Database Design, Archaeological Classification and Geographic Information Systems: a Case Study From Southeast Queensland

James Reginald Smith (BA Honours)

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Statement of originality

The work presented in the thesis is, to the best of my knowledge and belief, original and my own work, except as acknowledged in the text. Furthermore, the material presented herein has not been submitted, either in whole or in part, for a degree at this or any other university.
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Chapter One

INTRODUCTION

Thesis aims
The genesis of this dissertation lies in my initial forays into the world of Geographic Information Systems (GIS) and the frustrations encountered when trying to extract information from the local State Government’s digital database and Site Index. The Environmental Protection Agency (EPA) (Queensland Department of Environment and Heritage) is the statutory body which oversees all heritage related matters in the Australian State of Queensland. The legislation it administers is the Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987. Landscapes Queensland refers to those areas of Queensland that have been or are being used or modified by human actions and that are significant from an anthropological, cultural, historical, prehistoric or social perspective. The Queensland Estate refers to those areas or features of Queensland which exhibit evidence of human occupation which is at least 30 years old. Under this act the EPA is the primary custodian of all heritage and archaeological information. As such, the management of this information within a controlled environment should be a primary task of the EPA. As will be shown this is not the case.

I was “seduced by the glitz” (Limp 1996) of GIS when I first began this thesis, although I could also see the potential of GIS as a tool for both research and management archaeologists (e.g., see Smith and Hall 1996). However, as the seductive glitz faded I began to develop an interest in the foundations on which the success or failure of a GIS-based project must ultimately rest: the database underpinning the system.
Thus the thesis aims to provide both research and management archaeologists with an Archaeological Information System (AIS) (Arroyo-Bishop and Zarzosa 1995:43) for analysing, recording, storing and managing baseline archaeological data in a digital environment. In doing so, it demonstrates how the generation of a well-founded knowledge base enhances both baseline quantitative and comparative analyses in a manner not currently possible. These aims are achieved by

1. examining the logic underpinning the relational model of data,
2. examining the rationale for employing a conceptual-level schema when designing a relational database,
3. comparing and contrasting two popular methods employed in database design and my rationale for using Object Role Modeling (ORM),
4. critically evaluating and highlighting the flaws in the present classificatory system used by the Heritage Branch,
5. presenting a new classification system based on components and attributes,
6. broadly defining GIS and discussing its present use in archaeology including the theoretical and technical issues facing archaeologists who employ this technology, and
7. using examples from Bribie Island, Southeast Queensland, to demonstrate that a better understanding of the baseline archaeological record may be obtained by employing a well-designed relational database in conjunction with a GIS and descriptive classificatory system.

Rationale
If the full potential of any GIS program is to be realised and the information retrieved both accurate and reliable, it must be underpinned by a database that is free from logical and factual inconsistencies (Halpin 1995:27). A logical inconsistency would occur if a database accepted that a country had two capital cities, or that one archaeological site had more than one identification code. Factual inconsistencies occur when incorrect data is entered into the database (e.g., Canberra is the capital city of the USA, or a site containing shellfish is
recorded or entered as a scatter of stone artefacts). While the onus for eliminating factual inconsistencies is primarily conditional on accurate data entry and/or recording, eliminating logical inconsistencies depends upon the data model’s accuracy.

*When we design a database for a particular application, we create a model of it. . . .To build a good model requires a good understanding of the world we are modeling, and hence is a task ideally suited to people rather than machines. The main challenge is to describe the universe of discourse clearly and precisely. Great care is required here, since errors introduced at this stage filter through to later stages in software development, and the later the errors are detected the more expensive they are to remove (Halpin 1995:5).*

Building a reliable data model requires a thorough understanding of that aspect of the world being modeled. For archaeologists this world is the archaeological record and it is at this point that the Heritage Branch database and Site Index Form come to the fore. Archaeologists working in Queensland record site data on a form which is then transferred to the Heritage Branch database, the primary source of baseline information for cultural heritage managers, consultants and researchers. However, the database contains numerous factual and logical inconsistencies because the classification system used on the Site Index Form (and consequently in the database) does not accurately model the archaeological record. Furthermore, the Database Management System (DBMS) employed is a relic dating to the formative years of personal computer software and contains little of the functionality found in contemporary DBMS.

Despite the fact that Australian archaeologists are showing an increasing reliance on digital databases for storing, managing and manipulating their data, the subject of data modeling rarely appears in Australian archaeological literature. Likewise, references to the classification of the archaeological record are scarce and the results of this lack are exemplified by the Heritage Branch database and the Site Index Form. As this position is no longer tenable, this thesis may be viewed as one which takes up the challenge issued by Johnson some 20 years ago:
I believe that there is an urgent need for a systematic rethink of our attitude to the collection, recording and exchange of data. We are now in a situation of rapid expansion, not only in numbers of archaeologists but in the quantity of data being generated. Unless [this] raw data is made available to other workers much of the potential of the site is wasted, reducing inter-site comparison to broad generalities. We are in a unique situation in Australia in that archaeology is still a young and expanding subject and it is still possible to have at least occasional contact with the whole of the archaeological community. As the archaeological community expands and the backlog of unpublished and uncatalogued material grows inexorably, it becomes more and more difficult to get hold of the data relating to a particular topic (Johnson 1979:184).

Following Johnson, I argue that if Australian archaeologists are to have confidence in their data, classificatory issues can no longer be ignored. If the issue was urgent 20 years ago, where does it stand today? Surely after two decades of inactivity problems in the classification system must be addressed and addressed in conjunction with those issues relating to data modeling and the newest tool in the archaeologist’s tool kit, the GIS. Failure to do so will result in growing confusion for management and research archaeologists as they will no longer have any idea of what they are trying to protect, how to protect it or how similar research projects may dovetail.

In other words, management archaeologists in Australia generally operate within a framework that does not support the accurate assessment of variation in the distribution and nature of the archaeological record. This situation exists because their data sets are often corrupt and this corruption is often driven by the classification system employed. Thus management decisions tend to be arbitrary and the interpretation of available data is generally dependent “upon the experience and inclination of the management archaeologist” (Witter 1992:276). While experience may play a role in the decision-making process, such decisions must be objective and independent of the archaeologist’s inclination.

Likewise, research archaeologists undertaking regional projects are often frustrated in their efforts to obtain comparative data due to the often disparate methods employed by others
to record sites, the results of which are subsequently stored on the Heritage Branch
database. This disparity includes properties of the archaeological record itself and
contextual data such as site formation processes and physical environment factors.

If reliable models of prehistoric human activities are to be developed and plans initiated to
manage those aspects which exemplify these activities, they must be founded on a
knowledge base that allows both quantitative and comparative analyses to be undertaken
with a high degree of confidence in the data employed. Furthermore, the steps followed to
arrive at these models must be underpinned by a logical framework that both guides the
analysis and allows others to replicate the results. These ideas are not new and can be
traced back to at least the mid-1940s, well before Johnson's plea and the employment of
computers by archaeologists. Brew (1946, cited in Cowgill 1967:48-49) argued there was
more to "good archaeological classification than a certain intuitive astuteness as to which
things go together and which things are best put into separate categories." This call was
repeated in the early 1960s by Green, following the introduction of digital data banks to
archaeology: "The advent of the electronic computer is about to rupture [the] old wall of
practical limitations and open a whole new era in archaeological investigations" (1967:34).
In this new era archaeologists envisaged they would be able to access a regionally
networked computer system to seek data relating to their research. This data could be
stored off-line for future reference, or rejected and the search continued (Green 1967:35-
38). In conclusion Green argued that employing computers in archaeology could result in
"a renaissance of thought that will add patterns to the whole fabric of anthropology never
before conceived by either ourselves or our colleagues" (1967:36). The key to such a system
however, would be a standardised cataloguing system for the recording of data (Green 1967:35-36,
emphasis mine).
The importance of a solid classification system was also recognised by other archaeologists. For example, Cowgill (1967:48) argued that comparative analysis was often "needlessly spotty and inconclusive" and that regardless of computers, for real progress to be made in the comparative area, "a great clarification and standardisation of the concepts and terms used in archaeological description and classification" was required (Cowgill 1967:48, emphasis mine). However, the use of computers would not enforce greater rigidity on standardisation (as suggested by some archaeologists) but rather allow for greater flexibility (Cowgill 1967:49).

I entirely agree with this argument and demonstrate that by employing a descriptive, replicable classification system in conjunction with a well-designed database and GIS it is possible for management and research archaeologists to gain greater data retrieval flexibility and thus develop a greater understanding of the archaeological record.

**Background to this research**

This section places DBMS, GIS and archaeological classification within an Australian context. It does so in two different ways. In the case of DBMS and GIS it provides an historical overview of the development of these aspects in Europe and North America in relation to what has occurred in Australia. For classification the position taken tends towards method and theory.

**Databases in archaeology**

The feasibility of employing databases for storing and managing archaeological data was first recognised during the early to mid-1960s in Europe and North America. However, it was not until the late 1960s that the first attempts to design and implement archaeological databases were made. By 1967 Chenhall (Scholtz and Chenhall 1976) had developed a database framework that allowed for the recording of descriptive attributes relating to sites, features and artefacts. These attributes included function, form, material, manufacturing,
technique, surface treatment, design and location. With funding from the Arkansas Archaeological Survey, testing of this database structure began ca. 1970 using the Museum Computer Network (GRIPHOS) (Scholtz and Chenhall 1976:90). Initially designed to use a general computer file containing all the data relevant to one artefact, feature or site, modifications to this system in 1972 resulted in the creation of separate files to record different data types (e.g., a site file, a pottery file and a human remains file) (Scholtz and Chenhall 1976:90-96).

In Britain, during the early 1970s, a number of museums began placing their catalogues on computers using a format proposed by the Information Retrieval Group of the Museums Association (IRGMA) in late 1960s. Initially designed to employ one centralised database containing all United Kingdom museum records this format was abandoned in 1971, and emphasis was placed on creating individual systems to meet local requirements. While primarily intended for museum use it was hoped the system would also be employed by field archaeologists. To this end, an archaeological data recording form was designed to conform to the IRGMA software (Lock and Wilcock 1987:20-22; Wilcock 1981).

Likewise, in 1970 the Arizona State Museum began planning a database for recording archaeological site survey data. Allowing for the manipulation of various data types including that relating to cultural resource management, survey budgets and archaeological hypothesis testing, AZSITE came on-line in 1979 and by the early 1980s had become both an important research tool for archaeologists and a central data source for southern Arizona prehistory (Reiger 1981).

At the same time, archaeologists were also investigating the use of computers to assist in managing excavation data. One example of this type of application was the Koster Project Information Retrieval Application (Brown et al. 1981). Developed to provide a rapid and reliable method for managing excavation data at the Koster site in Illinois, it successfully
accomplished "high priority data processing tasks in order to resolve field stratification problems, to organize materials for specialized lab analysis, and to enable efficient sampling of flotation samples for each horizon" (Brown et al. 1981:78-79).

Like other early applications, the Koster system was designed to service a particular project, and following the project's completion the system was retired. However, in British Colombia during the early 1970s, a more generic system was developed (Loy 1974). The Glenrose system comprised two phases aimed at providing archaeologists with a cost-effective and timesaving tool that would allow for the storage and manipulation of a variety of excavated data types. Phase I involved recording field and laboratory data on forms designed to facilitate data entry and entering this into the system, while Phase II concerned the statistical manipulation of the data. The application was flexible and not limited to any one theoretical viewpoint or any particular type or amount of data (Loy 1974:68).

The use of remote terminals was a final development in archaeological databases during the early 1970s. Remote terminals at field sites allowed archaeologists to access mainframe computers through telephone lines and process their data. One example of this approach was pioneered in Arizona in 1971 (Gaines 1981). Developed to assist with the recording of excavation and survey data, the ADAM (Archaeological DAta Management) (Gaines 1981:80) system comprised three parts:

1. programs for data input and verification and daily report generation,
2. programs for sorting, merging, indexing and storing data, and
3. programs to analyse the data and prepare reports of the analysis (Gaines and Gaines 1980:468).

By employing a remote link, data could be rapidly processed, thus providing field archaeologists with information on a day-to-day basis. Overall, "the use of a properly
programmed computer accessed from a field location made a substantial contribution to the daily tactical decisions and was of significant value as a research tool" (Gaines 1981:89).

Australian archaeologists did not participate in this formative period of archaeological database development. While the reasons for this lack of participation are somewhat obscure, I suggest the following may have contributed. First, archaeology was overshadowed by anthropology until the mid- to late 1970s in Australia. Second, the questions being asked by Australian archaeologists were less complex than those asked by their overseas counterparts. Third, there was a relatively small number of sites recorded on the various State and Territory registers.

Despite the development of anthropology and archaeology as distinct disciplines in the latter part of the nineteenth century (Daniel 1967:126), the anthropologists were the first to focus on Australia. As nineteenth century anthropological theory suggested cultural evolution was linear the Aborigines of Australia were seen as representing Neolithic or Palaeolithic humans (e.g., Tylor 1881). Therefore, “why dig up remains when the living fossils were there to be inspected” (White and O’Connell 1982:23)? Such notions placed the study of archaeology in Australia somewhat in a backwater as most research was ethnological. It is thus not surprising that the first archaeologist was appointed to the University of Melbourne in 1953 (White and O’Connell 1982:20) and a further 12 years lapsed before the first Ph.D. in Australian prehistory was awarded (White and O’Connell 1982:20). By 1980, however, archaeology as a discipline had gathered considerable momentum with courses in prehistory available in eight universities, and by the mid-1990s this number had almost doubled.

While Australian archaeology was just developing, almost 100 years of research in Europe and North America had resulted “in a complexity of questions that necessitated inquiry and selective extraction of logically related items from a large range and diverse body of
information” (Gaines 1981:vii). This fact provided impetus for experimentation in digital databases. In comparison, Australian prehistory had developed no such body of information and in 1980 it was suggested that

...only in a few restricted areas of the continent... have we even got to the situation where simple questions as to the antiquity of human occupation and the main outlines of environmental change have been resolved, even if we restrict ourselves only to the past 20-25000 years, without taking cognisance of the ever dropping date for human occupation of the continent, which like a falling trap door, is revealing yawning depths beneath the false security of rope-bound theories (Jones 1980).

As late as 1994 there were still many areas of Australia “where even the basic outlines of human occupation and environmental change [had] not yet been addressed” (Rowland et al. 1994:23).

While the amount of data accumulated overseas may partially explain the drive towards the use of digital databases, the growth of Cultural Heritage Management (CHM) must also be considered. While the precursors of modern cultural heritage management date to the mid-1600s (Cleere 1989:1) it was only in the latter half of the twentieth century that heritage management, in the form of salvage excavation, was viewed as an essential aspect of economic and social planning (Cleere 1989:2). CHM gained a further boost during the late 1950s and 1960s when development became the major theme of world economics (Cleere 1989:2). In the mid 1970s, despite a decline in this growth, the pressures of development had grown to a point at which

extensive construction activities in many areas and the concomitant, often overwhelming, need to both rapidly and accurately assess the significance of a great number of impacted archaeological sites have also increased the need for methods to process these large and ever expanding data sets. Response to [this pressure] by many institutions [was] the adoption of computerized information retrieval systems for archaeological survey data. ... Rapid access to these large data sets makes it feasible to evaluate archaeological questions on a broad scale in ways totally impossible in the absence of an effective retrieval system (Limp and Cook 1981:57, 66).

While Limp and Cook were primarily referring to the USA, a similar situation was developing in Britain. The process of transferring the 46 county-based Sites and
Monuments Records (SMRs) from paper files to computerised databases began in the mid-1970s (Lock and Wilcock 1987:23). Chadburn (1989:9) described this transfer as “a significant achievement for the archaeological profession, as it [allows] informed decisions to be made about our cultural heritage, and provides a tool for a range of activities such as education, research, and planning.”

CHM in Australia developed out of a desire expressed by archaeologists to mitigate the impact of development on the archaeological record. During the 1940s New South Wales became the first Australian state to attempt protective legislation for archaeological sites. However, it was not until 1957 that the first piece of protective legislation, the Native and Historical Objects and Areas Preservation Act 1955-1960, was introduced in the Northern Territory (Ward 1983:21). In May 1969 the Queensland State Government introduced the Aboriginal Relics Preservation Act and in 1971 the Archaeology Branch of the Queensland Department of Aboriginal and Islander Affairs was established to administer this legislation (Rowland 1989:266). By 1974 all Australian States had passed similar legislation and created departments to administer such legislation (Ward 1983).

Despite such legislation and the appointment of administrative bodies to manage the archaeological record, no immediate plans appear to have been made to employ digital databases to store and manage the incoming data. Even in 1986 the primary tool for storing and managing State site registers in Australia was the filing cabinet, although digital methods were being either examined or implemented (Johnson 1989:146-148, 153). While reasons for not employing digital databases are unclear, I suggest a lack of vision and enterprise on behalf of the administrators.

The relatively small number of sites recorded in each Australian state (particularly when compared with those recorded overseas) must also be taken into consideration. In 1986 a total of 41,800 archaeological sites appeared on the registers of the various Australian State
administrative bodies (Johnson 1989:145) (Table 1.1). Compare this number with the National Archaeological Record database in England which contained records for some 140,000 sites in 1989 (Hart and Leech 1989:57). Likewise, the Sites and Monuments Records (SMRs) of the Greater London County was expected to contain some 65,000 records in 1991 (Jones 1989:35). In 1995 England's 46 SMRs were estimated to contain more than 650,000 records and this was expected to increase to over 1,000,000 early in the twenty-first century (Darvill 1995:1). In the USA the Arizona State Museum Site Survey Database contained some 12,000 records in the early 1980s (Reiger 1981:30). Likewise, in 1979 the Glenn Black Laboratory of Archaeology at Indiana University database contained data on 4000 sites (Limp and Cook 1981:57). In sum, these numbers indicate that the total number of sites recorded for Australia was considerably lower than that overseas at roughly comparable times.

Table 1.1 Number of sites on State registers in January 1986 (after Johnson 1989:145). (N.B. In 1989 Queensland's total had increased to ca. 5600.)

<table>
<thead>
<tr>
<th>State</th>
<th>Number of Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queensland</td>
<td>2,600</td>
</tr>
<tr>
<td>New South Wales</td>
<td>14,000</td>
</tr>
<tr>
<td>South Australia</td>
<td>4,000</td>
</tr>
<tr>
<td>Tasmania</td>
<td>3,500</td>
</tr>
<tr>
<td>Victoria</td>
<td>7,700</td>
</tr>
<tr>
<td>Western Australia</td>
<td>10,000</td>
</tr>
<tr>
<td><strong>Total on State registers</strong></td>
<td><strong>41,800</strong></td>
</tr>
</tbody>
</table>

The advances made in archaeological database management were timely for overseas heritage managers and researchers as they occurred when rapid access to data was required to assist in decision-making processes. On the other hand, Australian archaeologists may have held the perception that they did not require computerised databases because the data sets were not large enough, nor were the questions sufficiently complex to warrant such.
As early as 1972 it was recognised that, like statistics, computer archaeology was “here to stay” and that computers would “rapidly fade into perspective as a means towards ends, intellectual machinery, which, as always may be employed usefully or stupidly” (Clarke 1979:77). For archaeologists in North America and Britain the 1970s proved to be a “nuts and bolts infancy” (Gaines 1981:vii) in the development of computer-assisted archaeological data management and it certainly was a period for experiment, exploration, and in some cases disaster. However, despite being faced with the “wreckage of abandoned projects and ‘active’ white elephants…we can still say that archaeological data banks are worth the effort” (Scholtz and Chenhall 1976:96). It was also during this period that the first conferences concerned with the employment of archaeological databases were held. These were at the University of Arkansas in 1971 and in France in 1972 (Chenhall 1981:1). A third conference, the Computer Applications in Archaeology Conference, began in Britain in 1973 and continues to be held annually.

The most important aspect of this period of infancy was that of learning, and not simply learning how to use computers in a mechanical sense or to write programs. Many of the archaeological data management systems designed during the 1970s and early 1980s were not actually created by archaeologists. Rather, they resulted from collaboration between archaeologists and computer experts. While archaeologists could provide the necessary details concerning the contents of the database, unlike the experts they were not generally trained in formal logic, a necessary requirement for preparing data management systems at this time (Wilcock 1981:118). By rubbing shoulders with database designers during the 1970s (e.g., Bourrelly and Chouraqui 1981; Le Maitre 1981; Limp and Cook 1981) archaeologists in North America and Europe obtained valuable insights into not only the advantages of employing computers for data storage and management but also into vital aspects of database design. Three of the most important aspects of design were as follows:
1. Data categories had to be clearly defined.

2. Databases had to be designed with a specific purpose and that purpose explicitly specified.

3. Data integrity had to be maintained by using a data dictionary to define each data category and the format for each data type, e.g., character or integer (Chenhall 1981:1-2; see also Scholtz and Chenhall 1976).

By the early 1980s in both Europe and North America the period of infancy had developed into one of adolescence, although the field was still experimental (Gaines 1981:vii). It was also about this time that archaeologists in Australia first began to investigate the advantages afforded by digital data management. Computerised data management in Australia was pioneered by Ian Johnson who describes himself as “a programming archaeologist rather than an archaeological programmer” (1979:158). A strong advocate for developing applications that would allow non-programmers to enjoy the advantages afforded by computer managed data, Johnson’s first database, like Loy’s (1974) system, was a generic application designed to facilitate the management of data recovered from excavations (Johnson 1979:158). Consisting of a number of programs, it allowed for

\[
\text{the creation of a basic excavation data file from data collected in the field (sediment and residue weights, start and end levels of excavation units, preliminary stratigraphic attributes) and subsequent addition of data collected during laboratory analysis (Johnson 1979:173).}
\]

While this application was not widely employed, Johnson’s following application certainly was. Between 1981 and 1988 he developed the MINARK (Management of INformation in ARKaeology) DBMS which was specifically designed to handle a variety of archaeological data (Johnson 1989:296). MINARK employed an indexed, flat file data structure (Ian Johnson personal communication 1996) rather than the hierarchical structure favoured by overseas programmers (e.g., Scholtz and Chenhall 1976). This structure made the program relatively easy to use as the operator did not require assistance from
programmers to enter, manipulate and extract data or to modify the structure of the database (Johnson 1989:296).

MINARK also had the advantage of being able to run on computers employing either the 8-bit CP/M or 16-bit MSDOS operating systems, rather than the machine-dependent operating systems employed by many of the mainframes used overseas (Johnson 1989:296). Thus the program and any databases could be transferred from machine to machine without modification. This and other data management and manipulation features saw MINARK become virtually the database standard in Australian archaeology. Its flexibility also meant that it could be employed to manage a wide variety of data types. Thus not only excavation data but also museum catalogues, bibliographies and survey data could be managed. MINARK was and is still used by many archaeologists in Australia to manage their data (e.g., Hall and Sale 1994:54, Waarden and Wilson 1994). It is also still used by the Queensland Government Department of Environment (Heritage Branch) to manage its Archaeological Site Register.

Ironically, it may have been the outstanding success of MINARK that served to limit development and discussion of digital data management in Australia. It is not unusual for articles published by European and North American archaeologists to discuss various aspects of design (e.g., Caelli 1978; Cheetham and Haigh 1992; Eisner 1991:38; Le Maitre 1981; Ryan 1992; Suhajda 1995), recognition of the importance of integrated software systems (e.g., Huggett 1989; Semeraro 1992), and methods for overcoming potential problems in data retrieval resulting from unsuitable vocabulary (e.g., Chadburn 1988). Also apparent in overseas discussions is a move away from specialist archaeological software to commercially available programs (e.g., Booth 1988; Chadburn 1989:16; Hart and Leach 1989; Huggett 1988; Iles and Trueman 1989; Jones 1989; Semeraro 1993; Wood 1989). Discussions of this nature are not found in Australian publications. Because MINARK
users did not require assistance from programmers, they were not concerned with questions relating to database design per se. Likewise, MINARK’s ability to operate on desktop computers meant its users were liberated from the complexities of mainframe computers and their programmers.

More recently, the increasing availability of commercially available spreadsheet applications with GUI (Graphical User Interface) and WYSIWYG (What You See Is What You Get) screen formatting have completely divorced Australian archaeologists from issues relating to database design. Applications of this type (e.g., Microsoft Excel) are considerably more user-friendly than MINARK and in the majority of cases have greater flexibility for data analysis. Unlike MINARK, however, spreadsheet software are not DBMS despite being able to effectively manage flat file databases.

Another, equally acceptable reason for the lack of database design discussion is that there were (and I would argue still are) archaeologists diametrically opposed to the use of computerised databases. These archaeologists believe their authority comes from controlling the dissemination of the data they have obtained over a lifetime of research. By making this data freely available in a digital format they believe this authority would be eroded (Wilcock 1981:119). A further negative position taken during the mid-1980s assumed that databases would either simply recreate “the dusty museum basement as a repository of unorganised and rarely consulted archives” (Ryan 1992:1) or result in the recording of “everything in sight” (e.g., McVicar 1985:102). A final perception was that computers are a magical “black box” into which data would be entered and processed and an answer to the problem provided (Figure 1.1).

While the above discussion may help to explain why Australian archaeologists have not entered into serious discourse concerning digital data management there is another, more compelling reason and one that is cause for some concern. It is simply that Australian
archaeologists do not perceive database design as being "real archaeology" (Ian Johnson personal communication 1997). Consequently, database design issues are viewed as somewhat removed from the more traditional problem-solving, "hands on" aspects of archaeology. In short, it is not "dirt" archaeology. If this is the a priori reason, then it must be explicitly recognised and reversed. It is for this reason that a major section of this thesis is concerned with providing a rationale for designing databases including a detailed overview of the data modeling method I employ in designing my own baseline database.

GIS and archaeology

As with databases, the first experiments in GIS application (or more correctly proto-GIS) to archaeological problems began in Europe and North America during the 1970s. This roughly coincides with the period when archaeologists began taking an interest in using statistics such as spatial autocorrelation and trend surface analysis to investigate patterns in the archaeological record (see, for example, Doran and Hudson 1975; Hodder 1978; Hodder and Orton 1976; Renfrew and Cooke 1979). I would not suggest that computer access was responsible for this interest in spatial analysis, as the first archaeological distribution maps aimed at problem-solving were produced in 1912 (Hodder and Orton 1976:1, citing Clarke 1957). However, there can be little doubt that access to computers to undertake the required calculations certainly provided archaeologists with a timely tool to assist in such research.
These early attempts to bring computers into the realm of spatial archaeology were often aimed at modeling or simulating artefact distributions or settlement/subsistence patterns. As Kvaamme (1995:1) suggests, such early work was both facilitated and promoted by the ready availability of SYMAP, the first successful spatial analysis and mapping application. One early example for using of SYMAP dates to 1970 when Redman and Watson employed it to “draw contour and proximal maps of the artefact distributions at Çayönü” (1970:289), a mound site in Turkey. They were attempting to test the hypothesis that the surface distributions of artefacts, including their proportions and types, were directly related to their sub surface distribution (Redman and Watson 1970:289). The site was divided into 5 by 5m quadrats and a 10% random sample undertaken. Artefact frequencies were then
tabulated for each quadrat sampled and entered into SYMAP. While not explicitly stated, it appears that the artefact frequencies obtained from each square were used as point data to produce contour maps based on a trend surface interpolation algorithm. Contemporary GIS capable of handling data with X, Y and Z coordinates can manipulate data sets of this type in a similar fashion.

Chadwick (1978, 1979) employed his own programs in conjunction with SYMAP to construct a simulated spatial model of Mycenaean settlement patterns. Using a 2 by 2km gridded base map each grid cell was encoded with a synthesis of environmental factors viewed as relevant to Mycenaean settlement. The resulting map clearly depicted those areas perceived as being attractive to Mycenaean settlement (Chadwick 1979:249) by shading them darker than those considered unattractive. An approach such as this closely resembles one aspect of modeling that a raster-based GIS may be called upon to undertake today. Indeed Kvamme (1995:2) indicates that Chadwick’s work would qualify as an “early raster GIS application” and “was quite an achievement in the late 1970s because, in terms of functionality, it represents much of what we do now with GIS.”

While these examples indicate an early interest in the application of computer software to assist in answering spatial questions there were still problems to overcome. Despite the availability of programs like SYMAP archaeologists usually had to write their own programs. Not only was this a daunting task, it also restricted the use of GIS to a few individuals or institutions (Kvamme 1995:4). Likewise, the statistical approaches employed (e.g., Hodder and Orton 1976) were not always applicable to spatial data. While spatial autocorrelation and similar statistical methods may be used to compare artefact distributions across a site, they lack “analytical or visual description. . . . An auto correlation value does not describe broadly a distributional pattern, nor does it visually present it” (Green 1990a:4). While interpolation statistics such as trend surface analysis do produce
descriptive and analytical patterns, problems arise when attempting to compare second order (quadratic) surface maps of one variable with another. Doing so requires the results being reduced to a statistic and thus the original descriptive force of the surface maps is lost (Green 1990a:4).

Green (1990b) makes some pertinent comments based on his experience with SYMAP. Following unsatisfactory attempts to investigate spatial relationships between historical grain production in Denmark and environmental factors via traditional statistical regression, SYMAP was employed in an attempt to overcome the problems (Green and Ulrich 1977, cited in Green 1990b). By statistically combining independent environmental factors through principal-component analysis and then regressing the resulting combinations to prioritise their effect on grain production, a data set was created that could be entered into SYMAP for trend surface analysis. Green (1990b:359-360) concludes:

our output was confusing, perceptually inconclusive and aesthetically horrid. . . .The results pointed more to the difficulties with solving this sort of spatial problem than to the answers. . . .To begin with we had to derive much of our data from maps, only to concoct statistical factors to be once again mapped. These statistical factors (in this case principal components) provide mathematical simplification at a very high interpretive cost. Interpretation had to be based on understanding abstract combinations of variables rather than the original down-to-earth measures of temperature, soils and rainfall etc. . . .In other words, the methodology drove us from simple to complex-and therefore to patterns that were more difficult to interpret.

It is exactly spatial problems of this nature that GIS are able to handle with relative ease.

The first true GIS program was developed during the early 1970s to meet the requirements of Canada’s Land Inventory (Tomlinson 1976). Initially developed to assist in developing aid programs for rural areas, the Canada Geographic Information System’s (CGIS) ability to handle a variety of general geographic data, including archaeological sites, was quickly recognised and utilised (Tomlinson 1976:27). Indeed, Marble (1990:12) argues that for almost two decades CGIS remained one of the most technically advanced GIS applications.
It was during the early 1980s, however, that one of the most significant developments in GIS technology occurred. This was the release by Environmental Systems Research Institute (ERSI) of ARC/INFO. Marble (1990:13) notes this release as marking the final and critical transition of GIS technology from a base consisting of non-standardized, ‘home-brew’ systems to the widespread use of a standardized industrial technology which could be adapted to a variety of spatial problems.

The use of commercially available GIS by archaeologists began slowly and was likely due to a lack of funds to purchase the Unix workstations required to run these applications (Kvamme 1995:5). However, during the late 1980s and early 1990s the employment of GIS as a tool for analysing archaeological data began to accelerate. At the 1989 International Union of Prehistoric and Protohistoric Sciences only one in 14 papers presented was on GIS compared to 1993 where almost 50% of the papers presented were on GIS. While these figures are neither independent nor necessarily representative of world trends, similar patterns are visible in other archaeological associations (Stancic 1994:74). It is interesting to note that this is not the case with Australia’s principal conference, the annual Australian Archaeological Association conference; only on rare occasions have papers dealing with computer applications in archaeology been presented, let alone GIS.

Reasons for this increase in the use of GIS by archaeologists may in part be related to the increasing power of desktop computers, the increasing popularity of Microsoft Windows as an operating system and the development of many GIS applications designed to take advantage of these factors. While some of these applications may not have the full analytical capabilities of the more powerful Unix-based programs, they are certainly capable of undertaking fundamental spatial analysis.

Like their more sophisticated relations many of these less powerful applications have their own development language, allowing end-users to design applications specific to their
requirements, thus enhancing the analytical power of the original program. One example is MapInfo and its associated MAPBASIC language. Furthermore, growing demand for these less powerful applications has seen their overall analytical power increasing through development of the application itself and/or the availability of third-party add-ons. Again, in the case of MapInfo, the 3D MAPPS add-on allows end-users to manipulate data with X, Y and Z coordinates. Despite these developments the majority of Australian archaeologists do not appear to have fully realised the potential of GIS. This is in stark contrast to their overseas counterparts.

The first Australian archaeologist to investigate the use of computers for analysing spatial data was Cribb (1986, 1987) who developed the program SITEPAK. However, this package was not employed by Australian archaeologists to any great extent. The first references to GIS in Australian archaeological literature appeared in the early 1990s (Gollan 1990; Witter 1992). While these references do not report on the use of a GIS, their authors certainly recognise the potential for GIS to be employed in a heritage management environment. The first published reference to the employment of GIS in a research project appears in the mid-1990s (Waarden and Wilson 1994). Using ARC/INFO Waarden and Wilson created sophisticated hydrological models of the Lake Condah fish-trap systems situated in western Victoria. At the time of publication the authors were able to generate a water flow model to determine not only flood-water levels required to fill each fish trap, but also the direction taken by flood waters to enter and leave the traps (1994:90). While it was anticipated that further GIS analysis would be undertaken on the fish traps, the results have yet to be published.

Another innovative use of GIS is found in Theunissen's (1995) BA Honors thesis. Employing IDRISI Theunissen was able to analyse the effects of rockshelter topography (e.g., wall shape and ceiling height) on the spatial patterning of flaked stone artefacts at
Petzkes Cave, northern New South Wales. By modeling the topography of the cave in IDRISI, Theunissen visually demonstrated via a series of experiments that topography influenced drip-line disturbance and the effects of human trampling as much as the human behavior that originally produced the patterning. He concluded that Petzkes Cave and similar cave sites were “inappropriate for the spatial study of discrete human activities” (Theunissen:1996:45).

A third application of GIS in Australian archaeology is found in Smith and Hall’s (1996) Beaudesert Shire Regional Archaeological Project. This project was aimed at investigating regional technological changes in stone artefact manufacture in the subcoastal zone of the Moreton Region, Southeast Queensland, both temporally and spatially. By mapping chronologically sensitive technological characteristics of stone artefact manufacture (Hiscock 1986, 1988) it was envisaged that spatial/temporal changes in artefact distribution would be identified. MapInfo was employed in this project to select survey areas that were located in specific environments, to manage and manipulate transect data and to plot the location of all artefacts either collected or observed. While the results, at least in terms of the initial aim, were not realised due to a lack of artefact data, Smith and Hall (1996:94) were able to conclude:

...our employment of GIS from beginning to end represents not only the first time this has been attempted for a Queensland archaeological project, but also demonstrates the power of this technology for other such regional studies. ... We feel that the project has provided at least some impetus for future archaeological study in this area with the GIS approach setting a fruitful direction for such.

While the number of Australian archaeologists using GIS is growing, little has been published. Notwithstanding, a number of archaeologists are actively involved in pursuing the application of GIS at both the research and cultural heritage management levels and there are publications in the pipeline (personal observation). Overseas the picture is considerably different.
With the acceleration of GIS-based archaeological and heritage management projects in Europe and North America during the late 1980s archaeologists began to rapidly explore this new tool's potential. Subsequently, the results of a large number of projects concerned with a wide variety of different applications of GIS to archaeological problems have, and continue to be, reported in both edited books (e.g., Allen et al. 1990; Lock and Stancic 1995) and journals (e.g., *Computer and Quantitative Applications in Archaeology*, *Archaeological Computing Newsletter*, *Internet Archaeology* and *Antiquity*). While it is not fruitful to outline every published project, it is important to note that the impact of GIS on archaeology is well recognised and sometimes heatedly debated. Topics range from cultural resource management issues to discussions concerning hardware, environmental determinism, digital elevation models (DEM) and digital terrain models (DTM). All include some discussion concerning the relative merits and advantages afforded by the employment of GIS as well as the associated problems. These issues are discussed in further detail in Chapter 6.

To date, the most successful application of GIS-based archaeological data management system is that of the state of Arkansas, USA (Farley et al. 1990; see also Kvamme 1995:5). By combining sophisticated database management, GIS, remotely sensed image processing and exploratory data analysis software, this toolbox approach provides an integrated system for both management and research archaeology (Farley et al. 1990:141). Data is available at a variety of different scales to provide both management and research archaeologists with information ranging from multi state levels of analysis to small regional scale projects (Farley et al. 1990). Farley et al. (1990:162) conclude it is neither the technology nor the tools that are of significance but rather, their arrangement into a symbiotic environment in which large amounts of disparate yet interrelated information can be assembled to address numerous management and research problems. By removing many of the more mundane comparative analytical tasks and associated multivariate data manipulation constraints “an
atmosphere is created where virtually any perceived relationship may be examined and quickly evaluated” (Farley et al. 1990:162).

**Classification**

The classification of the archaeological record is a perennial and often contentious issue. Since Thomsen’s development of the Three Age system in the early nineteenth century archaeologists have continued to define and redefine their classification systems. In Australia discussions on classification tend to focus on measures for determining site discreteness or the identification of site-type profiles. As such, there is a general consensus within the Australian archaeological community that a certain number of site types exist (Table 1.2, p:28), although they can be modified to suit the recorder’s inclination. However, this consensus does not imply that the classification system works.

The site concept dominates archaeology providing a focal point for administrative and interpretive frameworks (Robins 1993:47). Problems relating to site classification were recently highlighted in attempts to identify site-type profiles in Australia’s archaeological record (e.g., see Aiken et al. 1992; Hiscock and Mitchell 1993; L. Smith 1991; Truscott 1993). I concur with L. Smith (1991:42-43) that the terms “open site” and “open campsites” are often used to describe surface scatters of stone artefacts despite the fact that these terms could logically refer to two different types. Furthermore, not only may there be as many terms to describe archaeological material as there are archaeologists, but not all archaeologists use straightforward definitions (L. Smith 1991:43). Consider the problems that would occur if medical practitioners described diseases according to their own personal classificatory system. While this may be considered absurd, these are exactly the self-imposed conditions under which archaeologists are working. We locate a “site,” place our “learned” caps upon our heads and term the site a factory, a workshop, a tula adze manufacturing site, despite the fact that “scientific procedure requires that such categories
be...efficiently defined and made repeatable between different investigators where possible" (Williams et al. 1973:220).

A further problem relates to the identification of sites as discrete entities. Such notions have resulted in the development and growing acceptance of formalised methods for recording archaeological sites (Robins 1993:48). In other words, sites are identified as distinct entities by using quantitative or relative measures such as artefact density or a standard measurement between artefacts. For example, McNiven (1984) employed an arbitrary distance of 10m between artefacts as a measure of site in the Cooloola region of coastal Southeast Queensland (see also Robins 1983). Similarly, Hiscock's baseline study of the Naccowlah Block in Southwestern Queensland used a complex formula comprising artefact densities, artefact numbers and site area to identify sites (1985:30). Certainly such rigid approaches are problematic and are likely to result in interpretations "driven by subjectively derived criteria that may bear no relationship to the human behavior that is being interpreted" (Robins 1993:49). Furthermore, the use of formalised methods and/or "site types" is not suited to recording baseline archaeological data and thus storage in a database.

Table 1.2 Major site types recognised by Australian archaeologists.

<table>
<thead>
<tr>
<th>Site Types</th>
<th>Subtypes</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artefact scatter</td>
<td>Surface scatter</td>
<td>Scatter of flaked stone artefacts over ground surface</td>
</tr>
<tr>
<td></td>
<td>Isolated artefact</td>
<td>Single stone artefact</td>
</tr>
<tr>
<td></td>
<td>Campsite</td>
<td>As for surface scatter</td>
</tr>
<tr>
<td></td>
<td>Background scatter</td>
<td>Stone artefacts that are perceived to have a lower density than surface scatters/campsites</td>
</tr>
<tr>
<td>Quarry</td>
<td>Stone source</td>
<td>Source of stone for knapped artefacts, axes</td>
</tr>
<tr>
<td></td>
<td>Ochre source</td>
<td>Source of ochre</td>
</tr>
<tr>
<td>Grinding grooves</td>
<td>Axe-grinding grooves</td>
<td>Grooves formed by manufacture of edge-ground axes</td>
</tr>
<tr>
<td></td>
<td>Abraded grooves</td>
<td>Grooves formed by tool manufacture or food processing</td>
</tr>
<tr>
<td>Rockshelter/cave</td>
<td>Shelter with deposit</td>
<td>Rockshelter that contains unspecified cultural deposit but generally shellfish remains or stone artefacts</td>
</tr>
<tr>
<td></td>
<td>Shelter with midden</td>
<td>Rockshelter that contains shellfish remains</td>
</tr>
<tr>
<td></td>
<td>Shelter with art</td>
<td>Rockshelter generally containing painted art, although may include engravings</td>
</tr>
<tr>
<td></td>
<td>Shelter with artefacts</td>
<td>Shelter containing stone artefacts</td>
</tr>
<tr>
<td>Site Types</td>
<td>Comments</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>
| Art site            | Rock paintings
                      Rock engravings
                      Rock surface with painted, stenciled art work
                      Rock surface with engraved art
| Arranged stone/earth | Stone arrangement
                      Stone circle
                      Earthen Circle
                      Earthen circle
                      Earthen Arrangement
                      Earthen Arrangement
                      Bora ground/ring
                      Ceremonial ground
                      Pathway
                      Stone arrangement
                      Stone circle
                      Earthen Arrangement
                      Earthen circle
                      Bora ground/ring
                      Ceremonial ground
                      Pathway
                      Term often used to describe ceremonial ground regardless of material used
                      As for bora ground
                      Formed pathway, generally associated with connecting stone/earthen circles
| Modified tree       | Scarred tree
                      Carved trees
                      Tree from which sheet of bark has been removed for manufacture of an
                      item, e.g., canoe or shield. Also used to described toeholds cut to facilitate
                      removal of possums or honey
                      Tree which has been carved with patterns; may indicate burials, group
                      boundaries
| Fish traps           | Shell mound
                      Shell scatter
                      Dinnertime camps
                      Processing sites
                      Home bases
                      Stone/wood structure across a river or in intertidal zone used to trap fish
                      Mound of shellfish remains may include many other types of artefactual
                      material, e.g., bone, stone, charcoal
                      Scatter of shellfish remains across ground surface
                      Discrete piles of shellfish remains generally resulting from a single meal of
                      shellfish; may be associated with hearths.
                      Site where shellfish have been cooked and the flesh removed for later
                      consumption. Generally comprise one shellfish species; may be associated
                      with hearths
                      Scatters of shellfish remains indicating complex dispersal patterns and a
                      variety of other discarded material
| Burial              | Interment of human remains although not necessarily buried below ground
                      surface
| Hearths             | Fire-cracked stones often in a circular arrangement; may be associated with
                      charcoal
| Ovens               | Mound of fire-baked earth

When employing a DBMS to manage any data types it is imperative that the terms used to identify the various entities or objects being modeled are explicitly defined. If not, the oft-quoted "Garbage In, Garbage Out" principle will apply to any information derived. "For computerisation to work, it is an intrinsic necessity that we structure and formalise the fundamental way we record . . . data" (Arroyo-Bishop and Zarzosa 1994:43; see also Booth 1988:387-388). In other words, if archaeologists are to fully realise the potential of their data they must have a high degree of confidence in the methods used to obtain and describe that data. To achieve this degree of confidence, classification of the archaeological record must be undertaken in a manner that effectively removes ambiguity in data recording.
Echoing Orton (1980:33), I argue that archaeologists “must have a good classification system if [they] are to obtain useful results.” A good classification system should have the following properties:

1. Entities of the same type should be similar in terms of some of their attributes.
2. Entities belonging to different types should be less similar than those entities belonging to the same type.
3. Types should be properly defined so that initial results can be repeated by others, except for some borderline cases.
4. It should be possible to decide which type a new entity belongs to with relative ease (Orton 1980:33).

Despite recognising the importance of classification archaeologists have tended to place more importance on classifying than on developing classification theories relevant to their discipline (Dark 1995:81).

To the archaeologist the process of grouping objects within “sensible” groups, clusters, or populations has been a normal activity for decades. The nature of these groupings seemed quite clear; one made a list of attributes, intuitively prejudging that it encompassed the “best” grouping, and then placed entities in the group if they possessed the attributes and outside if they did not. The intended nature of these groupings was transparently clear, they were solid and tangible defined entities like an artefact or cultural assemblage, each possessed a necessary list of qualifying attributes and they could be handled like discrete or solid groups (Clarke 1979:156-158).

The crux of Clarke’s statement is that archaeologists tend to employ monothetic criteria when classifying the various entities which comprise the archaeological record. That is, the classification of the archaeological record is underpinned by the notion that each class of archaeological entities is “formed by rigid and successive logical divisions so that possession of a unique set of features is both sufficient and necessary for [group] membership” (Sneath and Sokal 1973:29). Recognising this problem Clarke argued monothetic concepts were an ideal that had never been demonstrated in archaeology: “. . .no group of assemblages from a single culture ever contains, nor ever did contain, all of the cultural artefacts; no group of artefacts within a single type population are ever identical in their list
of attributes” (Clarke 1979:156-157). Rather, Clarke (1979:157) argued that archaeologists
were aware that the groups they create can be identified by a range of attributes, some of
which will be shared within the group and others that may be attributes of other groups.
Groups of this type equate with Sneath and Sokal’s (1973:21) polythetic group; i.e., entities
are “placed together that have the greatest number of shared character states, and that no
single state is either essential to group membership or sufficient to make an [entity] a
member of the group.”

A formal definition of a polythetic group is as follows:

A class is ordinarily defined by reference to a set of properties which are both necessary
and sufficient (by stipulation) for membership in the class. It is possible, however, to
define a group K in terms of a set G of properties \( f_1, f_2, \ldots, f_n \) in a different manner.
Suppose we have an aggregation of individuals...such that:

1. Each one possesses a large (but unspecified) number of the properties in G.
2. Each \( f \) in G is possessed by a large number of these individuals and
3. No \( f \) in G is possessed by every individual in the aggregate.

By the terms of 3, no \( f \) is necessary for membership in this aggregate; and nothing has been
said to either warrant or rule out the possibility that some \( f \) in G is sufficient for
membership in the aggregate (Beckner 1959 cited in Sneath and Sokal 1973:21).

Williams et al. (1973:219) argue the polythetic method “is a more rigorous approach to the
definition of intuitively valid categories, since no single criterion will adequately separate the
given class.” In other words, it allows for exceptions in membership rules rather than
explicitly stating those rules.

To illustrate the problems associated with monothetic concepts consider the category of
site type known in Australia as a “shell midden” or simply a “midden.” Middens are a
perfect example of a polythetic group; archaeologists intuitively know that shell middens
may contain a variety of materials apart from shell. However, following Williams et al.
(1973:220) I employ an indirect proof by assuming definitions provided for middens are
monothetic and show how this may lead to absurdity.
One such definition provided by Hughes and Sullivan (1984) lists the following criteria for identifying shell middens in Australia:

1. Middens contain charcoal, burnt wood, blackened shell, stone artefacts and hearth stones.
2. Middens only contain shells of edible species and economic sizes.
3. Middens contain bones of mammals exploited by humans.
4. Middens are generally unstratified or roughly stratified.
5. Middens do not contain forms of marine life such as coral.
6. Middens do not contain shells which have wear patterns indicative of waterborne transport.

If we accept this as a monothetic definition of middens (i.e., each one of these attributes is both sufficient and necessary for membership of the class midden) problems will arise. For example, McNiven (1990:96-109) describes in some detail Teewah Beach Site 26, a midden he excavated in the late 1980s. Included in the attributes described are

1. three major stratigraphic units which appear to be clearly definable,
2. mollusc remains,
3. fish bones,
4. stone artefacts, and
5. charcoal.

On the basis of Hughes and Sullivan's monothetic definition, Teewah Beach Site 26 can not be defined as a midden. It does not contain the burnt wood or hearth stones required by Criterion 1 or the mammal bone of Criterion 3 and it appears to be clearly stratified, a state not accepted by Criterion 4. Furthermore, it contains fish bone, an attribute not allowed by any of the criteria. The reason why this definition fails is no fault of the site or the Hughes and Sullivan definition. Instead, it is the result of considering shell middens as monothetic when they are clearly polythetic.
Thus, archaeologists are locking themselves into a vicious, self-inflicted classificatory bind. We are conscious that the assemblages being classified can be defined by a range of attributes, whereby group membership is based on having a high proportion of attributes, i.e., polythetic groups. Yet at the same time we continue to refine the procedures that allow us to state that a given site type must contain x, y and z, attributes, i.e., a monothetic group. Williams et al. (1973:220) suggest that polythetic groups “offer archaeologists [their] best hope in quantifying intuitive feel.” Certainly Australian archaeologists would intuitively identify Teewah Beach Site 26 as a shell midden. Indeed no “site without shells is termed a midden in Australia” (Truscott 1994:132). This highlights a further problem which appears to have been largely ignored in Australian archaeology. How useful are the apparently entrenched site types when it comes to quantifying results or making management decisions? How many shellfish remains, whether by weight, minimum number of individuals, or as a percentage of the entire contents of a site, are required to identify a site as a midden?

Consider, for example, Bowdler’s (1983:135) statement that shell middens will consist of 50% by weight or more of marine or freshwater shells. This is clearly a monothetic definition as this criterion is both necessary and sufficient to classify a site as a midden. However, if a site contains 5kg of shellfish remains and 15kg of fire-scorched stones can the site be considered a midden under Bowdler’s definition? No! Likewise, a site that contains more chipped stone artefacts by weight than shellfish remains may be recorded by some archaeologists as a stone artefact scatter while others would maintain that the site is a midden. The question is which is correct?

The overall problem with definitions such as these is that archaeologists are trying to “squeeze” the polythetic nature of the archaeological record into monothetic site types while implicitly recognising that the record is in fact polythetic. In doing so, the terms
employed to identify site types tend to obscure rather than clarify the material variability in the archaeological record. Furthermore, this problem is not unique to middens; it covers the whole spectrum of site types recognised in Australia.

More attention must be given to the polythetic nature of types and continuous variation in our data because, while variation may make classification difficult and categories untidy, it is also the most important information for understanding any behavioral system (Plog 1975:211).

It is also important to note that employing polythetic criteria only results in a de-facto construct and the resulting groups should be considered as operationally polythetic (Williams et al. 1973:219) and thus nothing more than a “temporary and approximate convenience” (Clarke 1979:158). The reason for this is that despite the apparent monothetic/polythetic dichotomy some groups may ultimately be proven monothetic (Williams et al. 1973:219).

The recording of baseline archaeological data must, in the first instance, be undertaken using a classification system that recognises the polythetic nature of the archaeological record. Rather than concentrating on the identification of sites, more attention must be paid to the actual materials on the ground. If these materials are recorded accurately then the classification of the various aspects of the archaeological record monothetically (and thus site types) may be possible at a higher level of analysis. As indicated above, it is not possible to create monothetic groups without first having a polythetic base on which to base such higher level analysis.

If inappropriately defined categories are used, no amount of mathematical finesse can remedy the trouble. There is of course, no single ‘right’ set of categories for all purposes. The essential thing is that, for a given purpose we must not lump in ways that obscure important differences and we must not split on the basis of differences that are irrelevant for that purpose (Cowgill 1989:132).

**Thesis organisation**

This thesis covers a range of very different but related topics all of which are drawn together in the final chapters. There are, however, chapters which directly impact on
others despite the fact they do not follow a logical progression. For example, the chapters dealing with database design and data modeling are obviously related and follow each other logically. At the same time, they also impact on those chapters discussing the classification of the archaeological record and dealing with GIS. To assist the reader in understanding these logical but somewhat disjointed links an organisational chart is provided in Figure 1.2 which also divides the thesis into five sections. The first section is essentially aimed at defining the problem, section two examines issues relating to database design and GIS while section three deals with classification issues. Section four covers the development and testing of my database while the final section concludes the thesis.
Figure 1.2  Thesis organisational chart showing the relationships between the various chapters.
Chapter Two

THE QUEENSLAND SITE FILES

Introduction

In this chapter I critically review the data management systems employed by the Environmental Protection Agency (EPA), formerly the Heritage Branch (Queensland Department of Environment) for recording and administering archaeological sites in the State of Queensland. Loosely divided into four sections, the chapter first examines the Site Index Form which must be submitted to the EPA by any archaeologist who records a site. Second, it assesses the digital database which is the primary source for the storage, retrieval and manipulation of site data. Third, it discusses issues relating to site location, and the “dots on maps” approach to mapping archaeological sites.

The Site Index Form

The Archaeology Site Register commenced in 1971 when the Branch was formed to administer the Aboriginal Relics Preservation Act (1967-76). . . .The Register was designed as a record of the location and contents of all [prehistoric Aboriginal archaeological sites] in the state with the aim of being able to inform local and State Government departments, developers, researchers and interested members of the public on their location, significance and requirements for conservation (Johnston and Rowland 1987:17).

The original form employed to record archaeological site data was abandoned in the mid-1980s and replaced with the current Site Index Form. Reasons for replacing the original form were numerous and included the fact that there were a limited number of categories provided for the capture of site data and that these were inadequate for the types of questions being asked by archaeologists, developers, etc. Obtaining information was difficult as the files were messy, site numbers were duplicated and the information tended to be poor and inaccurate because the cards were incorrectly filled out. As such, it was
impossible to extract basic information from the cards and accurate significance assessment of sites and/or regions was difficult at best (Rowland 1989:272).

As Rowland (1989:272) stated:

_The new Site Index Form was redesigned to overcome [these] problems by providing more relevant categories for data capture along with a set of cards which allowed for more in-depth recording of individual site attributes. Overall it was envisaged that once the new system was fully functional it would provide an "efficient and easy to use system."_

A final perceived advantage of the new Site Index Form was that the data recorded on it could be "easily abstracted" for entry into a digital database (Rowland 1989:269). However, I believe that, like its predecessor, the Site Index Form has outlived its usefulness.

Rather than recognising the various site types outlined in the previous chapter, the EPA takes the position that only two types of site exist, _Open Sites_ and _Caves/Rockshelters_, and this position is reflected in the Site Index Form. The site types generally recognised in the wider Australian context are viewed as site attributes on the form. In theory, therefore, sites containing shellfish remains and knapped artefacts would not be identified as either shell middens or artefact scatters; rather, they would be recorded as attributes of an open site or cave/rockshelter. Furthermore, as each of these attributes can be associated with a variety of different materials it possible to indicate that a shell midden and artefact scatter may contain not only shell and stone, but also bone and charcoal (Figure 2.1).

Linked to the Site Index Form are the Site Cards which allow each attribute to be described in greater detail (e.g., artefact densities, species or artefact types present, motif styles for paintings and engravings, etc.). These cards are discussed more fully below. While it would appear the linking of the Site Index Form with the Site Cards provides a reliable and efficient means for the recording of archaeological sites, this is not actually the case.
<table>
<thead>
<tr>
<th>Site Type</th>
<th>Site Attribute</th>
<th>Open Site</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paintings(s)</td>
<td>Engravings(s)</td>
<td>Burials(s)</td>
<td>Stone Circle(s)</td>
</tr>
<tr>
<td>Stone Arrangement(s)</td>
<td>Earthen Circle(s)</td>
<td>Earthen Arrangement(s)</td>
<td>Pathways(s)</td>
</tr>
<tr>
<td>Carved Trees(s)</td>
<td>Scarred Trees(s)</td>
<td>Fish Traps(s)</td>
<td>Wells(s)</td>
</tr>
<tr>
<td>Weirs(s)</td>
<td>Axe Grinding Grooves(s)</td>
<td>Dwelling(s)</td>
<td>Hearth/ovens(s)</td>
</tr>
<tr>
<td>Quary(s)</td>
<td>Shell Midden(s)</td>
<td>Artefact Scatters</td>
<td>Other</td>
</tr>
</tbody>
</table>

**BRIEF DESCRIPTION OF SITE:** Site comprises a small scatter of shellfish remains. Small fragments of mammal and fish bone noted along with small pieces of charcoal. A few stone artefacts were also noted.

**Figure 2.1** Facsimile of Site Type, Attributes and Materials section of the EPA Site Index Form showing how an open site with the attributes Shell Midden and Artefact Scatter may be recorded.

**Site attributes: problems and issues**

Despite its apparent transparency and simplicity there are four problem areas with the Site Index Form. First, the use of explicit site attributes on the Site Index Form can result in recorder bias through selection of only those components in which the recorder is interested or which he or she considers to be the major attribute(s) of the site. Second, a recorder may consider a particular component too small to warrant recording as an attribute on the Site Index Form and thus explicitly exclude it on the form. Third, as the categories were believed to be self-explanatory, no guide has been prepared to assist in completing either this or other sections of the Site Index Form. Thus different archaeologists may interpret the attributes as they view them and not as originally intended by the card’s designers. Finally, the list of site attributes comprises a mixture of functional (interpreted cultural function) and morphological (descriptive) classes.
In the case of the first and second points it is difficult to identify specific instances of bias or deliberate exclusion, although some indication of a recorder's interpretation of the form can be gained by examining completed forms. Regardless of the reason the result is that potentially important information may be excluded from the Site Index Form and thus the database. Figure 2.2 presents examples of recorded sites drawn from the Queensland State site files to highlight the aforementioned problems. In each example the site attributes have been extracted from the Site Attributes section of the Site Index Form while the comments have been obtained from the Site Cards or the Brief Description of Site section of the Site Index Form.

Example 1 records the attribute Paintings only, despite the fact that the comments indicate cultural deposits. While the deposit contents are not described it probably included one or more of the following: shell, stone artefacts, charcoal or bone. It is, therefore, incorrect to indicate that this site's only attribute is Paintings. Much the same applies to Example 2 which records the attribute Shell Midden; however, the description also indicates the presence of stone artefacts. In both examples sites exhibiting more than one attribute have been recorded as having only one. In Example 1 the recorder was possibly biased towards paintings and did not record the deposit in detail. In Example 2 the recorder may have considered the small number of artefacts inconsequential and excluded them as an attribute. A further possibility is that the recorder did not consider two artefacts as an Artefact Scatter. If this was the case then it raises the question, how many stone artefacts comprise an artefact scatter?
### Table 2.2

<table>
<thead>
<tr>
<th>Example Number</th>
<th>Site Attributes</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shell Midden, Artefact Scatter</td>
<td>No values provided</td>
</tr>
<tr>
<td>2</td>
<td>Shell Midden, Artefact Scatter</td>
<td>No values provided</td>
</tr>
<tr>
<td>3</td>
<td>Shell Midden, Artefact Scatter</td>
<td>No values provided</td>
</tr>
<tr>
<td>4</td>
<td>Shell Midden, Artefact Scatter</td>
<td>No values provided</td>
</tr>
<tr>
<td>5</td>
<td>Shell Midden, Artefact Scatter</td>
<td>No values provided</td>
</tr>
<tr>
<td>6</td>
<td>Shell Midden, Artefact Scatter</td>
<td>No values provided</td>
</tr>
<tr>
<td>7</td>
<td>Shell Midden, Artefact Scatter</td>
<td>No values provided</td>
</tr>
<tr>
<td>8</td>
<td>Shell Midden, Artefact Scatter</td>
<td>No values provided</td>
</tr>
<tr>
<td>9</td>
<td>Shell Midden, Artefact Scatter</td>
<td>No values provided</td>
</tr>
<tr>
<td>10</td>
<td>Shell Midden, Artefact Scatter</td>
<td>No values provided</td>
</tr>
</tbody>
</table>

The problem of not indicating the attributes present at a site may be further exacerbated by incorrect use of the Site Index Form's Materials, although the lack of instructions makes it difficult to comprehend what correct usage might be. Consider a site recorded as having the attribute Shell Midden and the Materials stone and shell. If the Brief Description section of the form does not specify what form the stone takes and the Site Card for stone materials has not been completed then it is impossible to know whether the stone represents knapped artefacts, manuports, a hearth, or perhaps the natural matrix on which the midden is located. Examples such as this do exist in the current QFRA site files.

---

**Figure 2.2**

Excerpts from the Queensland site files.

The contents of this table are not translatable to natural language.
Returning to the examples, note that 3 through 5 each have the attributes Shell Midden and Artifact Scatter. However, the descriptions indicate a third attribute, Hearths/Ovens, should have been checked as each site contains fire-cracked rocks. Apparently, the recorder(s) considered the term "artefact scatter" to include fire-cracked rocks. This again raises the question what did the form's designers have in mind? The confusion caused by this lack of definitions is further compounded in the other examples considered. Example 6 records no fire-cracked rocks despite exhibiting the same attributes as Examples 3 through 5. Furthermore, as there are only two stone artefacts recorded the recorder obviously considered an artefact scatter could comprise only two artefacts. Examples 3 through 5 are also in direct contrast to Example 7 which has the attributes Hearth/Oven and Artefact Scatter. It would appear in Example 7 that charcoal scatters have been classified as Hearths/Ovens. The question remains, however, did the form's designers intend scatters of charcoal to be recorded as Hearths/Ovens? If so, why are numerous other sites on file where the presence of charcoal is indicated in the description and/or materials section of the Site Index Form but not as having the attribute Hearths/Ovens?

Conversely, the attribute Hearths/Ovens could be taken to mean something completely different. For example, it could be a roughly circular arrangement of stone whose inside faces have evidence of scorching. Inside this arrangement there may be fragments of charcoal and scorched earth. Based on this definition it is possible that the fire-cracked rocks and scattered charcoal recorded in Examples 3 through 5 and 7 are not hearths or ovens. Indeed, the recorded descriptions do not indicate patterning for either the rocks or charcoal. Thus Examples 3 through 7 highlight some of the ambiguity that occurs in EPA site files because the attributes were seen as self explanatory and not defined.

A similar situation occurs with Examples 8 through 10 which have the attributes Painting and Artefact Scatter. The recorders indicated on the Site Index Forms that each site has the
attribute * Artefact Scatter*, but not *Shell Midden*, despite the descriptions indicating the presence of shellfish remains. As with Examples 3 through 7 the attributes recorded on the Site Index Form do not match the descriptions. While shellfish remains may be considered artefacts, most Australian archaeologists would record a site containing shellfish remains as a shell midden, not an artefact scatter.

Examples 11 through 14 again demonstrate the various ways in which similar components of a site may be recorded, in this case grinding grooves and nut-cracking holes/stones. At Example 11 a series of oval-shaped grooves were recorded as axe-grinding grooves. It is unlikely these are axe-grinding grooves as their morphology is considerably different from that described for this artefact (e.g., Hiscock and Mitchell 1993). Likewise, the triangular groove recorded at this site is unlikely to have resulted from axe grinding. This set of examples clearly highlights the problem of employing a strictly functional approach to the classification of site attributes. While some grinding grooves may be the result of axe grinding it is untenable to suggest they all are and yet the Site Index Form appears to presuppose this. A different situation occurs in Examples 12 and 13 where both the nut-cracking stones and grindstones are recorded as components of the * Artefact Scatter* attribute. Conversely, in Example 14 the recorder has used the *Other* attribute and used the terms *Grooves* and *Nut-cracking holes*. As with the previous examples the recording of these sites indicates a degree of confusion on the part of the recorder in terms of defining attributes. As discussed below use of the term * Other* also has major implications for data retrieval from the EPA digital database.

**Environmental recording**

The use of environmental variables in site recording reflects a long-held notion by Australian archaeologists concerning the correlation between the landscape and prehistoric Aboriginal settlement/subsistence patterns. Detailing environmental data has been and
continues to be an integral part of the recording process and often plays a role when
determining significance and representativeness. Despite this fact, the Site Index Form
does not provide for accurate recording of these factors. I shall focus on the first part of
the environment section which specifically aims at recording a site’s immediate
environment. As shown in Figure 2.3 provision is made to record 10 environmental
factors on the Site Index Form. When these are not adequate the category Other may be
used in conjunction with the recorder’s definition. It appears that little consideration was
given to the terms used to describe the environment or how some of them may be
interpreted. For example, why have the terms River Flat and Creek Bank been employed,
but not “river bank” and “creek flat”? Likewise, the term Dune is present but not “beach”.
This ignores the fact that many coastal sites are located on the beaches of both open and
sheltered bodies of water where dunes are not present. Likewise, for Slope it is not possible
to indicate the degree of slope and no guide exists on the form to explain the division
between flat and sloping terrain. Based on my own observations some archaeologists
would consider flat terrain as having a slope of less than five degrees, whereas others may
consider flat terrain having a slope that is less than one or two degrees. Furthermore, is
slope a topographic feature in its own right or is it an attribute of many different types of
topography (e.g., see Speight 1990)? Use of the Other category is also problematic, as it can
lead to inconsistencies in the terms employed to describe the landscape. For example, one
recorder may consider a feature to be a dune, while another may identify it as a beach ridge.
The final issue examined concerning the Site Index Form relates to site visibility. For this category the recorder is asked to estimate the percentage of vegetation cover at a site in order to assess its effect on surface visibility. While only an estimate, my own field experience demonstrated that without a standardised method on which to base the estimate, considerable variability in the information recorded can result. Furthermore, the values noted can be reversed. Thus rather than indicating that 20% of the site is covered by vegetation the recorder may indicate that only 20% of the site is visible which translates to an 80% vegetation cover.

**Site Cards**

Compared with the Site Index Form the Site Cards are much less problematic. These cards allow the recording of baseline data relating to the various types of materials and features at a site. It is interesting to note that they are called *Site Cards* and not *Attribute Cards*. This matter aside, these cards should be the primary source for a site’s descriptive data. However, as they are invariably linked to the attributes listed on the Site Index Form, when a recorder incorrectly completes a Site Index Form the errors can flow over onto the Site Cards. If a site containing stone artefacts and shellfish remains has been listed as having the attribute *Shell Midden* only it follows that the Site Card relating to stone materials will not normally be completed.
A further anomaly is found within the *Art Site* card which, apart from describing rock art, also has space for recording data relating to cultural deposits. Obviously data of this type is important; however, on this card it is somewhat superfluous, particularly in reference to charcoal/ash and the presence/absence of stone artefacts. First, provision for these components is made elsewhere on the *Plant and Animal Materials* and *Stone Materials* Site Card and this is simply not required on a card dedicated to the recording of paintings. Second, by indicating that charcoal and stone artefacts are present, a recorder may not feel compelled to complete the *Plant and Animal Materials* and *Stone Materials* Site Cards. Third, if charcoal and stone artefacts are considered an attribute of an art site, why not shell and bone, etc?

The problems outlined in the previous sections are obviously cause for concern in their own right. However, when these problems are combined the implications are wide ranging and must impact negatively on both research and management decisions. This is exactly what happens when the recorded information is entered into the digital database. The Site Index Form is the primary source of data for the digital database used by the EPA and errors and/or omissions on the form are reflected and magnified in this database. Thus any information extracted from it by heritage managers and/or researchers is likely to be exceedingly corrupt and misleading.

**The database**

The DBMS employed by the EPA is Ian Johnson’s MINARK. Originally named ARCHDATA the database was renamed NEWARK following modifications during the early 1990s. Under the flat-file format of MINARK each site comprises one record in the database and each record can contain up to 39 variables each describing various aspects of a site (Figure 2.4). Surprisingly, all these variables, with the exception of a site’s dimensions, have been drawn from the Site Index Form. In other words, a minimal amount of data has
been included from the Site Cards which, in theory, provide far greater morphological
detail than the Site Index Form, particularly in relation to identifying archaeological
variation. Recognising this as a problem plans were made to include more specific
variables from the Site Cards (Johnston and Rowland 1987:Appendix A) as follows:

1. paintings: data on the number, colour and variety of motifs for each art site;
2. shell middens: the types of shellfish remains present in a site and the dominant
   species;
3. stone materials: data summarising stone raw material types, artefact density and
   implement types.

For reasons unknown, these additions to ARCHDATA were not made. This is despite the
fact that they would have greatly enhanced the variety of information that could have been
extracted from the database and Rowland's (1989:272) statement that following the
implementation of the system the Heritage Branch

\[
\text{would be in a position to assess the record of sites so far obtained and make predictions}
\]
\[
\text{concerning site location factors; more accurately assess the significance of sites found during}
\]
\[
\text{environmental impact statements; direct rangers, researchers and others into areas of high}
\]
\[
\text{research priority and develop a structured program of survey and management priorities.}
\]

To more fully appreciate the nature of the problems with the Site Index Form discussed
above and how these affect any retrieval made on the database it is necessary to return to
the examples presented in Table 2.1. Consider a search for those sites with the attribute
Hearth/Oven. Any search would result in only one site being returned when in fact there
are at least three. Example 1 may have this attribute because cultural deposits are indicated
in the description; however, only the Paintings attribute was recorded. What is even more
misleading is that the one site (Example 7) which would be returned does not contain a
hearth or oven but rather scatters of charcoal. Likewise, a search for sites with axe-grinding
grooves would result in one site being returned when it is unlikely that the grooves were the
result of axe-grinding activities at all.
<table>
<thead>
<tr>
<th>Variable</th>
<th>DB Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>State File Number</td>
<td>SITETYPE</td>
<td>The alpha-numeric number assigned to a site by the government</td>
</tr>
<tr>
<td>Site type</td>
<td>SITETYPE</td>
<td>Basic classification of the site as either open or cave/rockshelter</td>
</tr>
<tr>
<td>Site attributes</td>
<td>SITEATTR</td>
<td>List of seven common raw materials that may be found in a site. Unlisted types can be included in the “Other” category.</td>
</tr>
<tr>
<td>Material</td>
<td>MATERIAL</td>
<td>List of seven common raw materials that may be found in a site. Unlisted types can be included in the “Other” category.</td>
</tr>
<tr>
<td>Structure</td>
<td>STRUCTURE</td>
<td>List of four categories indicating if a site is surficial, stratified, etc.</td>
</tr>
<tr>
<td>Site Cards Attached</td>
<td>SITECARD</td>
<td>Indicates which Site Cards were completed</td>
</tr>
<tr>
<td>Brief Description</td>
<td>DESCRIPT</td>
<td>Provides brief description of the site and its content</td>
</tr>
<tr>
<td>Recorder</td>
<td>RECODER</td>
<td>Name of the site's recorder, drawn from list of top 55 recorders</td>
</tr>
<tr>
<td>Other Recorder</td>
<td>OTHRECDR</td>
<td>Used when the recorder was not a member of the top 55, deleted</td>
</tr>
<tr>
<td>Recorder Type</td>
<td>RECTYPE</td>
<td>The types of recorders in terms of their occupation when recording a site</td>
</tr>
<tr>
<td>Site Name</td>
<td>SITENAME</td>
<td>Records the name of the site as supplied by the recorder</td>
</tr>
<tr>
<td>Date Recorded</td>
<td>DATE</td>
<td>Calendar date in dd/mm/yy format</td>
</tr>
<tr>
<td>Map Sheet Name</td>
<td>MAPSHEET</td>
<td>Name of the map sheet on which the site is located</td>
</tr>
<tr>
<td>Edition</td>
<td>EDITION</td>
<td>Map sheet edition number; problematic as it was not possible to determine between imperial and metric sheets</td>
</tr>
<tr>
<td>Scale</td>
<td>SCALE</td>
<td>List of map scales</td>
</tr>
<tr>
<td>Easting</td>
<td>EASTING</td>
<td>Two-or-three digit number; problematic as leading zeros were not displayed</td>
</tr>
<tr>
<td>Northing</td>
<td>NORTHING</td>
<td>As for Easting</td>
</tr>
<tr>
<td>Latitude</td>
<td>LATITUDE</td>
<td>Latitude of site in degrees, minutes and seconds.</td>
</tr>
<tr>
<td>Longitude</td>
<td>LONGITUDE</td>
<td>As for latitude</td>
</tr>
<tr>
<td>Property Name</td>
<td>PROPERTY</td>
<td>Name of the property on which the site is located</td>
</tr>
<tr>
<td>Land Tenure</td>
<td>TENURE</td>
<td>Nominal list of the various types of land tenure</td>
</tr>
<tr>
<td>Land Use</td>
<td>LANDUSE</td>
<td>Nominal list of the land use when the site was recorded; also allows for unlisted use via “other” category</td>
</tr>
<tr>
<td>Land Unit System</td>
<td>LANDUNIT</td>
<td>Name of the biogeographic region in which the site is located</td>
</tr>
<tr>
<td>Topography</td>
<td>TOPOGRAPH</td>
<td>List of 12 options to describe the sites topographic location. This is 2 more than shown on the Site Index Form. Claypan and headland were added to the database. Ridge was entered as Hilltop</td>
</tr>
<tr>
<td>Bedrock</td>
<td>ROCKTYPE</td>
<td>List of 12 common types of bedrock, 3 more than the Site Index Form. Basalt, Gibber and Conglomerate were added</td>
</tr>
<tr>
<td>Other Rock</td>
<td>OTHROCK</td>
<td>Allows for inclusion of bedrock types not listed in the “Bedrock” variable</td>
</tr>
<tr>
<td>Soil</td>
<td>SOIL</td>
<td>List of 6 options to describe on which soil a site is located</td>
</tr>
<tr>
<td>Vegetation</td>
<td>VEGETATN</td>
<td>List of 5 options to describe the vegetation</td>
</tr>
<tr>
<td>Dominant Vegetation</td>
<td>DMOVEGN</td>
<td>Provides detailed description of the vegetation around the site</td>
</tr>
<tr>
<td>Fauna</td>
<td>FAUNA</td>
<td>Allows for entry of faunal species observed during the recording</td>
</tr>
<tr>
<td>Drinking Water Sources</td>
<td>WATER</td>
<td>List of 7 types of water source as an indicator of which type is nearest to the site. Types not listed can be entered in “other.”</td>
</tr>
<tr>
<td>Distance to H2O</td>
<td>H2ODIST</td>
<td>Numeric value based on distance of site to water.</td>
</tr>
<tr>
<td>Water Distance Index</td>
<td>NDXH2O</td>
<td>Provides units of measurement for distance of water source, e.g., meters</td>
</tr>
<tr>
<td>Water Supply Status</td>
<td>H2OSTAT</td>
<td>Indicates permanency of nearest drinking water; list of 3 options</td>
</tr>
<tr>
<td>Environment</td>
<td>ENVDESCN</td>
<td>Allows for description of the general or site-specific environment</td>
</tr>
<tr>
<td>Conservation</td>
<td>CONSERVE</td>
<td>Nominal list of three options. This list is supposed to be located on the Site Index Form. It is not.</td>
</tr>
<tr>
<td>Site Condition</td>
<td>SITECOND</td>
<td>List of 11 options to indicate the agent(s) responsible for damage to a site</td>
</tr>
<tr>
<td>Damage Description</td>
<td>DAMDESC</td>
<td>Description of the damage caused by the agent</td>
</tr>
<tr>
<td>Additional Remarks</td>
<td>ATTREMKS</td>
<td>Provides for entry of additional information to describe a site’s attributes</td>
</tr>
<tr>
<td>Additional Variables</td>
<td>LENGTH</td>
<td>Provides for the entry of width and length measurements, site area (ha), the height of the drip line for rockshelters and the estimated depth of any deposit. The area is calculated in hectares. This variable is rarely, if ever, used.</td>
</tr>
</tbody>
</table>

Figure 2.4 List of the variables contained in each record of ARCHDATA. Note DB name refers to the name of the variable in the database (adapted from Johnston and Rowland 1987: Appendix A).

Use of the attribute Other can also lead to misleading data extraction. Consider the possibility that nut-cracking holes could also be entered as “nut-cracking rocks,” “nut-cracking stones” or possibly “holes, nut-cracking.” Exactly the same situation occurs when
Other is used in the environmental section; the same topographic feature could be described then entered in a variety of ways and the result of a query for a particular topographic feature would be spurious. Obtaining an accurate result would require a number of searches for each permutation of the attribute or a complex query in which all possible variations were entered. Unfortunately MINARK does not support wildcard searches where it is possible to only enter part of a word to obtain a more accurate result. Even then, the use of wildcards does not guarantee that all spelling variations would be included in the result.

The effectiveness of the EPA database was greatly reduced after its reorganisation during 1992. Following the creation of NEWARK at least seven of the original variables were dropped, including those relating to water sources, topography, soil type, bedrock type, vegetation and land use. The reason for this was the EPA's desire to have one database containing both Aboriginal and historic European sites. Why these variables were excluded was never clarified, although mention was made that more space was required for the new historical attributes. However, it should have been possible to add new variables without removing those relating to prehistoric sites as a MINARK database record can contain up to 250 variables. While possible, it is unlikely that NEWARK would have exceeded hardware limitations or that the parameters for the 39 existing and/or new variables would have exceeded MINARK's software limitations. Regardless of the reasons, removal of these variables resulted in the loss of an important data set, despite the fact that many of these were ill defined.

The most damning evidence of NEWARK's capabilities, or lack thereof, comes from an independent report to the EPA which stated:
the requirement for correct definitions is fundamental to any kind of collected information. It is pointless to collect data if different things mean the same thing or the same thing means different things. In the existing DEH heritage database even the fundamental entity for which data is being recorded i.e. a site is not clearly defined. A cultural heritage sites database is of limited usefulness if it cannot answer the simple query: 'How many sites do we have?' (Sharma 1995:22).

While Sharma (1995:23) concluded that the EPA database was “beyond redemption,” he suggested that the problem relates not to general data processing but to how archaeologists and anthropologists obtain their data.

Dots on maps...located where?
The base maps used by the EPA to record site locations are the 1:250 000 map series published for Queensland. When Site Index Forms are lodged by archaeologists a dot is placed on the appropriate map sheet at the grid coordinates provided. Rowland (1989:269) argued that following the reorganisation of the site files, of which the placing of the dots was a major component, the EPA was ready to “move onto the next level of interpretation where patterns in the distribution of these dots can be identified and an attempt can be made to explain them.” While this may provide a broad indication of site distribution on a given map sheet, it should not be considered an accurate representation of either a site’s location or its location on the landscape in relation to other sites or groups of sites. In other words, two problems exist with this approach; the first relates to the accuracy of locating sites on small-scale map sheets, whereas the second concerns paradigmatic issues underpinning the use of “dots on maps”.

While the scale of the maps employed by the EPA is of some concern the problem extends well beyond this issue. Most maps employed in site recordings have scales of 1:100 000 or smaller (Sharma 1995:13). Table 2.2 presents the results of Sharma’s (1995) analysis of the different map scales employed by archaeologists working in Southeast Queensland. It indicates that 42% of all sites in this region have had their locations plotted on small scale maps, i.e., those with a scale of 1:100,000 or greater. If this figure were extrapolated to the
entke State I would expect the figure to be much higher, as much of the State is not covered by large scale maps.

Table 2.1 Summary of map scale of NEWARK records for sites in Southeast Queensland (Sharma 1995:14).

<table>
<thead>
<tr>
<th>Map Scale</th>
<th>No. of Records</th>
<th>Percentage of Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:25 000</td>
<td>348</td>
<td>35</td>
</tr>
<tr>
<td>1:50 000</td>
<td>186</td>
<td>19</td>
</tr>
<tr>
<td>1:100 000</td>
<td>117</td>
<td>12</td>
</tr>
<tr>
<td>1:250 000</td>
<td>293</td>
<td>30</td>
</tr>
<tr>
<td>Other scale</td>
<td>28</td>
<td>3</td>
</tr>
<tr>
<td>Unknown</td>
<td>26</td>
<td>3</td>
</tr>
<tr>
<td>Total SEQ</td>
<td>998</td>
<td>100</td>
</tr>
</tbody>
</table>

Regardless of scale, all maps contain an inbuilt error factor, and the smaller the scale the greater the error. For example, on a 1:250,000 scale map the location of well defined features have a horizontal accuracy of 100m. Furthermore, an archaeological site represented by a dot 3mm in diameter would cover an area of ca. 400,000m², have a diameter of some 750m and a perimeter of around 2.5k. With this in mind, a scarred tree would cover an area well beyond its conceivable diameter. Another way of viewing this problem is that on a 1:250,000 scale map a error of 1mm in locating a site is the equivalent of 250m on the ground. Likewise, on a 1:100,000 scale map a 1mm error equals 100m on the ground. Sharma (1995:13) argues that even a moderately competent map user is likely to have difficulty in locating a point within 3mm on a small scale map.

The EPA is dependent upon the skills of the archaeologist in calculating a grid reference, the accuracy of which is conditional on both the skill of the archaeologist and the map scale employed. Thus it is not unusual to find grid references that may be out by 2k or more on small-scale maps. It is also not unusual to find grid references that are reversed; i.e., eastings are entered as northings and vice versa either by the site recorder or during data entry. Sites supposedly located well inland have grid references which place them in the
Pacific Ocean and on some occasions in the northern hemisphere! While some of these problems are due to errors in data entry, many result from the archaeologists' lack of skill in calculating coordinates.

Based on a sample of 998 sites from Southeast Queensland Sharma (1995:51) found that location data for many sites was "significantly incomplete with regard to a proper map coordinate based reference." The information presented in Table 2.2 is based on the assumption that some variation of the xxxxxx, yyyyyyy (i.e., six-digit eastings, seven-digit northings) has occurred whereby the first digit of the easting has been excluded and the first two digits of the northing have been excluded. Based on my own experience in working with the site files cases exist where more than the first number of the easting and more than the first two numbers of the northing are excluded. Furthermore, of the 998 sites analysed by Sharma it was not possible to "make any sense" of the location information for 201 sites. He concludes that the procedures employed for recording site locations are "cavalier rather than following any professional mapping standards" (Sharma 1995:11).

Accuracy was also compromised by the format employed in ARCHDATA for entering grid references and the way MINARK stores numeric data. The grid coordinates stored in ARCHDATA comprised four numbers, two for the easting and two for the northing, not the six-digit easting and seven-digit northing. To identify a site's location the two-letter prefix indicating the 100,000m grid identification was required. However, the entry of the alphabetical identifier was undertaken by the EPA, not the recording archaeologist. Furthermore, because MINARK drops leading zeros any coordinate beginning with zero was reduced to a single figure (e.g., 01 became 1). Following the reorganisation of the database the problem with grid referencing was overcome to some degree with provision
made for entering 13-digit grid references. As suggested by Table 2.2, however, a full grid reference has never been recorded in Southeast Queensland.

Certainly issues relating to the accurate recording of archaeological sites must be addressed by both field archaeologists and the EPA. However, the EPA does not consider the accurate positioning of sites on map sheets an important issue as it may expose sites to risks such as vandalism or looting (personal observation). Such thinking is shortsighted; sites should be located as accurately as possible, and publication/display of data could occur at a lower resolution to protect the location (see also Sharma 1995:11). Certainly GIS has the potential to mask locational data. If the EPA is interested in interpreting spatial variation, then accurately locating sites on the largest scale map sheets should be an imperative. Analysis of site distributions on small-scale maps may not only result in errors of interpretation, but errors which are accepted by other archaeologists as correct and thus go unrecognised for some time.

Table 2.2  Analysis of location data quality for archaeological sites in Southeast Queensland (Sharma 1995:51).

<table>
<thead>
<tr>
<th>Easting Length</th>
<th>Interpretation</th>
<th>Northing Length</th>
<th>Interpretation</th>
<th>Nominal Accuracy</th>
<th>No. of Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>-xxxxxx</td>
<td>5</td>
<td>--yyyyy</td>
<td>1m</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>-xxxx-</td>
<td>5</td>
<td>--yyyyy</td>
<td>10m</td>
<td>79</td>
</tr>
<tr>
<td>4</td>
<td>-xxxx-</td>
<td>4</td>
<td>--yyyy-</td>
<td>10m</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>-xxxx-</td>
<td>3</td>
<td>--yy--</td>
<td>10m</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>-xxx--</td>
<td>5</td>
<td>--yyyyy</td>
<td>1m</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>-xxx--</td>
<td>4</td>
<td>--yyyy-</td>
<td>100m</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>-xxx--</td>
<td>3</td>
<td>--yyy--</td>
<td>100m</td>
<td>535</td>
</tr>
<tr>
<td>3</td>
<td>-xxx--</td>
<td>2</td>
<td>--yy--</td>
<td>1km</td>
<td>66</td>
</tr>
<tr>
<td>3</td>
<td>-xxx--</td>
<td>1</td>
<td>--y--</td>
<td>1km</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>-xx----</td>
<td>3</td>
<td>--yyy--</td>
<td>1km</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>-xx----</td>
<td>2</td>
<td>--yy--</td>
<td>1km</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>-xx----</td>
<td>1</td>
<td>--y--</td>
<td>1km</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>-x----</td>
<td>3</td>
<td>--yyy--</td>
<td>1km</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>-x----</td>
<td>2</td>
<td>--yy--</td>
<td>1km</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Records 797
Consider the following example drawn from Southeast Queensland. Since the early 1980s archaeologists, and in particular consulting archaeologists, have taken for granted the accuracy of Lilley's (1982, 1984) model for site location in the subcoastal zone of Southeast Queensland. Basically this model argues that all sites within this zone will be within 500m of streams. However, Smith and Hall (1996) demonstrated that this model was at best misleading. Based on a GIS analysis of the distance between streams in one section of the hinterland Smith and Hall were able to illustrate that there were few, if any, areas where the distance between streams exceeded 500m! One reason they cite for the inaccuracy of Lilley's model was the small-scale maps he employed when developing it. In other words, locating sites on small-scale maps is not a desirable method for spatial analysis; it is simply not possible to obtain the accuracy required for such analysis. "If the intention is to map ‘sites’ then the scale should be 1:25,000 or better" (Sharma 1995:13).

The "dots on maps" approach also suffers from another important problem. Ellis (1994:16) refers to this approach as the "tyranny of dots" and argues that historically "archaeology has [had] little concern for the perceptions of Aboriginal custodians about the interrelationship of places, or the characteristics of places which impart a ‘sense of place’ and cultural heritage significance." Rather he sees archaeologists being more concerned with organising sites typologically and manipulating these on a regional scale to establish settlement/subsistence patterns. At the same time Ellis acknowledges that this is "a perfectly proper consideration for the discipline" (1994:13) but believes that this preoccupation with data manipulation, exemplified by the dots on maps approach, has imposed itself upon the recording methods employed by archaeologists to the detriment of cultural heritage management. Employing single point grid references is a standard means for locating sites despite the fact they are virtually useless in a management situation. Thus any meaning of "place" is effectively destroyed as those elements of the landscape which may culturally link groups of "sites" together are effectively hidden (Ellis 1994:16). In
other words, sites are seen to occur in isolation from one another and thus not part of a cultural landscape. The result of this preoccupation with dot on maps is manifested today in the following manner:

Managers struggling to achieve some protection for places which may have been recorded by archaeologists ten years earlier face repeated frustrations and developer hostility as they negotiate to represent Aboriginal community interests or to integrate features not previously considered relevant or even part of the cultural landscape, into the concept of 'site' (Ellis 1994:17).

The points made by Ellis highlight a final problem with the Site Index Form, and one which accurately reflects archaeologists' preoccupation with single-point grid references. The Site Index Form only allows for the recording of one set of grid references for each site and makes no provision for the recording of culturally significant aspects of the landscape.

Conclusions

At first glance it would appear the EPA has a relatively well designed system in place to assist with the recording, management and protection of Aboriginal archaeological sites. However, serious cracks are beginning to appear in the system and it is my contention that the Site Index Form, MINARK and to a lesser extent the associated Site Cards are no longer adequate or viable tools for assisting in these areas of operation.

The Site Index Form and Site Cards which have been in use for over a decade are now beginning to display similar problems to those they replaced in that:

1. the categories are inadequate for answering the questions currently being asked by heritage managers and archaeologists,
2. the information is often poor and inaccurate,
3. site cards are not being filled out in the manner originally intended by the designers because no user's guide has been published,
4. bias can be detected in some Site Index Forms whereby only those attributes which are of interest to the recorder are recorded,
5. site attributes which are considered insignificant by the recorder may go unrecorded, and
6. they do not allow for the recording of multiple grid references or of culturally relevant aspects of the landscape.

It should also be apparent from the above discussion that MINARK can no longer function as a reliable DBMS for the EPA. It is an antiquated program severely lacking in the functionality found in contemporary DBMS and its flat file format allows for the inclusion of factual and logical inconsistencies. Furthermore, NEWARK and the original ARCHDATA do not contain the large volume of data that is particularly suited to database storage and manipulation (i.e., the descriptive data relating to site size, material types and material densities). Despite provision having been made to store data relating to these aspects of the archaeological record this was never implemented. Finally, Sharma (1995) argued that the map reading skills of archaeologists are somewhat below par.

Mention was also made of problems associated with determining the location of sites using grid references. Sharma (1995) argued that the methods employed by archaeologists and the EPA were somewhat cavalier and resulted in location data that was misleading and difficult or impossible to interpret. Obviously if GIS are to be used in management and research these problems require addressing. One method that would assist in this and which is currently being employed more often is the use of Global Positioning Systems (GPS). However, caution must be taken when using GPS as they are also susceptible to error.

A critical examination of the “dots on maps” approach employed by the EPA to show the location of sites on 1:250,000 scale maps was also undertaken in two distinct areas. The first focused on Sharma’s (1995) argument that rather than blurring site locations from the outset to mitigate interference with them, the blurring should only occur when such
information is displayed or published. This is a point of view I am entirely in concordance with and GIS can be used to effectively blur accurate site locations if necessary. The second criticism centred on Ellis's (1994) position that the "dots on maps" approach does not provide any relevant management information; rather it effectively masked the cultural landscape because sites are seen to exist in isolation. This is another area where I believe that GIS can assist.

In sum, the system presently employed by the EPA to assist in the management and protection of Aboriginal archaeological sites has long since passed its "use by" date. The remainder of this thesis is devoted to developing and testing a new approach to the collection, storage and manipulation of baseline archaeological data for both management and research archaeologists.
Chapter Three

RELATIONAL DATABASE DEFINED

Data, information and databases
Data represents both a raw material that feeds archaeological endeavors and a product of these endeavors. Archaeologists record data during field work, create more data when analysing their field results and often present these results as information in publications. But what exactly are data\(^1\) and information in a database sense? “Data . . .is not tangible. It is not something that can be picked up and handled. . .[and] only becomes tangible when it is recorded on some media” (Modell 1992:3). Data may be defined as the numbers and words used to describe and record objects (Modell 1992:3). In this sense data may be viewed as the facts, values or attributes that describe those aspects of the real world or Universe of Discourse (UoD) (Halpin 1995) being modeled in a database. Therefore, if a database is to function accurately it is crucial that the terms describing the data are precisely defined and that these definitions have a high level of acceptance within the community using the database.

Consider the character string JF:B11. It is simply a series of individual letters and numbers, (i.e. J, F, :, B, 1, 1) and as such is the most basic element that can be processed by a computer (Montgomery 1993:247). Some applications may be able to increase the numerical value, 11, by an increment of one each time the complete string is entered, the result being the creation of the new character strings JF:B12, JF:B13, JF:B14 and so on. While this character string does exist, it only does so only in isolation; it has no meaning. To be identified as data it must be explicitly defined and this definition must be widely

\(^1\) Following the convention widely used in database discussions the term “data” is applied to both singular and plural occurrences in this thesis.
accepted. Archaeologists working in Queensland may recognise the string JF:B11 as representing a Queensland Department of Environment archaeological site identification code, or site number. Thus it could be stated that JF:B11 is a member of the "site number" data set. As this is an explicit and widely accepted definition the character string JF:B11 may be accepted as data pertaining to a particular archaeological site. However, this site number does not impart any meaningful information beyond the fact that it is a site number. To convey meaningful information it must be decoded and placed in its proper context.

Decoding the site number requires knowledge that the first two characters (i.e., JF) refer to a 1:250 000 scale map sheet named Rockhampton. The string B11 indicates the actual number of the site. Thus site number JF:B11 refers to an archaeological site located on the Rockhampton map sheet. It should also be noted that Rockhampton is a character string that on its own does not impart information. Even if Rockhampton was recognised as a name, i.e. data belonging to the data set "name", it could refer to the town in Queensland, the map sheet or a person's last name. This further highlights the importance of having explicit and widely accepted definitions.

To impart further information about the site JF:B11 it is necessary to provide data from related data sets such as site type and map coordinates. In doing so it would become possible to state that "the archaeological site with the Queensland State number of JF:B11 is a stone reduction quarry located on the Rockhampton map sheet at easting 588700 and northing 3338700." Seen in this light, information may be defined as "data that has been organised and arranged to convey knowledge" (Modell 1992:5) and thus it is possible to identify a clear distinction between the terms 'data' and 'information'. While some authors tend to employ these terms synonymously when discussing databases (e.g. Date 1995:4) in this thesis the terms are treated separately.
With the above definitions in mind it is now possible to define the term database. A database is simply a collection of related data stored in an organised and meaningful manner that describe real-world objects. To ensure that data is stored in an organised manner a database management system (DBMS) must be employed. While this thesis concerns only computerised data management, a DBMS may also include filing cabinets or set of index cards. Simply stated a DBMS is the software that manages a database. Despite a variety of different types of computerised DBMS being available they all have the same basic properties, i.e., they are tools for database creation, data manipulation and information output via a computer screen or as printed hard copy (Martin 1976:74). A DBMS also has the capacity to manage many different and unrelated databases concurrently. For example, a DBMS could manage one database containing information about stone artefact attributes, another that records field work expenses and yet another containing bibliographical information. Where DBMS do differ significantly is in the method or scheme they employ to store data.

**DBMS schemata**

The concept of database design as a discipline in its own right began during the early 1960s and was primarily due to the rapid increase in the storage capacity and data manipulation speeds of computers at the time (Gillenson 1990:25). Since then a variety of schemata have been proposed for structuring databases (Halpin 1995:12). These schemata or models are generally referred to as logical models, as they graphically depict how data are organised within the DBMS (i.e., its logical structure). They are generally based on, or are variations of, the network, hierarchic or relational data models.

**The network model**

The network model, developed by the Conference on Data Systems and Languages (CODASYL) Database Task Group, is quite complex. Data are stored as records or record-links and each record may contain a single value or sets of values. As records are
related by various owner-member links, a single record may not only be a member of a number of other records but may also own many records itself. For example, an archaeologist’s name and address may be stored in one record while the sites they have located are stored in a different record. To identify which sites have been located by an archaeologist, their record must be owned by the site’s record. Likewise, the fact that the archaeologist works for a particular consulting company could be shown by having the archaeologist’s record owned by the company record. If you wished to know which company had recorded what sites, you ensure that the access path “company - sites” had been defined. If not, one search would have to identify all the archaeologists who had worked for the company and then another search would have to be initiated to locate the site records owned by the archaeologist’s record. As the database grows, the access paths become more complicated and thus less flexible. A diagram of the connections between the records resembles a network, and thus this term has been adopted for the schema.

The hierarchic model
The hierarchic model, developed by IBM, is less complicated than the network schema as each record can only store one value (i.e., last name). Records are related through “parent-child links,” whereby each child record can only have one parent link. Logical models of this type are ideal for storing information of a hierarchical nature such as the management structure of a company. Like the network model, however, this one is somewhat dependent on predefined access paths. Diagrammatically this model represents a hierarchy.

The relation model
The third model is the relational model and, as it is the one employed in this thesis, it is described in much greater detail than the other two. My rationale for employing a relational database is based on four points:

1. The relational model is viewed by many as the “single most important development in the entire history of the database field” (Date 1995:22).
2. While both hierarchic and network models are still employed (Halpin 1995:13), since the late 1970s the majority of database research has tended to concentrate on the relational model (Date 1995:22) and by the late 1980s “efficient relational models had become commonplace” (Halpin 1995:13).

3. As most GIS databases are table based it is possible to employ relational theory when creating GIS databases (e.g., Johnson 1996:10).

4. As many archaeologists use the Microsoft Office suite of programs they are likely to have the Microsoft Access relational DBMS already installed on their personal computers. For this reason, and because Access is a powerful and relatively stable DBMS with a user-friendly interface, it is the program used throughout this thesis.

The relational model was developed by IBM researcher E. F. Codd in 1970. While it is beyond the scope of this thesis to describe the 333 features that Codd (1990:29) identified as integral to relational database structure, it is critical that an understanding of the basic underlying concepts is obtained. In pre-relational models the database held all the primary records or files while the application programs maintained the links. Codd (1970) saw this as a problem because it superimposed an additional structure over the data that could confuse end-users. He argued that the solution lay with a relational model as it would “provide a means of describing data with its own natural structure only” (Codd 1970). In other words, links in the relational model are based on attributes of the objects being modeled and as such, are stored in the database (Worboys 1995:56). However, as discussed below these are not links as in the pre-relational models; rather they occur as a function of key columns in each table within the database.

The non-relational systems also contained ordering, indexing, and access path data dependencies requiring the end-user to have an understanding of how the data was stored in the computer, something from which Codd (1970) argued they should be divorced. Ordering dependence occurs when a file containing data such as site numbers is stored in,
for example, ascending order. In such cases the operating programs or software often assume this ascending ordering is closely matched to the machine-stored or physical address of the file in the computer. If changes in this ordering occur then the application program is likely to fail (Codd 1970). Indexing is a method employed to improve response time to a given query and as such is purely related to database performance. If an application program employs indexes, it is likely that removal of the index from a given file will result in faulty operation of the application program (Codd 1970). Access paths are employed to provide links between the various files containing data. The operation of the database is dependent upon the continued existence of these access paths or pointers. If the structure of an access path is changed it is likely that the application program will crash (Codd 1970).

By using the relational schema these problems would disappear and the end-user would be protected from the intricacies of data file storage (Codd 1970). This is certainly the case with contemporary Relational Database Management Systems (RDBMS); data can be entered, updated or deleted by the end-user regardless of how the data is stored on the machine. The relational model is also “logically cleaner” (Halpin 1995:13) than the other models as information extraction is not dependent upon predefined access paths or pointers (Halpin 1995:13).

The relational model is based on mathematical relations, specifically “the set-theoretic relation which is a subset of the Cartesian product of a list of domains” (Ullman 1982:19), and can be defined as:

Given sets S1, S2, ..., Sn (not necessarily distinct), R is a relation on these n sets if it is a set of n-tuples each of which has its first element drawn from S1, its second element from S2, and so on. More concisely, R is a subset of the Cartesian product S1 x S2 x ... x Sn. As defined above Relation R is said to be of degree n. Each of the sets S1, S2, ..., Sn on which one or more relations are defined is called a domain (Codd 1970:1-2).
While the database relational model does differ from the mathematical model (see Table 3.1 for a summary of these differences), the mathematical model has two specific properties which allowed Codd to develop the relational database schema: domains, and relations or tables.

Table 3.1 Comparison between mathematical relations and the relational model for databases (Codd 1990:4).

<table>
<thead>
<tr>
<th>Mathematical Relations</th>
<th>Relational Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconstrained values</td>
<td>Atomic values</td>
</tr>
<tr>
<td>Columns not named</td>
<td>Each column named</td>
</tr>
<tr>
<td>Columns distinguished from each other by position</td>
<td>Columns distinguished from each other and from domains by name</td>
</tr>
<tr>
<td>Normally constant</td>
<td>Normally varies with time</td>
</tr>
</tbody>
</table>

A domain is a set of data values from which atomic data or attributes can be drawn. Data may be formally described as being atomic if it cannot, as far as the database is concerned, be decomposed any further without losing its internal structure (i.e., to a point where it no longer makes sense). “Each attribute must be ‘defined on’ exactly one underlying domain, meaning that the values of that attribute must be taken from that domain” (Date 1995:81). For example, JF:B11 is an attribute of the domain Queensland State Government site numbers.

When represented graphically a relation takes on the form of a two-dimensional or flat table which contains a finite number of rows and columns and whose cells contain atomic data only. If the cells contain non-atomic data they are said to have a third dimension, depth (Jennings 1995:843). These tables, which Codd (1990:17) defines as R tables are special as they provide a picture of a relation. Date (1995:86) states that R tables may be only be regarded as a picture of a relation “provided we can agree on how to read such a picture.” That is, they have underlying domains, each row is a tuple (i.e., no single row contains exactly the same data as another row) and each data value is drawn from the domain from which it is derived (Figure 3.1).
Figure 3.1 Components of a relational model for the personal details of archaeologists (after Date 1995:80).

Thus a relational data model may be described in the following manner. "A relation R on a collection of domains $D_1, D_2, \ldots, D_n$ - not necessarily distinct - consists of two parts, a heading and a body" (Date 1995:86).

1. Headings are drawn from domains and comprise a fixed set of pairs, i.e., $<A_1:D_1>, <A_2:D_2>, \ldots, <A_n:D_n>$ where $n$ = the number of domains (degrees or arity), with each attribute precisely corresponding to its underlying domain, i.e., $A_j$ is drawn from $D_j$ where $j = 1, 2, 3, \ldots, n$. Each attribute name is distinct.

2. The body contains sets of tuples in which each tuple comprises a set of $<\text{attribute-name}:\text{attribute-value}>$ pairs, i.e. $<A_1:v_1>, <A_2:v_2>, \ldots, <A_n:v_n>$, where $(i = 1, 2, 3, \ldots, m)$ and $m$ = the number of tuples in the set (cardinality). For each tuple there can only be one $<\text{attribute-name}:\text{attribute-value}>$ pair $<A_j:v_j>$ for each attribute $A_j$ in the heading. For a given pair $<A_j:v_j>$, $v_j$ is a value from the unique domain $D_j$ that is associated with attribute $A_j$ (Date 1995:87).

In sum, a database relation may be viewed as a two-dimensional table, provided that specific criteria are met. As indicated in Figure 3.1 each row in the table refers to a particular archaeologist; the cells of each row contain atomic data values or attributes with the exception of address. Both dwelling number and street name are distinct attributes and therefore not atomic; however, as discussed in the section dealing with normalization, there are cases where non-atomic attributes may be stored in a single cell. Data and information retrieval is not affected by the ordering of rows or columns; however, the attribute data
stored in each cell of a column must be drawn from its underlying domain. Thus it would be incorrect to store address data in the surname column. Furthermore, the name given to each column must be derived from its corresponding domain. Finally, table names are based on that aspect of the UoD which is being modeled in the table. In Figure 3.1 the table is modeling biographical information about individual archaeologists and thus has been named Archaeologists' Details.

Having defined what a table is in the relational database sense, it is now necessary to examine some further properties of relational databases. Included in the following discussion are issues relating to how links between the various tables in a database are maintained, the types of links that exist, data integrity and a process referred to as normalization. A basic understanding of each of these is necessary as they, along with the notion of an R table, provide the foundations for the development of any successful relational database.

### A relational view of data

In a relational database the end-user is primarily dealing with a set of time-varying relationships which exist between domains (Codd 1970). Time-varying simply indicates that over the life of a database each relation is likely to be subject to insertion, modification and deletion of data (Codd 1970). Users therefore need know little more about any relationship (rather than relations) than its name (i.e., the table name) and the names of the columns contained within (Codd 1970). Thus it is possible for users to retrieve information by creating queries using table and column names. However, underlying this relatively simple procedure is a complex set of rules referred to as relational algebra (Jennings 1995:842). While it is not necessary to understand the advanced mathematics associated with relational algebra, it is important to have an understanding of its basic rules.
Relational keys

A relational database contains three types of relational keys: candidate keys, primary keys and alternate keys. A fourth key, the foreign key, is discussed below. The sole aim of these relational keys is to specify the uniqueness of each row in a table. Codd (1970) states, “one domain (or combination of domains) of a given relation has values which uniquely identify each element (n-tuple) of that relation.” In other words, no two rows in a given table can contain exactly the same attributes or sets of data. Each row must be uniquely identified by values drawn from one or more of the tables underlying domains.

Candidate keys

The domain(s) or column(s) that identify a row’s uniqueness are referred to as candidate keys. There are no restrictions on how many columns may be candidate keys, although columns containing null values (i.e., no data) are not permitted as there is no guarantee they are unique (Dwelle 1996a). Figure 3.2 provides an example of a table in which a number of candidate key combinations are possible. The only column that cannot be a candidate key in its own right is FirstName as the value “John” is repeated. Once identified a primary key for the table must be selected from these candidates. Instances do occur in which row uniqueness cannot be determined using naturally occurring attributes and methods for overcoming this problem are discussed below. For the purpose of this discussion row uniqueness is taken for granted.
Primary keys

The primary key of a table is “any candidate key of that table which the database designer arbitrarily designates as primary” (Dwelle 1996a; see also Codd 1970). As such, a primary key shares all the properties of a candidate key with the exception of its arbitrary selection as a primary key. Primary keys should be non-redundant Codd (1970) and if based on a single column or simple domain they must be non-redundant. In Figure 3.2, both Surname and Address could be considered non-redundant as no values are repeated (i.e., they uniquely identify each row).

If, however, the primary key is based on a set of domains (i.e., two or more) none of the simple domains in the set should be superfluous to the key. Such sets often known as concatenated or composite keys (Jennings 1995:836). Referring again to Figure 3.2 it would be possible to create a concatenated primary key based on one of the following combinations:

1. FirstName, Surname, Address
2. Surname, Address
3. FirstName, Surname
4. FirstName, Address
Of these possibilities combinations 1, 3 and 4 contain a domain that is superfluous to the primary key, i.e., **FirstName**, the reason being that as the value "John" is repeated it does not provide further uniqueness constraints to the primary key than already contributed by **Surname** and **Address**. In other words, the domain **FirstName** does not assist in uniquely identifying any one row. If a single column cannot be employed as the primary key then the candidate keys with the least number of columns should be employed (Date 1995:115).

While not common and not recommended, occasions may arise where the primary key of a table may require changing. In such cases the new primary key should be selected from alternate keys.

*Alternate keys*

Alternate keys are those candidate keys which are not included in the current primary key of a table. Once a candidate key has been selected as a primary key, all others (if any) are designated as alternate keys (Date 1995:115). Therefore, an alternate key may be defined as a "function of all candidate keys minus the primary key" (Dwelle 1996a). In Figure 3.2 if **Address** were selected as the primary key, the alternate keys would be **Surname** and **Address** and **Surname**.

*Determining uniqueness*

As indicated previously occasions arise where row uniqueness and thus a primary key cannot be determined by a combination of domains in a table. Consider a series of shell middens all of which contain the remains of one shellfish species. Each midden is located on a beach ridge, covers the same area and has the same maximum, minimum and average densities of shell. While these middens may be located any number of kilometres apart on the basis of the attributes employed to identify them (i.e., site type, species, location, area and shell density) they all appear the same. While each midden is a distinct object and exists in its own right, none are unique. Much the same could be applied to humans. If you tried to uniquely identify each person in a group on the basis of eye and hair colour it
would be impossible despite the fact that each member of the group existed. In other words, while existence may be considered a naturally occurring property, uniqueness is not necessarily so (Dwelle 1996b). Obviously this fact creates problems when determining candidate keys, as it may not be possible to uniquely identify each row on the basis of naturally occurring attributes.

To overcome this problem a non-natural property is often created to identify each row (Dwelle 1996b). In the case of the shell middens presented above a site number could be employed. Because an individual site number would only occur once in the database it would uniquely identify each row in the table and thus it is possible to uniquely identify each midden regardless of its other attributes. However, care must be taken when using non-natural identifiers as it is possible to exclude candidate keys from the primary key that enforce natural uniqueness (Dwelle 1996b). Consider that no two sites can have exactly the same geographic location and that this can be captured in a database by using grid references.

Figure 3.3a provides an example of grid references for a series of shell middens. The primary key of this table comprises the easting and northing columns in the table. By employing this concatenated key it ensures that each combination of easting and northing is unique. In other words, only one shell midden can be located at the combination easting \(X\)/northing \(Y\). The fact that some eastings or northings may repeat does not impinge upon row uniqueness as each combination can only occur once. If a decision were made to replace this combination with the system-supplied auto-counter column \(LocationID\) as the primary key (Figure 3.3b) problems would arise. Despite the fact that each row is still uniquely identified it would be possible to locate any number of sites to a particular grid reference because the uniqueness properties of the original primary key were not retained. Therefore, if an identity is employed as a primary key it is also necessary to indicate which
columns act as alternate keys to ensure that the original uniqueness of the rows is captured (Dwelle 1996b). In other words, if an identity is used to ensure row uniqueness it should, if possible, be used in conjunction with other alternate keys. Thus in Figure 3.3b, if a combination of LocationID, Easting and Northing were employed as a concatenated primary key, it would not be possible to have any duplicated grid references because each row must contain a unique combination of Easting, Northing and LocationID.

![Figure 3.3](image-url)  
(a) Site location table in its original form. (b) Site location table after adding a primary key based on a unique ID number.

**Foreign keys and relationship types**

**Foreign keys**

The final type of key to be found in a relational database is the foreign key which is defined as "a column whose values correspond to those in a primary key...in another related table" (Jennings 1995:836). In other words, the links between tables are maintained by the primary key/foreign key relationship. As with the other key types, a foreign key may comprise either single or multiple columns. Unlike primary keys, however, foreign keys are not required to be unique because they are not used to uniquely identify each row.

Take for instance two tables containing data sets that are related. The first contains various details about a site, while the second contains information about map sheets (Figure 3.4). In order to determine which sites are located on which map sheet and vice versa it is necessary to link these tables. One linking method would be to record the map details in the same table as the site details. However, as discussed in Section 3.4 below relational
algebra does not allow this to occur. To maintain the relationship between archaeological sites and map sheets a foreign key is employed in one of the tables, in this case the Site Details table. As shown in Figure 3.4 the map number column occurs in both the Map Details table and the Site Details table. In the Map Details table it is the primary key, whereas in the Site Details table it acts as a foreign key and thus maintains the relationship between the two objects, sites and maps. Because MapNo acts as a foreign key in the Site Details table repeating values are allowed as a given map sheet may provide the location of more than one site. Also note that unless indicated otherwise, the following colour conventions are used to identify primary keys and foreign keys:

1. primary key - red
2. foreign key - blue
3. foreign key that also acts as part of a concatenated primary key - magenta.

Having defined foreign keys it is now possible to examine the relationship types that exist between linked tables.

Figure 3.4 Example of a primary key/foreign key relationship between sites and map sheets based on the MapNo column.

Relationship types

The linking together of tables with a primary key/foreign key combination results in one of three relationship types being formed. These are one-to-one, one-to-many and many-to-many and each is defined separately below.
One-to-one relationships

A one-to-one relationship is the most basic of relationship types between tables found in a relational database and simply means that a one-to-one correlation exists between the primary and foreign keys in the tables concerned. In other words, for each row in the table containing the primary key there is exactly one corresponding row in the table containing the foreign key. Figure 3.5 presents an example of a one-to-one relationship between a table containing site details and another providing a significance rating for each site. The rule applying to the significance rating is that each site can only have one rating although an individual rating may apply to more than one site. In this case the relationship is based on the SiteID column. While it is not incorrect to record the significance rating in the same table as the site details, it is likely that such information would have restricted access. To ensure that the rating can only be accessed by authorised personnel a one-to-one relationship must be created between the tables. This is a common reason for employing one-to-one relationships (Jennings 1995:848). By using the SiteID column to set the primary key/foreign key relationship it is possible to create a one-to-one relationship between the two tables.

![Table: Site Details](image)

<table>
<thead>
<tr>
<th>SiteID</th>
<th>Sitename</th>
<th>Easting</th>
<th>Northing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site1</td>
<td>JF:B11</td>
<td>589780</td>
<td>3338700</td>
</tr>
<tr>
<td>Site2</td>
<td>GK:A02</td>
<td>689540</td>
<td>6855600</td>
</tr>
<tr>
<td>Site3</td>
<td>GK:A35</td>
<td>996680</td>
<td>4101400</td>
</tr>
<tr>
<td>Site4</td>
<td>GK:A64</td>
<td>155890</td>
<td>8594460</td>
</tr>
<tr>
<td>Site5</td>
<td>EP:C04</td>
<td>431500</td>
<td>8816950</td>
</tr>
<tr>
<td>Site6</td>
<td>KE:A17</td>
<td>521000</td>
<td>5860000</td>
</tr>
<tr>
<td>Site7</td>
<td>KE:A06</td>
<td>619170</td>
<td>2194180</td>
</tr>
</tbody>
</table>

![Table: Significance](image)

<table>
<thead>
<tr>
<th>SiteID</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site1</td>
<td>JF:B11</td>
</tr>
<tr>
<td>Site2</td>
<td>GK:A02</td>
</tr>
<tr>
<td>Site3</td>
<td>GK:A35</td>
</tr>
<tr>
<td>Site4</td>
<td>GK:A64</td>
</tr>
<tr>
<td>Site5</td>
<td>EP:C04</td>
</tr>
<tr>
<td>Site6</td>
<td>KE:A17</td>
</tr>
<tr>
<td>Site7</td>
<td>KE:A06</td>
</tr>
</tbody>
</table>

For each site there can only be one significance level

Figure 3.5 Example of a one-to-one relationship between two tables.

In the Significance table, note that SiteID is both the foreign key and the primary key. This ensures that row uniqueness is enforced to comply with the UoD rule that one site has one rating.
One-to-many relationships

The one-to-many relationship is the most one common found in relational databases and
simply means that a single row in one table is linked to one or more rows in another table.
In this case while a given value in the primary key is unique, the same value acting in the
foreign key may be repeated any number of times. An example of a one-to-many
relationship between map numbers and map edition numbers is shown in Figure 3.6. In this
case MapNo is the primary key in the Map Details table and the foreign key in the Map
Edition table. As each map may have a number of editions the map number of a given map
in the Map Details table must be repeated for each edition in the Map Edition table. In other
words, the fact that one map may have many editions must be captured. It is also possible to
have a many-to-one relationship between related tables whereby the relationship is a mirror
image of the one-to-many relationship. Such relationships are referred to as reflexive
(Jennings 1995:850).

<table>
<thead>
<tr>
<th>Map Details</th>
<th>Scale</th>
<th>MapNo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooktown</td>
<td>1:250 000</td>
<td>7967</td>
</tr>
<tr>
<td>Bowling Green Bay</td>
<td>1:250 000</td>
<td>8359</td>
</tr>
<tr>
<td>Cape Upstart</td>
<td>1:250 000</td>
<td>8458</td>
</tr>
<tr>
<td>Rockhampton</td>
<td>1:250 000</td>
<td>9051</td>
</tr>
<tr>
<td>Miriam Vale</td>
<td>1:250 000</td>
<td>9249</td>
</tr>
<tr>
<td>Bundaberg</td>
<td>1:250 000</td>
<td>9348</td>
</tr>
<tr>
<td>Moreton (Special)</td>
<td>1:250 000</td>
<td>9543-1-NE</td>
</tr>
<tr>
<td>Mt Tempest (Special)</td>
<td>1:250 000</td>
<td>9543-1-SSE</td>
</tr>
<tr>
<td>Kooringal</td>
<td>1:250 000</td>
<td>9543-11-NE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Map Edition</th>
<th>MapNo</th>
<th>Edition</th>
</tr>
</thead>
<tbody>
<tr>
<td>7967</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8359</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8458</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9051</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9249</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9348</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9543-1-NE</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9543-1-SSE</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9543-11-NE</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.6 Example of a one-to-many type relationship between two tables.

Many-to-many relationships

Unlike the previous relationships which are based on primary key/foreign key links, many-
to-many relationship are the result of joining two tables to create a third that has a reflexive
or many-to-one relationship with the two original tables. Figure 3.7 presents an example of a
many-to-many relationship based on the primary keys for the Archaeologists Details and Site
Details tables. The new table, Recording Details, has a many-to-one relationship with each
of these tables as seen in the multiple occurrences of ArchID and SiteID from the Archaeologists Details and Recording Details tables respectively.

Table: Site Details

<table>
<thead>
<tr>
<th>Easting</th>
<th>Northing</th>
<th>SiteID</th>
</tr>
</thead>
<tbody>
<tr>
<td>588780</td>
<td>3338700</td>
<td>JF:B11</td>
</tr>
<tr>
<td>685540</td>
<td>6855600</td>
<td>GK:A02</td>
</tr>
<tr>
<td>968080</td>
<td>4104100</td>
<td>GK:A35</td>
</tr>
<tr>
<td>156800</td>
<td>8594450</td>
<td>GK:A64</td>
</tr>
<tr>
<td>431500</td>
<td>8815500</td>
<td>EP:C04</td>
</tr>
<tr>
<td>521000</td>
<td>5860000</td>
<td>KE:A17</td>
</tr>
<tr>
<td>619170</td>
<td>2194180</td>
<td>KE:A06</td>
</tr>
</tbody>
</table>

Table: Recording Details

<table>
<thead>
<tr>
<th>SiteID</th>
<th>ArchID</th>
</tr>
</thead>
<tbody>
<tr>
<td>JF:B11</td>
<td>1</td>
</tr>
<tr>
<td>GK:A02</td>
<td>2</td>
</tr>
<tr>
<td>GK:A35</td>
<td>3</td>
</tr>
<tr>
<td>GK:A64</td>
<td>4</td>
</tr>
<tr>
<td>EP:C04</td>
<td>4</td>
</tr>
<tr>
<td>KE:A17</td>
<td>5</td>
</tr>
<tr>
<td>KE:A06</td>
<td>6</td>
</tr>
<tr>
<td>JF:B11</td>
<td>4</td>
</tr>
<tr>
<td>GK:A64</td>
<td>7</td>
</tr>
</tbody>
</table>

Table: Archaeologist's Details

<table>
<thead>
<tr>
<th>ArchID</th>
<th>FirstName</th>
<th>Surname</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>John</td>
<td>Bonham</td>
</tr>
<tr>
<td>2</td>
<td>Ian</td>
<td>Paice</td>
</tr>
<tr>
<td>3</td>
<td>Keith</td>
<td>Moon</td>
</tr>
<tr>
<td>4</td>
<td>Charles</td>
<td>Watts</td>
</tr>
<tr>
<td>5</td>
<td>John</td>
<td>Coughlan</td>
</tr>
<tr>
<td>6</td>
<td>Richard</td>
<td>Stanley</td>
</tr>
<tr>
<td>7</td>
<td>Ginger</td>
<td>Baker</td>
</tr>
<tr>
<td>8</td>
<td>Sandy</td>
<td>West</td>
</tr>
</tbody>
</table>

Figure 3.7 An example of a many-to-many relationship between tables.

**Types of tables**

Prior to the next section, which discusses how the contents of each table, i.e., the columns, are determined, it is important to identify the two types of tables that may be found in a relational database, base tables and relational tables (Jennings 1995:386). With the exception of the Recording Details table (Figure 3.7), each of the previous examples has employed base tables which are identified by two specific properties. First, all base tables must contain a primary key, either single column or concatenated. Second, each base table is unique within the database structure as it only contains data relating to one aspect of the UoD (Jennings 1995:836). Thus it is incorrect to include an archaeologist's personal details in the same table containing site details.

As a relational table links two base tables it contains only foreign keys (e.g., the Recording Details table in Figure 3.7); it should not contain any of the descriptive data used in modeling the UoD (Jennings 1995:836). Furthermore, it is likely that in a relational table row uniqueness will be lost. Returning to the Recording Details table (Figure 3.7) it should be noted that as the archaeologist with the ID number “1” recorded the site GK:A64 twice this information is repeated twice thus resulting in a loss of uniqueness. In this example the loss of uniqueness is not a problem as this archaeologist did record the same site twice and
thus the UoD is being modeled accurately. However, there are cases where the inclusion of columns that are not foreign keys is required to maintain data integrity (Jennings 1995:839).

**Overview**

The preceding sections have described in some detail the components that comprise a relational view of data. The discussion began with descriptions of the three relational keys found in the relational model of a database. The first of these keys was the candidate key which is determined by identifying which column(s) uniquely identify each row in a given table. The second key was the primary key which is selected from the list of candidate keys and designated as primary. However, when two or more columns are employed redundant columns must be excluded. Thus, if one candidate key comprises three columns and another only two, then that candidate key with two columns should be designated as primary. The final type was the alternate key which simply comprises candidate keys not selected for the primary key.

A critical aspect of relational databases concerns the determination of row uniqueness. Essentially, if every row in a base table is not unique the database will malfunction and extracted information may be misleading if not incorrect. Ideally, row uniqueness should be based on an object’s naturally occurring attributes although situations do arise where this is not possible. In such cases an identity column must be placed in the table, although attempts should be made to include other columns to assist in maintaining row uniqueness.

Once a table’s primary key has been defined it is necessary to link it with related tables. This is achieved by reproducing the table’s primary key, or part thereof, and placing it in related base tables. This duplicated primary key is referred to as a foreign key and the relationship formed by the primary key/foreign key is named on the basis of the relationship between the two. If a given value in a primary key occurs only once in its foreign key role a one-to-one relationship is formed. When primary key values are repeated
in the foreign key a one-to-many relationship is formed whereas many-to-many type relationships result when two base tables are joined to form a third or relational table.

In sum, the preceding has described those attributes comprising a relation or table, the methods employed to ensure the identification and maintenance of row uniqueness and the way in which the relationships between the tables in a relational database are created. What has yet to be described is the process that determines which domains or columns are placed in which tables. Take, for example, the tables containing attributes specific to map sheets depicted in Figure 3.6. Why was this data presented in two tables rather than one? The answer lies in a complex process known as normalization.

**Normalization**

Normalization “is a formalised process by which data...are grouped into tables, and tables are grouped into databases” (Jennings 1995:842) using either decomposition or synthesis (Halpin 1995:386). Of these, decomposition is the most commonly employed process for developing relational databases and as such my discussion is limited to it. Moreover, it is this process which consistently appears in RDBMS manuals to assist software purchasers unfamiliar with database design in developing their own databases and, as such, is the method most archaeologists are likely to encounter.

Halpin (1995:386) describes the decomposition method of normalization as an iterative process involving five stages which aim to ensure that

1. future changes in the structure of tables can be accommodated,
2. duplicate or redundant data is eliminated from tables, and
3. anomalies resulting from insertion, deletion or modification of data do not occur (Betz 1994:4; Jennings 1995:842).
Of these three points, the most critical are those relating to redundant data and anomalies. Indeed, if these two problems are eliminated from the database then future changes to table structure should be relatively seamless.

Figure 3.8 presents an extract from a database to illustrate occurrences of data redundancy and insertion, deletion and modification anomalies. The first point to note about this Figure is that it contains numerous instances of redundant data. In fact, each column contains instances of data redundancy. This means that the data in some cells of a given column occurs more than once. Thus site identification codes, recorder identification numbers and their names and addresses are repeated. This repetition represents redundancy which would likely result in anomalies and problems with the database’s operation.

![Table](image)

**Figure 3.8** Examples of redundant data and anomalies.

In the Figure 3.8 examples an insertion anomaly would occur if a new Recorder was added prior to their actually recording a site. In other words, the design of the table does not allow for the addition of new Recorders in their own right; they must first record a site. Likewise, if a new Recorder type (e.g., State Archaeologist) was identified it would not be possible to enter this value into the database until a State Archaeologist recorded a site. Conversely, deletion of a Recorder from the table would result in a loss of information concerning sites they have recorded. For example, deleting Recorder #1 would result in the loss of data relating to the location of two sites. Deletion anomalies such as these have the potential to be highly destructive.
A modification anomaly would occur if, for example, Recorder #1 changed his address because each occurrence of the old address would have to be replaced with the new one. Anomalies of this type are most often associated with databases developed using spreadsheet software or flat file applications. Despite the fact that many flat file DBMS and spreadsheet programs do have search and replace functions, there is no guarantee they will work in the desired manner. If the original address had been misspelled in one or more entries it would not be changed during a search and replace action as only exact matches of the address would be found. Conversely, if a wildcard was employed in the search to overcome spelling errors it is possible that other, unrelated addresses may be inadvertently changed. Consider, for example, that Recorder #6 lives in Ring Rd and that in other instances of the database it had been recorded as Bring Rd and Rink Rd. A wildcard search and replace could specify:

\begin{verbatim}
Begin:
search: column address for character string "*in*" (where * = wildcard characters)
replace: character string "*in*" with character string "Ring"
end.
\end{verbatim}

A search and replace of this type is designed to pick up all instances of the character string “in” and in this case replace it with the correct name Ring. The wildcards simply indicate that any number of letters may occur before or after the string being searched for. Certainly this would correct any spelling errors in Ring Rd. However, as Zeppelin St. also contains the character string “in” all instances of Zeppelin would be replaced with Ring. Greater efficiency would be achieved if addresses could be stored at a single location in the database so that modifications need only be made at this location and updated throughout the database automatically. This is exactly how a relational database works; rather than storing multiple instances of the same data, the data is stored in one place and linked to related data via the primary key/foreign key relationship. In order to achieve this it is
necessary to split the table presented in Figure 3.8 into two or more smaller tables. In other words, the table needs to be normalized.

The way in which tables are split is determined by specific rules relating to each stage of normalization or normal form. These normal forms are

1. first normal form,
2. second normal form,
3. third normal form,
4. fourth normal form, and
5. fifth normal form.

Each step in the normalization process is dependent upon correctly completing the preceding step. Thus execution of the third normal form can only take place if a table is already in the first and second normal forms. Consequently, as normalization proceeds from stage to stage there is a concomitant reduction in the amount of redundancy and the number of anomalies until the table reaches a fully normalized state.

Normalization begins with unnormalized data, i.e., the type of data that may be found in spreadsheets, recording forms, reports and thesis, etc. In the following demonstration of the normalization process a fictional CRM database, dubbed ArchBase is used and Figure 3.9 represents an extract of data to be included in the database.
## Archaeological Site Recording Report

### Site Details

<table>
<thead>
<tr>
<th>SiteID</th>
<th>Easting</th>
<th>Northing</th>
<th>Management Priority</th>
<th>Significance Code</th>
<th>ArchID</th>
<th>Recorder Name</th>
<th>Address</th>
<th>DateRec</th>
<th>RecType</th>
<th>MapNo and Name</th>
<th>EditionNr</th>
</tr>
</thead>
<tbody>
<tr>
<td>EP:C04</td>
<td>431500</td>
<td>8815500</td>
<td>3</td>
<td>C</td>
<td>4</td>
<td>Charles Watts</td>
<td>45 Stone Av</td>
<td>15/06/91</td>
<td>Ranger</td>
<td>7967</td>
<td>Cooktown</td>
</tr>
<tr>
<td>GKA02</td>
<td>685540</td>
<td>6855000</td>
<td>3</td>
<td>C</td>
<td>2</td>
<td>Ian Peace</td>
<td>24 Purple Rd</td>
<td>2/04/92</td>
<td>Researcher</td>
<td>8458</td>
<td>Cape Upstart</td>
</tr>
<tr>
<td>GKA35</td>
<td>968080</td>
<td>4101400</td>
<td>2</td>
<td>B</td>
<td>3</td>
<td>Keith Moon</td>
<td>36 Wizard La</td>
<td>25/11/96</td>
<td>Researcher</td>
<td>8458</td>
<td>Cape Upstart</td>
</tr>
<tr>
<td>GKA64</td>
<td>156800</td>
<td>8594450</td>
<td>2</td>
<td>B</td>
<td>1</td>
<td>John Bonham</td>
<td>11 Zeppelin St</td>
<td>5/01/97</td>
<td>Consultant</td>
<td>8159</td>
<td>Bowling Green Bay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>John Bonham</td>
<td>11 Zeppelin St</td>
<td>25/11/96</td>
<td>Consultant</td>
<td>8159</td>
<td>Bowling Green Bay</td>
</tr>
<tr>
<td>JF:B11</td>
<td>588780</td>
<td>3338700</td>
<td>1</td>
<td>A</td>
<td>4</td>
<td>Charles Watts</td>
<td>45 Stone Av</td>
<td>27/08/90</td>
<td>Ranger</td>
<td>9051</td>
<td>Rockhampton</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>John Bonham</td>
<td>11 Zeppelin St</td>
<td>1/12/94</td>
<td>Consultant</td>
<td>9051</td>
<td>Rockhampton</td>
</tr>
<tr>
<td>KE:A06</td>
<td>619170</td>
<td>2194180</td>
<td>1</td>
<td>A</td>
<td>6</td>
<td>Richard Starkey</td>
<td>65 Rings Rd</td>
<td>27/08/90</td>
<td>Consultant</td>
<td>9249</td>
<td>Miriam Vale</td>
</tr>
<tr>
<td>KE:A17</td>
<td>521000</td>
<td>5800000</td>
<td>1</td>
<td>A</td>
<td>5</td>
<td>John Coughlan</td>
<td>12 Bar St</td>
<td>3/06/89</td>
<td>Consultant</td>
<td>9348</td>
<td>Bundaberg</td>
</tr>
</tbody>
</table>

### Figure 3.9
Example of unnormalized data.
The first normal form

The first normal form (1NF) rules state that data be presented in flat tables, that there be no repeating columns and that columns relating to the same subject are grouped together in their own tables. To maintain links between the tables, primary/foreign key relationships must be determined. Thus the first step in decomposing Figure 3.9's data requires the creation of a series of tables each of which are based on columns of related data. As in the case of many forms, this one already contains groups of related data under the two main section headings. These section headings, Site Details and Recorder Details, provide two table names; a third table relating to Map Details must also be created. The subheadings in each section provide the basis for some of the column names, albeit in a shortened form (Figure 3.10).

As the rules of the 1NF also require that cells must contain only atomic values, the subheadings Map Name and Number, and Recorder Name must also be split as they contain non-atomic data. In other words, a map's name and its number are both drawn from different domains, as are a person's first name and surname. To meet this requirement these subheadings are decomposed into the following columns:

1. MapName, MapNo in the Map Details table, and
2. FirstName, Surname in the Recorder Details table.

The final step in placing the data from the Site Recording Form into the 1NF is the creation of links between the individual tables via primary and foreign key columns. For Site Details the primary key is the column SiteID, as it meets the requirements of a primary key in that it contains no repeating values and thus uniquely identifies each row in the table. For Map Details and Recorder Details it is necessary to create concatenated primary keys. In Map Details this key employs the MapNo and EditionNo columns as some mapsheets may have more than one edition and therefore the map sheet number may be repeated.
However, as the edition number of a given map sheet will not be repeated, the combination of these two columns provides a unique primary key.

Table: Site Details

<table>
<thead>
<tr>
<th>SiteID</th>
<th>MapNo</th>
<th>Easting</th>
<th>Northing</th>
<th>Significance</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>JF:B11</td>
<td>9051</td>
<td>588700</td>
<td>3338700</td>
<td>1 A</td>
<td></td>
</tr>
<tr>
<td>GK:A2</td>
<td>8458</td>
<td>685540</td>
<td>8556000</td>
<td>3 C</td>
<td></td>
</tr>
<tr>
<td>GK:A3</td>
<td>8468</td>
<td>960030</td>
<td>4101400</td>
<td>2 B</td>
<td></td>
</tr>
<tr>
<td>EP:A6</td>
<td>8359</td>
<td>156000</td>
<td>8594450</td>
<td>2 B</td>
<td></td>
</tr>
<tr>
<td>KE:A7</td>
<td>9348</td>
<td>520000</td>
<td>8560000</td>
<td>1 A</td>
<td></td>
</tr>
<tr>
<td>KE:A06</td>
<td>9249</td>
<td>819170</td>
<td>2194180</td>
<td>1 A</td>
<td></td>
</tr>
</tbody>
</table>

Table: Recorder Details

<table>
<thead>
<tr>
<th>SiteID</th>
<th>DateRec</th>
<th>ArchID</th>
<th>FirstName</th>
<th>Surname</th>
<th>Address</th>
<th>RecType</th>
</tr>
</thead>
<tbody>
<tr>
<td>JF:B11</td>
<td>01-Dec-84</td>
<td>1 John</td>
<td>Bonham</td>
<td>11 Zeppelin St</td>
<td>Consultant</td>
<td></td>
</tr>
<tr>
<td>GR:A02</td>
<td>02-Apr-92</td>
<td>2 lan</td>
<td>Place</td>
<td>24 Purple Rd</td>
<td>Researcher</td>
<td></td>
</tr>
<tr>
<td>GK:A3</td>
<td>24-Nov-86</td>
<td>3 Keith</td>
<td>Moon</td>
<td>36 Wizard St</td>
<td>Researcher</td>
<td></td>
</tr>
<tr>
<td>GK:A4</td>
<td>24-Nov-86</td>
<td>4 John</td>
<td>Bonham</td>
<td>11 Zeppelin St</td>
<td>Consultant</td>
<td></td>
</tr>
<tr>
<td>EP:C04</td>
<td>15-Jun-91</td>
<td>5 John</td>
<td>Coughlan</td>
<td>12 Bar St</td>
<td>Consultant</td>
<td></td>
</tr>
<tr>
<td>KE:A17</td>
<td>03-Jun-88</td>
<td>6 Richard</td>
<td>Starkey</td>
<td>65 Ring Rd</td>
<td>Consultant</td>
<td></td>
</tr>
<tr>
<td>KE:A06</td>
<td>27-Aug-90</td>
<td>7 Richard</td>
<td>Starkey</td>
<td>65 Ring Rd</td>
<td>Consultant</td>
<td></td>
</tr>
<tr>
<td>JF:B11</td>
<td>27-Aug-90</td>
<td>8 John</td>
<td>Starkey</td>
<td>65 Ring Rd</td>
<td>Consultant</td>
<td></td>
</tr>
<tr>
<td>GK:A4</td>
<td>04-Jan-97</td>
<td>9 John</td>
<td>Bonham</td>
<td>11 Zeppelin St</td>
<td>Consultant</td>
<td></td>
</tr>
</tbody>
</table>

Table: Map Details

<table>
<thead>
<tr>
<th>MapNo</th>
<th>EditionNo</th>
<th>MapName</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>9051</td>
<td>1</td>
<td>Rockhampton</td>
<td>1:250 000</td>
</tr>
<tr>
<td>8458</td>
<td>1</td>
<td>Cape Upstart</td>
<td>1:250 000</td>
</tr>
<tr>
<td>8468</td>
<td>2</td>
<td>Cape Upstart</td>
<td>1:250 000</td>
</tr>
<tr>
<td>8359</td>
<td>1</td>
<td>Bowling Green</td>
<td>1:250 000</td>
</tr>
<tr>
<td>7967</td>
<td>1</td>
<td>Cooktown</td>
<td>1:250 000</td>
</tr>
<tr>
<td>9248</td>
<td>2</td>
<td>Bundaberg</td>
<td>1:250 000</td>
</tr>
<tr>
<td>9249</td>
<td>2</td>
<td>Mount Vale</td>
<td>1:250 000</td>
</tr>
<tr>
<td>8561</td>
<td>1</td>
<td>Rockhampton</td>
<td>1:250 000</td>
</tr>
<tr>
<td>8359</td>
<td>1</td>
<td>Bowling Green</td>
<td>1:250 000</td>
</tr>
<tr>
<td>8359</td>
<td>2</td>
<td>Bowling Green</td>
<td>1:250 000</td>
</tr>
<tr>
<td>9643-1-NE</td>
<td>1</td>
<td>Moreton</td>
<td>1:25 000</td>
</tr>
<tr>
<td>9643-1-SE</td>
<td>1</td>
<td>Mt Tempest</td>
<td>1:25 000</td>
</tr>
<tr>
<td>9643-11-NE</td>
<td>1</td>
<td>Kooringal</td>
<td>1:25 000</td>
</tr>
</tbody>
</table>

Figure 3.10  The three tables created from the data presented in Figure 3.9 by applying the rules of the INF.

A similar situation occurs in Recorder Details. As one archaeologist may record more than one site, and in some cases may record the same site more than once, values in the ArchID column may be subject to repetition and cannot act as a primary key in their own right. Likewise, a combination of ArchID and DateRec does not provide a unique identifier as a given archaeologist may record more than one site on one date. Note, however, that to maintain the link between Site Details and Recorder Details the foreign key SiteID has been included in Recorder Details (Figure 3.10). If this column is combined with both DateRec and SiteID a unique concatenated primary key is formed, as no recorder would record the same site more than once on a given date (Figure 3.10).
While the tables in Figure 3.10 are now in the 1NF, numerous modification/deletion anomalies still exist. For example, the data relating to each site recorder must be repeated every time he or she records a site. Similarly, each time a new edition of a map is published all information relating to that map must be repeated. Likewise, it is still not possible to include an archaeologist who has not recorded a site in the database. To remove these and other anomalies the normalization process continues by placing the tables in the second normal form.

**The second normal form**

The 2NF aims to eliminate redundant data by creating separate tables for attribute sets that apply to multiple records. If the primary key of a table comprises a single column (i.e., it has non-repeating values) then that table is in the 2NF. As in the 1NF primary keys/foreign keys must be determined for all tables.

The key to understanding how the 2NF operates is based on the aspect of relational algebra that states that the attributes of the non-key columns in a table must be functionally determined by the primary key column(s) (e.g., Date1995; Halpin 1995; Jennings 1995). Thus the 2NF states that all tables must be in the 1NF and that all non-key columns in each table be functionally dependent on the primary key (Jennings 1995:844). If the primary key is concatenated then all key columns must be functionally dependent on one another and the non-key columns must be functionally dependent on the whole key and not just part of it (Halpin 1995:389). A functional dependency may be defined as follows:

Given attributes X and Y of a relation, X functionally determines Y if and only if Y is a function of X (i.e., given any possible population of the table, for each value X there is only one value for Y) (Halpin 1995:389).

Returning to the Site Details table (Figure 3.10) it is safe to state that it is already in the 2NF as the SiteID column is the primary key and contains no repeating values. The Map Details and Site Recorder tables are not.
The Map Details table (Figure 3.10) is not in the 2NF as the non-key columns, MapName and Scale, are not functionally dependent on the whole key. Rather, the name and scale of a given map are functionally dependent on the map number not the edition number. This is because each map number is associated with exactly one map name and one scale. On the other hand, no matter how many editions of a given map are produced neither the number, name nor scale will change. Thus if a map number is taken as X and the edition number as Y it follows that there may be many Y values for each X value, not one. Therefore, the Map Details table must be split to create a new table Map Edition (Figure 3.11) with MapNo forming the primary key/foreign key link between the tables. The Map Details table is now in the 2NF as it has a single column primary key. The same applies to the Map Edition table as it comprises a concatenated primary key based on MapNo and EditionNo. Remember, as both map and edition numbers will repeat in this table the primary key must be concatenated to ensure row uniqueness is maintained.

The situation for the Recorder Details table is more complex. First, this table contains insertion, deletion and modification anomalies. Second, because of these anomalies the columns comprising the primary key are not functionally dependent on one another. This also means that the non-key columns cannot be functionally dependent on the whole primary key. The table must split to place it in the 2NF.

![Figure 3.11 Results of applying the 2NF to the Map Details table from Figure 3.10.](image-url)
While the name and address of a Site Recorder are functionally dependent on his or her ArchID, it is incorrect to state that a recorder's ID number and therefore name and address are a function of a site's ID number as each recorder may record more than one site. To overcome this problem all columns relating to recorders, except for the RecType and DateRec column, are removed from Recorder Details and placed in the new table Archaeologists (Figure 3.12). The result is a table in which

1. the repetition of values relating to the biographical details of each recorder no longer exists as each recorder is only documented once,
2. the ArchID column can now act as the primary key in its own right, and
3. the addition of previously unlisted archaeologists is possible regardless of whether or not they have recorded a site, e.g. the person with the ArchID #8 (Figure 3.12).

Figure 3.12 The new Archaeologists table resulting from the application of the 2NF.

However, the link between Site Details and the new Archaeologists table must be maintained. This is achieved by abandoning the Recorder Details table and creating the Site Recorded By table that includes the SiteID and ArchID columns as foreign keys (Figure 3.13). As the new Site Recorded By table has many-to-one relationships with both Site Details and Archaeologist and contains only foreign keys it is considered a relational table, not a base table.

As indicated previously, recorder types and site recording dates were excluded from the Archaeologist table as neither were functionally determined by an archaeologist's ID number. Consider that one archaeologist may be a researcher when recording one site and
a consultant when recording another. Similarly, more than one archaeologist can be a consultant, researcher or ranger. In other words, the recorder type is functionally dependent upon the work being undertaken by the archaeologist at the time of the recording. There is no need to actually capture this in the database as it is already reflected in the attribute entered for Rec Type.

Likewise, a site's recording date is not a function of an archaeologist's ID and each site could be recorded on more than one date. Despite this fact, both columns are required in order to avoid information loss. As the values associated with these two columns relate to every instance of an archaeologist recording a site, they can be placed in the Site Recorded By table. As indicated previously, this is allowable if columns other than foreign keys are required in a relational table to maintain database integrity (Figure 3.13). The rules of the 2NF do not apply to the Site Recorded By table as it does not contain a primary key. At this point all tables are in the 2NF and it is possible apply the rules of the third normal form.

**The third normal form**
The requirements for the third normal form (3NF) are that “all non-key columns of a table be dependent on the table's primary key and independent of one another” (Jennings 1995:845). To meet these requirements non-key columns cannot be functionally dependent on other non-key columns; if they are, then the table is said to contain a transitive dependency. In other words, if attribute $B$ is functionally dependent on attribute $A$, and attribute $C$ is functionally dependent on $B$, then it follows that $C$ is transitively dependent on $A$. In such cases the transitive dependency must be removed by splitting the table and determining primary key/foreign key relationships.
Figure 3.13 The reference table Site Recorded By resulting from the application of the 2NF rules.

Returning to Archbase, it should be clear that the Map Details, Archaeologists and Map Edition tables are in the 3NF as each of the non-key columns is functionally dependent on the primary key and not another non-key column. The Site Recorded By table can be ignored as it does not contain any primary keys. The Site Details table (Figure 3.10), however, does contain a transitive dependency. This dependency is based on the relationship between the two non-key columns Significance and Priority. Certainly the significance of any site whether cultural, scientific, etc., is functionally dependent on that site. In the example presented here, however, management priority is determined by significance and not the site. This transitive dependency may be stated as follows:

1. Significance Code is functionally dependent on SiteID,
2. Management Priority is functionally dependent on Significance Code, therefore
3. Management Priority is transitively dependent on SiteID.

To remove this transitive dependency it is necessary to create the new table CRM Details (Figure 3.14). In this case the Significance column becomes the primary key in the new table and the foreign key in the Site Details table (Figure 3.14).
Figure 3.14  The result of removing the transitive dependency from the Site Details table to meet the 3NF requirements.

From a theoretical position the rules of the 3NF should be strictly adhered to; however, there are cases where doing so may cause problems, not with the database per se but with the hardware or DBMS. For example, strictly adhering to the rules of the 3NF would result in separate tables being created for postcodes, states and countries in the Archaeologists table if they were shown. In a large database the continuous splitting of tables to meet the rules of the 3NF may result in too many open tables and thus exceed, for example, the physical memory capabilities of the machine (personal observation). Halpin (1995:374) refers to occurrences such as those mentioned for the Archaeologists table as controlled redundancy, because the database is actually undergoing a state of denormalization. Further, while controlled redundancy may slow down database updates because the redundant values must be kept consistent, it can, if properly managed, speed up query response times as the DBMS does not have to contend with a large number of tables (Halpin 1995:374). Therefore, the use of controlled redundancy should be judicious and is best used with those values of the database which are likely to remain fairly static such as postcodes, addresses, etc.

Once decomposition to the 3NF has been achieved it is possible to disregard the fourth and fifth normal forms. Jennings (1995:846) states that some “designers consider these forms too esoteric, or applicable only in specialised cases.” However, ignoring the fourth and fifth normal forms may cause serious problems in terms of database integrity, particularly in larger databases.
The fourth normal form

Unlike the previous normal forms, the fourth normal form (4NF) is concerned with multivalued dependencies (MVDs) rather than functional dependencies (Halpin 1995:393; Sasse and Fulton 1996). For an MVD to occur, a table must have at least three columns. In a table with at least three columns (e.g., X, Y, and Z) an MVD will occur if the values stored in column X multidetermines the values stored in column Y, regardless of the values in column Z (Halpin 1995:393). Obviously if X multidetermines Y then it must also hold that Y multidetermines X. Another way of explaining MVDs is that independent data values should not be stored in the same table when a many-to-many type relationship exists between those values (Jennings 1995:846). As with the previous normal forms when MVDs occur in a table it should be split.

In Figure 3.15 an example of a multivalued dependency is depicted. It is important to note that both the Type and Raw Material columns are independent values and that the table is in the 3NF as both non-key columns are functionally dependent on ArtefactNo. As indicated in Figure 3.15 a many-to-many or multivalued relationship exists between artefact types and raw materials as more than one flake is made on chert and both cores are silcrete. In other words,

1. Artefact type multidetermines Raw Material, and
2. Raw Material multidetermines Artefact Type.

![Figure 3.15 Example of a multivalued dependency, or many-to-many relationship between two independent columns.](image)

With the above in mind it now possible to examine Archbase for MVDs. The only table not in the 4NF is the Site Recorded By table which has been reproduced in Figure 3.16.
Remember, the initial purpose of this table was to ensure adherence to the rules of the 2NF and create a link between the Archaeologists Details and Site Details tables. In creating this table, however, two independent columns, RecType and DateRec, were included to enforce data integrity during the application of the 2NF rules. In examining the Site Recorded By table (Figure 3.13) it is possible to identify an MVD between values in these columns as two “researchers” recorded sites on the 25th of November 1996. Thus it is possible to state that RecType is multidependent on DateRec but it is not functionally dependent on DateRec. A given recorder type does not functionally determine a recording date. Likewise, the date a site is recorded does not functionally determine the type of recorder. As such, the table in Figure 3.16 violates the rules of the 4NF as it contains independent values which have a many-to-many relationship.

![Table: Site Recorded By](image)

**Figure 3.16** The Site Recorded By table as it appeared in the 2NF.

To overcome this MVD it is necessary to remove the RecType column and create a new table Recorder Type. To maintain the links between this table and the Sites Recorded By table it would appear necessary to first create a primary key/foreign key relationship based on ArchID. Doing so, however, would create redundancy problems as every time an archaeologist recorded a site both the ID number and recorder type would have to be entered; i.e., it would violate the 4NF rule as it would contain many-to-many relationships or a non-functional multivalued dependency between the ArchID and RecType columns. Furthermore, it would no longer be possible to determine which recorder type a particular archaeologist was when a given site was recorded as there is no direct relationship between
the site and the recorder type. To solve this problem the Recorder Type table is created as a base table, with each recorder type entered once and the RecID column as the foreign key in the Site Recorded By table which has been renamed Recording Details to better describe the data it contains (Figure 3.17). At this point it could be said that the table is in the 4NF. However, consider the DateRec column.

It is possible that dates may also be employed elsewhere in the database (e.g., for photographs, publications or reports) so it makes sense to create an independent Date table with links to the various related tables. Furthermore, by creating a separate date table the Recording Details table remains a proper relational table containing only foreign keys.

Figure 3.17 Results of applying the 4NF to the original Site Recorded By table.

With all tables now in the 4NF it is possible to advance to the final step in the normalization process, the fifth normal form.

**The fifth normal form.**

A table is considered to be in the fifth normal form (5NF) "if and only if, for each ... join dependency, each projection includes a key of the original table" (Halpin 1995:394). Essentially this means that the information presented in the original, unnormalized table(s) ought be reconstructed exactly from the tables into which it has been decomposed (Jennings 1995:846). Join dependencies depend on two operations, joins and projections. "The join operation ... involves combining two tables by matching values referencing the same object to form a new table" (Halpin 1995:117) (Figure 3.18). Referred to as natural
inner joins (Halpin 1995:98-99) they simulate a method for replicating the results of a database query to determine the accuracy of the results. Other join types, e.g., outer joins also occur in relational databases but are not discussed here.

Like joins, projections also produce tables, the difference being that projections are only performed on single tables (Halpin 1995:117). Projection of a table involves taking those columns that are of interest and then ensuring that each row resulting from the projection appears only once in the results (Halpin 1995:118). If the projection is made on the key of a table the results must have the same number of rows as the original table as a key cannot contain repetitive values. To be projected a table must have an arity of three or more. In such cases the projection is referred to as being nontrivial (Halpin 1995:394). If the table has an arity of two or less the projection can only be made on the whole table thus the projection is considered trivial (Halpin 1995:394).

![Figure 3.18 Example of a natural inner join. Table 3 is the natural inner join of Tables 1 and 2 (adapted from Halpin 1995:99).](image)

An example of projecting a table is shown in Figure 3.19. While only two projections are shown, any table with an arity of three e.g. X-Y-Z may be split four ways: X-Y, X-Z, Y-X, Y-Z; Z-X, Z-Y; X-Y, X-Z, Y-Z. The X-Y, X-Z, Y-Z split is referred to as 3-way splitting, and any joins made on such must be done in two stages: X-Y and X-Z first and then join the result X-Y-Z with Y-Z using Y and Z as common (Halpin 1995:120).
Figure 3.19 Examples of projections on two different columns of the same table.

Following a table’s projection it is necessary to determine if any information has been lost by employing the natural inner join described previously. If the original table can be reconstructed without information loss then the table can be split by employing the column on which the projection occurred as the primary key in one table and the foreign key in another. If the original table cannot be reconstructed in its original form then it can not be split.

With the above in mind it is now possible to determine if the all the tables created for *Archbase* are in the 5NF and if the original Archaeological Site Recording Report can be reconstructed successfully from these tables. This testing was undertaken by actually creating *Archbase* in Access and running a simple query which asked for all the details relating to the recording of all sites in the database to be returned. This query resulted in a total of 15 records being returned rather than the expected nine. Therefore, in its current state the database will not recreate exactly the information contained in the original Archaeological Site Recording Form. This occurred because there was no join dependency between the Site Details table, the Map Edition table and the Recording Details table. The roots of this problem can be traced back to where the initial table was split to conform with the 1NF rules. In splitting the original table the join between Site Details and Map Details was based on part of the primary key in the Map Details table only (i.e., MapNo). It did not
include the other part of the primary key EditionNo. Therefore, when the database attempts to link sites with their appropriate map sheets and edition numbers it is not possible to determine which site is located on which specific map edition. Likewise, when the join between Site Details and Recording Details was created it ignored the fact that each recording requires data relating to a map sheet and its edition number.

Take, for example the site JF:B11. The original Archaeological Site Recording Report indicates this site was recorded twice. One recording occurred on Edition 1 of map sheet 9051, and the other on Edition 2. However, when a join of the Site Details and Map Edition tables is undertaken four records are returned, not two (Figure 3.20). Therefore, it is not possible to use the column MapNo as a foreign key in the Site Details table. One way to solve this problem would be to place the SiteID column in the Map Edition table. Certainly this allows for each site to be identified with the relevant map sheet and edition number. However, as there is no join dependency between the Recording Details table and the Map Edition table (i.e., the join is based totally on the foreign key SiteID) a problem arises similar to that presented above (Figure 3.21).

Another way of viewing this problem is to examine the relationship that actually exists between the Site Details table and the Map Edition table. This relationship was created when the rules of the 2NF were applied to show that a given map sheet could have more than one edition number. It has nothing to do with recorded sites at all. Thus on the basis of this and the join results presented previously it appears necessary to place both MapNo and EditionNo in the Recording Details table (Figure 3.22).
Figure 3.20  The result caused by the lack of a join dependency between Site Details and Map Edition.

Figure 3.21 Result of the join on SiteID between Map Edition and Recording Details based on SiteID column.

Figure 3.22 The final format of the Recording Details table with the MapNo and EditionNo columns included.

It is also important to note that in this table EditionNo is not a foreign key. Rather it is an
independent value used to indicate on which edition number(s) of a map sheet a given site
is located. As such, it does not violate the rules of the 4NF. Furthermore, as the above join tests demonstrate, it is not possible to place either the MapNo or EditionNo columns in any other table without information loss. At this point all tables are in the 5NF and all the information contained in the original Archaeological Site Recording Report can be reconstructed exactly. The database has been normalized.

Discussion
Understanding the basic principles underpinning the relational database model and the process of normalization is a complex undertaking. In this chapter an introduction to these concepts couched in archaeological terms has been provided. The normalization rules have been explained in some detail and some of the potential pitfalls that may arise by not adhering to these rules have been discussed. As will be shown in Chapter 5 it is not necessary to understand these principles or the normalization process to construct a relational database. However, if archaeologists are to use RDBMS successfully and to have confidence in the results obtained, it is important that they have an understanding of these basics as it helps in gaining an understanding of what is going on “under the hood”. Furthermore, by having such understanding it is possible to have some idea of how the different tables comprising the database should fit together. For example, when designing tables to store data on scarred trees do you have the one side of a one-to-many relationship on the table storing data about the trees or the table with data about scars, or can you store all the information in one table? Questions such as these continue to pop up when designing a database and often the best way to resolve them is to understand the relational model and all that underpins it. Even using the methods I discuss in Chapter 5 it is still possible to come across problems that can best be solved by looking at how the tables have been constructed and how they relate.
In the two following chapters methods are examined that simplify the modeling process by concentrating on what is termed the ‘conceptual’ view of a database rather than its logical view.
Introduction
Designing a database is not a straightforward matter and designing one that actually works is even more difficult. Many database failures occur because of the difficulties involved in communicating ideas and objectives clearly and accurately to all persons with an interest in the database (Figure 4.1). To overcome such problems database designers employ data modeling techniques which aim to create as transparent a model of the data as possible.

![Figure 4.1 The problem with communication (Sasse and Fulton 1996).](image)

Data modeling
Data modeling is neither a natural nor an intuitive process (Dwelle 1996c). It is also a “complex subject, no matter how easy some people think it is” (Betz 1994:3, emphasis mine).
Ultimately, the success of any database project rests upon the designer's ensuring that the database is organised in a manner that

1. consistently and economically fulfills the end-user's needs;
2. accurately describes the type of facts to be stored in the database;
3. is well organised in respect to how the facts are stored, i.e., the tables, their corresponding columns and how they relate;
4. provides quick access to specific data in the database;
5. accommodates expansion without compromising existing data;
6. allows only validated data to be entered thus ensuring the database integrity is maintained; and
7. provides a user-friendly interface or front-end for the editing, display and reporting of information (Halpin 1995:4; Jennings 1995:828-829; Simsion 1994).

The starting point for achieving these aims is the data model. "For an information system to be useful, reliable, adaptable, and economic it must be first based on sound data modeling" (Dwelle 1996c). A data model is somewhat analogous to an architect's house plan (Halpin 1995:1) and "just as a house built from a good architectural plan is more likely to be safe and convenient for living, a well-designed database simplifies the task of ensuring that its facts are correct and easy to get at" (Halpin 1995:1). A data model is also a model in the real sense of the word as it provides a visual representation of the data structures thus allowing an assessment of how accurately and completely they reflect those aspects of the real world being modeled (Dwelle 1996c). In other words, it provides all those having a vested interest in the database with a view that is a compacted and integrated whole (Dwelle 1996c). Because the model is able to do this, it is possible to identify those areas which may be obscured by the complexities and relationships of the objects being modeled. The types of information being obscured, however, are not necessarily obscure in their own right, and failure to model such information may have major consequences for both data input and information retrieval.
Consider the fact that one archaeologist may record some sites as a researcher, some as a consultant and yet others as a regional archaeologist. Facts like this may be obscured to some extent while the database designer is wading through the material relating to the various categories of archaeologists that record sites. Therefore, the implemented database may only allow each archaeologist to belong to one category instead of multiple and varied categories. A similar problem occurred in Chapter 3 where the relationship between sites and map edition numbers was not initially captured. It is also possible that while occurrences such as those mentioned above might not have yet occurred in the real world, they might have the potential to do so in the future (e.g., a researcher may become a regional archaeologist or vice versa). A model that accurately describes objects and their relationships ensures that such instances should be visible and, consequently, represented in the model. Likewise, if previously unexpected circumstances arise following implementation, a well designed database should allow for changes to be made in a seamless manner.

The essence of [any form of] model lies in efficient representation, achieved by eliminating uninteresting detail and substituting symbols for bulkier components of the subject. Thus a model need not be simply a smaller copy of the real thing; it may use words, pictures, numbers, or any combination of media. So a data model drawn on a few pages of diagrams can represent the structure of a database which occupies megabytes or gigabytes of database storage (Dwelle 1996c).

To ensure that the data model provides an accurate and complete picture of the real world considerable input is required from all parties with an interest in the database. Therefore, even those with no technical expertise should be able to gain a clear understanding of how both the modeled objects relate to one another in the database and whether these accurately reflect the relationships extant in the real world.

The house plan drawn by an architect again provides a useful analogy. Such plans are viewed from a number of different perspectives with different levels of understanding depending on the viewer's role (i.e., architect, carpenter, electrician, plumber or owner). An
architect’s plans therefore provides a formalised method for communicating the owner’s ideas to the builder and associated tradespersons. It is not important for the owner to understand every aspect of the plan, apart from ensuring that the location of power points, faucets, sinks, etc. are correct. Database modeling is much the same. If communication between the parties involved is undertaken at a formalised level the resulting data model and thus database should accurately reflect the requirements of all concerned. Like the architect’s plan, a database also has a number of levels or abstractions from which it can be viewed.

Levels of abstraction

Databases are often described as having different levels of abstraction or viewing levels and while no explicit and formal definitions of these levels exist (Dwelle 1996c), there is general agreement that during the design process a database will pass through the following levels of abstraction:

1. external,
2. conceptual,
3. logical, and
4. physical.

Each of these levels is concerned with converting real-world data management problems into database solutions (Dwelle 1996c). As the design process passes through each level the character of the database changes, not only in how it may be represented graphically but also, and perhaps more importantly, in how it may be understood by those with a vested interest. Generally those involved in the design of a database can be divided into five groups, each of which have a different view:

1. Analyst: those actually designing the database;
2. Client: those for whom the database is being developed;
3. *Project Managers*: those in charge of the whole process;
4. *End-users*: those who will actually use the database; and
5. *Recipients*: those whom the database has been designed to serve (Anonymous 1996:6).

Certainly "each of these views is important and each serves its own purpose, but not all are useful or even meaningful to everyone who participates in the design process" (Anon 1996:2) due the participants' depth of knowledge and technical limitations. For a database to accurately reflect the real world the analyst must be fully conversant with how the various objects being modeled relate to each other and this information can only come from the UoD expert (Halpin 1995) such as the client or end-user. Conversely, the UoD expert must have a clear picture of what they require to ensure that the analyst's data model does reflect the UoD. Even when the UoD expert is the designer he or she must still ensure that the model is accurate.

**The physical view**

The physical or internal view is particular to a given DBMS and in the case of a relational database provides all the details about the physical storage and access structures, table and field definitions, primary and foreign keys, etc. Figure 4.2 provides a physical view of the script employed by Access to create a simple database containing information relating to site recorders and the location of sites. It should be evident that this view would be incomprehensible to virtually all persons unfamiliar with the script employed for constructing a relational database.

**The logical view**

The various aspects of the logical structure of a relational database were described in some detail in Chapter 3 and will not be repeated here. Figure 4.3 depicts a logical view of the database derived from the script presented in Figure 4.2. In this case the database is seen as
a series of interconnected tables with notations such as FK, I and U. Clearly, if modeling
were undertaken at this level of abstraction it would be difficult to understand for a group
unfamiliar with the concepts underpinning relational database design.

---

**Generated SQL DDL Script**

```sql
-- Create database
Create Table 'Recorded by' (  
'SiteID' CHAR(10),  
'ArchID' LONG , constraint 'Recorded by_PK' primary key ('ArchID','SiteID'))

Create Table 'ArchaeologicalSite' (  
'SiteID' CHAR(10),  
'Easting' CHAR(10),  
'Northing' CHAR(10) , constraint 'ArchaeologicalSite_PK' primary key ('SiteID'))

Create Table 'Archaeologist' (  
'ArchID' LONG,  
'Address' LONGTEXT,  
'Surname' LONGTEXT,  
'FirstName' LONGTEXT , constraint 'Archaeologist_PK' primary key ('ArchID'))

-- Add foreign key constraints for table 'Recorded by'
alter table 'Recorded by'  
foreign key ('SiteID')  
references 'ArchaeologicalSite' ('SiteID')
alter table 'Recorded by'  
foreign key ('ArchID')  
references 'Archaeologist' ('ArchID')

-- Add primary key, unique and non-unique index constraints for table 'ArchaeologicalSite'
create unique index 'ArchaeologicalSiteJDX on 'ArchaeologicalSite' ('Northing','Easting')
```

---

**Figure 4.2** Example of script or code required for creating a database with its relevant
tables, indexes, and primary and foreign keys.

---

**Figure 4.3** Example of a logical view of a database.

**The external view**

The external view of a database (Figure 4.4) comprises real world information and as such
could be considered unnormalized data. Information presented in such a manner is fairly
self-explanatory and would require little explanation to gain an understanding of the
information contained within the report.
Figure 4.4 Example of real-world data, the external view of a database.

Essentially, then, an external view is one that can be understood by all those involved in the design process regardless of their technical expertise as it provides data on those aspects of the real world to be included in the database (Anonymous 1996:5).

The Conceptual view

The conceptual view of a database falls between the external and logical abstractions and is the view at which the actual modeling process should occur. It is the point at which communication between all parties involved in the design process is formalised. Ideally, this communication should occur by making use of "natural language, intuitive diagrams and examples" (Halpin 1995:5). By making use of such descriptors, the model produced at the conceptual level should be transparent to all concerned as it both suppresses the technical detail found in the logical and physical views and exposes those details or rules often hidden by the external view. Developing a data model that meets these requirements is not a simple task, and in many respects the type of model employed will affect the level of transparency. These issues aside modeling at the conceptual level produces a formalised view of the database which in turn provides a platform for effectively communicating ideas and highlighting problems not possible at any other level.
Discussion
As indicated earlier even the simplest database can contain errors, some of which may only come to light following the database’s implementation. To ensure that such problems are detected prior to implementation it is necessary to construct a data model which accurately reflects the UoD. However, the accuracy of the model ultimately relies on clear and precise communication between those groups involved in the database project, each of which has a different perspective and level of understanding of the technicalities involved in transforming the database from the external to the physical views. Thus, if the modeler is not well acquainted with the data, problems are likely to arise. The only way to eliminate potential problems is to construct a data model at the conceptual level. The following chapter discusses two methods for achieving this aim.
Chapter Five

CONCEPTUAL DATA MODELING

Introduction
Many different techniques for modeling data at the conceptual level have been developed since the early 1970s. Unlike the normalization process these conceptual level models concentrate on modeling objects or entities and the relationships that exist between them rather than on table construction. This chapter overviews two conceptual level modeling methods: Entity-Relationship (E-R), and Object Role Modeling (ORM). To maintain uniformity between these methods I use the same Archaeological Site Recording Report example as that presented in the normalization section. I also compare and contrast these two methods and include a rationale for selecting ORM as the modeling method employed in this thesis.

Computer assisted software engineering tools
As the data model presented in this thesis was developed using a Computer Assisted Software Engineering (CASE) tool, it is useful to briefly discuss what a CASE tool is. Essentially, a CASE tool is a program that automates the database design process by

1. drawing the conceptual diagram,
2. combining the various attributes to create entities and relationships,
3. assigning primary, non-primary and candidate keys,
4. defining the various types of relationships,
5. automatically creating a data dictionary and
6. automatically creating the required relational DBMS structure.

While the availability of the features listed above varies between products, the overall aim of CASE software is to prevent design errors and save time (Jennings 1995:840). At the
same time, however, the models generated by a CASE tool are only as good as the designer's understanding of the UoD. A CASE tool will not define the UoD!

Some CASE software (e.g., InfoModeler) allows verification of the data model prior to its implementation in the DBMS. Others (e.g., Information Base Modeling System [IBMS]) do not provide this facility and mistakes in the model are not identifiable until after implementation (personal experience). Differences in user-interface and database design knowledge also vary considerably. For example, IBMS requires a fairly substantial knowledge of the normalization process and E-R modeling, whereas InfoModeler does not require any knowledge of normalization although a good working knowledge of ORM is obviously required. However, based on personal experience an understanding of the basic concepts underpinning the relational model is important regardless of the modeling method employed, including ORM.

Some available packages also provide a reverse-engineering module that allows analysts to take an existing database and extract information concerning its structure. Once achieved, it is possible to identify and rectify faults in the original design or to modify it (e.g., add new columns to existing tables or create new tables).

**Entity-relationship modeling**

Entity-Relationship (E-R) or Entity-Relationship-Attribute (E-R-A) modeling, developed in the mid-1970s (Chen 1976), is the most popular of all database modeling techniques (Halpin 1995:5). Unlike normalization, it is more attuned to application at the conceptual level as it provides an avenue for more effective communication by specifying both “user views and logical requirements in information systems” (Sasse and Fulton 1996). While E-R models can be constructed in a freehand manner or by using flow chart software, as I do in the following examples, a variety of E-R models are available as
CASE tools (e.g., ERWIN and IBMS). E-R models are underpinned by three essential concepts:

1. Entities are unique representations of objects which occur in the UoD. An entity is the thing that is being described and as such is not a value (Halpin 1995:537; Jennings 1995:834).

2. Attributes are the values used to describe a particular entity and in some E-R diagrams they may model relationships (Sasse and Fulton 1996).

3. Relationships describe how different entities relate to one another (Sasse and Fulton 1996).

Over the years, many additions have been made to Chen’s original schema as it was considered “too inexpressive to capture detailed features of an information model” (Halpin 1995:6). This has resulted in many different notations being developed rather than a widely accepted standard, although some similarities do exist (Figure 5.1).

The first three E-R models depicted in Figure 5.1 are similar in terms of their graphic representation; entities are represented by rectangles and relationships by diamonds. In Model 1 attributes are shown in ovals, whereas Model 2 lists the attributes and links them to the appropriate entities or relationships. On the other hand, Model 3 simply lists attributes under their respective entities and relationships. Likewise, Model 1 does not associate attributes with relationships, whereas Models 2 and 3 do. A further difference is that both Models 2 and 3 identify primary and foreign keys by underlining them, while no such indication is provided in Model 1. The final contrast between Models 1 to 3 is the method each employs to show the cardinality between entities and relationships. Model 1 indicates cardinality by employing “0” and “m,” indicating that a given archaeologist may record zero, one or many sites. In Model 2 the symbols “(0, m)” and “(1, m)” indicate that each archaeologist may record zero or more sites and that each site may be recorded by one or more archaeologists. Model 3 on the other hand uses only “[1]” or “[m]” indicating that all archaeologists may record one or more sites.
Figure 5.1 Some examples of the various notations employed in E-R modeling.

The IDEFX1 model (Model 4) uses a totally different notation. Independent entities are represented as rectangles with square corners while dependent entities are depicted as rectangles with rounded corners. Independent entities are those which are uniquely identified by their own attributes while the primary key of an dependent entity includes one or more foreign keys. Relationships in IDEFX1 are termed ‘role names’ and are depicted by the words (e.g., records, recorded by) appearing over the lines connecting independent and dependent entities. Unlike Models 2 and 3 attributes can not be attached to relationships. The IDEFX1 notation also distinguishes between key and non-key attributes. Key attributes appear in the upper sections of the rectangles and non-key in the lower section. Foreign keys have the suffix ‘(FK)’ and alternate keys
"(AK)" while primary keys have no suffix. The cardinality between entities is shown by the addition of crow's feet to the connecting line on the "many" side of the entity, although different representations are also available (Anonymous 1996: 295-305).

Due to the large number of E-R notations that have been developed, each notation has its own specific set of rules, as indicated in Figure 5.2. Despite this fact, Sasse and Fulton (1996) identify seven basic conventions that apply to E-R modeling and these are used in the following examples.

**Rule one**
The first rule of E-R modeling is that "entities can only be connected together via a relationship" (Sasse and Fulton 1996). Furthermore, all relationships must be binary and any which appear as ternary or greater must be reduced to a binary (Figure 5.2). As such, the relationship joining the entities must now become an entity in its own right (Sasse and Fulton 1996).

**Rule two**
The second rule states that as entities represent distinct data sets within the application they should be labeled as noun phrases. Conversely, as relationships describe the action linking entities they should be labeled with verb phrases.

**Rule three**
When employing E-R notation it is possible to include the UoD as an entity in the model, resulting in unnecessary redundancy. If such redundancy occurs it must be deleted from the model. Figure 5.3 provides an example of modeling the UoD whereby the entity Archaeological Record has been added to the model. However, as the UoD in this example is the archaeological record there is no need to include it as part of the model. On the other hand, if the database contained information on a variety of
heritage-related issues (e.g., built environment, national parks etc.) it may be necessary to include Archaeological Record as an entity.

![Diagram](image)

**Figure 5.2** Example of splitting a ternary relationship into three binary relationships. Note that the Records relationship in (a) has been changed to the entity Recording in (b).

![Diagram](image)

**Figure 5.3** Example of modeling the system.

**Rule four**

Rule four states that derived relationships should be avoided. One temptation when employing E-R notation is to relate entities in as many ways as possible to ensure all facets of the UoD are captured. In doing this it is possible to include redundant derived relationships which are already in the model. Figure 5.4 demonstrates how the relationship *contains* is a derived relationship (and thus redundant) as it is already specified in the Cultural Discard entity.
Rule five
Rule five states that all attributes should represent basic concepts. It is not difficult to include attributes of a complex nature. For example, the attribute Address may contain a street address, post code and state details. Complex attributes such as this should be broken down into simpler ones (Figure 5.5).

Rule six
The relationship between two entities must contain all of the unique keys (primary keys) which occur in each entity. In other words, the primary key(s) of each entity must appear as an attributes of the relation, regardless of which other attribute(s) appear in the relation (Figure 5.5).

Rule seven
This rule specifies that while the labels given to relationship keys (i.e., primary keys) may be repeated in both entities and other relationships the label or name of all non-key
attributes must be unique.

Having defined these rules I return to the Archaeological Site Recording Report example and examine how it would be presented in an E-R diagram. Figure 5.6 presents an initial draft of the Site Recording E-R model. Note, that as a draft this model does not necessarily comply with all the above E-R rules. Following production of the model its accuracy must be checked by mapping it to a logical view and normalizing it. One point to note in this draft diagram is that the relationship between archaeological sites and map editions has been captured as it is much easier to see the relationship between these entities in a data model than when normalization is used.

Mapping an E-R model to a logical model is not an overly complex process and basically involves translating each entity and relationship into tables. When entities or relationships use the same relation keys they are combined. Likewise, when a relation comprises only foreign keys it is mapped separately (Sasse and Fulton 1996). At each stage of the normalization process it is possible to reconstruct the E-R model to reflect any changes. Figure 5.7 provides a fully normalized E-R model of the Site Recording Form.

Object role modeling

Like E-R modeling, object role modeling (ORM) has its foundations in the 1970s as a semantic modeling method with objects in the UoD playing roles (Halpin 1995:6). The ORM version used in this thesis is referred to as Formal Object Role Modeling (FORM). Developed by Halpin in the late 1980s and early 1990s it is based on the Natural-language Information Analysis Method (NIAM) (Nijssen and Halpin 1989). FORM (from here on referred to as ORM) employs a step-by-step approach in constructing a data model "which is based on verbalisation in natural language" (Halpin 1995:7). The result of employing ORM notation and its associated language, Formal Object Role Modeling
Language (FORML), is a conceptual model that maps to a fully normalized logical view. ORM is supported by the CASE tool InfoModeler which was used to assist with the database designed for this thesis.

Figure 5.6 Draft E-R notation for the Site Recording Form.

Figure 5.7 The fully normalized E-R model for the Site Recording Form.
Prior to constructing an ORM model the analyst must become familiar with a sample of the data being modeled. As most archaeologists would already be familiar with the data being modeled this step may appear somewhat superfluous. However, based on my own experience this is a dangerous supposition to make. While archaeologists may be familiar with their data, this familiarity can lead to a false sense of security, an inaccurate model and a database that will not function.

Figure 5.8 presents an external view of data relating to postgraduate archaeology students, their activities and supervisors. By becoming familiar with the information presented in this external view it is possible to generate a number of descriptive statements concerning the roles played by the objects.

<table>
<thead>
<tr>
<th>Supervising Archaeologist</th>
<th>Student Archaeologist</th>
<th>Excavated</th>
<th>Site</th>
<th>Squares Excavated</th>
<th>Materials Analysed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jay</td>
<td>Jon</td>
<td>✓</td>
<td>JF:B11</td>
<td>B1, B3</td>
<td>Stone Artefacts,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Shellfish Remains</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wallaby Bone, Stone Artefacts</td>
</tr>
<tr>
<td>Tammy</td>
<td>Pat</td>
<td>X</td>
<td>EP:C04</td>
<td>C2, B1, J7</td>
<td>Ochre, Charcoal</td>
</tr>
</tbody>
</table>

Figure 5.8  A sample of external data. (N.B. a tick indicates a student excavates, a cross indicates the student does not.)

These observations include:

1. archaeologists have a first name and are either students or supervisors but not both,
2. students have a supervisor,
3. some students excavate sites while others do not,
4. a student can analyse a site without having excavated it,
5. a student can have a supervisor without having excavated or analysed a site,
6. students who excavate do so at particular sites in particular squares,
7. each site is identified by a unique ID code, and
8. each square has an alpha-numeric designator (not necessarily distinct).
Once familiarity with the data has been achieved it is transformed into a data model by following the seven steps of the Conceptual Schema Design Process (CSDP) (Halpin 1995:43) presented below:

1. Transform familiar information examples into elementary facts, and apply quality checks.
2. Draw the fact types, and apply a population check.
3. Check for entity types that should be combined, and note any arithmetic derivations.
4. Add uniqueness constraints, and check arity of fact types.
5. Add mandatory role constraints, and check for logical derivations.
6. Add value, set comparison and subtyping constraints.
7. Add other constraints and perform final checks (Halpin 1995:43).

As I employ InfoModeler many of these steps are combined and in some cases they are completed automatically. Regardless of whether the ORM schema is generated manually or via InfoModeler, once completed it will map to a fully normalized relational or logical view without reference to the normal form rules.

CSDP Step one: transform familiar information examples into elementary facts, and apply quality checks

Step one is the most difficult and most important part of the CSDP (Halpin 1995:56) and involves the conversion of sample information into elementary facts by verbalising or expressing the sample in simple natural-language statements and then into Formal Object Role Modeling Language (FORML). In ORM an elementary fact is an assertion that particular real world objects play particular roles (Halpin 1995:44). Basic objects have only two types, entities or values. Entities are objects that can be identified in the real world as either an object or concept (Halpin 1995:45). An archaeologist, for example, is a tangible entity, whereas a site’s significance level is a concept. To identify a specific instance of an entity, it must have a reference mode of some description. Thus, an archaeologist may be identifiable by a name or an identification number, while each significance level may be identified numerically. Values, on the other hand, are objects which have no means of reference within the system; they are nothing more than
character strings which are employed to reference entities (Anonymous 1996:36; Halpin 1995:45). For example, a person's name is nothing more than the character string J-o-n. While it is not possible to ask the first name 'Jon' to undertake an excavation it is possible to ask the archaeology student with the first name Jon to undertake an excavation. With these definitions in mind it is now possible to discuss FORML.

The aim of FORML is to take familiar external data and express it as elementary facts. From the sample data in Figure 5.8 it is possible to state, "Jon excavates." In this case, the object "Jon" is playing the role "excavates." This is also an elementary fact as further splitting would result in information loss. However, the statement does not explicitly define whether Jon is a dog who likes digging holes, a wombat, or the brand name of an earth-moving machine. Jon must be defined.

Thus, the first step in developing a FORML sentence involves explicitly defining the object by providing three specific object designators: entity type, reference mode and value. In keeping with Halpin's (1995) schema the names of object types have capitalised first letters while values are enclosed in inverted commas. Thus, in the above example "Jon" could be identified as:

<table>
<thead>
<tr>
<th>entity type</th>
<th>Archaeology Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>reference mode</td>
<td>first name</td>
</tr>
<tr>
<td>value</td>
<td>&quot;Jon&quot;</td>
</tr>
</tbody>
</table>

The FORML equivalent to this is: "The Archaeology Student with the first name Jon..." While not a complete sentence, in FORML this part of a sentence is referred to as an object-designator or object-term. To complete the sentence it is necessary to define the role(s) the object plays.

In FORML, a role is defined using logical predicates which are sentences containing one or more object-holes (Halpin 1995:47). Simply stated, the predicate identifier in FORML
equates to the role(s) played by the object. In the above example the predicate is "excavates." Therefore, once the predicate has been identified it is possible to construct the whole statement in FORML by filling in the object-holes with the associated object-term. Thus in FORML the statement "Jon excavates" would translate to

The Student Archaeologist with the First Name 'Jon' **excavates.**

This statement is also a unary fact as it only has one object-hole i.e., . . **excavates.**

Another way of stating this is that the predicate has an arity of one. A binary predicate would have two object-holes or an arity of two e.g.:  

The Archaeologist with the first name 'Jay' **supervises** the Student Archaeologist with the first name 'Jon'.

When a sentence has an arity of two or more, the ordering of objects is important. In the above example while it may be correct to state that Jay supervises Jon, it may not be correct to state that Jon supervises Jay. Thus care must be taken during the familiarisation process to ensure the ordering is correct. At the same time, however, by using FORML such errors are likely to be noticed by the UoD expert and remedied.

ORM also allows for reverse predicates to be included in a fact. Thus the above fact could be written as:

The Student Archaeologist with the first name 'Jon' is **supervised by** the Archaeologist with the first name 'Jay'.

When the reverse predicate is used the fact is usually stated with both predicates included but separated by a slash /. In such cases the predicate to the left of the slash is used for standard left-to-right reading while the reverse predicate is placed to the right of the slash for the inverse reading (Halpin 1995:49), e.g.,

The Archaeologist with the first name 'Jay' **supervises/is supervised by** the Student Archaeologist with the first name 'Jon'.

As already indicated facts must be elementary and determining whether or not a fact is elementary is usually a matter of searching for logical connectives or conjunctions (e.g.,
and, or, not, if) or logical qualifiers (e.g., all, some) in the sentence (Halpin 1995:44).

Consider the following statement:

The Archaeological Site with the ID number ‘JF:B11’ contains Stone Artefacts and Shellfish remains.

This is not an elementary fact as it contains the conjunction “and.” In FORML this sentence would be split into two binary predicates:

1. The Archaeological Site with the ID number ‘JF:B11’ contains Stone Artefacts.
2. The archaeological site with the ID number ‘JF:B11’ contains Shellfish remains.

On the other hand, if a sentence contains a preposition (e.g., at, in, by) it is likely to be an elementary fact and, if split, would result in information loss.

Referring back to Figure 5.8 it is possible to create the following FORML statements:

1. The Archaeology Student with the first name ‘Jon’ excavated the Square designated ‘B3’.
2. The Archaeology Student with the first name ‘Jon’ excavated the Archaeological Site with the ID code ‘JF:B11’.

In creating these statements, however, some information has been lost as it is not possible to determine if square B3 is associated with site JF:B11 or GK:A64. By combining these two facts the following elementary fact is obtained:

The Archaeology Student with the first name ‘Jon’ excavated the Square designated ‘B3’ at the Archaeological Site with the ID code ‘JF:B11’.

Notice that in this fact the preposition “at” is employed to hold together the meaning of the statement. This predicate has an arity of three as it has three object-holes; that is, ‘...excavates...at...’.

Unlike E-R diagrams which only accept unary or binary relationships, ORM diagrams allow for relationships with an arity between 1 and n, although this is restricted to nine in InfoModeler due to software constraints.
At this point, it is possible to return to the Archaeological Site Recording Report and examine how this would be modeled in ORM. In doing so it is necessary to accept that the data being modeled are familiar and that the facts (not necessarily elementary) listed below have been verified as correct by the UoD expert. Note that only the standard left-to-right predicate is shown and that the list is not complete.

1. Each Archaeologist has an unique ID number.
2. The Archaeologist with the ID number '1' has the First Name 'John' and the Surname 'Bonham'.
3. The Archaeologist with the ID number '1' lives at the Street Address '11 Zeppelin St'.
4. Each archaeological site has an unique ID code.
5. The Archaeological Site with the ID code 'JF:B11' is located on the Map sheet numbered '9051'.
6. The Archaeological Site with the ID code 'JF:B11' is located at Easting '588780' and Northing '338700'.
7. The Archaeological Site with the ID code 'JF:B11' was recorded on the Date '1-Dec-94' by the Archaeologist with the ID number '1'.
8. The Archaeological Site with the ID code 'JF:B11' was recorded on the Date '27-Aug-90' by the Archaeologist with the ID number '4'.
9. The Archaeologist with the ID number '1' has the Recorder Type 'Consultant'.
10. The Archaeologist with the ID number '4' has the Recorder Type 'Other'.
11. The Map sheet with the number '9051' has the Name 'Rockhampton'.
12. The Mapsheet with the number '9051' has the Edition Number '1'.
13. The Archaeological Site with the ID code 'JF:B11' has a Significance Level of '1'.
14. The Archaeological Site with the ID code 'JF:B11' has a Management Priority of 'A'.

Once the external data has been translated into elementary facts it is possible to begin expressing the facts graphically using the ORM notation developed by Halpin (1995).

**CSDP Step two: draw the fact types, and apply a population check**

ORM employs a graphical notation that is vastly different from an E-R diagram. Unlike an E-R diagram, which has three basic elements, an ORM diagram comprises four basic elements. An entity type is depicted as a named solid ellipse, while values are depicted as
named broken ellipses (Figure 5.9). Roles are shown as a contiguous sequence of \( n \) role boxes, in which \( n \) equals the arity, and each object is joined to a role box by a solid line or role connector (Halpin 1995:59:60) (Figure 5.9).

![Diagram of ORM elements](image)

**Figure 5.9** Basic elements of an ORM diagram representing a simple binary fact.

Figure 5.10 presents a draft ORM diagram for *ArchBase*. Where the facts outlined previously were not elementary they have been split to form elementary facts. Reference modes have also been added to the entity type objects which can be identified by a particular value. In such cases both the entity name and the reference mode are contained within the solid ellipse. As reference modes generally comprise a one-to-one relationship between the entity type and the value they are said to be “simple 1:1 reference schemes” (Halpin 1995:61).

Once a draft diagram has been created the relevant predicates indicating the role played by each of the objects in a given fact are included along with a sample data population for each object. This helps to determine if the diagram has been drawn correctly. Figure 5.11 presents some of the data relating to archaeologists’ details showing both predicates and sample populations.
Figure 5.10 Draft ORM diagram for ArchBase.
CSDP Step three: Check for entity types that should be combined, and note any arithmetic derivations

The third step of the CSDP involves checking to see which entity types should be combined to form primitive entity types, and to determine if any data can be derived from existing data rather than being stored in the database.

In any UoD "there will always be a top level partitioning of its entities into exclusive or primitive types (Halpin 1995:70). The main characteristic of primitive entity types is that they never overlap (Halpin 1995:70). For example, archaeologists and stone artefacts are both primitive entity types as an archaeologist can never be a stone artefact. In the Site Recording Form there are no examples of entity types which could be combined to form primitives. However, if the new entity type "Author" was added to indicate the authors of reports and theses it is possible to discuss the notion of primitives (Figure 5.12).

The schema shown in Figure 5.12 is faulty as it suggests that both archaeologists and authors are primitive entity types. Modeled in this way, no archaeologist could be the author of a report or thesis and no author could record a site. Obviously this situation is incorrect as any archaeologist can write a report or thesis and many authors may record archaeological sites. By applying step three of the CSDP the correct representation can
be achieved (Figure 5.13). This diagram correctly indicates that any person, the new primitive entity type, can be both a recorder and an author.

![Figure 5.12](image)

**Figure 5.12** Conceptual schema showing Archaeologist and Author as primitive entity types.

![Figure 5.13](image)

**Figure 5.13** The corrected conceptual schema for Figure 5.12.

The second part of step three states that all arithmetic derivations be identified. Again there are no examples in the Site Recording Form. Consider, however, if the visible boundaries of a rectangular or square shaped site were recorded in terms of its length north-to-south and width east-to-west along with the visible area of the site. As area is calculated by multiplying length by width it is considered a derived fact type and its representation is shown in Figure 5.14. To indicate a derived fact the asterisk symbol is employed and the set of rules which apply to the derivation are shown below the fact. While derived fact types are not always shown on ORM diagrams (Halpin 1995:73) the rules that apply must be specified in the data dictionary.

The CSDP steps covered to date have been concerned with identifying elementary facts and ORM’s graphical notation. The final four steps are concerned with the addition of constraints to the schema. The aim of the various types of constraint which can be
modeled in ORM is to place restrictions on the various objects in the database and the roles they play (Halpin 1995:79-80).

![Diagram of archaeological site with measurements](image)

**Figure 5.14 Schema for showing arithmetic derivations. (N.B. “iff” is an abbreviation for if and only if, indicating the conditional rule works in both directions [Halpin 1995:72]).**

**CSDP Step four: add uniqueness constraints, and check arity of fact types**

Internal and external uniqueness constraints ensure that redundancy or the repetition of elementary facts within the CSDP does not occur. Internal uniqueness constraints apply to either a single role or multiple roles within a single predicate, whereas external uniqueness constraints apply to a minimum of two roles from different predicates (Halpin 1995:98).

Prior to applying uniqueness constraints it is necessary to ensure that a significant sample population is available to ensure the accuracy of the constraints. Significance here means that all possible combinations of data for a given fact type are represented. The graphic representation of the sample is referred to as a fact table. It is also important to ensure that the sample population has no repeating rows of data and does not include empty or null values (Anonymous 1996:47). While null values may actually occur in the UoD, ORM does not allow for their inclusion. Thus, “for any given fact type each role is associated with a corresponding column of the fact table” (Halpin 1995:87).
Internal uniqueness constraints are depicted as an arrow-tipped line spanning one or more of the role boxes in a predicate. This line may be placed either above or below the role. If the predicate is a unary it must have an internal uniqueness constraint as each row in the sample population can only occur once. For predicates having arity of two or more the situation is slightly different. The basic rule of internal uniqueness constraints is that the line is placed over the role(s) which cannot contain repeating values (Halpin 1995:87). Those roles which are spanned by the constraint line(s) are said to provide a key for that fact type (Halpin 1995:106). If the line only spans one role then the key is said to be simple. If the line spans two or more roles then the key is referred to as composite (Halpin 1995:106).

There are four possible constraint patterns that define uniqueness in a binary predicate (Halpin 1995:88), three of which can be found in the Site Recording Form example. Figure 5.15 shows an example of an internal uniqueness constraint over the two roles in the binary predicate MapNumber has MapName. In this case the placement of the two lines indicates that the values in each column are unique as each map number can only correspond to one map name. The test for this uniqueness can be identified in the accompanying fact table. Essentially this constraint is an example of a one-to-one relationship. In FORML this constraint would be stated:

```
MapNumber has MapName / MapName is of MapNumber
Each 'MapName is of at most one MapNumber.
Each MapNumber has at most one MapName.
```

The second internal uniqueness constraint in the Site Recording Form example relates to the predicate MapNumber has Edition. While a given map sheet can have only one number it may have a number of editions. Therefore, as indicated in the fact table (Figure 5.16) each MapNumber may occur a number of times, as can a given edition number. To show this constraint a single line is placed over both role boxes (Figure
This constraint represents a relationship of the type many-to-many and in FORMIL would be stated as:

\[
\text{MapNumber has MapEdition / MapEdition is of MapNumber}
\]

It is possible that some MapNumber has more than one MapEdition and that some MapEdition relates to more than one MapNumber.

Figure 5.15 Example of a binary predicate in which the values for each role are unique.

Figure 5.16 Example of internal uniqueness constraint in which the column values may repeat but each row must be unique.

The final constraint pattern shown in the Site Recording Form example is one that frequently occurs. In this case the line only spans one role box, indicating that the values in the fact table under the line must be unique while those on the other side may repeat.

Figure 5.17 shows this constraint pattern on the ArchaeologicalSite is located at Easting predicate. In this case ArchaeologicalSite cannot be repeated. However, as any number
of sites may be located along a given easting this value may be repeated (i.e., a one-to-
many type relationship). The FORML statement for this example is

ArchaeologicalSite is located on Easting/Easting partly locates ArchaeologicalSite.

Each ArchaeologicalSite is located on at most one Easting.

Figure 5.17 Internal uniqueness constraint over a single role.

While no examples of the fourth internal uniqueness constraint are found in the ArchBase model it is basically a reversal of that shown in Figure 5.17. In other words, the constraint is applied to the inverse side of the predicate (Halpin 1995:88).

For ternary predicates there are eight possible constraint patterns (Figure 5.18). Unlike a binary fact where the constraint must span at least one role, in a ternary fact a constraint must span at least two roles, although these do not have to be contiguous. To ensure that the correct constraint(s) are applied a fact table should be employed.

Returning to the Site Recording Form example, the only ternary predicate is that which exists between archaeologists, archaeological sites and a site’s recording date. The ORM diagram for this fact is shown in Figure 5.19. In this case the constraint indicates that the combination SiteID and RecordingDate are unique and thus a given site cannot be recorded more than once on a given date. The FORML statement for this ternary predicate is

ArchaeologicalSite recorded on RecordingDate by Archaeologist.

Given any Archaeological Site and Recording Date that Archaeological Site recorded on that Recording Date by at most one Archaeologist.
The second type of constraint applied in step four of the CSDP is the external or inter-predicate uniqueness constraint (Halpin 1995:100). Constraints of this type occur when two or more predicates joined to the same entity type uniquely identify the object (Halpin 1995:98). The graphic notation for an external uniqueness constraint is a dotted line extending from the relevant role boxes to a circle containing a “u”. The “u” stands for unique (Halpin 1995:100).

Figure 5.19  Uniqueness constraint for the ternary predicate “...recorded on...by...”.

Figure 5.18  The eight possible uniqueness constraints for a ternary predicate (Halpin 1995:94-95).
In the *ArchBase* example a constraint of this type is found between the entity type 'ArchaeologicalSite' and the roles it plays with the value types 'Easting' and 'Northing' (Figure 5.20). The simplest way of understanding how this type of constraint works is to refer back to the Normalization section presented on natural join operations (Chapter 3, see also Halpin 1995:117-120). The fact tables in Figure 5.20 indicate that a join operation performed on these tables using the object 'ArchaeologicalSite' would result in a uniqueness constraint across the 'Easting, Northing' columns (Figure 5.21). The FORML statement for this constraint is

For each Easting e and Northing n
there is at most one ArchaeologicalSite that is located on Easting X and is located on Northing Y.

The final stage of CSDP step four involves checking the arity of the various fact types to determine if fact types with an arity of three or more can be split to form elementary facts. One method for determining the possibility of a split is to apply the key length check. Essentially this means that any internal uniqueness constraint(s) must minimally span all roles in the predicate minus 1. Therefore, if the fact is a ternary the constraint(s) must span at least two roles. Likewise, if the fact is a quaternary the constraint(s) must span a minimum of three roles. In other words, if more than one role in an n-ary fact is excluded from the constraint it is not elementary and can be split. Furthermore, if a fact is elementary then all its keys must be the same length; i.e., they must span exactly the same number of roles (Halpin 1995:107). Examples of the application of these key length check rules can be found in Figure 5.18.
Figure 5.20 Applying the uniqueness constraint to northing and easting.

Figure 5.21 Uniqueness constraints shown across the fact table.

The other method available for determining if a fact can be split is the projection-join check discussed in the section on normalization in Chapter 3. The checking of predicate arity is a central issue in ORM if the model of the UoD is to be correct. However, this analysis is underpinned by a basic question “can the fact type be rephrased as a conjunction of smaller fact types” (Halpin:1995:117)? Obviously, as the database designer becomes more familiar with the UoD, problems of this type will diminish because rephrasing the facts to test the arity will become easier.

CSDP Step five: add mandatory role constraints, and check for logical derivations

Once all internal and external uniqueness constraints have been determined it is possible to continue with next step of the CSDP which involves applying another type of
constraint, the mandatory role constraint, and determining if any facts may be logically derived from others (Halpin 1995:123). A role is said to be mandatory “if and only if, for all states of the [database], the role must be played by every member of the population of the attached object type; otherwise the role is optional” (Halpin 1995:126). In the ORM diagram a mandatory role is indicated by attaching a dot at the end of the role line where it attaches to the object, whereas an optional role is indicated by the dot's absence (Halpin 1995:127). As for the previous step of the CSDP this one also requires that a significant population be employed to test the validity of the constraint.

In some cases, given a significant population sample, the decision may simply involve looking for those instances which are fully populated and those which contain null values. The fully populated instances are likely to be mandatory whereas those containing null values are optional. Mandatory roles only apply to predicates with an arity of two or greater as the roles played by unary predicates are mandatory by definition.

Figure 5.22 presents examples of four mandatory constraints and one optional constraint. As in the case of the internal and external constraints it is possible to express these constraints in FORML. For example, the mandatory constraint between archaeologists and their street addresses would be stated:

Archaeologist resides at Street Address
Each Archaeologist resides at some Street Address.
Each Archaeologist resides at at most one Street Address.

The optional constraint between archaeologists and their home telephone numbers would be presented as:

Archaeologist has HomePhone / HomePhone is of Archaeologist
Each Archaeologist has at most one HomePhone.
The difference between these two FORML statements is that the archaeologist/street address declaration indicates that every archaeologist must have some street address, whereas the archaeologist/home phone declaration states that each archaeologist may have one home phone number.

The final type of mandatory constraint that may be added is the disjunctive mandatory constraint. Constraints of this type are used between two or more roles which are joined to the same object type. Basically this constraint indicates that at least one of the roles must be played by the object. In Figure 5.22 a disjunctive mandatory constraint has been added between the 'Surname' and 'FirstName' objects, indicating that at least one of these must be recorded for each archaeologist (i.e., the surname or first name or both).

Once mandatory and uniqueness constraints have been added to the model it is possible to examine how objects with a composite or compound identification scheme can be represented. There are three ways objects with a composite identification scheme may be represented: flattened, nested or co-referenced (Halpin 1995:336). In Figure 5.20 the notation for modeling the grid reference for a site's location was provided employing the flattened approach. In modeling this aspect a uniqueness constraint was placed between the predicates involved indicating that

For each Easting e and Northing n
there is at most one Archaeological Site that
has Easting e and has Northing n.
What is not explicit in Figure 5.19 is that aspect of the UoD being modeled, i.e., the grid reference of an archaeological site. To overcome this problem a new object, 'Grid Reference', is created (Figure 5.23). Unlike primitives, a composite object's primary reference scheme is based on its relationship with other objects. In Figure 5.22 'Grid Reference' is modeled as a co-referenced object as its primary reference scheme is based on the uniqueness constraint between easting and northing; i.e., each grid reference comprises a unique combination of easting and northing.

The third method for modeling a composite object is by nesting, which like co-referencing involves creating an object whose primary reference mode is defined by other objects. With nesting, however, the new object is formed by objectifying the predicate. The notation for nesting is a round-cornered rectangle that fully encompasses the relevant predicate and this rectangle represents the new object.
Figure 5.24a presents the original flattened version of the predicate relating to the recording of an archaeological site while Figure 5.24b presents the results of objectifying this predicate. The new object has been named ‘Recording’. Each of the models presented in Figure 5.24 map to the same tables in a logical view, the only difference being that the nested version is more explicit in describing what is being modeled.

The final requirement in step five of the CSDP is a check for non-arithmetical logical derivations, which as a general rule can be found where transitive dependencies occur (see the normalization section in Chapter 3 for the definition). In the example only one logical derivation exists, that between significance and management priority. Figure 5.25 shows how the facts ‘archaeological site given significance’ and ‘archaeological site given priority’ were originally modeled although they now have constraints added.

![Diagram of nested predicate example](image-url)
As discussed in the normalization section, as each management priority is determined or logically derived from a site's significance, each priority code relates directly to a significance code. In its current state the model does not show this derivation explicitly nor does it even imply it. Rather, it suggests that both significance and priority are separate entities. In order to model this logical derivation explicitly it is necessary to redraw the diagram as shown in Figure 5.26. The FORML statements for this logical derivation are:

Archaeological Site given Significance/Significance allocated to Archaeological Site
Each Archaeological Site given some Significance.
Each Archaeological Site given at most one Significance.

Significance determines Management Priority/Management Priority determined by Significance
Each Significance determines some Management Priority.
Each Management Priority determined by some Significance.
Each Significance determines at most one Management Priority.
Each Management Priority determined by at most one Significance.

Once mandatory roles and logical derivations have been determined it is possible to proceed to the next step of the CSDP which involves adding a further set of constraints.
CSDP Step six: Add value, subset, equality, exclusion and subtype constraints
The constraints dealt with in this step of the CSDP relate to values, set comparison and subtype constraints. Value constraints simply place restrictions on the values associated with a particular entity (Halpin 1995:161-165). Set comparison constraints specify whether subset, equality and exclusion constraints exist between roles played by the same object type or object types with a common supertype. Subtyping essentially allows one object (a supertype) to be broken down into various smaller types while maintaining the basic characteristics of the supertype.

Value constraints
The Site Recording Form provides a number of examples where value constraints may be set. Values can be set to either limit what may be entered (Figure 5.27a) or restrict numerical or character entries to a specific length (Figure 5.27b). In addition to the constraints shown in Figure 5.27 there are a number of other value constraints and in these examples listed below “c” denotes a character string, “a” a letter and “d” a digit. A number appearing before one of these symbols indicates an exact occurrence; i.e., “6d” indicates the value must contain exactly six digits, whereas a number after the symbol indicates a maximum string length only (e.g., “d6”) (Halpin 1995:163).

<table>
<thead>
<tr>
<th>Constraint</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c30)</td>
<td>a string with a maximum of 30 characters</td>
</tr>
<tr>
<td>(a20)</td>
<td>a string with a maximum of 20 letters</td>
</tr>
<tr>
<td>(d4.3d)</td>
<td>a maximum of 4 digits, followed by a decimal point and 3 digits</td>
</tr>
<tr>
<td>(ddaaa)</td>
<td>2 digits followed by 3 letters</td>
</tr>
<tr>
<td>(2d3a)</td>
<td>same as previous</td>
</tr>
</tbody>
</table>
The addition of value type constraints to the model makes it possible to identify those entity type objects that may be candidates for lazy entity types or types whose roles are optional. As such, lazy entities map to reference tables in a logical view of a database and can only be applied to entity type objects, not value type objects (Halpin 1995:164). The candidates for lazy entities in the Site Recording Form example are Recorder Type and Date. Lazy entities are identified by including an "I" after the object's name (Figure 5.24).

Figure 5.27  Examples of adding value constraints to the model.

Set comparison constraints
Subset, equality and exclusion constraints are employed to "restrict the way one role, or role sequence, relates to the population of another" (Halpin 1995:172). While no set comparison constraints occur in the Site Recording Form example it is necessary to have
a basic understanding of their roles in the model. Subset constraints may be placed between roles which are optional to indicate that if one particular role (i.e., the subset) is played by the object then the other (i.e., the superset) must also be played. If one role is mandatory then the subset constraint is implied and should not be shown diagrammatically. The notation for a subset constraint is a dotted line between the superset and subset with an arrow pointing to the superset role.

Consider the example of the relationship between an archaeological site and radiocarbon (C-14) dates. While not all sites are dated, some are; thus the relationship "archaeological site has C-14 date" is optional. It is also possible that for some sites the C-14 date has been calibrated, another optional role. However, if a site has a calibrated date then it must also have a C-14 date. In other words, a calibrated date is a subset of the superset C-14 date and its existence relies on the fact that a site has been dated. In F0RML this would be stated:

If Archaeological Site a has some Calibrated Age then Archaeological Site a has some C-14 Date.

The notation for this relationship is shown in Figure 5.28.

![Figure 5.28 Example of a subset constraint.](image)

An equality constraint is similar in some respects to the subset constraint, in that the roles involved must be optional. In this case, however, if the object plays one role then it must also play the other role. The graphic notation for this constraint is a dotted line.
drawn between the roles involved with an arrow at both ends (Halpin 1995:175). One example of an equality constraint can be found in the relationship between archaeological sites, stone artefacts and average artefact density.

While not all archaeological sites contain stone artefacts, if they do the average density of stone artefacts per square meter can be determined. To ensure that the average artefact density is captured for sites an equality constraint should be included in the model (Figure 5.29). In FORML this constraint would be expressed:

\[
\text{Archaeological Site } a \text{ has some Average Stone Artefact Density if and only if Archaeological Site } a \text{ contains some Stone Artefacts.}
\]

![Figure 5.29 Example of an equality constraint.](image)

The final set comparison constraint is the exclusion constraint which indicates that while an object may play more than one optional role, it can only play one of these roles for a given database state (i.e., the roles are mutually exclusive). The notation for this constraint is a dotted line connecting the roles dissected by an encircled X (Halpin 1995:176-177). Consider that shellfish remains are either marine or freshwater and that this fact must be included in the database. However, one remains type can not be recorded as being both marine and freshwater it is either one or the other and this constraint must be modeled (Figure 5.30).
Subtyping

The final stage of CSDP step six is the addition of subtype constraints which are basically object type entities that form a smaller part of a larger supertype (Halpin 1995:188). Thus entity type 'object B' is a proper subtype of entity type 'object A' if, and only if, the population of B is a subset of the population of A, and $A \neq B$ (Halpin 1995:188). The notation for a subtype is a heavy line extending between the objects with an arrow head pointing to the supertype. As for subset constraints no example of subtypes exist in the Site Recording model. However, the following example demonstrates the notation for subtypes.

While 'archaeologists' may be considered a primitive entity they are also a subset of the supertype 'persons', as are 'academics' and 'students', although in some cases archaeologists may be a subtype of both 'academics' and 'students'. Likewise a 'student' could be considered a subtype of 'academic'. Figure 5.31 shows how these subtype/supertype relationships are modeled. The important point to note in this example is that each subtype must play some mandatory role that would only be optional if assigned directly to the supertype persons. Modeling subtypes does not result in a different logical view being created for the database unless a subtype is identified as being an independent entity. Rather, subtyping provides a much clearer view of the relationships between the various objects and the roles they play.
CSDP Step seven: add other constraints and perform final checks.

The final step of the CSDP involves adding frequency constraints and join constraints among others. As such constraints occur infrequently and none appear in the Site Recording Form example they are not discussed here. Once all constraints have been set final checks are made to ensure that the database model is consistent, is free from redundancy and covers all the necessary requirements of the client (Halpin 1995:243).

Some final changes were made to the model to fully optimise its mapping to the logical view. ‘Date’ has now been included as part of the nested object ‘Recording Details’ to ensure that each site can only be recorded once on a given date. The objects ‘Map Number’ and ‘Edition Number’ have been provided with roles that connect them to ‘Recording Details’ to ensure that each recording of a site specifies which map number and edition number were involved. A uniqueness constraint has also been placed between ‘Map Number’ and ‘Edition Number’ to indicate that each recording of a site can only occur on a unique pair of these objects. The co-referenced object ‘Grid Reference’ has been made optional for archaeological sites as other methods for recording a site’s location may also be used (e.g., latitude and longitude or digital latitude and longitude). The uniqueness constraint between ‘Easting’ and ‘Northing’ has been replaced by a primary uniqueness constraint to signify that each grid reference is primarily identified by a unique easting and northing pair. An index constraint, indicated by a dotted line with an encircled “I”, has also been added to some objects to assist with queries on the database. Objects which have their own specific reference schema are automatically indexed. A final point to note about this completed model is that some object names have a small triangular symbol placed above them. This simply indicates that the object occurs elsewhere in the model. The rationale for repeating objects is that it provides additional clarity to the diagram but has no effect on the final mapping. The
completed model shown in Figure 5.32 is now ready to be mapped to its logical view (Figure 5.33). Mapping to the logical view in the example presented here was undertaken using InfoModeler; however, Halpin (1995) does provide a detailed explanation for manually mapping a model.

Figure 5.31  (top) Showing original notation where each role played by a person is optional. (bottom) Notation employing subtypes/supertypes.
Figure 5.32 The completed ORM model for the Site Recording Form example.
Figure 5.33  The fully normalized logical view of the Site Recording Form example produced by InfoModeler.

About InfoModeler

As I employ the CASE tool InfoModeler in this thesis some of the steps presented in the above discussion can be completed in one step via the software. For example, internal uniqueness constraints, mandatory role constraints and predicate text may all be entered in one step. Likewise, examples of data can be entered into InfoModeler to check for the appropriateness of constraints and these in turn, may then be applied manually or automatically. Figure 5.33 shows some of the aspects of the fact editor module where
much of the modeling is actually undertaken. Once InfoModeler has mapped the conceptual model to a logical view it is possible to make further changes at this level. However, if the model has been constructed accurately it should not require modification, although any changes made at this level can be migrated back to the conceptual model.

Figure 5.34  Two of the main windows in the InfoModeler's fact editor. The top window shows how the roles that objects play may be entered while the bottom window shows how role constraints are set.
Conclusions
I have discussed in some detail two methods that may be used for conceptual level data modeling: Entity Relationship (E-R) and Object Role Modeling (ORM). It should now be clear that both modeling methods have distinct advantages over the normalization process. Rather than concentrating on tables, columns, primary/foreign keys and the various types of relationships, E-R modeling is based on entities, attributes and relationships, whereas ORM is based on objects, roles, facts and constraints. Despite the fact that both E-R and ORM are conceptual level models there are some major differences between them and it these differences that have led me to favor the ORM approach over E-R.

A major problem with E-R modeling is that it does not allow relationships which have an arity of three or more to be modeled. Thus relationships that appear as ternaries or higher must be broken down into binary relationships and the relationship joining the entities becomes an entity in its own right. ORM, however, can model facts having an arity from 1 to n, thus allowing for a more accurate model of the roles that an object may play in conjunction with other objects. E-R models also suffer from the fact that they are unable to indicate if an object’s roles are, for example, mandatory, disjunctive or optional. ORM does allow for an object’s roles to be captured and modeled accurately. Furthermore, the language employed in ORM modeling is closer to natural language than that used in E-R, thus making the reading of fact types easier. Consider, for example, the fact ‘archaeologist works at university’. In E-R modeling this would actually equate to the university being an attribute of the archaeologist. Try explaining that to a person not familiar with database design! In ORM on the other hand, this would be shown as the object ‘archaeologist’ works at the object ‘university’. While these advantages certainly tend to place ORM above E-R notation there are even more compelling reasons for employing ORM over E-R.
The first of these is that ORM does not require any knowledge of the normalization process. By employing the mapping algorithms presented by Halpin (1995) the model translates directly into a fully normalized logical view that can be manually entered into a DBMS. By employing a CASE tool such as InfoModeler the model can be exported directly to the DBMS as a fully functional database. In other words, the complexities of the normalization process are effectively by-passed by employing ORM. This is not possible using E-R. The other major advantage ORM has over E-R notation is that sample populations can be included at the conceptual level, regardless of the arity of the facts. Thus the validity of each aspect of the model may be checked for accuracy prior to its implementation. In sum, ORM is a much more user-friendly modeling method than E-R. It is a relatively straightforward method to use and the basics are relatively easy to grasp in comparison to E-R and normalization. It is for these reasons I have selected ORM as the modeling tool employed in this thesis.

In the following two chapters issues relating to database design may appear to have been replaced by discussions concerning classification of the archaeological record along with a detailed examination of GIS. However, underpinning each of these chapters is the notion that each of these aspects of information management must tightly dovetail within a database framework to meet the overall aims of this thesis.
Chapter Six

GEOGRAPHIC INFORMATION SYSTEMS

Introduction

"The retrieval of archaeological information from various kinds of spatial relationships is a central aspect of the international discipline of archaeology and a major part of the theory of that discipline wherever it is practiced" (Clarke 1977:1). Spatial archaeology is concerned "with human activities at every scale, the traces and artefacts left by them, the physical infrastructure which accommodated them, the environment that they impinged upon and the interaction between all these aspects. Spatial archaeology deals with sets of elements and relationships" (Clarke 1977:9-10).

Traditionally, identifying, quantifying and analysing spatial patterns has focused on the visual examination of data manipulated statistically. For example, Hodder (1977:223) posited that to gain an understanding of archaeological distribution patterns attempts should be made to develop explicit mathematical models using statistical methods. More recently such approaches to spatial analysis (e.g., spatial autocorrelation and interpolation) have been viewed as problematic for the following reasons:

- Statistics are difficult to use for describing and analysing continuous data;
- Spatial data often have no boundaries so that classic set theory does not apply;
- There are no inherent internal partitions to enable one to set up meaningful nested spatial units;
- Traditional statistics are not equipped to deal with simultaneous description and correlation of multiple forms over space (Green 1990:4).

Furthermore, the sheer "volume of data used in spatial data limits the application of traditional statistics and mathematics in spatial modeling" (Berry 1993:3-4). By employing such non-spatial procedures the mapped areas of interest are reduced to typical values "expressing the central tendency of a variable over that area" (Berry..."
1993:4) resulting in a high level of data loss and thus loss of extractable information. In other words, analysing spatial data statistically presupposes that a given value has an even distribution across a given area when clearly this is not the case (Berry 1993:3-4). These issues aside, the overall problem with traditional statistics is that when space is reduced to “a statistic it loses its descriptive force” (Green 1990:4) and the spatial patterns graphically represented on a map are lost to the perfect tool for pattern recognition, the human brain (Stancic 1994:79).

While “maps actually map the details of spatial variation” (Berry 1993:4) identifying spatial patterns on analogue maps is often difficult because they can depict numerous and often complex sets of relationships. Consider the types of information obtainable from the elements or data sets depicted on analogue maps:

- Elements on maps have distributions which may be statistically summarized
- Elements on maps have qualitative and quantitative values
- Elements on maps may have structure (statistical non-randomness or geometrical regularity)
- Elements on maps may have associations or correlations with other sets of elements within and beyond the system at hand (Clarke 1977:10).

Furthermore, as the number and complexity of the relationships grow, the potential of extracting information diminishes (Marble 1990a:10). The traditional dilemma of cartographers is “how to insert the maximum amount of information into a given map without making it unintelligible to the reader or increasing its size to an unmanageable level” (Marble 1990a:10). Even the retrieval of simple or complex relationships is restricted to simple manual tools such as rulers, compasses and protractors thus limiting the speed, volume and accuracy of data retrieval (Berry 1993:4, Marble 1990a:10; 1990b:5). Consequently,

*a substantial amount of the spatial data which are stored in map form is heavily under-utilised and...many spatially orientated activities take on sub-optimal forms...this inadequate access to spatial data has also had a significant impact upon the nature of scientific investigations of human spatial behaviour* (Marble 1990a:11).
In sum, numerous problems are associated with the methods archaeologists employ to extract, manipulate and present spatial data. Despite their graphical nature analogue maps are awkward to use and retrieving even basic data sets is often arduous and inaccurate. Similarly, statistics are designed neither to manipulate spatial data sets nor to present them graphically. Conversely, Geographic Information Systems (GIS) do allow for the rapid extraction, manipulation and presentation of spatial data based on the user's requirements; archaeologists are now investigating how such systems may assist in overcoming the problems associated with analogue maps and statistics.

The aim of this chapter is to introduce some of the basic concepts underpinning GIS and to provide a brief overview of how a GIS can assist archaeologists. To this end, it highlights what GIS are and are not, the major issues facing archaeologists when employing GIS and the sources of error which can influence the reliability of information extraction. While this is not a discussion about a particular GIS, the examples presented have been produced using MapInfo, the program used throughout this thesis.

The origins of GIS

The first GIS were manually operated and consisted of sets of transparent maps each depicting a different data set (e.g., geology, soils, topography and land use). By overlaying these transparent maps it was possible to derive new information and create new maps. For example, by using soil type and land use overlays variations in land use based on soil types could be identified and mapped.

...these techniques marked a turning point in the use of maps, from techniques that emphasize the physical descriptors of geographic space to those that spatially characterize management actions. This movement from descriptive to prescriptive mapping set the stage for computer assisted analysis (Berry 1993:3).

National and state government agencies were the principal designers and users of the first computer based GIS (Star and Estes 1990:21) to assist in managing both physical and cultural environments, a crucial role which continues to this day. A significant push
in the development and subsequent acceptance of GIS was a growing disillusionment with manual data handling techniques and an increasing reliance on computer-driven data manipulation (Peuquet and Marble 1990:5). At the same time, spatial analysts were pulled towards computers because

1. computers could store and manage the large and complex geographic data sets,
2. computers were likely to impose uniform methods of data storage and management,
3. manual methods were time-consuming and thus had limited practical application, while computers were considerably faster and
4. the revolution in digital geographic data capture e.g., Global Positioning Systems (GPS) and remotely sensed digital imagery made such data readily available (Peuquet and Marble 1990:5; see also Star and Estes 1990:22).

This push/pull towards the management, manipulation and capture of geographic data saw GIS being used to address complex multi-disciplinary issues at local, regional and global levels (Peuquet and Marble 1996:6). Without good systems of data management the “many spatial data sets... being generated... would be ineffectively used and result in wasted resources” (Bonham-Carter 1994:2). Likewise, “without digital systems for the processing and display of images, the enormous volumes of remote sensing data collected daily would simply remain on computer storage devices and the wealth of information they contain would remain unrevealed and indigestible” (Bonham-Carter 1994:2). It is for these reasons that GIS has had and will continue to have an enormous positive impact on a variety of disciplines. Archaeology is but one of these.

GIS defined

Perhaps the most misleading and yet one of the most popular myths about GIS is that they are programs that draw maps. This is incorrect. Certainly GIS produce maps; however, any drawing program is able to produce a map that can be viewed on a monitor
or printed, but this does not qualify them as GIS. Another myth is that GIS must be able to model in three dimensions, i.e., objects having \( x, y, z \) coordinates. Many applications model in three dimensions including members of the group of programs referred to as CAD (Computer Aided Design/Drafting). However, these applications are not GIS. CAD programs are not designed to handle "data or information with implicit or explicit information about location" (Star and Estes 1990:274). Thus "it is difficult to link attributes in a data base to specific geographical entities and then automatically assign symbology on the basis of user defined criteria" (Cowen 1990:55). For example, it would be impossible to produce a thematic contour map using CAD software showing the distribution of shellfish remains across a site based on the average density per \( m^2 \) of those remains.

Certainly there are programs that contain a "rudimentary linkage between a data base and a graphical display system" (Cowen 1990:55). Automated or computer mapping systems are capable of producing thematic maps. SYMAP, for example, could assign symbology to spatial entities on the basis of attributes stored in a database. Despite this capability, such programs are restricted to data retrieval and the automatic application of symbology and classification (Cowen 1990:56).

Misconceptions also occur concerning the range and types of analysis a GIS should be capable of undertaking. What can be achieved in one application may not be possible in another. For example, not all GIS can undertake view-shed analysis, i.e., they are unable to determine what parts of a region are visible from a given point. For GIS with this capability variations occur in how such analysis is undertaken. For example, GRASS will identify all visible sections of a landscape, whereas 3DMAPPS results are based on areas visible within a specified radius from the view point.
In sum, a GIS is not a map-drawing program, an application that models in three dimensions or a program that can create thematic or choropleth maps. Yet a GIS can undertake each of these tasks. Likewise, the types of analysis available to a GIS are dependent upon its analysis package, although such capabilities can be improved via a development language or third party add-ons. So what exactly is a GIS?

Simply defined a GIS is a collection of computer hardware and software organised and designed to capture, store, update, manipulate, analyse and display geographically referenced data sets effectively and efficiently. Lyons and Sharma (1994:86) define GIS as a:

\textit{locationaly defined, computerised database that answers queries of a geographical or spatial nature. A GIS can accept and edit any kind of geographic data (and) therefore information from different sources, in different formats, and at different scales.}"

In other words, GIS comprise hardware and software that allow geographic data to be analysed and this in turn can result in the creation of new data.

As with manual GIS, computer based GIS employ overlays to graphically present the spatial data stored in their databases and these can be combined to produce a map with any one of or a combination of overlays (Figure 6.1). An overlay is simply a set of data that can be mapped to show the data’s spatial distribution. How these overlays are displayed and the results of any analysis depends on the type of GIS being employed, i.e., raster or vector.
Figure 6.1 The overlay process in a GIS.

The raster model

Raster GIS are based on a grid containing cells of a specified size to present spatial data. Each cell in the grid, including those containing no data, is identified by a numeric value that represents one aspect of the entity being modeled (Figure 6.2). Consider the example presented in Figure 6.2 which models an area's potential for containing archaeological material. As shown, each cell is coded with a value indicating its potential for containing material, including those areas where no data has been obtained.

Raster based GIS have advantages and disadvantages. On the positive side as they have a simple data structure they are relatively easy to understand and operate. This data structure allows for relatively easy mathematical manipulation, particularly Boolean operations, and maps may be manipulated algebraically (Savage 1990:25). On the negative side the data files are large and require considerable computer storage space. Accuracy in a raster GIS is often compromised by grid cell resolution. If, for example, cell resolution is 50 x 50m objects having sides with lengths less than 50m will appear
larger than they are or will not be shown. Likewise, as cell resolution increases the more generalised the data becomes.

Figure 6.2 Raster based map showing archaeological potential.

The vector model
As vector GIS use points, lines and polygons to depict spatial data (Figure 6.3) they produce maps that closely resemble traditional mapping methods. Whereas the cell is the basic unit in a raster GIS, in the vector model it is the point or node, and objects not represented by points are created by joining related sets of points to form linear or polygonal objects. The data base in a vector GIS allows for the storage of any number of attributes including text strings (Figure 6.4) and each one of these attributes can be modeled either singularly or in combination with other attributes. Thus in Figure 6.4 it would be possible to generate a map showing areas with grasses and high potential.

A major advantage of vector GIS is that their databases require much less storage space than their raster counterparts, although this is not to say that vector databases are necessarily small. Vector GIS do not suffer from the resolution problem of raster models and thus objects of any size (at least in theory) may be modeled. Furthermore, as points form the basic unit, object boundaries may be modeled with greater accuracy and more smoothly than possible in a raster GIS.
Fig. 6.3 The vector model comprises points, lines and polygons.

Fig. 6.4 Vector model of the same data shown in Fig. 6.2. Instead of numeric codes text strings are used to identify attributes and as indicated more than one attribute may be attached to each object. Note that areas with no data are left blank.

Conversely, vector models require defined boundaries and from an archaeological perspective this is problematic as it sanctions the notion that sites have well-defined boundaries (Savage 1990:24). Similarly, using points to depict sites reinforces the "dots on maps" approach discussed in Chapter 1. A further disadvantage is that streams, roads and comparable objects are often modeled as simple lines (i.e., they have no width) when in fact they have both length and width.

Despite the advantages and disadvantages of raster and vector GIS, they must all include and efficiently execute the following functions identified by Marble (1990b:10):
1. a data input subsystem to collect and/or process spatial data,

2. a data storage and retrieval subsystem whose format and organisation provides rapid data retrieval for analysing, updating and correcting data,

3. a data manipulation and analysis subsystem that performs tasks such as changing the form of data through user defined aggregation rules, and

4. a data reporting subsystem capable of displaying in a tabular or map form all or part of the database, manipulated data and the resulting spatial models.

With the above in mind the following section provides a detailed examination of each function using an archaeological example.

GIS functions

Data input subsystem
Geographic data is available in two formats, primary and secondary. Primary data is “captured directly from the application world” (Worboys 1995:29) and includes that obtained during field work and/or laboratory analysis. For archaeologists this may include data relating to site environments, artefact analysis and surveys. Secondary data is captured from devices that store data in another form (Worboys 1995:29) and such sources include analogue maps, remotely sensed imagery, GPS and either commercial or government agencies that gather and supply digital data. Data of this type may require scanning and geo-referencing prior to its use in a GIS or translation to the native format of the GIS being used.

Data storage and retrieval subsystem
The data storage and retrieval subsystem of a GIS is essentially the database. In many cases the relational model is used, and retrieving, updating and modifying the data are undertaken by employing Structured Query Language (SQL). Additionally some GIS (e.g., MapInfo) support Open Data Base Committee (ODBC) drivers which allow a GIS to access tables from non-MapInfo databases. This is a valuable addition as it overcomes
some of the problems associated with MapInfo's SQL language (e.g., Johnson 1996: 164).

Apart from attribute data a GIS database must also store information about the spatial and graphical aspects of the object being modeled. How this is achieved depends upon the GIS application. For example, Arc/Info employs topology which is a process of encoding or identifying the relationships existing between polygons. Very simply this means that contiguous objects share common boundaries and each object is coded as being either to the left or right of the boundary. Therefore, if the boundary of one object is modified this change will be reflected in any neighbouring objects sharing the boundary. Conversely, in MapInfo each object is modeled discretely and relationships between contiguous objects are not identified in the data base. As such, changes in one object's boundary will not be automatically reflected in neighbouring objects. The spatial side of the database must also allow updates to be made to an object's locational data because this may change through time. For example, a river's course may change as may the visible boundaries of a site.

Data manipulation and analysis subsystem, and data reporting subsystem
These two subsystems are discussed jointly because a demonstration of data manipulation and analysis is best understood by viewing the results in the data reporting subsystem. GIS manipulate and analyse spatial data in many ways including generalisation, subset creation within a single overlay, through multiple overlays or by buffering. In addition GIS can also undertake Boolean overlays via a set of spatial operations which in MapInfo are contains, contains entire, within, entirely within and intersects (Figure 6.5).
Figure 6.5  Examples of the three MapInfo spatial joins.

To understand how these operations work, consider the problem in which an archaeologist wishes to extract site attribute information for a given area. The attributes of interest include

1. identifying sites containing millstones and cores,
2. the modal slope class of the landscape where these sites are located and
3. their distance from perennial streams.

 Undertaking this type of analysis manually would be difficult at best; for a GIS it is a relatively straightforward task\(^1\). Following the creation of a base map using contour, hydrology and site overlays (Figure 6.6) the GIS manipulation and analysis subsystems are used to extract the required information. Slope values are calculated from the contours theme (Figure 6.7), and once slope values are obtained data aggregation is used to construct a generalised modal slope class map (Figure 6.8).

Next, sites with the prerequisite artefact content, i.e., millstones and cores, are identified. The data set for all sites in the area is presented in Table 6.1. SQL is used to extract all those sites where both artefact types have the attribute T (Figure 6.9) and the results are saved as a new overlay.

\(^1\) All output provided in this example were produced by MapInfo and 3DMPGIS. Grid cell resolution for the slope models is 30m by 30m.
It is now possible to determine on which slope classes the sites of interest are located. Using the geographic function "contains" a search is undertaken between the modal slope class and the new site overlays to determine where these overlays join (Table 6.2) and the first piece of required information has been obtained, i.e., the modal slope classes for sites containing millstones and cores.

Figure 6.6 Map generated using hydrology, contour and site overlays.
Figure 6.7  Slope values generated from the contour overlay.

Figure 6.8  Modal slope class model generated by grouping together slope values.

Table 6.1  Data for the sites in the example. (T = True, i.e., the artefact is present, and F = False, i.e., the artefact is not present.)
Figure 6.9 Modal slope classes showing the distribution of sites with millstones and cores.

Table 6.2 Results of a query to identify on which slope class a site is located.

<table>
<thead>
<tr>
<th>Slope Class</th>
<th>SiteID</th>
<th>Flakes</th>
<th>Millstones</th>
<th>Cores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderately Inclined</td>
<td>8</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>Gently Inclined</td>
<td>1</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>Very Gently Inclined</td>
<td>4</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
</tbody>
</table>

To answer the next part of the question the distance from each site to the nearest perennial stream must be calculated. Thus it is necessary to identify permanent streams in the area by using a query that searches the database for streams with the attribute “perennial” (Figure 6.10) and then calculating the distance between these streams and the sites. Determining distance can be undertaken in many ways and this again may depend on the GIS application being used. Using MapInfo it is possible via the following:

1. measure the straight line distance with the programs ruler,
2. create buffers around each site until the edge of the buffer touches the stream,
3. calculate the distance from a either a point on the perimeter of the site or the centroid of each site to the nearest point of a perennial stream using SQL and
4. use the ruler tool to determine the distance between sites and perennial streams and then build a buffer around each site based on the result so that the distance can be presented visually (Figure 6.11).
Our archaeologist has now answered the initial questions and can begin interpreting what the patterns may mean or generate further data sets to refine the interpretation. It is important to realise that what has been shown here are the results of spatial data manipulation. This is what a GIS allows the user to do, manipulate, analyse and view spatial data sets and even create new data. A GIS does not interpret data, nor does it provide answers. Interpreting data and answering archaeological questions rests wholly with the archaeologist. While the above has provided some insight into the potential for GIS in archaeology it is equally important to highlight some potential pitfalls that may be encountered when using GIS.

![Figure 6.10 Perennial streams in the study area.](image)
Figure 6.11 The result of buffering around a site to show its distance to the nearest perennial stream.

**Issues and pitfalls**

While GIS may have revolutionised the ways spatial data can be manipulated and analysed, some issues require discussion. Apart from issues relating to the variety of GIS available and how they perform archaeologists must also be aware of problems that are more directly related to their discipline. These issues include the perception that GIS will provide definitive solutions to archaeological questions and the notion that GIS can direct theoretical positions (Allen *et al.* 1990:383).

The most important point to make about GIS is that all they produce is a model of the area of interest. Certainly they do this very elegantly in allowing for the creation of new data sets and models of past landscapes (Ogleby 1994; Stone and Decker 1990), the generation of predictive models for site location (Warren 1990), or examination of artefact manufacturing technology spatial distributions (Smith and Hall 1996). However, what is produced is simply a model; nothing more, nothing less. Furthermore, the accuracy of any model is dependent upon the data employed and the algorithms the GIS uses to manipulate the data.

As indicated previously data may be either primary or secondary. The capture of primary data is totally within the control of the archaeologist although problems may arise from
incorrectly read map coordinates or typographical errors made during data entry, for example. Secondary data errors include inaccurate digitising, distortion in scanned images and errors in geo-referencing. Problems can also arise when combining data obtained from maps with different scales or projections.

Figure 6.12 shows the result of combining data from two different sources, a digital cadastral data base (DCDB) and a 1:25,000 hydrology map. As demonstrated in this example the stream boundary depicted in the DCDB does not match the stream derived from the 1:25,000 scale map. The horizontal error factor between these maps is ca ±30m and could certainly cause problems when plotting site locations adjacent to the stream.

A further problem that occurs on small-scale maps is that some landscape features may be either smoothed out or absent. Thus minor drainage systems may be omitted when it is these features that are often the most important in regional settlement/subsistence pattern studies (e.g., Kvamme 1990:114).

Figure 6.12  The problems that can arise using data sets from different sources or of different scales.

The various algorithms employed by GIS are another potential error source and these can compound the errors already extant in a data set. For example, the algorithms used to generate Digital Elevation Models (DEM) calculate elevation, slope and aspect data based on either a grid or Triangulated Irregular Network (TIN). Regardless of the method used to generate the data, these models employ one of the hundreds of interpolation algorithms available (Kvamme 1990:115; Worboys 1995:210) to produce
the model. Basically interpolation “assumes a gradual and continuous change in
elevation across an area between places where the true elevation is known” (Anonymous
1997). These interpolation algorithms can be applied to both regularly and irregularly
spaced elevation points and digitised contour lines.

To demonstrate some of the problems that may arise when using DEM’s consider the
following example. Figure 6.13 shows a cross section along a stream obtained using
3DMAPPS cross-section module. While a cross section along any stream should show a
continuously decreasing slope this example shows sections of the stream actually flowing
uphill! In other words, there are problems with either the original data set or the
interpolation algorithm. Obviously users need to be aware of such problems and how to
overcome them. In this case it may be possible to edit the elevation data along the
stream to ensure that the flow was all downhill although the question still remains, is the
problem with the algorithm, the contour or hydrology data sets or a combination of
these?

Different interpolation algorithms also produce different results when used to model the
same data set. Consider the contour and irregularly spaced (point) elevation data
presented in Figure 6.14 and the four models shown in Figure 6.15. While each of these
models was derived from the same data set there are major differences in the resulting
DEM’s. Models A and B most accurately depict the landscape portrayed on the contour
map, while C suggests the landscape comprises a number of steps. D on the other hand
shows a number of peaks which do not occur on the contour map (see also Kvamme
1990 for a further discussion on interpolation algorithm problems). Furthermore,
different algorithms are designed to operate on different data sets. For example, the
nearest neighbour algorithm is best used with regularly spaced data whereas kriging
works equally well with either regular or irregularly spaced points. Thus it is important to
ensure that the algorithm selected to generate the DEM is matched to the data set.
ensure that the algorithm selected to generate the DEM is matched to the data set. Unfortunately it may not be possible to determine which algorithm is being used as the software designers closely guard such information. The publishers of 3DMAPPS would not divulge any information about the algorithms used in their software.

In sum, while GIS may allow archaeologists to manipulate their data in ways not previously possible, they must also be aware that what is being produced is nothing more than a model, and as with databases, the same rule applies: garbage in garbage out. The models generated by a GIS are dependent upon not only reliable data sets but consistency in data manipulation methods.
Figure 6.14  Contour and irregularly spaced elevation data set.

Figure 6.15  The result of applying different interpolation algorithms to the same irregularly spaced data set.

GIS in the drivers seat?
While the above issues may be of some concern, they can be avoided and resolved. A much greater, more serious threat to the acceptance of GIS as a legitimate tool in archaeology is what Allen et al. (1990:383) view as “the most dangerous pitfall...
inclination to allow a powerful methodology with its accompanying techniques to drive
the research and practice of a discipline.” Therefore, by using GIS are archaeologists
placing the technology in the driver’s seat and allowing it to dictate archaeological theory.
Central to this issue is Wheatley’s (1993:133) argument that GIS applications in
archaeology are underpinned by a largely hidden agenda that encourages functional or
deterministic approaches to archaeological explanations. This argument is based on
Wheatley’s observations that the majority of GIS applications to archaeology have
adopted an “ecological-systems theory paradigm within which to attempt archaeological
explanation” (1993:133). In other words, the use of GIS implicitly forces
environmentally deterministic explanations for spatial patterning in the archaeological
record. While agreeing that this position was defensible, he argued that such
explanations were underscored by a belief that GIS were “theoretically neutral”
(1993:134) and thus allowed for the “perpetuation of the current theoretical orientation
without any cause for its debate, and in this way [concealed] the theoretical debate”
(1993:134). Thus the question must be asked, does GIS have any self-contained
theoretical concepts?

The answer to this question is that GIS technology does not drive deterministic theories.
Indeed, it would be hoped that GIS does not have any self-contained theoretical
concepts (Stancic 1994:76) although there could be a “danger of practicing a theoretical
approach without being aware of it” (Stancic 1994:76). I agree with this position; a
computer program cannot dictate a theoretical position, nor does a GIS have any
archaeological theories, deterministic or otherwise, built into its programming. The
archaeologist using the GIS is a different proposition, however.

Certainly a theoretical position may be practiced unconsciously, and unquestionably GIS
has the potential to lead archaeologists down deterministic paths. In part, this is due to
the fact that a GIS is reliant upon geographically anchored data sets thus restricting the
types of data that can be manipulated by the software (Gaffney and van Leusen 1995:368). Furthermore, initial data acquisition, no matter how worthwhile in the long term (e.g., Farley et al. 1990), is expensive in terms of time and money, and thus many archaeologists tend to employ the standardised data sets produced by governmental bodies as base maps. These data sets invariably relate to topography, soils, geology, etc., which, as van Leusen (Gaffney and van Leusen 1995:368) argues, pushes archaeologists employing GIS "into producing models that focus on relationships between regional distribution patterns and mappable components (variables) of the environment." Furthermore, the apparent relationship between GIS and environmental determinism is fostered by the fact that "it has never been so easy to compare the relationship between the natural environment and the distribution of archaeological sites" (Stancic 1994:76).

Despite Wheatley's arguments that GIS promotes deterministic perspectives he is not arguing against the use of GIS in archaeology. Rather, he suggests that a different, non-deterministic approach should be taken, one that is based not on the processual paradigm but on the perceptions of the landscape held by past societies (i.e., cognitive models). He recommends a method based on cost-surface or friction analysis, an approach that uses a module found in some GIS which maps areas that may be accessed more easily than others (Wheatley 1993). To achieve this, various aspects of the landscape are coded according to their characteristics. Thus steep landforms would be coded as less accessible than flat areas, deep wide streams more difficult to cross than shallow, narrow streams and so on. A similar approach is view-shed analysis whereby a map is produced indicating the area(s) that can be viewed from a particular point on the landscape (e.g., Gaffney and van Leusen 1995).

While both view-shed and cost-surface analysis can provide explanations couched in social/cultural terms there are potential problems above and beyond those identified by
Gaffney and van Leusen. In both cases a number of assumptions must be made concerning the nature of the prehistoric landscape for which the view-shed or cost surface are being created. In the case of the view-shed analysis the two assumptions are that

1. the height of the person(s) looking out from the point from which the view-shed is being generated is known and
2. the height and density of any vegetation which may have existed in prehistoric times is known.

While the first of these assumptions could be considered moot, the second should not be ignored. Vegetation patterns change through time as the result of both human action and environmental shifts. If view-sheds are to be employed successfully to identify social/cultural landscapes then part of the equation must include the height of the vegetation for the time the view-shed is being generated. However, this point is further clouded by the fact that vegetation regimes may have varying densities and thus, while parts of the landscape may be obscured, other sections may be clearly visible through a corridor. Vegetation is not always of a uniform height or density and yet when entering a value for vegetation height the GIS assumes the vegetation is impenetrable and has a uniform height. To demonstrate the differences that may occur when creating a view-shed consider the following example.

Figure 6.16 shows the results of two view-shed analyses undertaken with 3D MAPPS. In both view-sheds I have assumed the height of the person to be 1.75m. In Figure 6.16A the vegetation value is zero (i.e., no vegetation restriction) while in Figure 6.16B the vegetation is assumed to have a height of 4m. These figures demonstrate considerable differences between the two view-sheds.
visibility
I Visible
I Not visible

Figure 6.16 View-shed analysis showing the differences that can occur when vegetation heights are included. A - no vegetation, observer height 1.75m. B - vegetation 4m high, observer height 1.75m. C - the difference between models A and B which amounts to approximately a 25% difference in the landscape visible between the two models.

A similar situation occurs with cost-surface or friction analysis. When creating models of this type it is possible to weight different landscape features on the basis of how they may have hindered or facilitated access to or from a given point. Thus cliffs may be given a factor of, for example, 5, while level ground may given a factor of 1. Likewise, major rivers may be weighted at 5 and smaller streams 2 or 3. Vegetation patterns can be weighted in much the same way. The result is a map indicating what is essentially a path of least resistance. As with the view-shed analysis there are factors which may be excluded from the analysis because the investigator may have no idea how the landscape has changed through time. For example, in the time frame under investigation a river may have had a ford which has subsequently disappeared (or perhaps the people used rafts or canoes); thick vegetation may have had pathways cut through it to facilitate travel. Just because a GIS informs the operator that a particular route follows the line of least resistance it does not necessarily mean that humans followed the same path. It is not always possible to reduce human actions either as individuals or within a cultural group to sets of binary numbers; we are not always that logical. Furthermore, such approaches
still involve measurable properties of the landscape (visibility analysis being based on a
derivative of the DTM [Digital Terrain Models], friction surfaces on elevation rules
for environmental variables such as slope, vegetation cover, etc.). Such models are
limited in exactly the same ways that ED [Environmentally Deterministic]
models are limited (Gaffney and van Leusen 1995:371).

A final point made by van Leusen concerns the use of GIS as a method for “data
cleaning” (Gaffney and van Leusen 1995:370, 371). This somewhat echoes an
observation I made in 1994 during a seminar presented in the Department of
Anthropology and Sociology, the University of Queensland. In this seminar I stated that
GIS could be employed to eliminate environmental variables from explanations of spatial
patterning leaving behind data sets that may be indicative of cultural decisions relating to
the location of prehistoric activities. Similarly, van Leusen states that “by applying an
ED model to a data set, one can eliminate environmental patterning leaving a clearer
view of whatever cultural factors may have influenced the data” (Gaffney and van

Discussion
GIS have the potential to allow archaeologists to manipulate and view their data in many
different ways, the only limitations being those imposed by the software itself. Thus
archaeologists can undertake both comparative and spatial research at levels not
previously possible. As GIS software development continues to improve this new
addition to the archaeologist’s toolbox is likely to have an even greater impact on the
discipline than it already has. At the same time, however, archaeologists need to be
aware that there are traps for the unwary, some of which have been outlined in this
chapter:

Good research and management is based on asking good questions—something GIS
does not do for us. . . . the importance of GIS is that it provides ways of asking
sophisticated questions—it is of course, up to the archaeologist to make good use of this
Introduction
The new classification system I propose for Australia's prehistoric archaeological record is based on a hierarchical premise that divides the archaeological record into descriptive components and component attributes. This system explicitly ignores the concept of site types and a site is defined as an area containing archaeological material. Central to this classification system is an interpretative model that provides well defined stages for recording and analysing these components and their attributes. As such, this system differs considerably from that currently used by the Heritage Branch and Australian archaeologists.

This classification system is not intended to be and should not be considered fixed in terms of the components or attributes identified. Rather, it is an experimental system that demonstrates how a different approach to recording baseline archaeological data may assist researchers and heritage managers to better understand variation in the archaeological record. While this system is not reliant on digital databases or GIS it certainly benefits when used in conjunction with them.

Towards a polythetic approach to recording the archaeological record
To overcome the classification problems discussed in Chapter 1 archaeologists must consider the archaeological record's polythetic nature. While recognised conceptually, the record's polythetic nature must also be recognised operationally, i.e., during recording and analysis. By viewing the archaeological record as comprising a number of basic
components that are described more fully by attribute states, the classification system presented here explicitly recognises this polythetic nature and provides a composite view of the record (Figure 7.1).

Figure 7.1 Diagrammatic representation of the classification system showing how the various components provide a composite view of an archaeological site.

In developing a new classification system for the Australian archaeological record it was necessary to completely ignore the traditional system to ensure its obvious shortfalls were overcome. Theoretically, this new approach has its foundations in the notion of idealised cognitive models (Lakoff 1987) and differs considerably from classical classification theory. Idealised cognitive models of classification posit that traditional classification systems are based on abstract symbols or words which rely on a “God’s eye view”, or a perspective from outside reality, when what is really required is an internalist perspective because we are part of it (Lakoff 1987:261).

It is a perspective that acknowledges that we are organisms functioning as part of reality and that it is impossible for us to ever stand outside it and take the stance of an observer with perfect knowledge, an observer with a God’s eye point of view (Lakoff 1987:261).

And yet this is what archaeological site classification often does. By stating that a site containing knapped artefacts and cores is a workshop site, archaeologists take a position
of having perfect knowledge. How can we classify a site as a workshop when we did not see how it functioned in the cultural system? In a nutshell, we cannot! At best we may infer it was a workshop but only after careful consideration of the material(s) present.

Traditional categories also assume that categorisation is structured logically and moves from primitive entities, i.e., those that do not have a complex structure, to those entities which do. Lakoff (1987:199) argues this is not the case and effectively demonstrates that the most basic level of human categorisation is not based on primitives but rather falls into the middle level of a taxonomic hierarchy where the basic categories identified by humans have a high degree of internal structure. Despite this internal complexity it is these “basic-level categories” that “human beings find easy to process—that is, easy to learn, remember, and to use. In short, what should be cognitively complex from an objectivist point of view is actually cognitively simple” (Lakoff 1987:199).

Human conceptual categories, i.e., basic-level categories, have properties resulting from the imaginative process and as such do not mirror nature. “Basic-level structure is partly characterised by human imaginative processes: the capacity to form mental images, to store knowledge at a particular level of categorisation, and to communicate” (Lakoff 1987:371). This process of categorisation also recognises that while cognitive models are idealised, humans have the ability to “extend categories from central to non-central members using imaginative capacities such as metaphor, metonymy, mythological associations and image relationships” (Lakoff 1987:371).

Consider an archaeologist locating what is termed in Australia a ‘horsehoof core’. Archaeologists recognise horsehoof cores on the basis of a set of complex characteristics, e.g., platform, negative flake-scars, overhang removal. Additionally, a horsehoof core is identifiable because of its shape; that is, it roughly resembles a horse’s hoof. In telling another archaeologist they have located a horsehoof core, he or she is likely to state,
“I’ve found a horsehoof core,” rather than going into a complex description. In doing so a complex set of characteristics along with a mental image is conveyed to the other archaeologist who can immediately construct an idealised mental image of the core prior to seeing it.

Most Australian archaeologists would agree that horsehoof cores come in a variety of shapes and sizes. However, despite such diversity archaeologists can recognise and communicate what they have found by stating, “I’ve found a horsehoof core.” In other words, they have the ability to move outwards from a central idealised cognitive model of a horsehoof core to include those on the periphery that do not fit their idealised mental image.

This basic level approach was employed in developing a classification system for Australia’s prehistoric archaeological record. Like the horsehoof core I argue that Australian archaeologists carry idealised cognitive models of the archaeological record that operate at the basic level of classification. Take, for example, archaeologists locating a scatter of stone artefacts. They do not state that they have found the archaeological record, the superordinate level, neither do they state they have found a backed blade site or a tula adze site, the subordinate level. Rather, they are likely to say “We’ve located a stone artefact scatter,” i.e., the basic level of categorisation.

There are, however, potential problems in classifying the archaeological record in this manner. “Since experience does not determine conceptual systems, but only motivates them, the same experiences may provide equally good motivation for two somewhat different conceptual systems” (Lakoff 1987:310). Therefore, archaeologists’ cognitive models depend upon their own experiences. As Thomas (1975:62) argues:
There is a mode of archaeological research in which the site concept is not only inessential, but even slightly irrelevant. I specifically refer to regional procedures which take the cultural item (the artefact, feature, manuscript, individual flake, or whatever) as the minimal unit, and ignore traditional sites altogether (see also Dunnell 1992; Dunnell and Dancey 1983; Foley 1981).

Thus while some archaeologists' cognitive models take a traditional perspective of sites as clusters of artefacts, others have developed different cognitive models due to their archaeological experiences and therefore different theoretical positions.

We use cognitive models in trying to understand the world. In particular we use them in theorizing about the world, in the construction of scientific theories as well as in the theories of the sort we all make up. It is common for such theories not to be consistent with one another. The cognitive status of such models permits this (Lakoff 1987:118).

The classification system presented below is based on my perceptions of the basic level categories or components (Table 7.1) of the archaeological record. Certainly, I do not presume that this classification system reflects the cognitive models recognised by every Australian archaeologist. At the same time, however, this provides the foundations for developing a system that has Australia-wide applicability. Furthermore, the structure ensures that once identified the descriptive profiles and subprofiles can be replicated by others.

Some of the terms in Table 7.1 will be familiar to Australian archaeologists, while others are likely to be considered unorthodox. It could be argued that these unorthodox terms are simply semantic variations on the more traditional terms. This is not the case, however; these terms are descriptive and aimed at removing functional definitions from the classification system. For example, rather than having the functionally defined class axe-grinding groove(s), the term “abraded nonportable artefacts” is employed. This removes the potential for identifying all grooves as resulting from axe-grinding. Furthermore, it allows for all those abraded artefacts that are not portable to be included under one clearly defined heading.
Table 7.1 List of components identified for the classification system.

<table>
<thead>
<tr>
<th>Components</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abraded non-portable artefacts</td>
<td>Manuport</td>
</tr>
<tr>
<td>Abraded portable artefacts</td>
<td>Modified landscape</td>
</tr>
<tr>
<td>Charcoal/ash</td>
<td>Modified tree</td>
</tr>
<tr>
<td>Contact artefacts</td>
<td>Petroglyph</td>
</tr>
<tr>
<td>Faunal material</td>
<td>Pictograph</td>
</tr>
<tr>
<td>Floral material</td>
<td>Shellfish remains</td>
</tr>
<tr>
<td>Human remains</td>
<td>Short pathway</td>
</tr>
<tr>
<td>Knapped artefacts</td>
<td>Stone source</td>
</tr>
<tr>
<td>Long pathway</td>
<td>Uncommon artefacts</td>
</tr>
</tbody>
</table>

While components form basic-level categories, they alone do not supply sufficient information for archaeological analysis and thus sets of descriptive attributes, not necessarily unique, were identified (Figure 7.2) although they are recorded separately for each component. Like the components, attribute sets are based on my perceptions of what is required to elicit baseline archaeological information and may require future modification.

Components and attributes

The component/attribute sets identified for the Australian archaeological record are defined and described in this section which is divided into five main subsections:

1. attributes that are shared by more than one component,
2. the components and their specific attributes,
3. general attributes that are shared by all sites,
4. environmental factors that impact on sites and
5. variables that describe a site’s location on the landscape.
Figure 7.2 Diagrammatic representation of the classification system based on components and attributes. (N.B. dotted lines indicate attributes that may be shared by more than one component.)

**Shared attributes**

Many components share attributes, and thus it is prudent to discuss these in detail once, and then indicate their presence for a given component.

I. Densities - the maximum, minimum and average densities per metre$^2$ for all artefacts in a given component. Traditionally density measurements take the form of $x$ number of artefacts for 1m$^2$ and in low-density situations it is common for measurements of $<1$ artefact per 1m$^2$ to be recorded. The approach used here is based on the visible area of the site and the results are presented in the form of 1 artefact per $x$ m$^2$.

II. Deposition - describes the relationship between artefacts and the ground surface.
   A. surficial - artefacts occurring on or above ground surface. If artefacts are visible at the bottom of a gully erosion feature or the like they should be recorded as surficial.
   B. subsurface - artefacts occurring below ground surface. This includes artefacts that are visible in the sides of erosion features, etc.
   C. combination - artefacts occurring on and below ground surface. This also applies to those sites where it is apparent that deposits occur below the ground surface.

III. Distribution - describes how particular artefacts are distributed across a site. This is not used to describe the distribution of all artefacts at a site; rather it refers to each component present. For example, where a site has a single knapped artefact and two or more abraded portable artefacts, the knapped artefact would be recorded as isolated, the abraded artefacts as scattered.
A. isolated - single occurrence of an artefact at a site.
B. scatter - two or more artefacts of the same component at a site.

IV. Abrading process - describes the abrasive process employed to form abraded artefacts and petroglyphs.
A. grinding - abrasion of two rocks with flat or gently curving surfaces by rubbing one against the other.
B. sawing - two-way longitudinal abrasion using an edge which is often notched.
C. engraving - one-way longitudinal abrasion using a point.
D. drilling - abrasion with a point in a circular motion.
E. scouring - abrasion with sand wedged between object and a flexible surface such as leather.
F. polishing - abrasion resulting in a polish being visible on the stone (Hiscock and Mitchell 1993:5-6).
G. beveling - abrasion resulting in a flat bevel along one edge as a result of pounding or scraping against another hard surface (Kamminga 1982:16-17, 42).
H. edge-ground - abrasion generally occurring on opposite sides of a piece of stone, bone or wood resulting in a V shaped cross section through the abraded section of the material.

V. Hardstone type - describes the type of hardstone the artefact is made of. Examples include silcrete, quartzite, chert, sandstone, etc.

VI. Pigment colour - describes pigment colours. This generally but not necessarily refers to ochre colours.

VII. Number - used to indicate the total number of artefacts or glyphs, etc., observed at a site. In some components this attribute is employed twice. First, the number of artefacts for each component is recorded, e.g., if a site contains 10 abraded portable artefacts then this is the number recorded. Likewise, the term “number” is also used to indicate the number of artefacts having a specific set of attributes in a component, e.g., of the 10 abraded portable artefacts located, five with the same groove cross section may be made on sandstone and five on another hardstone type.

VIII. Full count - indicates what the number attribute (described previously) represents.
A. full census - a complete count of all observed artefacts.
B. estimate - the number of artefacts has been estimated only.
C. unknown - the number of artefacts is unknown/not counted.

IX. Percentage - if it is not possible to count the number of artefacts observed then a percentage based on the overall assemblage can be given, e.g., shellfish remains, knapped stone artefacts. In such cases an approximation of the percentage should be recorded, for example, 50% silcrete cores, 20% chert flakes, 30% silcrete flakes.
X. Groove cross section - describes groove cross section(s) for abraded portable and abraded nonportable artefacts.
   A. distinctive V
   B. distinctive U
   C. stepped ✓
   D. shallow broad U shape

XI. Name - the common name of floral and faunal remains and modified trees observed.

XII. Species name - the species name of floral and faunal remains and modified trees observed at a site.

XIII. Not applicable - for some variables the term ‘NA’ is used to indicate the variable is not applicable to the site being recorded. This excludes the possibility of null values being stored in the database. A null value in a database may be interpreted to mean a number of things, e.g., the data does not exist, the data was not recorded, the data is unknown, the data hasn’t been entered yet. By providing the value NA potential misinterpretations can be avoided.

XIV. Condition - while somewhat subjective, this attribute is used to describe the condition of some artefacts, e.g., petroglyphs, pictographs, contact artefacts, uncommon artefacts. It is also used to describe the condition of floral, faunal and shellfish remains.
   A. For artefacts the values are:
      1. good - the artefact has no visible signs of damage.
      2. fair - the artefact has some minor damage.
      3. poor - the artefact is badly damaged.
   B. For floral and faunal remains, etc. the values are:
      1. complete - the remains are complete.
      2. fragmented - the remains are broken or fragmented.
      3. combination - a combination of both fragmented and complete.

XV. Rock formation - the type of rock formation on which the artefact occurs. Specific to pictographs, petroglyphs, abraded nonportable artefacts and stone sources.
   A. bedrock
   B. group of rocks
   C. isolated rock
   D. rockshelter/cave floor
   E. rockshelter/cave internal walls
   F. rockshelter/cave roof
   G. stream bed
   H. vein

XVI. Rock size class: describes the average size of rocks in mm (Table 7.2) which are inferred as being artefactual. This refers to stone sources, manuports and modified landscapes.
Table 7.2 Size classes for rocks (McDonald et al. 1990:87).

<table>
<thead>
<tr>
<th>Size class</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large pebbles</td>
<td>20 - 60mm</td>
</tr>
<tr>
<td>Cobbles</td>
<td>60 - 200mm</td>
</tr>
<tr>
<td>Stones</td>
<td>200 - 600mm</td>
</tr>
<tr>
<td>Boulders</td>
<td>600mm - 2m</td>
</tr>
<tr>
<td>Large boulders</td>
<td>&gt;2m</td>
</tr>
</tbody>
</table>

Abraded portable artefacts

Abraded portable artefacts are produced by “rubbing the artefact against another object so as to remove small particles from one or both objects” (Hiscock and Mitchell 1993:5). Portable refers to those abraded artefacts that may have been transported from one location to another by humans. The types of recognisable artefacts within this category include millstones, mullers, fishhooks, ochre with visible faceting and bone or wooden points. This component does not include composite artefacts containing an abraded component (see Uncommon artefacts). Due to the variety of materials used to form abraded artefacts this component is divided in two types, abraded stone artefacts and abraded organic artefacts.

The attributes recorded for both types of artefact are:

I. Abrasion type
II. Pre-abrasive reduction: often abraded artefacts such are roughly formed by crumbling or knapping, i.e. they have had some form of pre-abrasive reduction. Recording such may assist in identifying different manufacturing processes through time and/or across space.
III. Artefact type: types of artefacts may include edge-ground implements, millstones, bone points, wood points, faceted ochre.
IV. Deposition
V. Distribution
VI. Densities
VII. Condition
VIII. Number
For abraded stone artefacts the other attributes that are recorded are hardstone type, number of grooves and groove cross section. In the case of abraded organic artefacts the type of organic material, i.e., wood, bone or shell, and the common and species names are recorded.

**Abraided nonportable artefacts**

This component includes those artefacts produced by abrasive reduction that are not portable. Generally artefacts of this type are located on slabs of bedrock. While it could be argued that technically petroglyphs form a part of this category, in this classification system they are regarded as distinct, well-recognised artefacts (Hiscock and Mitchell 1993:11). Furthermore, including petroglyphs as abraded non-portable artefacts ignores idealised cognitive models.

The attributes recorded for abraded nonportable artefacts are:

I. Abrading process
II. Rock formation
III. Hardstone type
IV. Groove morphology - describes the groove’s plan shape, cross section, length, width and depth.
   A. plan shape
      1. elliptical
      2. circular
      3. rectangular - ends may be rounded
   B. groove cross section
   C. measurements
      1. maximum depth
      2. minimum depth
      3. maximum length
      4. minimum length
      5. maximum width
      6. minimum width
V. Number of grooves - the number of grooves for each morphological type recorded.

**Charcoal/ash**

This component consists of fragments of charcoal or ash inferred to be associated with prehistoric human activity. These may be difficult to identify where bushfires/burning
off has occurred.

I. Deposition

II. Distribution

III. Form - describes the form of the charcoal/ash.
   A. lens
   B. lumps
   C. ashy matrix

Contact artefacts
This component describes artefacts that are European in their origin or made on a combination of European and traditional materials. Artefacts in this component could include steel axe heads, knapped glass or cable insulators, china, tin cans or steel points hafted onto traditional spear shafts.

I. Material
II. Artefact type
III. Number
IV. Condition
V. Distribution
VI. Deposition
VII. Densities

Faunal remains
This component refers to vertebrate and invertebrate remains. While it is often difficult to determine whether the remains are the result of prehistoric human activities, natural death or the predatory habits of other animals it is better to record their existence rather than ignore them. This component does not include marine or freshwater shellfish remains or human remains (see Shellfish remains and Human remains) or faunal remains fashioned into artefacts by abrasion or any other manufacturing process. The attributes to be recorded are:

I. Habitat
   A. marine
   B. freshwater
   C. terrestrial
### Floral remains

This component describes floral remains that may be found at an archaeological site including seeds, bark, unburnt wood and any other floral remains that are not arranged in a recognisable manner. It does not include floral materials fashioned into implements by a manufacturing process (see Abraded portable artefacts, Uncommon artefacts), charcoal or ash (see Charcoal/Ash) or trees which have been marked (see Modified trees).

<table>
<thead>
<tr>
<th>Floral Material</th>
<th>Name</th>
<th>Species</th>
<th>Condition</th>
<th>Percentage</th>
<th>Densities</th>
<th>Deposition</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. wood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. leaves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. seeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. bark</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. nuts</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

### Human remains

Human remains result from either deliberate interment, i.e., primary or secondary, or remains not deliberately interred. Primary burials are those where the remains are still
articulated in their correct anatomical position. In some cases it may be evident that not all bones are correctly positioned anatomically and consideration must be given to the possibility that this disarticulation is the result of either soil movement and/or other forms of disturbance (Haglund 1976:9). Secondary burials are those where the remains are no longer articulated and may have been deliberately smashed or broken. Secondary interments are often found as bundles with remains wrapped in bark or animal skins.

The attributes to be recorded are:

I. Remains' location - describes the physical location of the interment.
   A. Rockshelter floor deposits - burial located in the floor deposits of a rockshelter whereby the remains have been buried deliberately or accidentally in the deposits. May be difficult to identify unless the deposit has been disturbed.
   B. Rock ledge - a stepped shelf that may be located along a cliff line or the inside walls of a rockshelter.
   C. Ground - burial where the remains are located below the ground surface in an open area as a result of deliberate burial or natural causes. May be difficult to identify unless erosion of some form has exposed the remains. Excludes remains found in rockshelter deposits.
   D. Fissure - crack, fault or crevice in a rock face.
   E. Hollow tree
   F. Tree platform

II. Number of individuals

III. Full count
   A. full census - a complete count of all individuals located.
   B. estimate - the number of individuals has been estimated only.
   C. unknown - the number of individuals represented is unknown.

IV. Remains' condition

V. Remains present - describes the basic anatomical form of the remains.
   A. cranial
   B. post cranial
   C. both

VI. Interment - indicates whether the remains have been deliberately interred.
   A. yes
   B. no
   C. uncertain

VII. Interment type - if the remains have been deliberately interred this describes the type of interment.
   A. primary
   B. secondary
C. unknown

VIII. Ochre pellets - indicates the presence/absence of ochre pellets with the remains or the staining of bones with ochre.

IX. Bundle - indicates whether or not the remains have been placed in a bundle.
   A. Yes
   B. No
   C. Unknown

X. Position - indicates the position the remains are lying in.
   A. back
   B. side
   C. front
   D. upright
   E. unknown

Knapped artefacts

This component comprises stone exhibiting evidence of being flaked or having been employed to produce flaked stone artefacts. It includes cores, hammerstones and anvils but excludes stone sources (see Stone sources) and stone artefacts that have been produced by abrasion (see Abraded portable and Abraded nonportable artefacts). If an abraded artefact has evidence of being shaped by knapping this should be recorded in the pre-reduction attribute of the abraded artefact and not as a member of this component. Attributes are:

I. Hardstone type

II. Artefact type - the type of artefact based on technological attributes of the artefact (see Hiscock 1988), not functional categories.
   A. flake
   B. amorphous retouched
   C. hammerstone
   D. flaked piece
   E. bifacial retouch
   F. unifacial retouch
   G. backed
   H. core
   I. broken flake

III. Conjoin sets - indicates the presence of artefacts which conjoin. The presence of conjoin sets may be indicative of stone reduction having taken place at a site and thus needs to be recorded (see Hiscock and Mitchell 1993:29-30).

IV. Micro debitage - indicates the presence/absence of micro debitage. As the presence of micro-debitage may be an indicator of stone reduction having taken place at a site it is important that the presence/absence be recorded. I define
micro debitage fragments having maximum dimensions of less than 1mm (Hiscock and Mitchell 1993:30).

V. Source - the nearest known location of stone source(s).
   A. local - the raw material can be found in the general area around the site
   B. exotic - the raw material comes from a known source which is some distance from the site.
   C. unknown - the raw material source is unknown.

VI. Deposition
VII. Distribution
VIII. Densities
IX. Percentages

**Long pathway**
Long pathways provided access for travel between various locations (e.g., Horsfall 1987:56). As such, it is possible these pathways may pass through a number of sites. The pathways described by this component are not those relating to stories from the Dreaming or the pathways that are sometimes associated with specific forms of arranged landscapes (see Short pathway). The attributes to be recorded are:

I. Pathway length - measured in kilometres.
II. Start site - the site at which the pathway begins.
III. End site - the site at which the pathway ends.
IV. Other sites - other sites which the pathway may pass through.

**Manuport**
Manuports comprise rocks or other material(s) at a site that have not been modified by human actions or arranged into an identifiable pattern but whose occurrence can only be explained by human activities. Generally this component will apply to hardstone materials, but others, e.g., coral, pieces of unmodified ochre or lumps of earth/clay, may also be included.

I. Material
   A. stone
   B. coral
   C. ochre
   D. clay/earth
II. Rock size class
III. Hardstone type
IV. Number
V. Firing - evidence of discolouration or shattering due to firing.
VI. Densities
VII. Deposition
VIII. Distribution

**Modified landscape**

This component describes sections of the landscape that have been deliberately modified by human activities. Usually the result of either raising earth or rocks above the surrounding ground surface, they may also be excavations. Occasionally organic materials may have been used either on their own or in conjunction with the earth and/or stone. The size and shape of modified landscapes can vary considerably and they may be found in isolation or in conjunction with other arrangements. In some cases these modifications may have one or more openings and these need to be recorded along with a compass bearing to indicate the direction of the opening(s). Artefacts of this type may be found on land, in water, salt or fresh, or in areas which are subject to inundation.

The attributes recorded for modified landscapes are:

I. Material
   A. rock
   B. earth
   C. organic

II. Hardstone type

III. Rock size class

IV. Cross section - describes the cross section through the arrangement.
   A. concave - for modifications which dip below the surrounding ground level.
   B. columnar - cross section takes the form of a column.
   C. triangular - cross section roughly takes the form of a triangle or pyramid.
   D. convex - modification forms a mound above the surrounding ground surface.
E. Bi-modal - a single modification having a cross-section which represents a statistical bi-modal distribution pattern in that it has two peaks.

V. Modification type - describes how multiple arrangements at a single site relate to each other
A. Single arrangement - an arrangement that occurs on its own with no other associated arrangements.
B. X number of arrangements with at least one shared side.
C. X number of arrangements with no shared sides.
D. Concentric arrangement where one arrangement contains a smaller inner arrangement.

VI. Shape - describes the plan shape(s) of the arrangement(s) and measurements for major axes, their orientation, and height and base width, and the orientation of any openings. In the case of concentric arrangements the inner and outer circles should be described independently.
A. Shape
1. Circular
2. Oval
3. Rectangular
4. Square
5. Lineal
6. U-shaped
7. Serpentine
8. Irregular - does not fit within any of the above descriptions.
B. Measurements
1. Axis length
2. Axis width
3. Height/depth
4. Base width
5. Opening(s)
6. Major axis orientation

VII. Number

VIII. Pathways - indicates whether pathways are associated with the arrangements and the number of such (see Short pathway).

IX. Condition

**Modified tree**
This component describes trees that have apparently been modified by human actions whereby a section or sections of bark and sometimes the wood have been removed.

There are two basic types of modifications that can be identified:

1. Distinct patterns comprising grids, serpentine lines, etc., and
2. Scars with roughly geometric shapes, e.g., elliptical, teardrop, oval.
It is often difficult to separate modifications resulting from human actions and those occurring naturally, although in some instances the presence of cut marks left behind by the tool(s) employed to make the modification can be observed. While wooden or bark artefacts such as canoes, shields, clubs and containers may be considered modified trees, in this classification system they are viewed as the result of a modification, not the modification itself (see Uncommon artefacts).

Attributes recorded for modified trees are:

<table>
<thead>
<tr>
<th>I. Modification type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. pattern</td>
</tr>
<tr>
<td>B. geometric shape</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. Modification style</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. grid</td>
</tr>
<tr>
<td>B. serpentine lines</td>
</tr>
<tr>
<td>C. parallel straight lines</td>
</tr>
<tr>
<td>D. concentric circles</td>
</tr>
<tr>
<td>E. teardrop</td>
</tr>
<tr>
<td>F. inverted teardrop</td>
</tr>
<tr>
<td>G. circle</td>
</tr>
<tr>
<td>H. oval</td>
</tr>
<tr>
<td>I. square</td>
</tr>
<tr>
<td>J. rectangular</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>III. Number</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>IV. Height AGL - modification's height above ground level, measured in cm from ground level to the modification's base.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>V. Modification width - modification's width at its widest point in cm.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>VI. Modification length - modification length in cm from lowest to highest point.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>VII. Condition</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>VIII. Tool - indicates the type of tool used for the modification.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. stone implement</td>
</tr>
<tr>
<td>B. steel implement</td>
</tr>
<tr>
<td>C. unknown</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IX. Tree height</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>X. Name</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>XI. Species</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>XII. Diameter - tree diameter measured at the middle of the modification.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>XIII. Modification aspect</th>
</tr>
</thead>
</table>
Petroglyphs are formed when an abrasive technique is applied to a surface of a rock resulting in the creation of a glyph. Glyphs take many forms ranging from apparently abstract patterns to animal tracks and human forms. Sometimes glyphs are grouped on individual panels which may be identified on the basis of fissures in the rock surface, different slabs of rock at the same location, or rockshelter walls as opposed to the roof and/or floor. In this system the panels provide the first level of recording followed by the glyphs present on each panel. Furthermore, by identifying panels an assessment may be made of the overall stability of the rock surface on which the glyphs are present.

Attributes are:

I. Number of panels.

II. Panel width - the width of the panel measured horizontally in cm.

III. Panel height - the height of the panel measured vertically in cm.

IV. Rock formation

V. Hardstone type

VI. Position - describes the position of the surface on which the petroglyph(s) have been executed.
   A. inclined
   B. vertical
   C. horizontal

VII. Technique - describes the technique employed to create the petroglyph. In some cases it may be difficult to determine the difference between, for example, abrasion and engraving or pecking and pounding. However, an attempt should be made to identify the technique and verification of the technique may be possible by more qualified persons at a later date.
   A. abrasion - repeated two-way friction resulting in a continuous groove. Synonymous with grinding.
B. pecking - precise, deep mark on rock surface resulting from indirect percussion employing a hammerstone and pointed tool.
C. engraving - one-way longitudinal abrasion using a point.
D. drilling - abrasion with a point in a circular motion.
E. pounding - employs direct percussion with a hammerstone resulting in a diffuse mark on the surface of the rock (David 1990:11; Flood 1987:120; Hiscock and Mitchell 1993:5-6).

VIII. Petroglyph type - indicates if petroglyph is either:
A. figurative
B. nonfigurative

IX. Motif - describes glyph patterning. The list provided below is only an example of the motif patterns that may be identifiable and should not be considered exhaustive.
A. grid
B. parallel lines
C. serpentine lines
D. animal track
E. animal name
F. male
G. female

X. Pigment in-fill - indicates pigment was used to trace or in-fill glyph.

XI. Number of glyphs

XII. Full count

XIII. Condition

Pictograph
Pictographs are created when one or a combination of methods are used to applying pigments(s) on a rock surface. The images created are diverse ranging from apparently abstract sets of dots to complex anthropomorphic forms. Sometimes pictographs are grouped on individual panels which may be identified on the basis of fissures in the rock surface, different slabs of rock at the same location, or rockshelter walls as opposed to the roof and/or floor. In this system the panels provide the first level of recording followed by the pictographs present on each panel. Furthermore, by identifying panels an assessment may be made of the overall stability of the rock surface on which the glyphs are present. Attributes recorded are:

I. Method - describes the method employed to apply the pigment to the rock surface.
A. print - the positive image achieved when an object is coated in wet pigment and then pressed onto the rock surface.
B. stencil - achieved by holding the object against the rock surface after which pigment is sprayed against the object resulting in a spattering of pigment falling outside the margins of the object i.e., a negative impression of the object is created.
C. painting - results from the use of an applicator of some form being used to apply the pigment. It is a freehand method of applying pigment to the rock surface.
D. drawing - the application of dry pigment to the rock surface. As with painting this is a freehand method of pigment application.

II. Panel position
III. Rock formation
IV. Hardstone type
V. Pictograph type - indicates whether the pictograph is:
   A. figurative
   B. nonfigurative
VI. Motif - describes the motifs depicted in the pictographs. The list provided below is only an example of the motif patterns that may be identifiable and should not be considered exhaustive.
   A. grid
   B. parallel lines
   C. serpentine lines
   D. animal track
   E. animal name
   F. male
   G. female
VII. Pigment colour
VIII. Pigment in-fill - indicates if any of the pictograph outlines have been filled with the same or other pigment colours.
IX. Damage
X. Number
XI. Full count

Shellfish remains
This component comprises remains of freshwater or marine shellfish inferred to reflect prehistoric human activity and occurring as discrete scatters, discontinuous scatters or mounds of varying dimensions. This component does not include shellfish remains modified by manufacturing processes. The attributes recorded for shellfish remains are:
I. Name
II. Species name
III. Habitat
A. mud/mangroves
B. rocky reefs
C. coral reefs
D. sand/rubble
E. gravel

IV. Condition
V. Percentage
VI. Deposition
VII. Distribution
VIII. Densities

Short pathway
Short pathways are those associated with particular forms of modified landscapes, i.e., those associated with ceremonial activities. These pathways link modified landscapes or may provide access to or from the modified landscape. In the database this component is a subset of modified landscapes. Attributes recorded are:

I. Length - the length of the pathway measured in meters.
II. Condition
III. From modification number - the modification number from which the pathway leads.
IV. To modification number - the modification number to which the path leads.
V. Orientation - the orientation of the pathway in degrees obtained by using a compass.

Stone source
Stone sources provided the raw material for numerous prehistoric activities including manufacture of knapped artefacts, stone manuports, modified stone landscapes, and ochres. As it is not always possible to identify specific attributes indicative of raw material being obtained (e.g., ochre or hardstone gathered from a stream bed) provision has been made to record potential sources. It is important to note that this component does not include references to knapping at the source. If it is apparent that knapping has occurred, data for this activity must be recorded in the knapped artefact component.

Attributes recorded for stone sources are:
I. Rock formation
II. Rock size class
III. Source type
   A. hardstone
   B. ochre
IV. Extraction method
   A. excavated - generally comprises circular or semicircular depressions and/or trenches indicating areas where subsurface stone was extracted.
   B. surficial - stone gathered from surface by either collecting convenient-sized pieces and/or by breaking up stone into manageable pieces. Where rocks have been broken up evidence may include flaking debris or negative flake scars on pieces of rock left behind.
   C. potential source - if a source is found that does not have any indicators of extraction it should be recorded as a potential source (Hiscock and Mitchell 1993).
V. Hardstone type - includes the value NA for those sources which are for ochres only.
VI. Ochre colour - the colour of the ochre obtained. Includes the value NA for those sources which are for hardstone only.
   A. red
   B. white
   C. yellow
   D. mauve
   E. orange
   F. NA

Uncommon artefacts
This component is reserved for artefacts that are uncommon or unusual and do not fit into any other component. Examples of such artefacts include canoes, shields, or composite artefacts made from a number of different materials. This component does not include artefacts containing European material(s) (see Contact artefacts). Attributes recorded are:
I. Artefact type - usually artefacts within this component will have types or names that are widely recognised across Australia.
II. Condition
III. Components - indicates whether the artefact has a single or multiple components.
   A. unary
   B. composite
IV. Material(s)
   A. stone
General attributes recorded for all sites

In addition to the components and attributes described above the final data set required relates to a site's general morphology. These attributes are recorded for all sites regardless of the components present.

I. Site area - measured in square meters. This refers to the visible area of the site and its perceived boundaries.

II. N/S axis - measurement in meters of site's north/south axis.

III. E/W axis - measurement in meters of site's east/west axis.

IV. Basic structure - indicates how material present at the site is structured overall.
   A. surficial - the artefacts present occur on or above the ground surface.
   B. stratified - the site is observably stratified in an erosion face or similar exposure.
   C. potentially stratified - the site may be stratified. This may be the case where artefacts are apparent in an erosion face but stratification is not readily visible.
   D. subsurface - the deposit begins below ground surface but is visible in an erosion face or the like.
   E. mound - the material forms a mound which is elevated above the surrounding ground surface.

V. Depth - if the basic structure of the site is recorded as subsurface this indicates the average depth in centimeters at which the deposit begins below the ground surface.

VI. Thickness - the average thickness of the visible deposit measured in centimeters. If the deposit is buried this is measured from the top to bottom of the deposit. If visible on ground surface this is measured from the ground surface to the deposit's base.

VII. Site shape - indicates overall shape of site.
   A. point - the site can be recorded with a single grid reference, for example, a modified tree.
   B. polygon - the site has an areal coverage requiring a number of grid references to define its shape. This excludes regular shaped sites (see below).
C. Linear - the site takes the form of a line and can be defined by two or more grid references along its length, e.g., a long pathway or modified landscape.
D. Rectangular
E. Square
F. Circular
G. Elliptical

VIII. Potential extent - in some cases sites may extend well beyond their visible boundaries. For example, vegetation cover may preclude observing the outer limits of a site. In such situations an estimate of the potential extent of the site in square meters should be provided.

IX. Site datum - the castings and northings which provide a central datum for the site.

X. Map details - the map number, map name, scale and edition number of the map on which the site datum and any additional grid references were obtained.

XI. Additional grid references - sets of castings and northings which allow for recording the visible area of a site.

**Additional notes for recording components**

It is important to recognise that in some situations it may be difficult to distinguish between naturally occurring phenomena and those resulting from prehistoric human actions. For example, Hiscock and Mitchell (1993:31-32) state it may be difficult to differentiate between natural depressions and those culturally formed through grinding.

In such cases it is better to record these potential artefacts and indicate doubt as to their origins rather than ignore them. It is only by compiling a database that contains this information that future research may be able to better identify the differences between natural and human artefacts.

In addition to the components and attributes discussed above provision has been made in the database to record comments at the site level, for each instance of a site recording, for each component and for each set of like attributes in a component. While not always necessary, such comments allow for the inclusion of additional descriptive and/or interpretive information about a site.
This concludes the archaeological record classification system in terms of components and attributes. The following section describes in some detail each of the attributes required to document environmental contexts and taphonomic details.

**Environmental and taphonomic attributes**

**Extent limiting factors**
Extent limiting factors refers to naturally occurring phenomena such as streams, cliff lines and swamps that may physically limit the areal extent of a site. Note these are not detection limiting factors such as leaf litter, or those relating to human disturbance such as roads or tracks. Recording this information can be of some assistance when the data is entered into the GIS and the visible or potential extent boundaries are being plotted.

**Detection limiting factors**
These are factors which hinder the detection of a site or the determination of its full extent. These factors include the likes of redeposited sediments, leaf litter, naturally fractured stone and light conditions. It does not include natural vegetation cover.

**Ground cover**
Estimating the degree of ground surface vegetation is an important aspect of the recording process for three reasons. First, it indicates what percentage of the ground surface at a site could not be examined for material. Second, it provides useful data concerning the potential for locating further archaeological material in an area where material has been located previously. Third, depending on the amount of coverage it may also assist in determining if material is part of a potentially continuous distribution or occurs in isolation; i.e., vegetation cover may separate groups of material which are part of a larger complex.

As indicated in Chapter 2 present methods of recording vegetation cover are somewhat subjective and thus require modification. The method described below and adapted
from Walker and Hopkins (1990:68) simply assesses the crown cover separation of the surface vegetation into seven readily identifiable categories (Figure 9.7).

I. Closed or dense - crowns touching to overlapping: >70%.
II. Mid-dense - crowns touching or slightly separated: 30 - 70%.
III. Sparse - crowns clearly separated: 10 - 30%.
IV. Very sparse - crowns well separated: <10%.
V. Isolated plants - low shrubs/grasses about 25m apart: <10%.
VI. Isolated clumps - clump of two to five plants 200m apart or further: <10%.
VII. No vegetation - site is devoid of vegetation: 0%.

Figure 7.3  Crown separation classes for assessing ground surface visibility (after Walker and Hopkins 1990:68).

**Human disturbance**

Human activities can impinge on sites in many ways with varying degrees of damage. The following list has been drawn in part from McDonald et al. (1990:88). This list is incomplete as it is not possible to fully identify every form of damage that may occur. Thus it may be necessary to further subdivide the categories in order to provide a more complete damage description.
I. No effective disturbance.

II. No effective disturbance other than grazing by hoofed animals.

III. Limited clearing as in the case of selective logging.

IV. Extensive clearing such as poisoning, ringbarking or nonselective logging such as may occur in timber plantations.

V. Complete clearing - pastures, native or improved but never cultivated.

VI. Complete clearing - pastures, native or improved, cultivated at some stage.

VII. Cultivation that is rainfed.

VIII. Cultivation that has been or is irrigated.

IX. Limited disturbance including foot traffic and camping.

X. Highly disturbed, for example, quarrying, road works, mining, landfill, urban development, vehicle tracks.

XI. Vandalism which may include graffiti, deliberate destruction by, for example, the bulldozing of structures, deliberate removal of artefacts or art panels.

**Biotic microrelief**

Biotic microrelief is that resulting from any biotic agent. The agents listed below may be subdivided in some cases to provide further information. When indicating the agent(s) responsible for the disturbance it is also necessary to indicate the type of relief which has been formed. By employing the criteria listed below it is possible to combine the various agents with the relief components to describe the microrelief, for example, termitic + mound = termitic mound. The agents and components identified by McDonald et al. (1990:90-91) are as follows:

I. Agents
   A. animal
   B. bird
   C. termite
   D. ant
   E. vegetation

II. Component of relief
   A. mound
   B. elongate mound
   C. depression
   D. elongate depression
   E. hole
   F. terrace
   G. burrow
**Accelerated erosion**

Accelerated erosion occurs when a landscape’s soil or vegetation has been removed as a result of human activities. It may be difficult in some cases to distinguish between accelerated and natural erosion and the agents involved. Despite these difficulties it is important to record at least the following basic attributes (McDonald *et al.* 1990:92). The first of these describes the actual state of erosion in terms of how active it may be; the remainder provide for descriptions of the various agents of erosion.

I. **State of erosion**
   A. **active** - one or both the following conditions apply: evidence of sediment movement where sides and/or floors of erosion form are relatively bare of vegetation.
   B. **stabilised** - one or both the following conditions apply: no evidence of sediment movement where sides and/or floors of erosion form are revegetated.
   C. **partly stabilised** - evidence of some active erosion and some evidence of stabilisation.

II. **Wind erosion** - wind erosion is that which is directly attributable to the wind removing landscape surface material.
   A. **not apparent** - no evidence suggestive of wind erosion.
   B. **no wind erosion** - wind erosion has not occurred.
   C. **minor or present** - some loss of surface.
   D. **moderate** - most of the surface removed leaving hard material.
   E. **severe** - most or all of the surface removed leaving hard material.
   F. **very severe** - deeper layers are exposed, leaving hard material such as subsoils, weathered rock or pans (McDonald *et al.* 1990:91).

III. **Scald erosion** - scald erosion occurs when the surface soils are removed by water and/or wind to expose more clayey subsoils which are relatively impermeable to water. The exposed subsoils are devoid of vegetation. Erosion of this type is most common in semiarid to arid areas (McDonald *et al.* 1990:93). Scald erosion is recorded in the following manner:
   A. **no scalding**.
   B. **minor scalding** where <5% of the site is scalded.
   C. **moderate scalding** whereby 5-50% of the site is scalded.
   D. **Severe scalding** whereby >50% of the site is scalded.

IV. **Water erosion** - at present there is no consensus in Australia concerning quantitative measurements for determining whether or not water erosion is minor, moderate or severe. This is primarily due to the soil types, landscape and climate in conjunction with variations in these which may alter concepts relating to the severity of erosion (McDonald *et al.* 1990:95). However, for archaeologists it is important that the effects of such erosion are recorded as it has the potential
to dramatically affect the distribution of artefacts and damage modified landscapes. As such, the assessment of erosion severity may be determined by examining the effect of the process on the archaeological record in conjunction with that on the landscape.

V. **Sheet erosion** - sheet erosion results in the relatively uniform removal of soils without developing readily identifiable channels. The general characteristics for evaluating the severity of sheet erosion are:

A. not apparent
B. no sheet erosion
C. minor - indicators may include shallow soil deposits in downslope sediment traps, e.g., fence lines. Often difficult to assess as evidence may be lost with cultivation or revegetation.
D. moderate - indicators may include partial exposure of roots, moderate soil deposits in downslope sediment traps.
E. severe - indicators may include loss of surface soil horizons and exposure of subsoil horizons, pedestalling, root exposure, substantial soil deposits in downslope sediment traps (McDonald et al. 1990:94).

VI. **Rill erosion** - rills are small channels which have a depth of no greater than 0.3m. Detection may be difficult in those areas which have been ploughed. Rills are recorded as follows:

A. no rill erosion.
B. minor - occasional rills.
C. moderate - common rills.
D. severe - numerous rills forming a corrugated ground surface (McDonald et al. 1990:94).

VII. **Gully erosion** - a gully is a channel with a depth that is greater than 0.3m and is described in greater detail in the landform elements glossary. Gullies are recorded by indicating the severity and depth of the erosion.

A. erosion severity
   1. no gully erosion.
   2. minor - gullies are isolated, linear, discontinuous, and restricted to primary or major drainage lines.
   3. Moderate - gullies are linear, continuous and restricted to primary and minor drainage lines.
   4. Severe - gullies are continuous or discontinuous and either tend to branch away from primary drainage lines and onto footslopes, or have multiple branches within primary drainage lines.

B. Gully erosion depth.
   1. <1.5m
   2. 1.5 - 3.0m
   3. >3m

C. **Stream bank erosion** - refers to the removal of soil from a stream bank, typically during periods of high stream flow (McDonald et al. 1990:95).
   1. not apparent.
2. no stream bank erosion.
3. stream bank erosion present.

D. Wave erosion - wave erosion results in the removal of sand or soil from the margins of beaches, beach ridges or dunes. While typically associated with the beach wave erosion may also occur on the margins of lakes. It is recorded as being:
1. not apparent.
2. no wave erosion.
3. wave erosion present (McDonald et al. 1990:96).

E. Mass movement - refers to the downslope movement of soils and/or rocks and includes landslides, soil slumping, earth flows and debris avalanches. This is simply recorded as being present or absent (McDonald et al. 1990:96).

F. Inundation - refers to a variety of factors including over-bank flow, inundation from local run-on and flows of water that move overland. As a rule information of this type may have to be obtained by local inquiry (McDonald et al. 1990:96). Inundation is recorded by indicating the frequency of occurrence.
1. no inundation.
2. less than one occurrence per 100 years.
3. one occurrence every 50 to 100 years.
4. one occurrence every 10 to 50 years.
5. one occurrence every 1 to 10 years.
6. more than one occurrence per year (McDonald et al. 1990:96).

**Landform patterns and landform elements**

Site environmental contexts are recorded using landform patterns and elements rather than the problematic site environment classification system employed by the Heritage Branch (see Chapter 2). Classification of the landscape into landform patterns and landform elements was devised by Speight (1990:9) to produce “a record based on observations rather than inferences.” This approach views the landscape as comprising a number of odd-shaped tiles that can be ordered into two distinct sizes. The largest tiles are referred to as landform patterns and are generally 600m across or greater. The smaller tiles, which form landform elements are 40 to 600m across, and each landform pattern is composed of a number of these elements. Each landform type is classified by the values of its landform attributes, i.e., each landform pattern and landform element has a distinct attribute set. For landform elements the major attributes are slope and
toposequence position, while landform patterns are largely identified on the basis of relief and stream occurrence (Speight 1990:9-10). By observing which attributes are present in a given landscape it is possible to identify both named landform patterns and landform elements (see Speight 1990 for complete details of this process). The following descriptions of landform patterns and landform elements have been taken from Speight (1990:24-34, 48-57).

I. Landform patterns

**Alluvial fan**

-level to very gently inclined complex landform pattern of extremely low relief. The rapidly migrating alluvial stream channels are shallow to moderately deep, locally numerous but elsewhere widely spaced. The channels form centrifugal to divergent, integrated, reticulated to distributary pattern. The landform pattern includes areas that are *bar plains*, being aggraded or eroded by frequently active channeled stream flow, and other areas comprising *terrace* or *stagnant alluvial plains* with slopes that are greater than usual, formed by channeled stream flow but now relict. Incision in the up-slope area may give rise to an erosional stream bed between scarps.

Typical elements: stream bed, bar, plain.

Common elements: scarp.

Compare with *Sheet-flood fan* and *Pediment.*

**Alluvial plain**

-level landform pattern with extremely low relief. The shallow to deep alluvial stream channels are sparse to widely spaced, forming a unidirectional integrated network. There may be frequently active erosion and aggradation by channeled and over-bank stream flow, or the landforms may be relict from these processes.

Typical elements: stream channel (stream bed and bank), plain (dominant).

Common elements: bar, scroll, levee, backplain, swamp.

Occasional elements: ox-bow, floodout, lake.

Included types of landform pattern are *Flood plain*, *Bar plain*, *Meander plain*, *Covered plain*, *Anastomotic plain*, *Delta*, *Stagnant alluvial plain*, *Terrace*, *Terraced land.*

**Anastomotic plain**

-flood plain with slowly migrating deep alluvial channels, usually moderately spaced, forming a divergent to multidirectional integrated reticulated network. There is frequent active aggradation by over-bank and channeled stream flow.

Typical elements: stream channel (stream bed and bank), levee, backplain (dominant).

Common elements: swamp.

Compare with: *Alluvial plain* and *Flood plain.*
<table>
<thead>
<tr>
<th>Landform Pattern</th>
<th>Description</th>
<th>Typical Elements</th>
<th>Occasional Elements</th>
<th>Compare with</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Badlands</strong></td>
<td>Landform pattern of low to extremely low relief (less than 90m) and steep to precipitous slopes, typically with numerous fixed erosional stream channels which form a nondirectional integrated tributary network. There is continuously active erosion by collapse, landslide, sheet flow, creep and channeled stream flow.</td>
<td>Ridge (dominant), stream bed or gully.</td>
<td>Summit surface, hillcrest, hillslope, talus.</td>
<td>Mountains, Hills, Low hills, Rises and Plain.</td>
</tr>
<tr>
<td><strong>Bar plain</strong></td>
<td>Flood plain with numerous rapidly migrating shallow alluvial channels forming a unidirectional integrated reticulated network. There is frequently active aggradation and erosion by channeled stream flow.</td>
<td>Stream bed, bar (dominant).</td>
<td>Compare with other types under Alluvial plain and Flood plain.</td>
<td></td>
</tr>
<tr>
<td><strong>Beach ridge plain</strong></td>
<td>Level to gently undulating landform pattern of extremely low relief on which stream channels are absent or very rare: it consists of relict parallel beach ridges.</td>
<td>Beach ridge (co-dominant), swale (co-dominant).</td>
<td>Beach, foredune, tidal creek.</td>
<td>Chenier plain.</td>
</tr>
<tr>
<td><strong>Caldera</strong></td>
<td>Rare landform pattern typically of very high relief and steep to precipitous slope. It is without stream channels or has fixed erosional channels forming a centripetal integrated tributary pattern. The landform has subsided or was excavated as a result of volcanism.</td>
<td>Scar, hillslope, lake.</td>
<td>Cone, hillcrest, stream channel.</td>
<td></td>
</tr>
<tr>
<td><strong>Chenier plain</strong></td>
<td>Level to gently undulating landform pattern of extremely low relief on which stream channels are very rare. The pattern consists of relict, parallel linear ridges built up by waves, separated by and built over flats (mud flats) aggraded by tides or over-bank stream flow.</td>
<td>Beach ridge (co-dominant), flat (co-dominant).</td>
<td>Tidal flat, swamp, beach, foredune, tidal creek.</td>
<td>Beach ridge plain.</td>
</tr>
<tr>
<td><strong>Coral reef</strong></td>
<td>Continuously active or relict landform pattern built up to the sea level of the present day or of a former time by corals and other organisms. It is mainly level, with moderately inclined to precipitous slopes below sea level. Stream channels are generally absent but there may occasionally be fixed deep erosional tidal stream channels forming a disintegrated nontributary pattern.</td>
<td>Reef flat, lagoon, cliff (submarine).</td>
<td>Beach, beach ridge.</td>
<td></td>
</tr>
<tr>
<td><strong>Covered plain</strong></td>
<td>Flood plain with slowly migrating deep alluvial channels, usually widely spaced and forming a unidirectional integrated nontributary network. There is frequent active aggradation by over-bank stream flow.</td>
<td>Stream channel (stream bed and bank), levee, backplain (dominant).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Delta

flood plain projecting into a sea or lake, with slowly migrating deep alluvial channels, usually moderately spaced, typically forming a divergent integrated distributary network. This landform is aggraded by frequently active over-bank and channeled stream flow that is modified by tides.

Typical elements: stream channel (stream bed and bank), levee, backplain (co-dominant), swamp (co-dominant), lagoon (co-dominant).

Common elements: beach ridge, swale, beach, estuary, tidal creek.

Dunefield

level to rolling landform pattern of very low or extremely low relief without stream channels, built up or locally excavated, eroded or aggraded by wind.

Typical elements: dune or dunecrest, duneslope, swale, blow-out.

Included types of landform pattern are: Longitudinal dunefield, Parabolic dunefield.

Escarpment

steep to precipitous landform pattern forming a linearly extensive, straight or sinuous inclined surface, which separates terrains at different altitudes, that above the escarpment commonly being a plateau. Relief within the landform pattern may be high (hilly) or low (planar). The upper margin is often marked by an included cliff or scarp.

Typical elements: hillcrest, hillslope, cliff-foot slope.

Common elements: cliff, scarp, scarp-foot slope, talus, footslope, alcove.

Occasional elements: stream bed.

Flood plain

alluvial plain characterised by frequently active erosion and aggradation by channeled or over-bank stream flow. Unless otherwise specified, “frequently active” means that the flow has an average recurrence interval of 50 years or less.

Typical elements: stream channel (stream bed and bank), plain (dominant).

Common elements: bar scroll, levee, backplain, swamp.

Occasional elements: ox-bow, flood out, scroll.

Included types of landform pattern are Bar plain, Meander plain, Covered plain, Anastomotic plain.

Related relict landform patterns are Stagnant alluvial plain, terrace, terraced land (partly relict).

Hills

landform pattern of high relief (90-300m) with gently inclined to precipitous slopes. Fixed, shallow erosional stream channels, closely to very widely spaced, form a nondirectional or convergent integrated tributary network. There is continuously active erosion by wash and creep and, in some cases, rarely active erosion by...
landslides.

Typical elements: hillcrest, hillslope (dominant), drainage depression stream bed.

Common elements: footslope, alcove, valley flat, gully.

Occasional elements: tor, summit surface, scarp landslide, talus, bench, terrace doline.

Compare with Mountains, Low hills, Rises and Plain.

Karst landform pattern of unspecified relief and slope, typically with fixed deep erosional stream channels forming a nondirectional disintegrated tributary pattern and many closed depressions without stream channels. It is eroded by continuously active solution and rarely active collapse, the products being removed through underground channels.

Typical elements: hillcrest, hillslope (dominant) doline.

Common elements: summit surface, valley flat, plain, alcove, drainage depression, stream channel, scarp, footslope, landslide.

Occasional elements: talus.

Lacustrine plain level landform pattern with extremely low relief formerly occupied by a lake but now partly or completely dry. It is a relict after aggradation by waves and deposition of material from suspension and solution in standing water. The pattern is usually bounded by wave-formed features such as cliffs, rock platforms, beaches, berms, and lunettes. These may be included or excluded.

Typical element: plain.

Common elements: beach, cliff.

Occasional elements: rock platform, berm.

Compare with Playa plain.

Lave plain level to undulating landform pattern of very low to extremely low relief typically with widely spaced fixed erosional stream channels that form a non-directional integrated or interrupted tributary pattern. The landform pattern is aggraded by volcanism (lava flow) that is generally relict; it is subject to erosion by continuously active sheet flow, creep, and channeled stream flow.

Typical elements: plain, hillslope, stream bed.

Occasional elements: tumulus.

Longitudinal dunefield dunefield characterised by long narrow sand dunes and wide flat swales. The dunes are orientated parallel with the direction of the prevailing wind, and in cross-section one slope is typically steeper than the other.

Typical elements: dune or dunecrest, duneslope, swale, blow-out.

Compare with Parabolic dunefield.

Low hills landform pattern with low relief (30-90m) and gentle to very steep slopes, typically fixed erosional stream channels, closely to very widely spaced, which form a nondirectional or convergent integrated tributary pattern. There is continuously active sheet flow, creep, and channeled stream flow.
Marine plain

- Plain eroded or aggraded by waves, tides, or submarine currents, and aggraded by deposition of material from suspension and solution in sea water, elevated above sea level by earth movements or eustasy, and little modified by subaerial agents such as stream flow or wind.

- Typical elements: hillcrest, hillslope (dominant), drainage depression, stream bed.

- Common elements: footslope, alcove, valley flat, gully.

- Occasional elements: tor summit surface, landslide doline.

- Compare with Mountains, Hills, Rises and Plains.

Meander plain

- Flood plain with widely spaced, rapidly migrating, moderately deep alluvial stream channels which form a unidirectional integrated nontributary network. There is frequently active aggradation and erosion by channeled stream flow with subordinate aggradation by over-bank stream flow.

- Typical elements: stream channel (stream bed bank and bar), scroll, scroll plain (dominant).

- Common elements: ox-bow.

- Compare with other types under Alluvial plain, and Flood plain.

Meteor crater

- Rare landform pattern comprising a circular closed depression with a raised margin; it is typically of low to high relief and has a large range of slope values, without stream channels or with a peripheral integrated pattern of centrifugal tributary streams. The pattern is excavated, heaved up and built up by a meteor impact and now relict.

- Typical elements: crater (scarp talus, footslope, and plain) hillcrest, hillslope.

Mountain

- Landform pattern of very high relief (>300m) with moderate to precipitous slopes and fixed erosional stream channels that are closely to very widely spaced and form a nondirectional or diverging integrated tributary network. There is continuous active erosion by collapse, landslide, sheet flow, creep, and channeled stream flow.

- Typical elements: hillcrest, hillslope (dominant), stream bed.

- Common elements: talus, landslide, alcove, valley, flat, scarp.

- Occasional elements: cirque, footslope.

- Compare with Hills, Low hills, Rises and Plains.

Parabolic dunefield

- Dunefield characterised by sand dunes with a long scoop-shaped form, convex in the downwind direction so that its trailing edge point upwind; the ground plan when perfectly developed approximates the form of a parabola.

- Typical elements: dune or dunecrest, duneslope, swale, blow-out.

- Compare with Longitudinal dunefield.

Pediment

- Gently inclined to level (<1% slope) landform pattern of extremely low relief, typically with numerous rapidly migrating, very shallow incipient stream channels which form a centrifugal to diverging integrated reticulated pattern. It is underlain by bedrock, eroded, and locally aggraded by frequently active channeled stream flow or sheet flow, with subordinate wind erosion. Pediments characteristically lie
downslope from adjacent hills with markedly steeper slopes.

Typical elements: pediment, plain, stream bed.

Compare with *Sheet-flood fan* and *Alluvial fan*.

**Pediplain**

level to very gently inclined landform pattern with extremely low relief and no stream channels, eroded by barely active sheet flows and wind. Largely relict from more active erosion by stream flow in incipient stream channels as on a pediment.

Typical element: plain.

**Pediplain**

level to very gently inclined landform pattern with extremely low relief and sparse slowly migrating alluvial stream channels which form a non-directional integrated tributary pattern. It is eroded by barely active sheet flow, creep, and channelled and over-bank stream flow.

Typical elements: plain (dominant), stream channel.

**Plain**

level to undulating or, rarely, rolling landform pattern of extremely low relief (<9m).

Compare with *Mountains, Hills, Low hills* and *Rises*.

**Plateau**

level to rolling landform pattern of plains, rises or low hills standing above a cliff, scarp or escarpment that extends around a large part of its perimeter. A bounding scarp or cliff landform element may included or excluded; a bounding escarpment would be an adjacent landform pattern.

Typical elements: plain, summit surface, cliff.

Common elements: hillcrest, hillslope, drainage depression, rock flat, scarp.

Occasional elements: stream channel.

**Playa plain**

level landform pattern with extremely low relief, typically without stream channels, aggraded by rarely active sheet flow and modified by wind, waves, and soil phenomena.

Typical elements: playa, lunette, plain.

Compare with *Lacustrine plain*.

**Rises**

landform pattern of very low relief (9-30m) and gentle to steep slopes. The fixed erosional stream channels are closely to very widely spaced and form a non-directional to convergent integrated or interrupted tributary pattern. The pattern is eroded by continuously active to barely active creep and sheet flow.

Typical elements: hillcrest, hillslope, (dominant), footslope, drainage depression.

Common elements: valley flat, stream channel.

Occasional elements: gully, fan, tor.

Compare with *Mountains, Hills, Low hills* and *Plain*.

**Sand plain**

level to gently undulating landform pattern of extremely low relief and without channels; formed possibly by sheet flow or stream flow, but now relict and modified by wind action.

Typical elements: plain.
Occasional elements: dune, playa, lunette.

**Sheet-flood fan** level (<1% slope) to very gently inclined landform pattern of extremely low relief with numerous rapidly migrating very shallow incipient stream channels forming a divergent to unidirectional, integrated or interrupted reticulated pattern. The pattern is aggraded by frequently active sheet flow and channel stream flow, with subordinate wind erosion.

Typical elements: plain, stream bed.

Compare with **Alluvial fan** and **Pediment**.

**Stagnant alluvial plain** alluvial plain on which erosion and aggradation by channeled and over-bank stream flow is barely active or inactive because of reduced water supply, without apparent incision or channel enlargement that would lower the level of stream action.

Typical elements: stream channel (stream bed and bank), plain (dominant).

Common elements: bar, scroll, levee, backplain, swamp.

Occasional elements: ox-bow, flood-out, lake.

Compare with **Flood plain** and **Terrace**.

**Terrace (alluvial)** former flood plain on which erosion and aggradation by channeled and over-bank stream flow is barely active or inactive because deepening or enlargement of the stream channel has lowered the level of flooding. A pattern that has both former floodplains and significant active floodplains, or that has former floodplains at more than one level becomes **Terraced land**.

Typical elements: terrace plains, terrace flats, scarps, scroll plains, stream channel.

**Tidal flat** level landform pattern with extremely low relief and slowly migrating deep alluvial stream channels which form nondirectional integrated tributary patterns; it is aggraded by frequently active tides.

Typical elements: plain (dominant) (intertidal flat, supratidal flat), stream channel.

Occasional elements: lagoon, dune, beach ridge, beach.

**Volcano** typically very high and very steep landform pattern without stream channels or with erosional stream channels forming a centrifugal interrupted tributary pattern. The landform is built up by volcanism and modified by erosional agents.

Typical elements: cone, crater.

Common elements: scarp, hillcrest, hillslope, stream bed, lake, maar.

Occasional elements: tumulus.
II. Landform elements

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alcove</strong></td>
<td>moderately inclined to very steep, short open depression with concave cross section, eroded by collapse, landslides, creep or surface wash.</td>
</tr>
<tr>
<td><strong>Backplain</strong></td>
<td>large flat resulting from aggradation by over-bank stream flow at some distance from the stream channel and in some cases biological (peat) accumulation; often characterised by a high water table and the presence of swamps or lakes; part of a covered plain landform pattern.</td>
</tr>
<tr>
<td><strong>Bank (stream bank)</strong></td>
<td>very short, very wide slope, moderately inclined to precipitous, forming the marginal upper parts of a stream channel and resulting from erosion or aggradation by channel stream flow.</td>
</tr>
<tr>
<td><strong>Bar (stream bar)</strong></td>
<td>elongated, gently to moderately inclined low ridge built up by channeled stream flow.</td>
</tr>
<tr>
<td><strong>Beach</strong></td>
<td>short, low, very wide slope, gently or moderately inclined, built up or eroded by waves, forming the shore of a lake or sea.</td>
</tr>
<tr>
<td><strong>Beach ridge</strong></td>
<td>very long, nearly straight low ridge, built up by waves and usually modified by wind. A beach ridge is often a relict feature remote from the beach.</td>
</tr>
<tr>
<td><strong>Bench</strong></td>
<td>short, gently inclined or very gently inclined minimal mid-slope element eroded or aggraded by any agent.</td>
</tr>
<tr>
<td><strong>Berm</strong></td>
<td>(i) short, gently inclined or very gently inclined minimal mid-slope in an Embankment or Cut-face, eroded or aggraded by human activity.</td>
</tr>
<tr>
<td></td>
<td>(ii) flat built up by waves above a Beach.</td>
</tr>
<tr>
<td><strong>Blow-out</strong></td>
<td>usually small, open or closed depression excavated by the wind.</td>
</tr>
<tr>
<td><strong>Breakaway</strong></td>
<td>steep maximal mid-slope or upper slope, generally comprising both a very short scarp that is often bare rock and, and a stony scarp-foot slope; often standing above a pediment. See stream channel.</td>
</tr>
<tr>
<td><strong>Channel</strong></td>
<td>See Stream channel.</td>
</tr>
<tr>
<td><strong>Channel bench</strong></td>
<td>flat at the margin of a Stream channel aggraded and in part eroded by over-bank and channeled stream flow; an incipient Flood plain. Channel benches have been referred to as low terraces but the term “terrace” should be restricted to landform patterns above the influence of active stream flow.</td>
</tr>
<tr>
<td><strong>Cirque</strong></td>
<td>precipitous to gently inclined, typically closed depression of concave contour and profile excavated by ice. The closed part of the depression may be shallow, the larger part being an open depression like an Alcove.</td>
</tr>
<tr>
<td><strong>Cliff</strong></td>
<td>very wide cliffed (&gt;72°) maximal slope usually eroded by gradational falls as a result of erosion by the base by various agencies; sometimes built up by marine organisms (cf. Scarp).</td>
</tr>
<tr>
<td><strong>Cliff-foot slope</strong></td>
<td>slope situated below a cliff, with its contours generally parallel to the line of the cliff, eroded by sheet wash or water-aided mass movement, and aggraded locally by collapsed material from above.</td>
</tr>
<tr>
<td><strong>Cone</strong></td>
<td>hillock with a circular symmetry built up by volcanism. The crest may form a ring around a Crater.</td>
</tr>
</tbody>
</table>
may form a ring around a Crater.

**Crater**
steep to precipitous closed depression or excavated by explosions due to vulcanism, human action, or impact of extra-terrestrial object.

**Cut face**
slope eroded by human activity.

**Cut-over surface**
flat eroded by human activity.

**Dam**
ridge built up by human activity so as to close a depression.

**Doline**
steep-sided closed depression eroded by solution directed towards an underground drainage way, or by collapse consequent on such solution; a typical element of Karst landform pattern.

**Drainage depression**
level to gently inclined, long, narrow, shallow open depression with smoothly concave cross section, rising to moderately inclined slopes, eroded or aggraded by sheet wash.

**Dune**
moderately inclined to very steep ridge or hillock built up by the wind. This element may comprise Dunecrest and Duneslope.

**Dunecrest**
crest built up or eroded by the wind (see also Dune).

**Duneslope**
slope built up or eroded by the wind (see also Dune).

**Embankment**
ridge or slope built by human activity.

**Estuary**
Stream channel close to its junction with a sea or lake where the action of channelled stream flow is modified by tides and waves. The width typically increases downstream.

**Fan**
large gently inclined to level element with radial slope lines inclined away from a point, resulting from aggradation or occasionally from erosion by channelled, often braided, stream flow, or possibly by sheet flow.

**Fill top**
flat aggraded by human activity.

**Flood-out**
flat inclined radially away from a point on the margin or at the end of a stream channel, aggraded by over-bank stream flow, or by channelled stream flow associated with channels developed within the overbank flow; part of a Covered plain landform pattern.

**Footslope**
moderate to very gently inclined waning lower slope resulting from aggradation or erosion by sheet flow, earth flow or creep (cf. Pediment).

**Foredune**
very long, nearly straight, moderately inclined to very steep ridge built up by the wind from material from an adjacent beach.

**Gully**
open depression with short, precipitous walls and moderately inclined to very gently inclined floor or small stream channel, eroded by channelled stream flow and consequent collapse and water-aided mass movement.

**Hillcrest**
very gently inclined to steep crest, smoothly convex, eroded mainly by creep and sheet wash; a typical element of mountains, hills, low hills and rises.

**Hillslope**
gently inclined to precipitous slope commonly simple and maximal, eroded by sheet wash, creep, or water-aided mass movement a typical element of mountains, hills, low hills and rises.

**Intertidal flat**
See Tidal flat.
Lagoon

closed depression filled with water that is typically salt or brackish, bounded at least in part by forms of aggraded dunes or built up by waves or reef building organisms.

Lake

large water-filled closed depression.

Landslide

moderately inclined to very steep slope, eroded in the upper part and aggraded in the lower part by water-aided mass movement, characterised by irregular hummocks.

Levee

very long, very low, nearly level sinuous ridge immediately adjacent to a stream channel, built up by over-bank flow. Levees are built usually in pairs bounding the two sides of a stream channel at the level reached by frequent floods. This element is part of a Covered plain landform pattern. For artificial levee, use Embankment. See also Prior stream.

Lunette

elongated, gently curved, low ridge built up by wind on the margin of a playa, typically with a moderate, wave-modified slope towards the playa and a gentle outer slope.

Maar

level floored, commonly water-filled closed depression with a nearly circular steep rim, excavated by volcanism.

Mound

hillock built up by human activity.

Ox-bow

long, curved, commonly water-filled closed depression eroded by channel stream flow but closed as a result of aggradation by channeled or over-bank stream flow during the formation of a Meander plain landform pattern. The floor of an ox-bow may be more or less aggraded by over-bank stream flow, wind, and biological (peat) accumulation.

Pan

See Playa.

Pediment

large, gently inclined to level waning lower slope, with slope lines inclined in a single direction, or somewhat convergent or divergent, eroded or sometimes slightly aggraded by sheet flow (cf. Footslope). It is underlain by bedrock.

Pit

closed depression excavated by human activity.

Plain

large, very gently inclined or level element of unspecified geomorphological agent or mode of activity.

Playa

large, shallow, level floored closed depression, intermittently water-filled but mainly dry due to evaporation, generally bounded by flats aggraded by sheet-flow and channel stream flow.

Prior stream

long, generally sinuous low ridge built up from materials originally deposited by stream flow along the line of a former stream channel. The landform element may include a depression marking the old stream bed and relict Levees.

Reef flat

flat built up to sea level by marine organisms.

Rock flat

flat or bare consolidated rock, usually eroded by sheet wash.

Rock platform

flat of consolidated rock eroded by waves.

Scald

flat, bare of vegetation, from which soil has been eroded or excavated by surface wash or wind.

Scarp

very wide steep to precipitous maximal slope eroded by gravity, water-aided mass movement or sheet flow (cf. Cliff).
Scarp-foot slope  
waning or minimal slope situated below a scarp with its contours generally parallel to the line of the scarp.

Scroll  
long, curved very low ridge built up by channeled stream flow and left relict by channel migration part of a Meander plain landform element.

Scroll plain  
large flat area resulting from aggradation by channeled stream flow as stream migrates from side to side; the dominant element of a Meander plain landform pattern. This landform element may include occurrences of Scroll, Swale and Ox-bow.

Stream bed  
linear, generally sinuous open depression forming the bottom of a stream channel eroded and locally excavated, aggraded or built up by channeled stream flow. Parts that are built up include Bars.

Stream channel  
linear, generally sinuous open depression forming the bottom of a stream channel eroded and locally excavated aggraded or built up by channeled stream flow. Comprises stream bed and banks.

Summit surface  
very wide level to gently inclined crest with abrupt margins, commonly eroded by water-aided mass movement or sheet wash.

Supratidal flat  
See Tidal flat.

Swale  
(i) linear, level-floored open depression excavated by wind, or left relict between ridges built up by wind or waves, or built up to a lesser height than them.
(ii) long curved open or closed depression left relict between Scrolls built up by channeled stream flow.

Swamp  
almost level closed or almost closed depression with a seasonal or permanent water table at or above the surface, commonly aggraded by over-bank stream flow and sometimes biological (peat) accumulation.

Talus  
moderately inclined or steep waning slope, consisting of rock fragments aggraded by gravity.

Terrace flat  
small flat aggraded or eroded by channeled or over-bank stream flow, standing above a scarp and no longer frequently inundated: a former valley flat, or part of a former Flood plain.

Tidal creek  
intermittently water-filled open depressions in parts eroded, excavated, built up and aggraded by channeled tidewater flow; type of Stream channel characterised by a rapid increase in width downstream.

Tidal flat  
large flat subject to inundation by water that is usually salt or brackish, aggraded by tides. An intertidal flat is frequently inundated; a supratidal flat is seldom inundated.

Trench  
open depression excavated by human activity.

Tumulus  
hillock heaved up by volcanism (or elsewhere built up by human activity where burial of material has occurred).

Valley flat  
small, gently inclined to level flat, aggraded or sometimes eroded by channeled or over-bank stream flow, typically enclosed by hillslopes; a miniature Alluvial plain landform pattern.
This concludes the section concerned with defining and describing the new classification system's components and component attributes. While an important aspect of the overall thesis, this system will fail in its objective if analysis of the data is undertaken in a haphazard manner. To this end, an interpretive framework has been developed to guide the interpretive process.

The interpretive model
To maximise information retrieval archaeological data analysis must follow a well defined and logical path. This is not possible using Australia's present classification system(s) due to the mixing of functional and descriptive site types. "Classification states only relations within and between units in the same system" (Dunnell 1994:18). While functional systems are explanatory, descriptive systems are not and as such, are members of different classification systems and involve different inferential levels (Hall 1996:3.36).

Descriptive classes are based on observable physical characteristics; e.g., a site containing shellfish remains is exactly that, a site containing shellfish remains, nothing more, nothing less. Certainly the site may be interpreted and classified as having functioned, for example, as a dinner time camp (Meehan 1982:112-118). However, such interpretations involve a different level of inference and explanations of how the interpretation was attained are required. Therefore, "to accurately model prehistoric human activities it is necessary to ensure that clear boundaries are maintained between several quite different analytical domains" (Hall 1996:3.57). Following a structured interpretive model ensures the relationship being described and subsequently interpreted only occurs on members of the same class. The model presented in Figure 7.4 and discussed below is based on Hall's (1996:3) model with modifications to better suit its use with databases and GIS.
Stage 1 of the model involves describing/recording the archaeological record's physical properties using the classification system presented above. As such, it provides a solid foundation for stepping through the subsequent levels of the interpretive model. This step is crucial as errors or omissions will compromise the analytical process resulting in misleading or incorrect interpretations and explanations.

Figure 7.4 Model of interpretive framework for the archaeological record. As indicated by the arrows, this model relies on continuous feedback between the stages to ensure reliability and updating to include further data sets.

Stage 2 is the first analytical stage and involves grouping or classifying sites on a components basis, e.g., all those sites with shellfish remains and knapped artefacts, or all sites with shellfish remains only. These groupings are termed descriptive profiles and once defined analysis of intersite relationships and site/landscape relationships can begin with the results forming the basis for Stage 3 of the model.

In Stage 3 the descriptive profiles are further divided on the basis of each components attributes. I have termed these sub-profiles. At this point the distribution of sites across
the landscape can be more fully explored thus gaining a "more holistic and integrated scenario of the past which is more useful for both researchers and site management than simple...lists of sites without environmental context or other kinds of interconnection" (Hall 1996:3-37). Likewise, Stage 3 allows for both spatial and comparative analyses to be undertaken at a high level of detail thus providing a secure foundation for Stage 4.

Stage 4 provides for the interpretation of inferred cultural function and it is not until this level that functionally defined types can be included in the model. "This order of inference is less straightforward and involves more abstract concepts; it is also much more susceptible to the possibility of differing opinions" (Hall 1996:3-36). It is only at this level that it would be possible to identify shellfish remains as dinner time or base camps or processing sites.

If the classification and analysis of the archaeological record is to be undertaken in a meaningful way and one which enhances our understanding of prehistoric activities it must be done in a way that clearly separates each step of the analysis (see also Hall 1996). The model presented here allows for the results obtained in Stages 2 and 3 to be replicated and/or modified by others and this is simply not possible with the present classification system. However, for this model to work efficiently it is necessary to have a high degree of confidence in the classificatory system underpinning the whole process.

The polythetic approach
It has already been demonstrated that the use of site types is monothetic and that in fact, the site type approach drives monothetic classificatory systems. To overcome site type classification traps I have proposed that a better classification system is one based on the archaeological record's components and attributes. However, it should also be clear that the components and attributes approach also contains monothetic aspects in that each component is necessarily monothetic. This is because the component 'shellfish remains'
is exactly that, shellfish remains. It is not knapped artefacts or manuports; to be a member of the component shellfish remains must be present. This then raises the question, where does the archaeological record actually become polythetic within my classification system?

My answer to this question is that what we are dealing with is different levels of classification, the aim being to enable comparative analysis to be undertaken on the basis of descriptive site profiles and sub-profiles, not site types. By using components the polythetic nature of the archaeological record is being explicitly recognised. The grouping of these components at a given site is defined by the information actually recorded on the ground at that site at that instance in time. Therefore a site containing knapped artefacts, abraded portable artefacts and faunal remains is precisely that. It is not a campsite, an artefact scatter or a workshop. It is a site containing the components 'knapped artefacts', 'abraded portable artefacts' and 'faunal remains'. By employing components at this level we are not restricted by notions of site types and all the baggage they carry. Thus while the individual components may be monothetic, their grouping together is based on the visible remains left behind by a culture and not on the archaeologists' perceptions of site types.

However, components are not the only elements that can be employed to identify descriptive profiles. Other attributes such as those relating to landscape patterns and/or site structure may also be entered into the equation. Therefore it is possible for sites with the same descriptive profile to belong to different groups due to their physical location and/or basic structure. This level of classification relates directly to the first and second levels of the interpretive model, i.e., recording, describing and grouping sites together on the basis of the components present.
The next level of classification relates to the third stage of the interpretive model and it is here that the descriptive profiles are divided into sub-profiles on the basis of their attributes. While components are necessarily monothetic, their attributes are not. Consider, for example, sites that only contain the component shellfish remains. The number and species found in these sites may vary considerably. Some sites contain species that inhabit mud and mangroves, another group of sites contains sand and rubble species, while others contain both. In each case the actual species present at each site varies. Some sites with mud and mangrove species have cockle and whelk; others have cockle and oyster or whelk and oyster. Similar variations can be identified at the other sites. At this level the sites may be classified together on the basis of the species’ habitat. Therefore, those sites with mud and mangrove species make up one grouping, those with sand and rubble species another, while the third group comprises those sites containing species from both habitats. As with the descriptive profiles, it is also possible to use other data sets in conjunction with the component attributes on which to base sub-profiles. For example, landscape elements could be used along with the distributions of materials and artefact densities.

For those sites that contain petroglyphs and pictographs distinctions could be made on the basis of the types of motifs present, i.e., figurative or non-figurative; the motif styles, e.g., animal tracks and hand stencils; and pigment colours. Likewise, for modified landscapes, distinctions can be made on the basis of their materials, cross sections and sizes.

Being able to generate descriptive profiles and sub-profiles and manipulate these in both the database and GIS allows polythetic models of the archaeological record to be generated for use in both comparative and spatial analysis. The results of this analysis will in turn allow researchers and heritage managers to obtain a much more detailed
understanding of what is on the ground. For heritage managers this will allow them to make management decisions based on knowledge and not intuition. Likewise, researchers will be better able to design their projects and generate higher level models relating to subsistence/settlement patterns and hypothesise about the cultural functions of sites.

Discussion and summary
This chapter has presented a new classification system for recording Australia's prehistoric archaeological record, a system that is underpinned by three arguments. First, the archaeological record is polythetic in nature and this must be captured when a site is recorded. This polythetic nature was clearly demonstrated in Chapter 1 by referring to site type definitions which when strictly applied lead to absurdity. In order to allow for the polythetic recording of the archaeological record I have identified a number of discrete components which provide the basic building blocks for such recording. This leads to the second argument.

The components I have identified are based on Lakoff's (1987) idealised cognitive or base-level models. All archaeologists carry these cognitive models in their minds and while they may vary, this approach provides a reliable base on which a classification system can be constructed. Certainly the components identified here are based on my own base-level models and even some of these had to be modified slightly to ensure I avoided the traps of employing functional type labels or implying cultural functions.

The third and final argument underpinning this classification system is that if the archaeological record is to be recorded and analysed in a meaningful manner these actions must accord with a logical interpretive model. To this end, a model was developed to provide a well-defined pathway for recording and interpreting the record with clear boundaries between each of the model's levels. As this is essentially an
experimental approach neither the interpretive model nor the classification system should be taken as fixed; they simply provide a method for recording and analysis that will allow archaeologists to gain a understanding of the record at a baseline level.

In sum, this chapter has presented an archaeological classification system that differs from the traditional methods employed in Australia. In designing the system it was important to ensure that the components and attributes would be relatively easy to import into a data base and GIS. In the following chapter I present the data model for the main aim of my thesis, i.e., the development of a baseline archaeological database. This followed by a chapter which brings together the main topics discussed to demonstrate the potential of the system proposed in this thesis.
Chapter Eight

DATABASE DESIGN FOR A BASELINE ARCHAEOLOGICAL DATABASE

Introduction

This chapter describes the conversion of the archaeological classification system into a data model using ORM (Object Role Modeling) and the migration of this model to a logical view and finally to a fully-functional relational database (from here on referred to as ArchBase) running under Access. Additionally, solutions to problems with the data model that came to light during the initial testing of the database are discussed.

Conceptual schema design procedure

The conversion of the classification system into a data model follows the seven CSDP (Conceptual Schema Design Procedure) steps outlined previously. Using InfoModeler it is possible to combine Steps 4 through 6 into a single stage as InfoModeler allows the addition of significant populations and constraints in a single step. This does not, however, impinge on the accuracy of the model.

CSDP Step 1: transform familiar information examples into elementary facts, and apply quality checks

This section describes the transformation of the various aspects of the classification system into elementary facts. Recall that elementary facts assert that “particular objects play particular roles” and form logical predicates, whereby each predicate is a sentence with object holes in it (Halpin 1995:44). To clarify this step of the CSDP, related predicates are grouped under common headings, e.g., general site attributes, knapped stone artefacts, etc.
Predicates for person's biographical details

The following predicates describe the various biographical details that may be recorded for each person. I have used the term 'person' rather than 'site recorder' as it is possible that some people will play more than one role and that others will never record sites. The predicates are:

1. Each Person has a unique ID Number 'N'.
2. The Person with the ID Number 'N' has the Surname 'S'.
3. The Person with the ID Number 'N' has the First name 'F'.
4. The Person with the ID Number 'N' resides at the Street address 'A'.
5. The Person with the ID Number 'N' Lives in the City named 'C'.
6. The Person with the ID Number 'N' lives in the area with the Postcode 'P'.
7. The Person with the ID Number 'N' has the Telephone number 'T' and the E-mail Address '@'.
8. The Person with the ID Number 'N' recorded the Archaeological site with the ID Code 'I'.
9. The Person with the ID Number 'N' was issued with Permit number 'N'.
10. The Person with the ID Number 'N' has the Recorder type 'R'.

Archaeological Site descriptions

General Site Attributes

The following predicates describe the general attributes of an archaeological site that must be recorded. When identifying the roles played by a site to generate these predicates, it was first necessary to consider what these roles were. In some respects, sites do not play any roles themselves, as role identifications, e.g., environmental setting, datum, and the components present, are reliant on the actual recording. Even a site's ID code is a result of its recording although once assigned it is unlikely to change. Like the ID code, there are attributes of a site that, once recorded, will rarely if ever require
modification. Thus it makes sense to consider these roles being played by the site rather than the recording. Ignoring such possibilities will result in the needless repetition of some data in the database and could lead to anomalies. To this end, I make a distinction between those roles played by a site and those played by recording details based on their expected repetition. The roles played by a site are:

1. Each Site has a unique ID Code 'I'.

2. The Site with the ID Code 'I' was recorded by the Person with the ID Number 'x' with the Recorder type 'RT' on the Date 'dd/mm/yyyy'.

3. The Site with the ID Code 'I' has the Basic structure 'B'.

4. The Site with the ID Code 'I' has the Datum easting '000000' is located on the 'X:000,000' Scale map sheet with the Map number 'X' and the Map name 'N' and the Edition number 'x'.

5. The Site with the ID Code 'I' has the Datum northing '0000000' is located on the 'X:000,000' Scale map sheet with the Map number 'X' and the Map name 'N' and the Edition number 'x'.

6. The Datum for the Site with the ID code 'I' was determined by the Method 'M'.

7. The Site with the ID code 'I' is located in the Biogeographic zone 'B'.

8. The Site with the ID code 'I' is located in the Landform pattern 'L'.

9. The Site with the ID code 'I' has the Management priority 'M'.

The next set of predicates are those most likely to change for each site recording and thus are roles played by a site’s recording details and not the site itself. For ArchBase I have opted to identify each recording as a unique object by using a numerical identifier rather than a nested object using natural identifiers as in Chapter 5. This allows for quicker response times to queries as the DBMS need only search for a single indexed field. The predicates are:
1. The Site with the ID Code 'I' has the Recording ID number 'N'.

2. Recording details with the ID number 'N' records the presence of Component 'X' and Component 'Y' and Component 'Z'.

3. Recording details with the ID number 'N' provides a Visible area measurement of 'Xm^2'.

4. Recording details with the ID number 'N' provides a North/south axis measurement of 'Xm'.

5. Recording details with the ID number 'N' provides a East/west axis measurement of 'Ym'.

6. Recording details with the ID number 'N' provides a Depth below ground surface measurement of 'Xcm'.

7. Recording details with the ID number 'N' indicates a Deposit thickness measuring 'Xcm'.

8. Recording details with the ID number 'N' indicates an Overall shape 'S'.

9. Recording details with the ID number 'N' indicates a Potential extent measuring 'Xm^2'.

10. Recording details with the ID number 'N' identifies the Extent limiting factors 'E'.

11. Recording details with the ID number 'N' indicates Ground cover 'G'.

12. Recording details with the ID number 'N' provides Additional grid reference(s) Easting '000000' and Northing '0000000'.

13. Recording details with the ID number 'N' identifies Landscape element(s) 'E'.

14. Recording details with the ID number 'N' indicates affect of Human disturbance(s) 'H'.

15. Recording details with the ID number 'N' indicates effect of Biotic disturbance(s) 'B'.

16. Recording details with the ID number 'N' indicates Erosion state 'E'.

17. Recording details with the ID number 'N' indicates effect of Wind erosion 'W'.

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18. Recording details with the ID number 'N' indicates effect of Scald erosion 'S'.
19. Recording details with the ID number 'N' indicates effect of Sheet erosion 'S'.
20. Recording details with the ID number 'N' indicates effect of Gully erosion 'G'.
21. Recording details with the ID number 'N' indicates effect of Stream bank erosion 'S'.
22. Recording details with the ID number 'N' indicates effect of Wave erosion 'W'.
23. Recording details with the ID number 'N' indicates effect of Mass movement 'M'.
24. Recording details with the ID number 'N' indicates effect of Inundation 'I'.
25. Recording details with the ID number 'N' indicates Vegetation cover of 'V%'.
26. Recording details with the ID number 'N' identifies Detection limiting factors 'D'.
27. Recording details with the ID number 'N' provides General Comments 'G'.

Map details
In the database maps play a number of roles in the recording process and descriptions of these roles are presented below. Additionally, I also include a predicate for the term 'determination method' which refers to the method employed to obtain a given grid reference, e.g., GPS, map sheets or GIS.

1. Each Map sheet has a unique Map sheet Number.
2. The Map sheet Number 'M' has the Scale '1:100 000'.
3. The Map sheet Number 'M' has the Map name 'A'.
4. The Map sheet Number 'M' has the Edition number 'x'.
5. Easting datum '000000' and Northing datum '0000000' are located on the Map number 'N'.
6. Easting datum '000000' and Northing datum '0000000' were determined by the Method 'M'.
7. The Additional grid reference with Easting ‘000000’ and Northing ‘000000’ are located on Map sheet number ‘M’.

8. Additional grid reference(s) Easting ‘000000’ and Northing ‘0000000’ were determined by Method ‘M’.

Site components and attributes
These predicates describe the various components and their attributes that may be located at a site.

Abraded portable artefacts
1. The Component Abraded portable artefacts is located at the Site with ID Code ‘I’.

2. The Component Abraded portable artefacts has the Subtype ‘Abraded stone artefacts’ or ‘Abraded organic artefacts’.

These are the only roles played by an abraded portable artefact. As suggested in the second predicate there are two subtypes of abraded portable artefacts, stone or organic. It is this type of information that can only come from the UoD (Universe of Discourse) expert. As will be seen in the following predicates while each abraded portable subtype does share common attributes, there are attributes that clearly set them apart. The following predicates describe the roles shared by both stone and organic abraded portable artefacts.

1. The Abraded portable artefact subtype Stone or Organic was manufactured using the Abrasion type ‘T’.

2. The Abraded portable artefact subtype Stone or Organic was shaped by Pre-abrasive reduction type ‘P’.

3. The Abraded portable artefact subtype Stone or Organic has the Artefact type ‘T’.

4. The Abraded portable artefact subtype Stone or Organic has Deposition characteristics ‘D’.

5. The Abraded portable artefact subtype Stone or Organic has Distribution characteristics ‘D’.

6. The Abraded portable artefact subtype Stone or Organic has a Maximum density of ‘x artefacts per m²’, and has a Minimum
density of 'x artefacts per m^2' and has an Average density of 'x artefacts per m^2'.

7. The Abraded portable artefact subtype Stone or Organic has the Condition ‘C’.

**Abraded hardstone artefacts**
1. The Subtype Abraded stone artefacts is manufactured on the Stone type ‘S’.
2. The Subtype Abraded stone artefacts has groove count of ‘X’.
3. The Subtype Abraded stone artefacts has the Groove cross section ‘G’.

**Abraded organic artefacts**
1. The Subtype Abraded organic artefacts is made on Material type ‘M’.
2. The Subtype Abraded organic artefacts has the Common name ‘C’.
3. The Subtype Abraded organic artefacts has the Species name ‘S’.

**Abraded non-portable artefacts**
1. The Component Abraded nonportable artefacts is found at the Site with ID Code ‘I’.
2. The Component Abraded nonportable artefacts is located on the Rock formation ‘R’.
3. The Component Abraded nonportable artefacts has the attribute Hardstone type ‘H’.
4. The Component Abraded nonportable artefacts has a Groove plan shape ‘P’.
5. The Component Abraded nonportable artefacts has the attribute Groove cross section ‘C’.
6. The Component Abraded nonportable artefacts has a Minimum groove depth ‘Xmm’.
7. The Component Abraded nonportable artefacts has Maximum groove depth ‘Xmm’.
8. The Component Abraded non-portable artefacts has a Minimum groove length ‘Xmm’.
9. The Component Abraded nonportable artefacts has a Maximum length ‘Xmm’.
10. The Component Abraded non-portable artefacts *has* a Minimum groove width ‘Xmm’.

11. The Component Abraded non-portable artefacts *has* a Maximum groove width ‘Xmm’.

12. The Component Abraded non-portable artefacts *has* groove count of ‘X’.

Charcoal/ash

1. The Component Charcoal/ash *is found at* the Site with ID Code ‘I’.

2. Component Charcoal/ash *has* Deposition characteristics ‘D’

3. The Component Charcoal/ash *has* the Distribution ‘D’.

4. The Component Charcoal/ash *has* the Form ‘F’.

Contact artefacts

1. The Component Contact artefacts *is found at* the Site with ID Code ‘I’.

2. The Component Contact artefacts *is manufactured from* the Material ‘M’.

3. The Component Contact artefacts *has* the Artefact type ‘T’.

4. The Component Contact artefacts *has* the Number ‘X’.

5. The Component Contact artefacts *has* the Condition ‘C’.

6. The Component Contact artefacts *has* Deposition characteristics ‘D’.

7. The Component Contact artefacts *has* the Distribution ‘D’.

8. The Component Contact artefacts *has* a Maximum density of ‘x artefacts per m^2’ and *has* a Minimum density of ‘x artefacts per m^2’ and *has* an Average density of ‘x artefacts per m^2’.

Faunal remains

1. The Component Faunal remains *is found at* the Site with ID Code ‘I’.

2. The Component Faunal remains *lives in* the Habitat ‘H’.

3. The Component Faunal remains *has* the attribute Common name ‘C’.

4. The Component Faunal remains *has* the Species name ‘S’.

5. The Component Faunal remains *has* the Condition ‘C’.
6. The Component Faunal remains comprises the Skeletal parts 'A'.

7. The Component Faunal remains has a Maximum density of 'x remains per m$^2$' and has a Minimum density of 'x remains per m$^2$' and has an Average density of 'x remains per m$^2$'.

8. The Component Faunal remains represents the total of the faunal remains measured by Percentage 'P'.

9. The Component Faunal remains has the Deposition 'D'.

10. The Component Faunal remains has a Distribution 'D'.

Floral remains

1. The Component Floral remains is found at the Site with ID Code 'I'.

2. The Component Floral remains has the material 'M'.

3. The Component Floral remains has the attribute Common name 'C'.

4. The Component Floral remains has the Species name 'S'.

5. The Component Floral remains has the Condition 'C'.

6. The Component Floral remains has a Maximum density of 'x remains per m$^2$' and has a Minimum density of 'x remains per m$^2$' and has an Average density of 'x remains per m$^2$'.

7. The Component Floral remains represents the total of the faunal remains measured by Percentage 'P'.

8. The Component Floral remains has the Deposition 'D'.

9. The Component Floral remains has the Distribution 'D'.

Human remains

1. The Component Human remains is found at the Site with ID Code 'I'.

2. The Component Human remains has the Remains location 'L'.

3. The Component Human remains has the Number of individuals 'X' whose accuracy is indicated by the attribute Full count 'F'.

4. The Component Human remains has the Condition 'C'.

5. The Component Human remains comprises type of Remains present 'A'.

6. The Component Human remains is an Interment 'I'.
7. The Component Human remains has the Interment type 'T'.
8. The Component Human remains is associated with Ochre pellets 'O'.
9. The Component Human remains is a Bundle 'B'.
10. The Component Human remains has the Position 'P'.

Knapped artefacts
1. The Component Knapped artefacts is found at the Site with ID Code 'I'.
2. The Component Knapped artefacts is manufactured on the Hardstone type 'H'.
3. The Component Knapped artefacts has the Artefact type 'T'.
4. The Component Knapped artefacts contains Conjoin sets 'C'.
5. The Component Knapped artefacts has evidence of Microdebitage 'M'.
6. The Component Knapped artefacts has Raw material source 'S'.
7. The Component Knapped artefacts has a Maximum density of 'x artefacts per m²' and has a Minimum density of 'x artefacts per m²' and has an Average density of 'x artefacts per m²'.
8. The Component Knapped artefacts has the Deposition 'D'.
9. The Component Knapped artefacts has a Distribution 'D'.
10. The Component Knapped artefacts represents the total of the artefact assemblage measured by Percentage 'P'.

Long pathway
1. The Component Long pathway is found at the Site with ID Code 'CB:A45'.
2. The Component Long pathway begins at the Site with ID code 'I'.
3. The Component Long pathway may finish at the Site with ID code 'I'.
4. The Component Long pathway covers a Distance of 'Xkm'.
5. The Component Long pathway may pass through Other sites with Site ID code 'I'.

Manuport
1. The Component Manuport is found at the Site with ID Code 'I'.

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2. The Component Manuport has the Material type ‘T’.
3. The Component Manuport with the Material type hardstone is a member of the Size class ‘S’.
4. The Component Manuport with the Material type hardstone is a member of the Hardstone type ‘H’.
5. The Component Manuport has the Number ‘X’.
6. The Component Manuport has evidence of Firing ‘F’.
7. The Component Manuport has a Maximum density of ‘x artefacts per m^2’, and has a Minimum density of ‘x artefacts per m^2’ and has an Average density of ‘x artefacts per m^2’.
8. The Component Manuport has the Deposition ‘D’.
9. The Component Manuport has the Distribution ‘D’.

Modified landscape
1. The Component Modified landscape is made from the Material type(s) ‘M’.
2. The Component Modified landscape may have the Hardstone type ‘H’ with the Rock size class ‘R’.
3. The Component Modified landscape has the Cross-section ‘C’.
4. The Component Modified landscape has the Modification type ‘M’.
5. The Component Modified landscape has the Shape ‘S’.
6. The Component Modified landscape has the measurements Axis width ‘Xm’ and Axis length ‘Xm’ and Major axis orientation ‘Y degrees’.
7. The Component Modified landscape has the measurements height/depth ‘Xm’ and base width ‘Xm’.
8. The Component Modified landscape has the Number of openings ‘X’.
9. The Component Modified landscape has the Number of modifications ‘X’.
10. The Component Modified landscape is associated with Short pathway(s) ‘S’.
11. The Component Modified landscape has the Condition ‘C’.
Modified tree
1. The Component Modified tree is found at the Site with ID Code ‘I’.
2. The Component Modified tree has the Modification type(s) ‘M’.
3. The Component Modified tree has the Modification style ‘P’.
4. The Component Modified tree has Number of modifications ‘X’.
5. The Component Modified tree has a modification pattern with an Elevation AGL measuring ‘Xm’.
6. The Component Modified tree has a modification pattern with a Width measuring ‘X m’ and a height measuring ‘Xm’.
7. The Component Modified tree has an modification pattern made using the Tool ‘T’.
8. The Component Modified tree has a Tree height ‘Hm’.
9. The Component Modified tree is located on a tree with the Common name ‘C’.
10. The Component Modified tree is located on a tree with the Species name ‘S’.
11. The Component Modified tree is located on a tree with a Diameter measuring ‘Xcm’.
12. The Component Modified tree has an Aspect ‘A’.
13. The Component Modified tree has the Tree condition ‘C’.

Petroglyph
1. The Component Petroglyph is found at the Site with ID Code ‘I’.
2. The Component Petroglyph has Panel numbers ‘X’.
3. The Panel number ‘X’ is located on the Rock formation ‘R’.
4. The Panel number ‘X’ is located on the Hardstone type ‘H’.
5. The Panel number ‘X’ has the Position ‘P’.
6. The Panel number ‘X’ has a Panel width ‘X cm’.
7. The Panel number ‘X’ has a Panel height ‘X cm’.
8. The Panel number ‘X’ contains the Petroglyph type(s) ‘P’.
9. The Panel number contains the Motif(s) ‘M’ with the Number ‘X’ and a Full count ‘F’.
10. The Motif 'M' **was created using** the Technique 'T'.
11. The Motif 'M' has a Pigment in-fill 'P'.
12. The Motif 'M' **has** the Condition 'C'.

**Pictograph**

1. The Component Pictograph is **found at** the Site with ID Code 'I'.
2. The Component Pictograph **has** Panel numbers 'X'.
3. The Panel number 'X' **is located on** the Rock formation 'R'.
4. The Panel number 'X' **is located on** the Hardstone type 'H'.
5. The Panel number 'X' **has** the Position 'P'.
6. The Panel number 'X' **has** a Panel width 'X cm'.
7. The Panel number 'X' **has** a Panel height 'X cm'.
8. The Panel number 'X' **contains** the Pictograph type(s) 'P'.
9. The Panel number contains the Motif(s) 'M' with the Number 'X' and a Full count 'F'.
10. The Motif 'M' **was created using** the Method 'T'.
11. The Motif 'M' **has** the Pigment Colour 'C'.
12. The Motif 'M' **has** a Pigment in-fill 'P'.

**Shellfish remains**

1. The Component Shellfish remains **is found at** the Site with ID Code 'I'.
2. The Component Shellfish remains **lives in** the Habitat 'H'.
3. The Component Shellfish remains **has** the attribute Common name 'C'.
4. The Component Shellfish remains **has** the Species name 'S'.
5. The Component Shellfish remains **has** the Condition 'C'.
6. The Component Shellfish remains **has** a Maximum density of 'x remains per m^2' and **has** a Minimum density of 'x remains per m^2' and **has** an Average density of 'x remains per m^2'.
7. The Component Shellfish remains represents the total of the faunal remains measured by Percentage 'P'.
8. The Component Shellfish remains **has** the Deposition 'D'.
9. The Component Shellfish remains **has** the Distribution 'D'.

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Short pathway
1. The Attribute Short Pathway leads from Modified landscape number 'X'.
2. The Attribute Short Pathway may lead to Modified landscape number 'X'.
3. The Component Short pathway has a Length 'Xm'.
4. The Component Short pathway has the attribute Condition 'good'.
5. The Component Short pathway has the attribute Orientation 'X degrees'.

Stone source
1. The Component Stone source is found at the Site with ID Code 'I'.
2. The Component Stone source has the Source type 'S'.
3. The Component Stone source is located at the Rock formation 'R'.
4. The Component Stone source with the Source type hardstone has the Hardstone type 'H'.
5. The Component Stone source has the Rock size class 'R'.
6. The Component Stone source with the Source type ochre has the attribute Ochre colour 'O'.
7. The Component Stone source was exploited using the Extraction method 'E'.

Uncommon artefacts
1. The Component Uncommon artefacts is found at the Site with ID Code 'I'.
2. The Component Uncommon artefacts has the Artefact type 'A'.
3. The Component Uncommon artefacts has the Component 'C'.
4. The Component Uncommon artefacts has the Condition 'C'.
5. The Component Uncommon artefacts is made from the Material 'M' and the Material 'Ml'.
6. The Component Uncommon artefacts has a Deposition 'D'.
7. The Component Uncommon artefacts has a Deposition 'D'.
8. The Component Uncommon artefacts has a Distribution 'D'.
This concludes the first stage of the CSDP, i.e., transforming familiar examples into elementary facts and applying quality checks.

**CSDP Step 2: draw fact types and populate**

This step involves the drawing of the fact types listed in Step 1 of the CSDP and providing a sample population for each of these drawn facts. As such, this section consists primarily of fact type figures. Significant populations are not shown in the diagrams here as InfoModeler analyses sample populations in later steps to ensure the correct constraints are being set. The following sets of figures depict the draft ORM.
Figure 8.1 presents the roles played by a person while Figures 8.2 through 8.6 show the roles played by general site attributes, site recordings and other associated roles.

Figures 8.7 through 8.24 model the relationships between components and attributes. Ideally natural identifiers should be used for components; however, as in the case of the shell midden presented previously this is not always possible. To this end, each recording of a component employs a numerical identifier. Figure 8.25 is the last of this set and models taphonomic details.

Figure 8.1 Person’s Biographical details.

Figure 8.2 The roles between sites and recording details.
Figure 8.3  The roles between a site's management priority, basic structure and map details and the roles played by a map sheet.

Figure 8.4  The roles played by a site's recording details and its areal description.
Figure 8.5 The roles played by recording details, grid references and map details. This aspect allows a number of grid references to be recorded for each site. Note that the roles played by a map sheet in this section of the model are exactly the same as those depicted in Figure 8.3.
Figure 8.6 The roles between components and recording details. Note the presence/absence of each component is indicated by a yes or no value.
Figure 8.7 Roles played by recording details and abraded portable artefacts.
Figure 8.8  Roles played by abraded portable organic and abraded portable stone artefacts.
Figure 8.9  Roles played by abraded nonportable artefacts.
Figure 8.10  Roles played by modified landscapes.
Figure 8.11   Roles played by charcoal/ash.

Figure 8.12   Roles played by faunal remains.
Figure 8.13 Roles played by human remains.
Figure 8.14  Roles played by contact artefacts.
Figure 8.15 Roles played by knapped artefacts.
Figure 8.16  Roles played by manuports.
Figure 8.17 Roles played by modified trees.

Figure 8.18 Roles played by long pathways.
Figure 8.19    Roles played by petroglyphs.
Figure 8.20  Roles played by pictographs.
Figure 8.21  Roles played by shellfish remains.

Figure 8.22  Roles played by stone sources.
Figure 8.23 Roles played by floral remains.
Figure 8.24  Roles played by uncommon artefacts.
Figure 8.25 Roles played by recording details and taphonomic factors.
CSDP Step 3: check for entity types that should be combined and note arithmetic derivations

This stage of the CSDP concerns identifying those entity types that may require combining. An examination of the draft ORM diagrams indicates there are entities that should be combined, i.e., those relating to the various measurements made during a recording. However, when objects are combined using InfoModeler the names of the objects being modeled are actually lost (Figure 9.1). Due to this change in object names I have not combined any entity types relating to measurement. These entities aside, there are no others to be combined in the model and therefore it is possible to move onto CSDP Steps 4 through 6.

Figure 8.26  An example of how InfoModeler loses information when objects are combined. Note that the east/west and north/south axis object names are reduced to LengthM and LengthM1.

CSDP Steps 4-6: add uniqueness constraints and check arity of fact types; add mandatory role constraints and check for logical
derivations; add value, subset equality exclusion and subtype constraints

These three steps in the CSDP provide for the addition of a variety of constraints between the various entities in the model and the roles they play. As indicated previously these three steps have been combined to simplify explanation and because InfoModeler makes it possible to add these constraints in one simple step.

Uniqueness constraints and arity of fact types

As a general rule all component attributes, a person's biographical details, map details and taphonomic details have a single role internal uniqueness constraint applied to them. There are, however, some exceptions to this rule. In the case of the roles between Recording ID and a given Component's ID an internal uniqueness constraint is placed above each role box indicating that each recording ID and Component ID is unique. For the relationship between an individual Component's ID number and Artefact numbers the uniqueness constraint spans both role boxes and they have been nested to create the Descriptions object. Also note that these constraints have been defined as primary by placing a "P" through the line indicating that the nested object is uniquely identified by its roles. Likewise, where two or more materials may have been used to manufacture an artefact the constraint spans both role boxes. Other examples of this type of constraint exist between Recording ID numbers and human and biotic disturbance types, landform elements, extent limiting factors and detection limits.

The only external uniqueness constraints found in the model exist between the objects Datum northing and easting and the Grid references easting and northing. In other words, each Site datum and Grid reference is primarily defined by its corresponding set of castings and northings, they are co-referenced objects.
There are no ternary or higher roles to decompose into binary roles in the model, nor do any roles require combining to form roles with an arity of three or higher.

**Mandatory role constraints and logical derivation check**

Mandatory role constraints are applied throughout the model to ensure the virtual exclusion of null values. The exceptions to this rule are those relating to a person's telephone number and e-mail address as it is possible that some people do not want these recorded or simply do not have either of these. It should also be noted that in the case of Recording ID and a Component's ID the mandatory role constraint is on the side of the component. This ensures that every component recorded has a corresponding Recording ID, but that not all Recording ID's have to have a corresponding Component ID. Obviously it would be absurd to state that each recording would result in the description of every component in the classification system. A similar situation exists between Person and Permit numbers; as not all people will be allocated a permit the mandatory role constraint is on the side of the Permit number not the Person. Finally, there are no logical derivations in the model.

**Value, set comparison and subtype constraints**

There are a number of value constraints that are required and that can be set in the model. These apply to those objects having a readily identifiable set of values that may be entered into the database. Examples include basic site structure, artefact deposition and distribution, taphonomic objects and those objects for which a yes/no value is required.

There is one component which is a candidate for subtyping, Abraded portable artefacts. This is because two types comprise this component, abraded hardstone artefacts and abraded organic artefacts. In the original predicates these were referred to as subtypes.
and in the draft schema they were modeled as nested entities to show the relationship between the Abraded portable ID number and the Artefact number. However, if these objects were shown as subtypes they would not provide an accurate representation of the UoD. The reason for this is that the definition for a subtype is that the entity type ‘object B’ is a proper subtype of entity type ‘object A’ iff the population of B is a subset of the population of A and $A \neq B$ (Halpin 1995:188). This is not the case in this aspect of the model. All Abraded portable artefacts are identified by an ID number to maintain the relationship with their recording details. As it is possible to have both abraded stone and abraded organic artefacts at one site, it is not possible to identify them as proper subtypes because they will both have the same ID number. Thus Abraded portable stone artefacts ID number = Abraded portable organic artefacts ID number and fail to meet the criteria for being proper subtypes.

**CSDP Step 7. add other constraints and perform final checks**

The only other constraints required are those relating to indexes. An index is essentially a tool used by the database to speed up the running of queries. Index constraints are generally applied to those roles which may be queried frequently, as well as to those roles associated with objects which are modeled as being independent, i.e., those which become look-up tables in the database. In this model index constraints have been placed on all roles which employ ID numbers or codes and all roles associated with independent objects.

This concludes the conceptual modeling section of this chapter. As InfoModeler was used to generate the model it is not necessary to perform final checks on the model as these are undertaken continuously throughout the modeling process. The completed ORM diagram is presented in Figure 8.27 (pp.272-290) and is now ready to be migrated to its logical schema.
The logical model

Migration from the conceptual to the logical view is straightforward and is entirely handled by InfoModeler's generate database wizard. During this process InfoModeler again checks the construction of the model to ensure there are no errors, such as repeating table names and/or field names, and that these names do not conflict with terms reserved by the DBMS. For example, the word "number" is reserved in Access for use with SQL and thus should not be used for either field or table names. If these checks fail, InfoModeler provides a list of the problems and they can be fixed in either the ORM or logical model. The logical model derived from ArchBase's conceptual model is shown in Figure 8.28 (pp291-303). To assist in understanding the diagram refer to the key presented below.

1. Primary keys are underlined.
2. Foreign keys are indicated by the notation FK.
3. Unique indexes, i.e., those which cannot have a repeating value for a given record, use the notation U.
4. Non-unique indexes use the notation l.
5. Mandatory columns, i.e., those that must have an entry, are shown in bold text.
6. Optional columns, i.e., those where an entry is not required, are shown in normal text. Note that in Access it is possible to set default values for all columns in the database. In those cases where an entry is optional the default value is set to an appropriate value, e.g., NA, No, None, 0, etc.
Figure 8.27 Completed ORM schema for ArchBase (Part 1 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 2 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 3 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 4 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 5 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 6 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 7 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 8 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 9 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 10 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 11 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 12 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 13 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 14 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 15 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 16 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 17 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 18 of 19).
Figure 8.27 Completed ORM schema for ArchBase (Part 19 of 19).
Figure 7.28 Logical view of ArchBase generated from conceptual view (Part 1 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 2 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 3 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 4 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 5 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 6 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 7 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 8 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 9 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 10 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 11 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 12 of 13).
Figure 8.28 Logical view of ArchBase generated from conceptual view (Part 13 of 13).
Migration to Access and setting up the database

Using InfoModeler migration from the logical model to the DBMS is relatively simple and results in a fully normalised database with all the tables and primary key/foreign key relationships identified. Despite this some changes were made to the structure of the database.

In previous discussions mention was made of controlled redundancy, or the process of denormalization. In the logical view presented above there is one table that can actually be removed from the database by modifying another. The tables involved are Grid reference and Grid references (Figure 8.28, part 2). At present the Grid references table defines the relationship between Recording details and Grid references thus allowing a site to have as many grid references as needed to define its visible boundaries. However, this relational type table can be removed and a new relationship set up between Grid references and Recording details. This is achieved by adding the Recording ID field to the Grid references table as a foreign key and also making it part of the primary key. Thus each Easting, Northing and Recording ID uniquely identifies each row in the table although each of the values stored in the table may be repeated many times (Figure 8.29). The result is less data stored in the database and an improvement in query response. In other words, fully normalize the database and then denormalize it 'til it works. This change in the database also highlights the ease with which a well-designed database can be modified. In a badly designed database identifying such changes could be difficult and make modification impossible.

At this point the database is ready for data entry. However, data entry directly into the tables may be confusing to many end-users as an understanding of the logical and physical views is required. To overcome these difficulties a series of forms which guide the end-user through data entry and other functions of the database is required. A form
provides a user-friendly interface with the database, particularly when the DBMS provides a Graphical User Interface GUI. Forms can contain custom menus, drop-down lists of validated values, and a variety of controls to assist the user in moving through the database.

![Recording details](image)

**Figure 8.27** The changed table Grid reference showing the addition of Recording ID as a foreign key and forming part of the concatenated primary key.

ArchBase employs many of these components to facilitate data entry and extraction. Figure 8.30 presents an overall picture of the main data entry forms and how they link together. As Access allows for the creation of forms within forms, or subforms, data entry and manipulation are apparently seamless and the user interface is somewhat intuitive as it follows a logical format (Figure 8.31 - 8.32). Controls can also be applied that are triggered by a change in a particular entry. These triggers then automatically open the next required form, thus allowing data entry to continue without end-users having to concern themselves about which form should be employed next.

While some fields in the database had their value constraints set in the conceptual model there were many where this was not possible simply because it was impossible to predict the total range of values. Consider those which are look-up tables, e.g., the Hardstone type table. While it is impossible to set value constraints on these tables it is still a requirement of the database that only validated values can be entered. In such cases a drop-down list is linked to the look-up table and only those values located in the look-up table can be entered. Any new data must first be entered into the look-up table. In sum,
the net result of employing forms, subforms, drop down lists of validated data and other controls not only assists the end-user but also assists in maintaining the integrity of the database.

Figure 8.28 Diagrammatic representation of the main forms employed for data entry. The nested forms indicate subforms in the database.

Figure 8.29 The main data entry form.
Figure 8.30  Main data entry form showing how additional grid references, extent and
detection limiting factors, and landform elements are entered.

It is also worth reiterating that I am not a programmer and have not used any code of my
own in the development of this database, nor have I written any programs to assist in the
design. The tools employed were those supplied with Access and InfoModeler and any
code that appears in the database is that written by Access when I have invoked one of
its “wizards” or in the construction of expressions to assist in the control of data flow.
The writing of such expressions is a relatively straightforward task and is learned as
required. I feel these are important points to make as they indicate that any archaeologist
who can come to grips with operating a computer has in his or her power the tools
required to develop a reliable database thus ensuring he or she and the wider
archaeological community can have greater confidence in the data on which their
hypotheses, research designs and management plans are based.

Problems with the database
During the initial testing of the database some problems were identified and rectified.

This section briefly examines these problems and explains how they were overcome. It is
worth noting that these problems were not with the relational structure of the database
per se, but with the design, the relationships between some objects and the way data was being entered into some fields.

The first problem relates to how an artefact’s maximum, minimum and average densities were modeled. Initially densities were modeled as roles played by individual artefacts but it quickly became apparent that this information would be better recorded for the component as a whole rather than individual artefacts or species. For example, when an artefact made on a particular hardstone type was recorded, the data model required that the density values for each artefact/hardstone combination were also recorded. Likewise, the model required that the densities of individual species of shellfish remains also be recorded. The rationale for making the changes was that it would be unlikely that densities for individual artefacts would be recorded in a baseline study. To this end the density fields were removed from the attributes tables and placed in the components tables except in the case of abraded portable artefacts where the densities of individual groove morphologies can still be recorded.

The second problem proved more difficult to solve. In the original model a component’s presence/absence at a site was recorded by a yes/no value. However, testing revealed the problematic nature of employing yes/no to indicate a component’s presence. Certainly you could identify the components at a site using the ‘and’ and/or ‘or’ operators in an Access query (Tables 8.1 and 8.2) but it was not possible to use this data in MapInfo to generate a thematic map based on component types. This is because MapInfo requires all the relevant data to be stored in a single field, or that the fields containing the data can be joined. When the component columns were combined the result was a field containing combinations of -1 and 0, with no indication as to what components these values represented (Table 8.3). Note that -1 and 0 are the database representations for yes/no values. Therefore, a value uniquely identifying each
component was required. To this end a code for each component was devised (Table 8.4) and the appropriate code is entered into ArchBase when the component is present or left as a null value when it is not. Using this code the various component fields can be combined to produce a table that can be used by MapInfo to generate thematic maps showing the distribution of sites by their components (Table 8.5).

Table 8.1  
Extract of records from Access based on a query requesting sites containing the components Knapped artefacts and Abraded portable artefacts.

<table>
<thead>
<tr>
<th>Site_code</th>
<th>Knapped artefacts</th>
<th>Abraded Portable artefacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 11</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BI 15</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BI 35</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BI 44</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BI 48</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BI 49</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BI 58</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 8.2  
Extract of records from Access based on a select query requesting sites containing the components knapped artefacts and/or abraded portable artefacts.

<table>
<thead>
<tr>
<th>Site_code</th>
<th>Knapped artefacts</th>
<th>Abraded Portable artefacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 09</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BSRAP 01</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BSRAP 02</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>KB:B42</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>LA:A13</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>KA:A21</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BI 01</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>BI 02</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BI 03</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BI 04</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BI 05</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>BI 06</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>BI 08</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 8.3  
Extract of records from Access based on a select query which combined the data contained in the Knapped artefacts, Shellfish remains and Manuports fields.

<table>
<thead>
<tr>
<th>Site_code</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA:A50</td>
<td>0,0,0</td>
</tr>
<tr>
<td>KA:A21</td>
<td>-1,0,0</td>
</tr>
<tr>
<td>LA:A10</td>
<td>0,0,0</td>
</tr>
<tr>
<td>BI 01</td>
<td>0,-1,-1</td>
</tr>
<tr>
<td>BI 02</td>
<td>-1,-1,0</td>
</tr>
<tr>
<td>BI 03</td>
<td>-1,0,0</td>
</tr>
<tr>
<td>BI 04</td>
<td>-1,0,0</td>
</tr>
<tr>
<td>BI 05</td>
<td>0,-1,0</td>
</tr>
<tr>
<td>BI 06</td>
<td>0,-1,0</td>
</tr>
</tbody>
</table>
Table 8.4  List of codes used to identify each component.

<table>
<thead>
<tr>
<th>Component code</th>
<th>Component name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANP</td>
<td>Abraded non portable artefacts</td>
</tr>
<tr>
<td>AP</td>
<td>Abraded portable artefacts</td>
</tr>
<tr>
<td>CA</td>
<td>Contact artefacts</td>
</tr>
<tr>
<td>ChA</td>
<td>Charcoal ash</td>
</tr>
<tr>
<td>FaR</td>
<td>Faunal remains</td>
</tr>
<tr>
<td>FIR</td>
<td>Floral remains</td>
</tr>
<tr>
<td>HR</td>
<td>Human remains</td>
</tr>
<tr>
<td>HS</td>
<td>Hardstone source</td>
</tr>
<tr>
<td>KA</td>
<td>Knapped artefacts</td>
</tr>
<tr>
<td>LP</td>
<td>Long path</td>
</tr>
<tr>
<td>Man</td>
<td>Manuports</td>
</tr>
<tr>
<td>ML</td>
<td>Modified landscape</td>
</tr>
<tr>
<td>OS</td>
<td>Ochre source</td>
</tr>
<tr>
<td>Pet</td>
<td>Petroglyphs</td>
</tr>
<tr>
<td>Pic</td>
<td>Pictographs</td>
</tr>
<tr>
<td>SP</td>
<td>Short path</td>
</tr>
<tr>
<td>SR</td>
<td>Shellfish remains</td>
</tr>
<tr>
<td>UA</td>
<td>Uncommon artefacts</td>
</tr>
</tbody>
</table>

Table 8.5  Extract from a query showing sites and their components.

<table>
<thead>
<tr>
<th>Site code</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 09</td>
<td>KA-MT-SR-</td>
</tr>
<tr>
<td>BI 01</td>
<td>FaR-Man-SR-</td>
</tr>
<tr>
<td>BI 02</td>
<td>KA-SR-</td>
</tr>
<tr>
<td>BI 03</td>
<td>KA-</td>
</tr>
<tr>
<td>BI 04</td>
<td>KA-</td>
</tr>
<tr>
<td>BI 05</td>
<td>ChA-SR-</td>
</tr>
<tr>
<td>BI 06</td>
<td>ChA-SR-</td>
</tr>
</tbody>
</table>

Discussion and conclusions

This chapter has demonstrated how the classification system presented in Chapter 7 was transformed into a fully functional relational database using ORM in conjunction with InfoModeler. Despite the apparent complexities of the classification system, the transformation was a relatively straightforward process using ORM. Undertaking the same task either by using E-R modeling techniques or by applying the normal form rules would have been extremely difficult. While ORM certainly simplifies the modeling process, it does not mean mistakes are not made, and indeed this was the case with the ArchBase model. However, these problems were not with the model per se, but rather with the way some aspects of the UoD had been interpreted and subsequently modeled.
Likewise, because ArchBase was based on a solid data model these problems could be addressed and modifications made once the database had been generated without impinging on its integrity.

This concludes that section of the thesis detailing the development of a system for recording, managing, and manipulating archaeological data. All the elements of the system, i.e., the classification system, the database and the interpretive framework underpinning the system, are now in place. It remains to bring together the whole system in a test situation and this is the subject of the next chapter.
Chapter Nine

BRINGING IT ALL TOGETHER

Introduction
With ArchBase having passed its initial set of tests all the elements presented in the preceding chapters can be combined to examine the system's potential for assisting archaeologists and heritage managers. While it would be beneficial to examine the complete range of data and information that could be obtained from this "archaeological information system" (AIS) (Arroyo-Bishop and Zarzosa 1995:43), this is simply not possible due to the wide range of data it can hold and the various permutations that can be obtained. ArchBase alone contains some 50 tables and over 300 fields which can be queried to generate additional data and information. Consider also that this data can be combined with GIS data sets to generate further data sets. Thus it is only possible to provide a demonstration of the system's capabilities and this is achieved by

1. showing how the system can be employed by both heritage managers and researchers to extract a wide variety of baseline information within the parameters set by the interpretive framework,
2. examining the types of information that can be extracted by heritage managers for management-related issues which fall outside the interpretive framework and
3. discussing how ArchBase can be used in conjunction with research-related databases to further enhance their capabilities.

A major problem associated with this project was obtaining accurate data sets that could be entered into the database and manipulated by the GIS. To this end, testing was undertaken on a suite of sites recorded on Bribie Island, Southeast Queensland. The rationale for selecting this island is based on my own involvement with research projects
in the area and the fact that the site recording forms employed allowed for the relatively straightforward extraction of data for entry into ArchBase.

The study area
Bribie Island is a low-lying sand island situated at the northern end of Moreton Bay (Figure 9.1). Its western margins are separated from the mainland by Pumicestone Passage while the eastern side fronts the Pacific Ocean. The island is primarily formed from remnant Pleistocene sand ridges along its north-south axis, while the southern quarter of the island comprises east-west running Holocene dune systems. While much of Bribie Island lies below an elevation of 5m, there are areas approaching 14 m (Wilmott and Stevens 1988). In the early 1960s a large pine plantation was seeded on the northern 75% of the island and this has significantly impacted on the detection of archaeological material. Areas within the plantation have a deep covering of pine needles which effectively reduce surface visibility to nil; thus, the only areas offering relatively good surface visibility are vehicle tracks in the plantation. Likewise, much of the of southern section’s archaeological record has been destroyed by commercial and residential development.

Bribie Island has been the focus of a number of studies since the late 1970s, particularly since the inception of the Moreton Region Archaeological Project (MRAP) (Hall 1980). The Island’s archaeological record is characterised by surface and subsurface deposits of shellfish remains, varying in area from a few square metres to upwards of 900,000m² with deposits up to 60 cm deep (A. D. Smith 1992, personal communication 1998). The oldest dated site on the Island is ca. 3820 BP. Knapped stone artefacts and a particular form of abraded portable artefact (commonly referred to as bungwall bashers) are also found, although not always associated with the shellfish remains. As Bribie Island has no hardstone sources all stone artefact material was imported from the mainland.
The data employed in phase one of the system tests were derived from two main sources, the MRAP Bribie Island files (Department of Anthropology and Sociology, the University of Queensland), and Smith’s (1992) BA Honors thesis which examined the Island’s prehistoric settlement/subsistence patterns. Furthermore, a large number of sites located on the western margins of the Island were excluded because of poor data quality. As such, the results obtained should be treated with caution as they are unlikely to reflect the actual distribution of archaeological material in the area. The aim of the testing is to demonstrate the potential of the system, not rewrite Bribie Island’s prehistory.

**The interpretive model Stage 1**

Stage 1 involves the entry of data obtained during field work or, as in this case, the entry of data from pre-existing records. As such, it is a straightforward process with the user being guided by the data entry forms. Once the data has been entered into the system Stage 2 of the interpretive model can be implemented.

**The interpretive model Stage 2**

Stage 2 of the interpretive model aims to group sites using broad morphological
characteristics. The simplest groupings possible are those based on a single variable and include components, basic structure or landform patterns. Slightly more complex groups could be based on any combination of these depending on the questions being asked. For example, which sites in a given area are stratified, or which sites are located along an escarpment and contain pictographs? Data sets contained in the GIS database (e.g., elevation, geology, vegetation, soils and distance to water) may also be imported into ArchBase and used to further group sites.

Determining which components are present in an area is likely to be one of the most common queries run on ArchBase and the structure of these will depend on the type of information required and how it is to be presented. One method provides a list of sites and their components (Table 9.1) that can be linked to MapInfo and a distribution map produced (Figure 9.2). Other possibilities include mapping each component individually or mapping a specific set of attributes (e.g., sites containing knapped stone artefacts and shellfish remains that may also contain manuports).

Table 9.1 Extract from a query listing site ID codes, components present and examples of other data that can be obtained.

<table>
<thead>
<tr>
<th>Site_code</th>
<th>Components</th>
<th>Erosion_State</th>
<th>Person</th>
<th>Rec_category</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 01</td>
<td>FaR-SR-</td>
<td>Stabilised</td>
<td>21</td>
<td>Researcher</td>
</tr>
<tr>
<td>BI 02</td>
<td>KA-Man-SR-</td>
<td>Stabilised</td>
<td>56</td>
<td>Researcher</td>
</tr>
<tr>
<td>BI 03</td>
<td>AP-KA-</td>
<td>Stabilised</td>
<td>12</td>
<td>Consultant</td>
</tr>
<tr>
<td>BI 04</td>
<td>KA-</td>
<td>Active</td>
<td>12</td>
<td>Consultant</td>
</tr>
<tr>
<td>BI 05</td>
<td>ChA-SR-</td>
<td>Stabilised</td>
<td>33</td>
<td>Consultant</td>
</tr>
<tr>
<td>BI 06</td>
<td>ChA-SR-</td>
<td>Stabilised</td>
<td>33</td>
<td>Researcher</td>
</tr>
<tr>
<td>BI 07</td>
<td>FSR-</td>
<td>Stabilised</td>
<td>33</td>
<td>Researcher</td>
</tr>
<tr>
<td>BI 08</td>
<td>SR-</td>
<td>Stabilised</td>
<td>33</td>
<td>Researcher</td>
</tr>
<tr>
<td>BI 09</td>
<td>AP-KA-Man-MT-SR-</td>
<td>Partly stabilised</td>
<td>33</td>
<td>Student</td>
</tr>
<tr>
<td>BI 10</td>
<td>KA-MT-SR-</td>
<td>Stabilised</td>
<td>45</td>
<td>Researcher</td>
</tr>
<tr>
<td>BI 11</td>
<td>AP-KA-SR-</td>
<td>Stabilised</td>
<td>45</td>
<td>Researcher</td>
</tr>
</tbody>
</table>

Referring again to Figure 9.2 it is possible to identify 15 descriptive profiles for Bribie Island sites based on components. These range from single component sites to one with five components. Based on these data alone some basic assertions concerning the nature and distribution of Bribie Island's archaeological record can be made. For example:
1. Sites with knapped artefacts only are scarce and tend to be located on the eastern side of the Island.

2. Sites with shellfish remains only are relatively common and generally occur on the western side of the Island.

3. Sites with both knapped artefacts and shellfish remains are common and generally situated on the Island’s eastern side.

4. Sites with knapped artefacts, manuports and shellfish remains are relatively common and evenly distributed across the Island.

A second method provides a similar result to that shown in the legend for Figure 9.2 as it returns the number of sites within each descriptive profile (Table 9.2). In this case, however, the results are presented in a tabular form that can be graphed (Figure 9.3). Other data sets can also be used in conjunction with components to group sites. For example, Table 9.3 shows the number of sites that exist for each combination of components, basic structure and landform. Likewise, Figure 9.4 shows how the combination of components, basic structure and landform can be mapped for individual sites.

Table 9.2 Results of a query designed to list the number of sites recorded with each set of components.

<table>
<thead>
<tr>
<th>Components</th>
<th>Nmbr of sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>23</td>
</tr>
<tr>
<td>AP-KA-</td>
<td>3</td>
</tr>
<tr>
<td>AP-KA-Man-MT-SR-</td>
<td>1</td>
</tr>
<tr>
<td>AP-KA-Man-SR-</td>
<td>4</td>
</tr>
<tr>
<td>AP-KA-SR-</td>
<td>3</td>
</tr>
<tr>
<td>ChA-SR-</td>
<td>2</td>
</tr>
<tr>
<td>FaR-KA-Man-SR-</td>
<td>1</td>
</tr>
<tr>
<td>FaR-KA-SR-</td>
<td>1</td>
</tr>
<tr>
<td>FaR-SR-</td>
<td>1</td>
</tr>
<tr>
<td>KA-</td>
<td>4</td>
</tr>
<tr>
<td>KA-Man-</td>
<td>2</td>
</tr>
<tr>
<td>KA-Man-SR-</td>
<td>13</td>
</tr>
<tr>
<td>KA-MT-SR-</td>
<td>1</td>
</tr>
<tr>
<td>KA-SR-</td>
<td>16</td>
</tr>
<tr>
<td>ML-</td>
<td>1</td>
</tr>
<tr>
<td>SR-</td>
<td>14</td>
</tr>
</tbody>
</table>
Figure 9.2  Distribution of components for Bribie Island.
Figure 9.3  The results of graphing Table 9.2 with the raw numbers converted to percentages.

Table 9.3  Number of components for each landform pattern based on site structure.

<table>
<thead>
<tr>
<th>Components</th>
<th>Basic_structure</th>
<th>Landform_pattern</th>
<th>Nmbr of sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP-KA-</td>
<td>Surficial</td>
<td>Beach ridge plain</td>
<td>2</td>
</tr>
<tr>
<td>AP-KA-</td>
<td>Surficial</td>
<td>Tidal flat</td>
<td>1</td>
</tr>
<tr>
<td>AP-KA-Man-MT-SR-</td>
<td>Subsurface</td>
<td>Beach ridge plain</td>
<td>1</td>
</tr>
<tr>
<td>AP-KA-Man-SR-</td>
<td>Surficial</td>
<td>Beach ridge plain</td>
<td>2</td>
</tr>
<tr>
<td>AP-KA-SR-</td>
<td>Mound</td>
<td>Tidal flat</td>
<td>1</td>
</tr>
<tr>
<td>AP-KA-SR-</td>
<td>Surficial</td>
<td>Beach ridge plain</td>
<td>2</td>
</tr>
<tr>
<td>ChA-SR-</td>
<td>Mound</td>
<td>Tidal flat</td>
<td>1</td>
</tr>
<tr>
<td>ChA-SR-</td>
<td>Subsurface</td>
<td>Beach ridge plain</td>
<td>1</td>
</tr>
<tr>
<td>FaR-KA-Man-SR-</td>
<td>Surficial</td>
<td>Beach ridge plain</td>
<td>1</td>
</tr>
<tr>
<td>FaR-KA-SR-</td>
<td>Subsurface</td>
<td>Beach ridge plain</td>
<td>1</td>
</tr>
<tr>
<td>FaR-SR-</td>
<td>Surficial</td>
<td>Beach ridge plain</td>
<td>1</td>
</tr>
<tr>
<td>KA-</td>
<td>Surficial</td>
<td>Beach ridge plain</td>
<td>2</td>
</tr>
<tr>
<td>KA-</td>
<td>Surficial</td>
<td>Floodplain</td>
<td>1</td>
</tr>
<tr>
<td>KA-Man-</td>
<td>Surficial</td>
<td>Beach ridge plain</td>
<td>1</td>
</tr>
<tr>
<td>KA-Man-SR-</td>
<td>Surficial</td>
<td>Beach ridge plain</td>
<td>12</td>
</tr>
<tr>
<td>KA-SR-</td>
<td>Surficial</td>
<td>Beach ridge plain</td>
<td>15</td>
</tr>
<tr>
<td>ML-</td>
<td>Surficial</td>
<td>Beach ridge plain</td>
<td>1</td>
</tr>
<tr>
<td>SR-</td>
<td>Surficial</td>
<td>Beach ridge plain</td>
<td>9</td>
</tr>
<tr>
<td>SR-</td>
<td>Surficial</td>
<td>Dunefield</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 9.4  Extract from query showing individual sites, the components they contain, their basic structure and the landform patterns on which they are located.

<table>
<thead>
<tr>
<th>Site_code</th>
<th>Components</th>
<th>Landform_pattern</th>
<th>Basic_structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 09</td>
<td>AP-KA-Man-MT-SR-</td>
<td>Beach ridge plain</td>
<td>Subsurface</td>
</tr>
<tr>
<td>BI 01</td>
<td>FaR-SR-</td>
<td>Beach ridge plain</td>
<td>Surficial</td>
</tr>
<tr>
<td>BI 02</td>
<td>KA-Man-SR-</td>
<td>Beach ridge plain</td>
<td>Surficial</td>
</tr>
<tr>
<td>BI 03</td>
<td>AP-KA-</td>
<td>Tidal flat</td>
<td>Surficial</td>
</tr>
<tr>
<td>BI 04</td>
<td>KA-</td>
<td>Dunefield</td>
<td>Subsurface</td>
</tr>
<tr>
<td>BI 05</td>
<td>ChA-SR-</td>
<td>Beach ridge plain</td>
<td>Subsurface</td>
</tr>
<tr>
<td>BI 06</td>
<td>ChA-SR-</td>
<td>Tidal flat</td>
<td>Mound</td>
</tr>
<tr>
<td>BI 07</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>BI 08</td>
<td>SR-</td>
<td>Beach ridge plain</td>
<td>Surficial</td>
</tr>
<tr>
<td>BI 10</td>
<td>KA-MT-SR-</td>
<td>Longitudinal dunefield</td>
<td>Subsurface</td>
</tr>
<tr>
<td>BI 11</td>
<td>AP-KA-SR-</td>
<td>Tidal flat</td>
<td>Mound</td>
</tr>
<tr>
<td>BI 13</td>
<td>KA-Man-</td>
<td>Tidal flat</td>
<td>Surficial</td>
</tr>
<tr>
<td>BI 14</td>
<td>KA-Man-SR-</td>
<td>Beach ridge plain</td>
<td>Surficial</td>
</tr>
<tr>
<td>BI 15</td>
<td>AP-KA-SR-</td>
<td>Beach ridge plain</td>
<td>Surficial</td>
</tr>
</tbody>
</table>

Despite the fact that only two tables in *ArchBar*, i.e., Archaeological site and Recording details, have been used groupings of sites based on a variety of factors has been attained. However, even at this level it is only a sample of what can be achieved, particularly if further data manipulation is undertaken by a GIS.

By employing a GIS observations made previously can be quantified statistically and new information generated on the basis of these statistics. For example, information relating to the distance of sites from the nearest potable water sources or topographic data such as elevation, slope and aspect may be obtained for all sites in a study area, a particular descriptive profile or a particular component. Table 9.5 shows the results of calculating the minimum distances for sites containing only shellfish remains from Bribie Island’s coastlines and the distance to the closest site with the same descriptive profile, while Figure 9.5 presents the results of this in map form. Obtaining information of this type is a relatively straightforward process using a GIS.
Figure 9.4  The distribution of shellfish remains based on landform patterns and basic site structure.
Table 9.5 The results of calculating minimum distances from each site containing only shellfish remains to the coastline and the same descriptive profile.

<table>
<thead>
<tr>
<th>Site_code</th>
<th>Nearest_coast</th>
<th>Distance to nearest coast (m)</th>
<th>Dist to nearest site with same profile (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 08</td>
<td>Western</td>
<td>258</td>
<td>5849</td>
</tr>
<tr>
<td>BI 40</td>
<td>Eastern</td>
<td>1228</td>
<td>2195</td>
</tr>
<tr>
<td>BI 43</td>
<td>Western</td>
<td>1652</td>
<td>969</td>
</tr>
<tr>
<td>BI 47</td>
<td>Western</td>
<td>2746</td>
<td>566</td>
</tr>
<tr>
<td>BI 50</td>
<td>Western</td>
<td>2590</td>
<td>610</td>
</tr>
<tr>
<td>BI 51</td>
<td>Western</td>
<td>2839</td>
<td>317</td>
</tr>
<tr>
<td>BI 52</td>
<td>Western</td>
<td>2790</td>
<td>317</td>
</tr>
<tr>
<td>BI 53</td>
<td>Western</td>
<td>2431</td>
<td>399</td>
</tr>
<tr>
<td>BI 54</td>
<td>Western</td>
<td>1938</td>
<td>500</td>
</tr>
<tr>
<td>BI 59</td>
<td>Western</td>
<td>2129</td>
<td>1400</td>
</tr>
<tr>
<td>BI 60</td>
<td>Eastern</td>
<td>169</td>
<td>5849</td>
</tr>
<tr>
<td>BI 65</td>
<td>Western</td>
<td>493</td>
<td>447</td>
</tr>
<tr>
<td>BI 66</td>
<td>Western</td>
<td>337</td>
<td>447</td>
</tr>
</tbody>
</table>

Figure 9.5 Map showing proximity to eastern and western coastlines for sites with only Shellfish remains.
Other methods for manipulating the data, such as view-shed analysis to investigate site inter-visibility or statistical analyses to further investigate spatial patterning, can assist in the development of, for example, predictive models or survey planning. Such statistical analyses may include chi-square tests to determine if distance to the nearest potable water source was a significant factor in either site location or sites with specific descriptive profiles. Likewise, the same test could be employed to ascertain if elevation was a significant factor in the location of sites with a particular set of components. Using elevation and slope, for example, least square regression could be employed to determine if the location of a newly recorded site is typical or significantly different in terms of these attributes.

This concludes the demonstration of what types of data and information can be obtained in Stage 2 of the interpretive model. By employing the AIS and following the rules of the interpretive model a number of different approaches were used to generate basic descriptive site profiles using broad morphological characteristics. Having the ability to extract basic information of this type is a major advance over what can be obtained from the Heritage Branch database. However, this is only just scraping the surface; once these broad groupings have been identified Stage 3 of the interpretive model can be implemented and a great deal more information generated.

**The interpretive model Stage 3**

Stage 3 of the interpretive model involves breaking down the broad descriptive profiles previously identified into more definitive descriptive subprofiles. Defining these subprofiles draws upon the attributes recorded for each component present at a site and other data sets that may be stored in the GIS such as elevation, slope, aspect, geology, vegetation, soils, rainfall or perhaps even seasonal wind direction or distance from a given resource. While some of these may have already been employed in Stage 2 there is
no reason not to use them to further refine the groups.

By drawing on a component’s attribute data a powerful analytical tool that provides fine-grained comparative data sets is brought into play. Using attribute data, readily identifiable differences and similarities between sites based on a single component or set of components are obtained. Thus, for example, it is possible to determine what if any differences exist between sites containing only shellfish remains and those containing shellfish remains and knapped artefacts, or any other combination of components.

At this point it is necessary to identify each subprofile. This should be kept relatively simple and be based on the profiles previously recognised with each subprofile identified alphabetically. Thus, for example, the SR profile could be divided into SR-a and SR-b. This makes the data easier to handle in the database and when describing or mapping the results. At no point should functionally derived terms be used to define subprofiles.

When subprofiles are generated they need not be dependent upon a unique set of attributes being sufficient and necessary for membership. For example, SR-a may include sites containing oyster and cockle remains and others containing oyster, whelk and cockle remains. Conversely, SR-b may include sites containing oyster or cockle or whelk and pipi. The distinction is that SR-a comprises sites with only estuarine species whereas SR-b contains both estuarine and ocean species. On the other hand, it may be important to base subtypes on individual species or artefacts present. Likewise, distinctions between sites with knapped artefacts may be made on the types of artefacts present, individual stone types or broader categories of stone types such as fine-grained or coarse-grained. Being able to classify the archaeological record in these ways gives a high degree of flexibility to any analysis and allows the record’s polythetic nature to be captured. Basically it all comes back to the types of questions being asked. With the above in mind it is now possible to return to Bribie Island and continue exploring sites
with the SR, KA-SR and KA-Man-SR profiles by generating descriptive subprofiles similar to the examples discussed above.

The first set of subprofiles to be generated based on habitat of shellfish are for the SR profile (Table 9.6) and the results can be summarised in the following manner:

1. All sites with the SR profile have a scattered distribution.
2. The majority of sites, i.e., ca. 79%, comprise species which are found in mud and mangrove habitats and all have the same three species present.
3. Only one site, BI 60, contains a single species, i.e., pipi.
4. Only two sites, ca. 14% contain species from two different habitats.

On the basis of these results three descriptive subprofiles can be identified:

1. SR-a sites contain mud and mangrove species only.
2. SR-b sites contain mud and mangrove and sand and rubble species.
3. SR-c sites contain sand and rubble species only.

Table 9.6  Attributes of sites with the SR profile. Note that the presence of the numeral 1 in the common name field indicates the presence of that shellfish species, while the numeral in the habitat field indicates the actual number of species present for that habitat.

<table>
<thead>
<tr>
<th>Site code</th>
<th>Distribution</th>
<th>Cockle</th>
<th>Mud whelk</th>
<th>Oyster</th>
<th>Pipi</th>
<th>Mud mangroves</th>
<th>Sand rubble</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 08</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>BI 40</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>BI 43</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>BI 47</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>BI 50</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>BI 51</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>BI 52</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>BI 53</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>BI 54</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>BI 57</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>BI 59</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>BI 60</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>BI 65</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>BI 66</td>
<td>Scattered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Having profiled those sites containing shellfish remains only, the next step applies the same procedure to sites with the SR-KA and KA-Man-SR profiles (Tables 9.7 and 9.8).
The only notable differences between sites with the SR, KA-SR and KA-Man-SR profiles is that the proportion of sites with the SR-b subprofile is slightly higher for KA-Man-SR sites (ca. 38%) compared to KA-SR sites (ca. 31%). These percentages are, however, considerably higher than those at sites with the SR profile where only 14% of sites exhibit the SR-b subprofile.

Moving on, it is now possible to identify subprofiles for knapped artefacts. This can be undertaken using hardstone types, artefact types, nearest source, the presence of debitage or conjoin sets, the percentage of artefact types or a combination of any of these. As hardstone sources for Bribie Island have not been identified this variable must be
excluded. Likewise, the presence of debitage or conjoin sets has not been recorded and
the percentages of artefacts are only known for a few sites. Thus the following
subprofiles are based on hardstone and knapped artefact types. When a number of
attributes are being used it is easier to generate the subprofiles one attribute at a time as it
allows patterns in the data to be more visible and reduces the potential for errors.

The first subprofile is based on the range of artefact types present in each profile at each
site (Tables 9.9 and 9.10). Note that the number shown for each artefact type in these
tables indicates how many times an artefact type has been recorded for each site, not the
number of artefacts actually recorded. This is due to the structure of the aggregate data
query. In fact, what is actually indicated is the number of different hardstone types on
which the artefacts have been made. If an aggregate query were not used the results
would appear as shown in Table 9.11 whereby each artefact type/hardstone type
combination is shown.

Returning to Tables 9.9 and 9.10 it is now possible to identify two broad subprofiles for
both the KA-SR and KA-Man-SR on the basis of artefact types:

1. KA-a sites have cores.
2. KA-b sites have no cores.

As sites with cores may be indicators of specific aspects of subsistence/settlement
patterns (i.e., stone reduction) defining subprofiles based on their presence/absence is
logical. Tables 9.9 and 9.10 indicate considerable variation between the two profiles in
terms of the number of sites recorded with cores. Some 62% of KA-Man-SR profile
sites contain cores compared to 19% of KA-SR profile sites. Also note that sites with
amorphously retouched flakes often contain cores.
Having identified these basic subprofiles, differences based on raw material types can be examined to determine if further subdivisions are possible. The data presented in Tables 9.12 and 9.13 indicates a number of possibilities for making further distinctions regarding...
sites with cores. For this example the distinction is based on the number of hardstone types used for cores and this results in subprofile KA-a being divided into:

1. KA-a1 sites have cores made on a single hardstone type.
2. KA-a2 sites have cores made on two or more hardstone types.

Table 9.12 Sites with the KA-SR profile and the KA-a subprofile showing raw materials on which cores are manufactured.

<table>
<thead>
<tr>
<th>Site_code</th>
<th>Profile</th>
<th>Hardstone type</th>
<th>artefact_type</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 18</td>
<td>KA-a</td>
<td>Chert</td>
<td>Core</td>
<td>KA-SR-</td>
</tr>
<tr>
<td>BI 61</td>
<td>KA-a</td>
<td>Silcrete</td>
<td>Core</td>
<td>KA-SR-</td>
</tr>
<tr>
<td>BI 69</td>
<td>KA-a</td>
<td>Silcrete</td>
<td>Core</td>
<td>KA-SR-</td>
</tr>
</tbody>
</table>

Table 9.13 Sites with the KA-Man-SR profile and the KA-a sub-profile showing raw materials on which cores are manufactured.

<table>
<thead>
<tr>
<th>Site_code</th>
<th>Profile</th>
<th>Hardstone type</th>
<th>artefact_type</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 02</td>
<td>KA-a</td>
<td>Chert</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
<tr>
<td>BI 02</td>
<td>KA-a</td>
<td>Quartz</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
<tr>
<td>BI 02</td>
<td>KA-a</td>
<td>Silcrete</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
<tr>
<td>BI 14</td>
<td>KA-a</td>
<td>Silcrete</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
<tr>
<td>BI 21</td>
<td>KA-a</td>
<td>Chert</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
<tr>
<td>BI 33</td>
<td>KA-a</td>
<td>Silcrete</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
<tr>
<td>BI 36</td>
<td>KA-a</td>
<td>Silcrete</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
<tr>
<td>BI 39</td>
<td>KA-a</td>
<td>Chert</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
<tr>
<td>BI 41</td>
<td>KA-a</td>
<td>Quartz</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
<tr>
<td>BI 41</td>
<td>KA-a</td>
<td>Quartzite</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
<tr>
<td>BI 68</td>
<td>KA-a</td>
<td>Chert</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
<tr>
<td>BI 68</td>
<td>KA-a</td>
<td>Silcrete</td>
<td>Core</td>
<td>KA-Man-SR-</td>
</tr>
</tbody>
</table>

Using the same criterion as above, sites with the KA-b profile can also be divided into sites with cores on one hardstone type (KA-b1) and those with cores on two or more hardstone types (KA-b2). With all the above information at hand it is now possible to investigate any relationships between these sites.

Table 9.14 shows the number of sites and the relationships between each of the subprofiles so far identified for KA-Man-SR sites. These patterns are:

1. Sites with cores made on one hardstone type are likely to be found in conjunction with shellfish remains comprising both mud/mangrove and sand/rubble species.
2. Sites with cores made on two or more hardstone types are found in conjunction with any combination of shellfish species, although sand/rubble
species are the least common.

3. Sites with no cores but containing artefacts made on a single hardstone type are only found with mud/mangrove shellfish species.

4. Sites with no cores but having artefacts made on two or more hardstone types are only found with mud/mangrove shellfish species.

Table 9.14 The number of sites and the relationships between each combination of subprofiles for the KA-Man-SR profile.

<table>
<thead>
<tr>
<th>Profile</th>
<th>SR-a</th>
<th>SR-b</th>
<th>SR-c</th>
</tr>
</thead>
<tbody>
<tr>
<td>KA-a1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>KA-a2</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>KA-b1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>KA-b2</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

For sites with the KA-SR profile the relationship between each of the subprofiles identified to date are shown in Table 9.15 and can be summarised as follows:

1. Sites with cores made on a single hardstone type may be found in conjunction with mud/mangrove species as well as mud/mangrove and sand/rubble species.

2. No sites in this profile contain cores made on two or more hardstone types.

3. Sites with no cores but having artefacts made on a single material appear to be more closely associated with mud/mangrove species than are other profiles.

4. Sites with no cores but having artefacts made on a variety of hardstone types seem to occur in equal proportions with mud/mangrove or mud/mangrove and sand/rubble species.

Table 9.15 The number of sites and the relationships between each combination of sub-profiles for the KA-SR profile.

<table>
<thead>
<tr>
<th>Profile</th>
<th>SR-a</th>
<th>SR-b</th>
</tr>
</thead>
<tbody>
<tr>
<td>KA-a1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>KA-b1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>KA-b2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

The final division of subprofiles involves the manuports found in the KA-Man-SR profiles. As manuports are not necessarily stone the first step is to identify which materials are present. A query to identify these materials indicates that on Bribie Island all recorded manuports are stone, thus it is possible to proceed without defining any
other material type subprofiles. Table 9.16 shows the number of different stone types recorded for each site in the KA-Man-SR profile and at least two groups can be identified:

1. Man-a sites have a single stone type
2. Man-b sites have two or more stone types.

Other attributes, such as the size class, stone types or densities could also be used to generate the groups.

Table 9.16  Number of manuport stone types for sites in the KA-Man-SR profile.

<table>
<thead>
<tr>
<th>Site code</th>
<th>Nmbr of Stone types</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 02</td>
<td>7</td>
</tr>
<tr>
<td>BI 14</td>
<td>1</td>
</tr>
<tr>
<td>BI 19</td>
<td>2</td>
</tr>
<tr>
<td>BI 21</td>
<td>4</td>
</tr>
<tr>
<td>BI 31</td>
<td>3</td>
</tr>
<tr>
<td>BI 33</td>
<td>3</td>
</tr>
<tr>
<td>BI 34</td>
<td>3</td>
</tr>
<tr>
<td>BI 36</td>
<td>6</td>
</tr>
<tr>
<td>BI 39</td>
<td>6</td>
</tr>
<tr>
<td>BI 41</td>
<td>4</td>
</tr>
<tr>
<td>BI 55</td>
<td>1</td>
</tr>
<tr>
<td>BI 56</td>
<td>1</td>
</tr>
<tr>
<td>BI 68</td>
<td>6</td>
</tr>
</tbody>
</table>

Having identified the manuport subprofiles the complete data set can be combined (Table 9.17) and the following observations made:

1. Sites with cores made on one hardstone type and with mud/mangrove and sand/rubble shellfish species contain manuports of one stone type.
2. Sites with cores made on a number of hardstone types and with shellfish remains from any of the three shellfish remains subprofiles are likely to contain manuports with a variety of stone types.
3. Sites not containing cores but with artefacts manufactured on one hardstone type and only mud/mangrove species have single hardstone type manuports.
4. Sites not containing cores but with artefacts manufactured on a variety of hardstone types and mud/mangrove species contain multiple hardstone type manuports.
Table 9.17 Combined subprofiles for KA-Man-SR sites.

<table>
<thead>
<tr>
<th>Knapped artefact Profile</th>
<th>Shellfish Profile</th>
<th>Man-a</th>
<th>Man-b</th>
</tr>
</thead>
<tbody>
<tr>
<td>KA-a1</td>
<td>SR-b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KA-a2</td>
<td>SR-a</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>KA-b2</td>
<td>SR-b</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>KA-c2</td>
<td>SR-c</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>KA-b1</td>
<td>SR-a</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>KA-b2</td>
<td>SR-a</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

In sum, it appears that sites containing knapped artefacts made on a variety of hardstone types, and either with or without cores, also contain multiple hardstone type manuports. Conversely, where artefacts have been manufactured on only a single hardstone type any manuports also consist of a single stone type. This then raises a question, if a site only contains knapped artefacts made on a single hardstone type will the manuports also be the same hardstone type and thus an unutilised raw material source? To answer this question ArchBase can be searched for specific subprofiles and their artefact/manuport hardstone combinations. Table 9.18 shows the results of such a query based on the Man-a subprofile and there is clearly no correlation of the kind suggested above between stone types. In other words, the manuports do not appear to have been an unutilised raw material source. Likewise a query to obtain information on the relationship between sites with a variety of knapped and manuport stone types did not show any significant correlation.

Table 9.18 Results of a search for a correlation between knapped artefact hardstone types and manuport stone types.

<table>
<thead>
<tr>
<th>Site_code</th>
<th>Artefact hardstone</th>
<th>Manuport stone</th>
<th>Knapped artefact Profile</th>
<th>Manuport Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 14</td>
<td>Silcrete</td>
<td>Och iron</td>
<td>KA-a1</td>
<td>Man-a</td>
</tr>
<tr>
<td>BI 55</td>
<td>Chert</td>
<td>Och iron</td>
<td>KA-b1</td>
<td>Man-a</td>
</tr>
<tr>
<td>BI 56</td>
<td>Silcrete</td>
<td>Och iron</td>
<td>KA-b1</td>
<td>Man-a</td>
</tr>
</tbody>
</table>

The final section of Stage 2 looks at the spatial distribution of sites using MapInfo. The following thematic maps are presented on the basis of individual profiles and their subprofiles (Figures 9.6 through 9.9) while Figure 9.10 shows the distribution of all subprofiles on a single map.
Figure 9.6 indicates some patterning in the subprofiles of SR sites. The location of SR-a sites in the central-west section of Bribie Island is consistent with habitats of mud/mangrove species. Likewise, the single occurrence of subprofile SR-c on the extreme eastern coast is consistent with the distribution of sand/rubble species. Furthermore, as the Island’s eastern coastline is subjected to frequent erosion little archaeological material has been or is likely to be located (Smith 1992:11). Subprofile SR-b also appears to have a loose association with the distribution of shellfish habitats. Certainly the site located at the southern tip of the Island is within reasonable distance of both mud/mangrove and sand/rubble habitats as is the site towards the north-eastern side of the Island.

For KA-SR sites the distribution of the SR-a and SR-b subprofiles is similar to that of sites with shellfish remains only (Figure 9.7). That is, sites with mud/mangrove species tend to be located on the western half of the Island while those with mud/mangrove and sand/rubble shellfish remains are generally located on the eastern side.

For the knapped artefact subprofile of KA-SR sites there does not appear to be any significant patterning in knapped artefact distributions (Figure 9.7). However, it is possible that any such patterns are hidden by the shellfish remains. Therefore, it is necessary to produce a thematic map based on the KA subprofiles only (Figure 9.8) to ensure that any patterns hidden by the SR aspect of the sub-profile are removed. Note that the SR subprofiles presented in Figure 9.7 could have also been shown the same way. By modeling the KA subprofiles in this way some general patterns do become apparent. KA-a1 subprofile sites are located on the southern half of the island, those with the KA-b1 subprofile are more centrally placed whereas KA-b2 sites are situated in the Island’s north-eastern quadrant. Having the ability to extract and model site attribute
data at this level highlights the overall flexibility and control that the AIS provides management and research archaeologists.

Figure 9.6  Distribution of subprofiles for SR profile sites.
Figure 9.7 Distribution of subprofiles for KA-SR profile sites.

The final data sets to be examined for patterning are those associated with the KA-Man-SR profile (Figure 9.9). Shellfish distribution patterns for this profile are similar to those discussed for KA-SR and SR profiles while sites containing multiple hardstone type cores and manuports have a fairly even distribution. Sites with single stone type manuports and multiple hardstone type knapped artefacts have a northerly location. Conversely, the
site with knapped artefacts made on a single hardstone type has a more southerly location. The central section of the island tends to contain sites with multiple stone type manuports and knapped artefacts.

Figure 9.8 Distribution of KA subprofiles for KA-SR profile sites.
Figure 9.9  Distribution of subprofiles for KA-Man-SR profile sites.
Figure 9.10  Thematic map showing the distribution of all subprofiles for the SR, KA-SR, and KA-Man-SR descriptive profiles.
This essentially concludes the discussion of Stage 3 of the interpretive model. Certainly some of the statements made about the spatial distribution of the subprofiles may be somewhat tenuous, particularly given the number of sites involved in some cases. However, the aim of this exercise was to demonstrate the information generating potential of ArchBase both on its own and in conjunction with a GIS. Once the profiles and subprofiles have been generated these can be examined and statements generated concerning:

1. relationships between profiles on an intersite basis and
2. subprofiles and their relationships within a given profile or set of profiles.

Furthermore, the flexibility of the system as a whole has been demonstrated whereby the researcher or heritage manager can either “zoom in” to examine a set of subprofiles based on various attribute sets or “zoom out” to view the overall distribution of sites in a given area.

Finally, these statements provide a stable platform for moving onto Stage 4 of the interpretive model because what has been extracted and analysed to this point are descriptive and measurable values, not vague and often contentious notions of site types or a mix of functional and descriptive categories. Armed with data and information of this type archaeologists *must* be able to begin a functional interpretation of the archaeological record with much greater confidence than was previously possible.

As Stage 4 is concerned with interpreting sites on the basis of inferred cultural function it is outside the overall objectives of this thesis and not discussed here. However, there are other aspects of the database which need to be discussed and these are the subject of the following section.
Further considerations

Apart from manipulating baseline data ArchBase has the potential to assist archaeologists and heritage managers in other ways. While many of the necessary object roles were not included in the data model it is important to recognise that they can be, and ArchBase's functionality further extended.

Heritage management issues

ArchBase can provide heritage managers with a great deal more information than has been discussed to date. Currently ArchBase can

1. extract data relating to the people who have recorded sites, e.g., the number of sites they have recorded, the areas in which they have worked and the reliability of the data they record;
2. identify areas where sites have been recorded and the types of recorders active in those areas, e.g., researchers, students and consultants;
3. monitor and modify a site's management priority; and
4. identify sites facing destruction from environmental and/or human factors and plan for mitigation of this damage.

Additionally, ArchBase could be modified to manage theses, consultancy and research reports, permit applications and photographic records. Digital photographs, site maps and access maps could also be stored as part of a site's recording history and Digital Cadastral Data Bases (DCDBs) could be included in the GIS to provide property details. In fact, much of the management process could be automated by providing site recorders with digital recording forms that could be submitted on a disk or via the Internet to the management authority's server. Likewise, consultants and researchers could have access to specific areas in the database to obtain information for their projects.
ArchBase and existing databases

ArchBase can be linked to pre-existing archaeological bases using ODBC. Many of these databases are likely to contain data sets relating to specific aspects of the archaeological record (e.g., measurements made on knapped artefacts for technological analysis) rather than baseline data. Linking ArchBase to these external data sources could only enhance the information obtained from both ArchBase and the linked database.

Consider a database containing technological data about knapped artefacts. Locational data for each artefact is likely to be restricted to a site ID code rather than sets of grid references. If the site ID is the same as or can be changed to the State ID code, then using ArchBase in conjunction with a GIS it would be possible to geocode each site ID in the artefact database. From this point subprofiles of each site using technological attributes could be generated and combined with other data in AIS to examine technological patterning. This is only one example of how ArchBase could be linked to an external database; many more exist. In fact, for each component/attribute set in the classification system it is likely there either has or will be research undertaken well beyond the baseline level which could be linked to ArchBase either to assist the researcher or to fill in any gaps in ArchBase's data. However, there are other equally important areas in which a system like that presented here can assist archaeological endeavor.

Site discreteness and dots on maps

As indicated previously, two issues requiring resolution in Australian archaeology are measures of site discreteness and the use of dots to map site locations. Essentially both problems suggest that sites exist in isolation. Clearly this is not the case, and by using the AIS potential solutions to these issues can be examined.

When dots are placed on analogue maps, the area covered is determined by the scale of both the dot and map. In a GIS the same problem exists. As point objects have no size
except that determined by the size of the symbol used to represent the point, changes in map scale are not reflected by concurrent changes in a point's symbol size (Figure 9.11). At a scale of 1:2000 the sites contained within the gray box appear close together. However, when viewed at a scale of 1:500 the same sites appear more dispersed. As such, point objects cannot accurately reflect a site's dimensions. This is not to say using points in a GIS should be avoided; indeed, they were employed throughout the discussion of Stages 2 and 3 of the interpretive model. In fact, there are occasions where the use of point objects is not only desirable but necessary. When plotting profiles and sub-profiles or simply viewing regional distributions of sites, the use of point objects will certainly suffice. However, there are situations where the use of polygons is advantageous, particularly when assessing site discreteness.

When a site has been recorded with additional grid references plotting its visible boundaries is a relatively simple task. As no sites have been recorded in this way for Bribie Island the following example is based on an estimate of site BI-09's shape and area. Table 9.19 shows an extract from a query containing the additional grid references for site BI-09.

<table>
<thead>
<tr>
<th>Site code</th>
<th>Easting</th>
<th>Northing</th>
<th>Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI 09</td>
<td>511700</td>
<td>7025500</td>
<td>GIS</td>
</tr>
<tr>
<td>BI 09</td>
<td>511463</td>
<td>7023959</td>
<td>Map</td>
</tr>
<tr>
<td>BI 09</td>
<td>511434</td>
<td>7024542</td>
<td>GIS</td>
</tr>
<tr>
<td>BI 09</td>
<td>511395</td>
<td>7024347</td>
<td>GIS</td>
</tr>
<tr>
<td>BI 09</td>
<td>511400</td>
<td>7024186</td>
<td>GPS</td>
</tr>
<tr>
<td>BI 09</td>
<td>511613</td>
<td>7023959</td>
<td>GIS</td>
</tr>
<tr>
<td>BI 09</td>
<td>511893</td>
<td>7023937</td>
<td>Map</td>
</tr>
<tr>
<td>BI 09</td>
<td>512108</td>
<td>7023990</td>
<td>GIS</td>
</tr>
</tbody>
</table>

By mapping these grid references in a GIS the resulting dots are joined to create a polygon (Figure 9.12) and the differences between using points and polygons to map a site are clearly apparent.
Figure 9.11  Map showing how changes in scale in a GIS map window do not affect the size of point objects but can exaggerate the distances between sites.
While this is the optimal approach it can only be used when the prerequisite data sets exist. There is, however, an alternative method whereby a buffer based on the data recorded for a site’s visible area and its datum are employed. This approach is not as accurate as the previous method inasmuch as it is based on the assumptions that the site is circular in shape and that the datum is located at the center of the site. Referring back to Figure 9.11 it is clear that these assumptions will not always hold. Despite these shortfalls, representing sites using buffers does indicate that a site is not simply an isolated point.

Creating a buffer around a site’s datum involves calculating the radius of a circle whose area will equal that of a site’s recorded visible area and using the result as the buffer’s radius. Figure 9.13 demonstrates the outcome of this process on a selection of Bribie Island sites.

Using polygons to plot sites may also assist in overcoming issues of site discreteness. This is not to say they will provide a solution, only that their use allows for more informed decisions concerning discreteness to be made. Consider, for example, the sites
BI-18, BI-75 and BI-76 (Figure 9.14). Of these sites, only for BI-18 was a visible area recorded. Prior to buffering, the distance between these sites using point-to-point measurements was:

1. BI-18 to BI-75, ca. 100m
2. BI-18 to BI-76, ca. 210m
3. BI-75 to BI-76, ca. 150m

By approximating BI-18's area with a buffer (Figure 9.15) the distance between this and the other sites has been reduced by approximately 60m. Thus the distance between BI-18 and BI-75 is now only 35m. Given this reduction in distance and taking into consideration the area's poor surface visibility, it is possible that BI-18 and BI-75 and possibly BI-76 are part of the same complex. Being able to view sites in this manner provides archaeologists with a different perspective of the archaeological record and allows for more informed decisions concerning discreteness to be made.
Using data like that presented above the validity of defining site discreteness by using arbitrary measures can also be questioned. Surely it is more important to see how sites may be part of a larger complex than to argue that artefact densities or distances between sites reflect isolated and thus differing aspects of prehistoric settlement/subsistence patterns. Certainly, differences in artefacts types and/or density may be indicative of different activities having been undertaken within an area, but this does not mean they
were not part of a larger complex. A concentration of artefacts with a high density in one area does not mean that an area of much lower density 10m away is not part of the same site.

Even employing point objects to map sites on the basis of profiles or subprofiles can produce patterns that indicate a group of sites may be related. Referring back to the SR profiles map (Figure 9.6) it is possible to highlight one very clear indication of a group of sites that may be part of a larger complex. Note the group of six sites located centrally on the island with the subprofile SR-a. As each site has the same subprofile and as the sites appear to be grouped together it may indicate that they are a complex and not individual sites. Such patterns can be further explored by mapping the sites as polygons and/or by undertaking surveys to test this hypothesis.

Discussion

This chapter has provided an overview of the AIS proposed to record and manipulate baseline archaeological data. It has demonstrated how the use of a well-defined interpretive model, a well-designed database and a classification system that eschews the concept of site types can assist and enhance our understanding of the archaeological record. The demonstration indicates that the system as a whole has the potential for recording, storing, managing, manipulating and extracting a wide range of baseline archaeological data.

The applicability of the classification system to record archaeological data in a database environment was tested and the results demonstrate that this approach far exceeds the capabilities of the system currently employed in Queensland. By shifting the recording focus from vague notions of site types to one which describes the material on the ground, archaeologists should no longer find themselves locked in their self-imposed, self-perpetuating classificatory bind.
However, the overall success of the system is reliant upon users working within the framework of the interpretive model. As illustrated in this chapter, the model clearly separates the recording, descriptive analysis and inferential stages of archaeological research into distinct tasks. As such, it not only provides a high degree of freedom when undertaking comparative analysis but also ensures that any results can be questioned, replicated and modified clearly and precisely. In sum, the AIS and presented here represents a complete and viable system for recording and analysing archaeological data.
Chapter Ten

CONCLUSIONS

Chapter 9 concluded this foray into the world of database design, classification and GIS. This Chapter reviews the main arguments and highlights the more pertinent points presented in this thesis. Finally, a plea is made to all Australian archaeologists to recognise the importance of digital data management regardless of their interests.

When I first began exploring the use of GIS in archaeology issues relating to database design and classification had not entered the equation. However, as I delved deeper into the various aspects of GIS it became increasingly clear that database design issues could not be ignored and were in fact, a critical aspect of digital data management. Today more than ever database design has a major role in archaeology, and as my realisation of its importance grew so did my disillusionment with Australian archaeologists' lack of interest in database design issues. Database design is not considered 'real archaeology' in the Land Downunder and it is glaringly apparent that this view is widely spread throughout the Australian archaeology community; this is a somewhat naïve position.

Database design is a critical aspect of any project involving digital data management regardless of whether it is being used with GIS, although this aspect was of particular interest to me. In gaining an understanding of the importance of modeling I also began to comprehend why databases I had previously 'designed' did not function as expected. It was this realisation, and frustration with the EPA database, that drew the focus of this thesis away from issues relating to GIS to those concerning database design and consequently classification.
As indicated, a variety of methods can be used for the design process and the ORM method used here may or may not find favour with other archaeologists. In fact, the particular method employed is of little concern provided the resulting model accurately reflects the real world. Nevertheless, a transparent model similar to that produced using ORM is easily comprehended by all persons with an interest in the project and does not require knowledge of the complexities of normalization. Methods aside, if a data model is to accurately reflect the real world it must be based on a reliable classification system and clearly this was not the case with the systems currently utilised in Australia and in particular, that employed by Queensland’s EPA. It is clear that the present classification/recording systems fail because they are monothetic and contain a mix of functional and descriptive categories. To this end a classification system was designed and presented that:

1. accurately reflected the polythetic nature of the baseline archaeological record and,

2. could be mapped to a data model and thus utilised in a database and GIS.

As demonstrated, by basing the classification system on the components, and their attributes, comprising the archaeological record it is possible to accurately capture the record’s polythetic nature and its high degree of variability. In other words, by using such a system archaeologists are no longer obliged to squeeze their data into monothetically defined site types. Rather, the materials located are recorded and described as they occur on the ground and a site is nothing more than the location of a component or set of components. It was also shown how the classification system could be transformed into a reliable, and functional relational database whose data can be manipulated in many ways depending on the questions being asked. As such, the results obtained from basic queries far surpass the capabilities of the EPA database.
Underpinning the system is an interpretive framework which reliably directs the flow of inquiry when extracting and analysing data from *ArchBase* and other sources. As demonstrated this procedural model is very effective and by following its stages it is possible to extract data that allows archaeological material to be analysed and compared in a meaningful manner with increasing levels of detail. Additionally, the level of detail can be controlled and modified depending on the questions being asked, and this will certainly assist both heritage managers and researchers in obtaining a greater understanding of the archaeological record.

By extracting, manipulating and mapping data based on the materials present at a site, i.e., components and their attributes, rather than often obscure notions of site types, heritage managers can make statements concerning significance and representativeness with a much higher degree of confidence than is currently possible. Likewise, not only will *ArchBase* assist researchers in designing research projects or undertaking comparative analysis it can also be employed to enhance existing data sets.

Despite the advantages afforded by manipulating and analysing archaeological data in databases and GIS it is important to recognise that the results are models, albeit in some cases very sophisticated ones. Certainly these models do allow us to view our data in variety of different ways and often in ways not previously possible; however, they cannot provide definitive answers to research or management questions. Such answers can only come from how we interpret the models.

In many ways this thesis could be viewed as an attempt to ‘drag’ Australian archaeologists and heritage managers into the 21st century and the IT age. Indeed, many of them are likely to be drawn into this era kicking and screaming, unwilling to acknowledge the fact that digital databases are as much a part of archaeology as trowels.
and section drawings. It is no longer tenable to suggest that digital data management and related issues are not real archaeology; they most certainly are.

Certainly the system developed in this thesis should not be considered the final word. As computer hardware and software technology develops so must the way archaeologists use these tools and this in turn will impact on how the archaeological record is recorded and analysed. If we are to fully utilise these tools we must be prepared to continually monitor what we are doing and how we are doing it, and when necessary modify these to take advantage of new developments.

Australian archaeologists have been sitting at a digital crossroads for some twenty years, and the majority have yet to decide which of these roads should be taken. One road is nothing more than a continuation of that so well followed to date, the other is known to the few who have taken up Johnson's (1979:184) initial challenge. The longer we sit at this crossroads the more likely it is we will take the path of least resistance, i.e., the one leading down the old familiar route, classifying sites based on a mix of functional and descriptive categories, making up site types to fit our own perceptions of how the site was used prehistorically and making do with antiquated databases.

If archaeology in Australia is to move forward, then the time has come to stop procrastinating about how we classify, record and manipulate our data by taking the road less traveled. Faced with increasing pressure from developers, heritage managers must ensure that what is being preserved does represent the full extent of the archaeological record. Likewise, as archaeologists continue investigating Australia's prehistory the questions being asked will become increasingly complex and the data obtained will require more exacting methods of management and manipulation. It is therefore imperative that all Australian archaeologists recognise the importance of taking the
correct turn at the crossroads. In this thesis I have suggested one method that will allow this to happen.

To conclude this dissertation I would like to reflect on a meeting of archaeologists that took place in Australia in 1983. The archaeologists present at this meeting included heritage managers and researchers with an interest in the use of databases to manage site records in Australia. They had met to discuss issues relating to Aboriginal site databases. This group identified three major aims of "Aboriginal site data banks": they were an important research tool; they were a crucial management tool; and they were crucial for the protection of data indispensable to Aboriginal people (Sullivan and Bowdler 1984 ix-x). Unfortunately these aims appear to have fallen by the wayside over the ensuing years.

Ultimately, the success or otherwise of the system developed and presented here rests with the archaeological community as a whole. No matter how well the database is designed, how accurately the classification system models the archaeological record, or how many different ways a GIS can manipulate data, if it is not recorded correctly in the field, "garbage in - garbage out."
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