authorities involved in the management of wetland in North–west England. This point emphasises that any such system would need to be flexible in both input and output, with continuations of the project in the management phase providing new data that would have to be incorporated into the project archive.

15.1.3.2 Problem solving

The principal academic objective of the project was to provide a framework for the explanation of human activity in and around the wetlands of North–west England in the past through archaeological and palaeoenvironmental studies. In order to achieve this, any system used would have to be able to manipulate the extensive data sets outlined above, to provide meaningful and useful output.

In the initial project design, importance was placed on the integration of the archaeological and palaeoecological data at both the data collection and manipulation stages. In particular, methods were required which permitted the manipulation of large, multi–layered paleaoecological data sets which contain many related strands of data referring to single points in the landscape. In some cases, this data may refer to an archaeological site either directly through analysis of excavated deposits or to an unexcavated ploughzone site. There had to be a capability for this data to be analysed effectively to determine patterns of vegetation change both spatially and temporally. The scale of change will vary according to the questions being asked of the data, whether on a regional scale by the analysis of pollen, or mapping locally variable bog surfaces by macrofossil analysis.

In a similar manner, the archaeological data must be capable of analysis which permits both inter–site comparisons across the landscape and intra–site comparisons between deposits on a particular site. Comparisons would also be made between sites in one hydrological system and those in another, across unsurveyed areas. The bases of comparison would range from details of site topography, elevation and relationship to peat, to the individual artefact level.

The implementation of GIS provides a means to facilitate archaeological explanation and to document change in human societies in the lowland peat of North–west England within their continually changing environment.

15.1.3.3 Publication

Another essential component of the project was the need for both swift publication and the provision of usable, digested data for use in the management phase. The format decided upon was a series of archaeological "period maps" which reflected the changes in human settlement mapped within its contemporary environment, supported by a narrative text.

The period maps require the several sets of data outlined above to be overlain upon base maps of modern features within each survey area. These maps have to be absolutely consistent in terms of presentation and scale across the project from the smallest basin mire to the largest raised bog. The complex nature of much of the data also required a lead–in time to establish correct procedures and format for data presentation. The multi–stranded nature of the project also required the data to be updated, if necessary, relatively close to the date of publication.

15.2 SYSTEM DESIGN

These requirements for a system that could:

1) be the project archive
2) act as a principal tool in problem–solving, and
3) provide a means for the publication of period maps

led to the installation of a GIS system that will be capable of all three of these important operations. A detailed project design was written incorporating GIS as a fundamental part of the project. Once the decision to use GIS was taken in principle, it remained to select the system most suited to the project needs.

15.2.1 Software

In terms of software, there were five specific issues that needed to be addressed:

1) The power to amass and analyse effectively the vast body of data that would be produced as a result of the project.
2) The capability to handle very detailed small–scale mapping of a large geographic area.
3) The production of maps with a "conventional" appearance for publication aimed at a wide audience.
4) Compatibility, in terms of both input and output, with as wide a variety of data formats as possible, to allow data transfer to and from other sources and bodies.
5) Cost effectiveness in terms of capital outlay and running costs in comparison to traditional methods.

It was felt that a vector, rather than a raster–based system would most successfully fulfil the first three criteria. Of the software packages available, the ARC/INFO system, produced by Environmental Systems Research Institute (ESRI), combined power and flexibility with the ability to utilise many different data formats (ESRI 1989, 1990). Its availability through the CHEST (Computers in Higher Education Software Trust) scheme, for the cost of an annual licence fee, also made it economically feasible.

The ARC/INFO system has a modular design with related functions grouped together within a number of subsystems. These include the following:

1) ARC — This is the main program environment. It allows access to the other subsystems and provides functions for data conversion, co–ordinate projection and transformation, digitising, editing and error identification, as well as data management and analytical operations.
2) INFO — Provides a relational database manager.
3) ARCEDIT — A graphics and database editor.
4) ARCPLOT — Allows interactive production and query of maps.
5) TIN — Analysis and display of Triangular Irregular Network terrain models.

15.2.2 Hardware

15.2.2.1 Platform

The next decision was to determine the most suitable platform for the software. ARC/INFO is available in a number of versions for Prime computers, DEC VAX, Data General, IBM mainframes, Sun and UNIX workstations and IBM PC–AT and AT compatibles using MS–DOS. As Lancaster University has taken its VAX out of service, the only possible platforms were either a workstation or PC. It was felt that the greater power, speed and flexibility of the former more than outweighed the increased initial costs and justified the initial outlay. Another consideration is that the PC version of ARC/INFO is more restricted than the full versions, and has limitations on the numbers of features per coverage, arcs per polygon, vertices per arc and the number of selection files. This has implications for the merging of individual 1:10,000 scale coverages to form new, "regional" coverages.

The final choice was of a Sun SPARCstation 1+ with a 104 Mb system disk and a 16 inch Sony Trinitron colour graphics monitor, together with a graphics accelerator board for increased performance. Additional disk space is provided by a 669Mb SCSI disk housed, together with a 150Mb tape drive, in an external storage module. ESRI's decision to optimise Version 6 of ARC/INFO for the Sun workstation has confirmed the suitability of this choice.

Advantage was taken, however, of the PC version, and the PC ARC/INFO Starter Kit, comprising the digitising system, together with functions for building topology and creating verification plots, was installed on an existing Opus PCV 386 machine in order to use it for data capture, thus freeing the Sun for editing and processing work.

The Sun is currently connected to an Ethernet network allowing access to a number of other graphics packages running on a mainframe under UNIX. It also takes advantage of the campus–wide system of automated dumps to provide data backups. The networking of the data capture machine in the future will decrease the transfer time of coverages to the Sun, currently carried out using Kermit.

15.2.2.2 Peripherals

Paper maps are converted into digital form using a TDS/Numonics Accugrid A0 digitising table with a sixteen button cursor. Hard copy maps and plots are output to a Hewlett–Packard DraftMaster SX eight pen plotter which is capable of producing plots in any size up to A0, on paper or film, using a variety of pen and ink types.

15.2.2.3 Training

After the initial expense involved in purchasing the equipment, it was felt that the additional cost of training was justified in terms of efficiency. This involved a five day introductory ARC/INFO course that provided a grounding in the basics of the system.

15.2.3 Strategy

As described in the first part of this paper, it had been decided at an early stage that all data should be keyed to the Ordnance Survey 1:10,000 map base. The total number of sheets required to cover all areas of wetland in the study area is approximately 240. Given the scope of the project, it was considered important to test some of the capabilities of ARC/INFO in relation to specific project needs and adopt a workable strategy encompassing data capture, database modelling, and presentation of results. To this end a trial area, encompassing six OS 1:10,000 map sheets, and combining a full set of results from field walking, peat depth data and detailed palaeoenvironmental analysis was selected.

Experiments with the test data suggested that it was not feasible, as originally intended, to digitise a complete OS base map coverage for the entire survey area. It takes approximately one week to digitise each 1:10,000 sheet together with any survey data, which gives a time scale of around five years for the digitising programme alone. This does not include any time for the analysis or presentation of results.

The other available option was to actually buy the Ordnance Survey digital data. Unfortunately this would have involved a capital outlay of approximately £30,000 which clearly is not feasible in this context.

The financial implications of using a full set of OS data led us to rethink the precise requirements of the project in terms of the GIS. Consequently we developed a strategy, outlined in some detail below, which involves a simplification of the OS data to suit project needs in respect of the archiving, analysis and presentation of results.

15.2.3.1 Data capture

For each mapsheet the spatial features are separated into layers representing different strands of information, these layers are then digitised to form separate thematic coverages. The 1:10,000 overlays of survey data are similarly converted into digital form.

The process of data simplification means that modern topography for each map is represented by a "roads" coverage, containing roads, settlements and farmsteads, a "drainage" coverage containing the principal features of modern drainage, both natural and artificial, and a "contours" coverage with contour lines and spot heights. The first two provide a visual reference as well as forming the basis for future analysis, whilst the third will be used to create a Triangulated Irregular Network (TIN) model for each wetland area.

Wetlands survey data is represented by peat distribution and depth coverages (Figure 15.3), modern land use polygons, often updating OS data, and field condition polygons specifying prevailing light and weather conditions, together with direction of field walking. Point data, including archaeological sites and find spots, together with the location of peat–coring sites, are represented on separate coverages.

The features identified by aerial survey are converted into either line or polygon coverages, depending upon their morphology. Currently all information from aerial photographs has to be re–digitised for entry into ARC/INFO, however, Version 4.11 of the Bradford Aerial program will allow direct input using DXF files.

The original method required all features, including field boundaries, on the Ordnance Survey base maps to be digitised. However, this is often extremely time consuming and prone to inaccuracy. By restricting such detailed work to the area that was physically surveyed, digitising time is significantly reduced, particularly where the wetland area forms a small proportion of a 1:10,000 mapsheet.

This strategy is applied to individual areas of major wetlands interest. All coverages for each area are edge–matched using the chequerboard method in order to distribute the amount and effects of adjustment evenly across the area, reducing inaccuracy due to distortion, and decreasing the amount of processing time required. They are then transformed into real–world units using National Grid co–ordinates.

15.2.4 Raster–scanned maps

A complete series of raster–scanned 1:10,000 scale maps for the study area were provided by English Heritage. ARC/INFO allows these to be registered to our transformed coverages and then viewed in conjunction with them using the Image Integrator in ARCPLOT and ARCEDIT. They provide a very effective mean of displaying information on the screen, and also allow minor digitising errors to be easily rectified on–screen using a mouse as the co–ordinate input device. It is unfortunate that revision 5.0.1 does not allow more integration of raster and vector data, and restricts hard copy output to screen dumps.

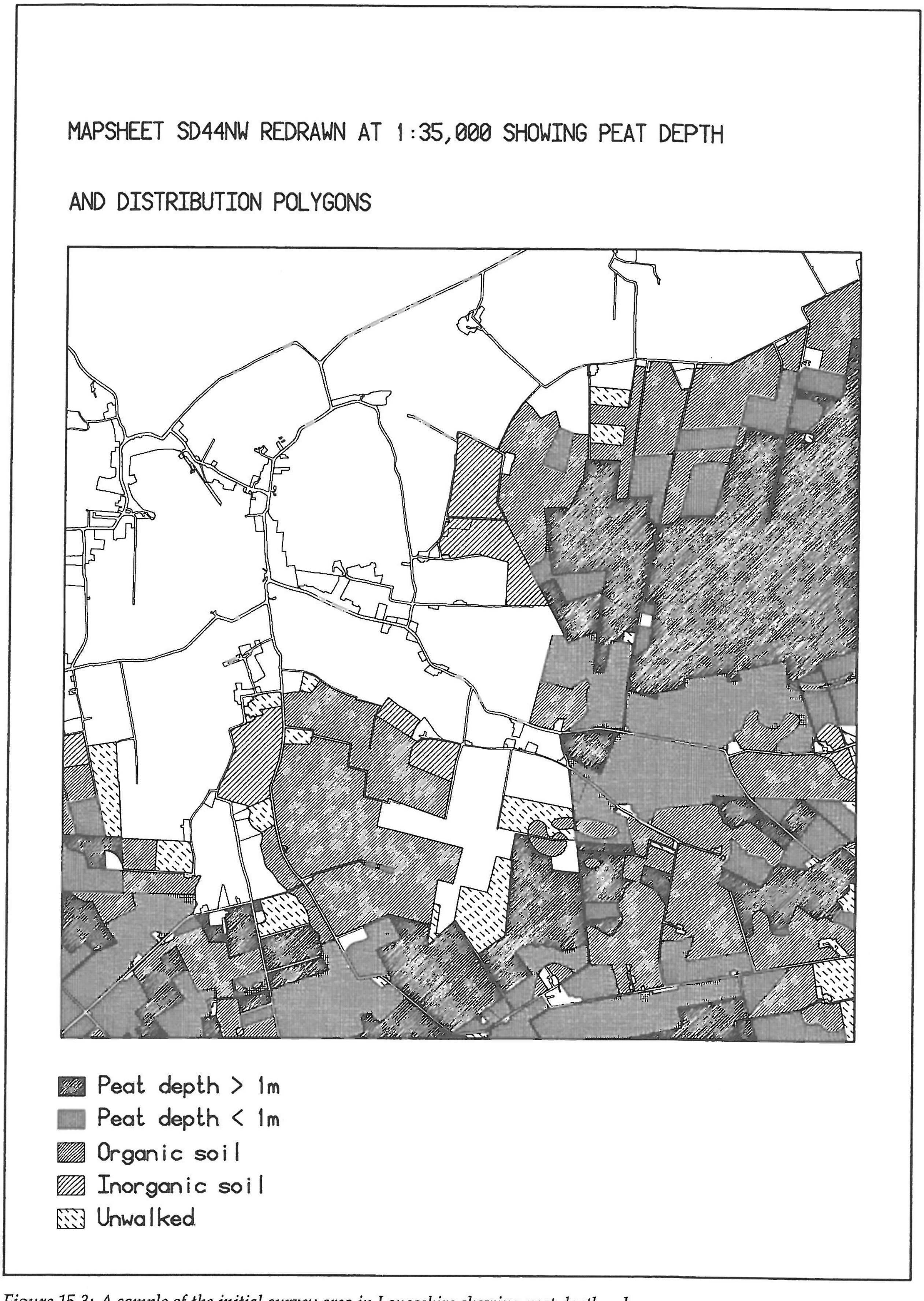

Figure 15.3: A sample of the initial survey area in Lancashire showing peat depth polygons.

For archive purposes the vector coverages are stored at 1:10,000. For analysis and publication, the individual coverages are appended to form larger coverages and the boundaries between adjacent polygons with the same attribute values dissolved. Updates are then carried out using a "cut and paste" function.

All maps for publication in the final volume for each county are to be produced in loose leaf form at a standard scale (currently planned as 1:25,000). In the case of the larger wetland areas this will require a further subdivision, not contingent with the original 1:10,000 sheets, in order to minimise publication costs. This will be achieved using the ARC "split" function to divide the area into a number of tiles based on publication requirements.

15.2.3.2 Database

All database functions during the initial trials on the test data, were carried out using INFO. In cases where it was a straightforward matter of simple, tabular attributes attached to a single spatial feature, INFO worked very well. However, a number of problems arose with the palaeoenvironmental data derived from coring sites. Each of these sites is described by a series of straightforward attributes, but each also has a core "profile", with a further set of attributes, this time relating to a series of depth bands, attached to them. INFO's handling of relational joins, notably the fact that one–to–many correspondence is not supported, means that a very complex series of relates, involving a duplication of data, would need to be set up in order to access this data. This has obvious cost implications in terms of staff and computer processing/system time. The limitations of INFO in this respect mean that an additional database must be used. At this stage ORACLE seems the most likely choice. This would provide some degree of compatibility with the Sites and Monuments Record, and with national bodies such as the Royal Commission for Historic Monuments. It would also take advantage of the ARC/ORACLE interface that is currently available.

15.3 CONCLUSIONS

The GIS outlined in this paper was selected as a response to a series of specific problems identified in the earliest stages of the North West Wetlands Survey. Its implementation has necessitated new practices and procedures to be devised in data recording and capture and database design. The implementation of the system is at an early stage and, at the time of writing, has been used to capture, manipulate and output data from a test area of survey work. The success of this stage has proved sufficiently convincing for the system to be fully implemented to cover all the survey area and the wide spectrum of data sources outlined above. It is anticipated that this will prove extremely beneficial to the project as a whole with the adoption and development of strategies aimed at a successful integration of fieldwork, analysis and publication.

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