THE *OOSTERLAND* GIS: APPLYING ASPECTS OF GEOGRAPHICAL INFORMATION SYSTEMS TO A MARITIME ARCHAEOLOGICAL PROJECT

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ABSTRACT

The ancestors of Geographical Information Systems (GIS) were first developed in the early 1960's as a computer mapping mechanism but with the development of the Canada Geographical Information System the base was set for a powerful spatial analytical tool that could be used in a wide range of applications from business through to map analysis and archaeology. GIS have been used in terrestrial archaeology with success for a number of years and have started to move into the maritime archaeological field, however, little has been published on the use of GIS in the regard to the latter.

On 24 May 1697, the VOC *retourschip, Oosterland,* was wrecked in Table Bay off Paarden Eiland, Cape Town, South Africa. With its discovery by sport divers in 1988, an ideal opportunity represented itself for the first scientific excavation of a shipwreck in southern Africa. With the development of the project, it was decided that GIS would be applied to surveyed artefacts recovered over the first fieldwork seasons. Early efforts, in 1991 and 1994, set up a GIS for this site that succeeded in plotting and mapping artefact groups selected by the user but failed in creating a system through which advanced spatial analysis could be undertaken. Because of the simplicity of the 1991 and 1994 versions of the *Oosterland* GIS and the fact that the format of analysis was changed from the ARC/INFO to ArcView GIS, it was necessary to re-enter all of the data. This was achieved by creating tables in the Tables feature of ArcView that contained x and y positions for all of the surveyed artefacts. Positioning of artefacts was achieved through a True Basic program that converted on-site tape measurements

into map co-ordinates. Other features included in these tables were artefact numbers, names, a classification and a description of each artefact created specifically for use in this system. Once data had been captured it was plotted and spatial analysis that hoped to test the viability and accuracy of the system was performed. These tests included the orientation of the wreck on the sea floor, and assigning ownership of personal trade items within the artefact assemblage to specific people or areas on board the ship. Tests also examined the position of artefacts whose place on the working vessel were known from historical documentation and related them to other artefacts present in their immediate neighbourhoods.

This system appears to posses the potential for being a powerful analytical tool which can be easily updated to include more advanced analysis and adapted to incorporate other wreck sites. Finally, this system has enormous potential as an educational tool that can be used to raise awareness of the importance of historically significant wrecks.

continents or across oceans. As the expansion of the known world took place, a greater demand for more accurate maps and charts became evident (Hale 1966:61). Chart makers of the time needed to create the best possible maps for use by sailors and other navigators. Maps were a mixture of navigational and social information for travellers making them not only representations of the physical environment, but also social documents. This expansion was possibly one of the most important events in the history of map making. Large sums of money were invested in voyages and European governments were eager to lay claim to newly discovered lands. Because of this, advances in navigational instruments were rapidly made and this allowed significant advancements in surveying of land masses and sea routes. The chart-makers drew on knowledge from every source available, from the maps produced by ancient Greeks mariners and the early concepts of latitude, longitude and a round world devised by Ptolemy, to the accounts of land surveyed by the new explorers. The problem with these early maps was that the detail concerning features present along coastlines could only be mapped in term of latitude and by short line of sight calculations by surveyors on board the ships. It was up to map makers to put all the information together to create maps that covered the coastlines of the world piece by piece. One of the main problems facing navigators of the time was the absence of a timepiece that could accurately keep time from the place of departure for long sea voyages, despite the constantly changing periods of heat and cold, wet and dry. A second problem faced by map makers was the task of displaying a round world on a flat surface. After some experimentation, a Flemish scholar, Gerhardus Mercator, devised the first practical solution the map projection. The maps that he produced using the Mercator projection system were amongst the most accurate of the time and the Mercator projection is still used in map making today (Hale 1966:70). Finally, it would seem that map makers on analogue or hard copy maps, it was possible to store data in a computer format. This meant that maps could be produced more quickly and that any changes or updates could be easily performed. Digital map storage also allows for more information to be added to a map set. For example, it is possible to create separate layers for every feature represented in a particular area and to overlay the required features to suit the type of map being produced. Features can be selected or deselected to suit the function of the map.

As maps have become more complex in terms of features, more specialised in terms of user groups and more simple to understand, they have become a means by which to analyse landscapes rather than just a tool for positioning people, places and features on the earth's surface. Maps are now used to test the viability of building development, recreational areas, roads, distributions of features, prediction of feature locations, route analysis etc. In order to perform these functions, through the use of quick digital mapping as opposed to the manual analogue systems, one final step had to be taken to make the process possible. This step was to create software and hardware that can handle spatial data and perform spatial analysis on those data. With the realisation of this Geographical Information Systems came into being.

The development of the first true Geographical Information Systems (GIS) in the 1960's opened the way for cartographic and spatial data analysis systems that go beyond the boundaries of mere mapping. The original concept of GIS was that they would be used as a means of analysing and monitoring land development and spatial data connected with large tracts of land, cities and towns. The systems have developed a great deal over the past 30 years and GIS, their mapping and their spatial analytical on analogue or hard copy maps, it was possible to store data in a computer format. This meant that maps could be produced more quickly and that any changes or updates could be easily performed. Digital map storage also allows for more information to be added to a map set. For example, it is possible to create separate layers for every feature represented in a particular area and to overlay the required features to suit the type of map being produced. Features can be selected or deselected to suit the function of the map.

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Despite the prevalent use of GIS in archaeology, most of the work that has been undertaken to date concentrated on terrestrial sites. Relatively little has been done to apply this technology to the maritime or underwater areas of the discipline and where work has been done, the results have not been published or made accessible to the general public. It is for this reason that this project can be seen as important in the context of maritime archaeological studies specifically, but also to archaeology as a whole.

The primary aim of this project is to create a GIS that can be used on a maritime archaeological site and test its worth as an analytical tool. Firstly, the study will give an overview of the development of GIS as a whole.

Because GIS technologies are in their infancy, there have been difficulties in defining the systems as being different from other mapping software. In the first part of Chapter 1 these issues will be addressed in an attempt to define the base criteria needed for a package to be classified as a GIS. Once the model has been examined, different definitions of GIS will be investigated in an effort to move closer to an encapsulating definition that includes all of the views and needs expressed. The arguments presented here will also examine the reasons why certain packages that present themselves as GIS can not be considered as being so. Once the criteria for GIS have been established, it will become possible to trace the predecessors of the systems and their development into what exists today and give a brief history of the development of GIS. Finally, Chapter 1 will briefly investigate the use of GIS as archaeological tools by looking at some examples in use on terrestrial and maritime sites.

Chapter 2 becomes specific to the site in question, the wreck of the Dutch East India Company ship, *Oosterland*. Because of the importance of knowing something about the ship itself and the social, political and economic context in which the vessel existed, this undertaking will look at the history, wrecking and discovery of the ship. This chapter will look at the history of the wreck under investigation, including the state of the Dutch East India Company (VOC) at the time and voyages which the ship undertook. The chapter will examine the last voyage of the *Oosterland* in some detail and the wrecking of the vessel on 24 May 1697. Following this, a brief summary of the discovery of the wreck and the subsequent project planning will be examined.

Chapter 3 deals specifically with the implementation of the ArcView GIS and its application to the *Oosterland* site. This part of the study is more specifically related to the creation of a GIS that can be applied to a maritime archaeological site. The chapter will deal with early attempts at creating a GIS for use on maritime sites and then describe how the process of setting up this project took place. It will describe the manner in which data were captured and entered into the system, including the conversion of on site data into computer readable files, incorporating the artefacts, their associated data and the conversion from on site tape measurements to map co-ordinates. This chapter will also look at the associated problems encountered while creating this GIS.

The system will be tested by asking relevant archaeological questions dealing with spatial distributions of artefacts on the sea floor in an attempt to check the manner in which the system can deal with these types of problems. The solutions derived from the use of the system will be given in the light of the internal organisation of a 160 foot VOC *retourschip*. In the process of answering these questions, a short description of the ArcView functions that have been used will be given so that the project can be easily accessed by future users and in future research. This will also include the processes involved in the actual creation and set-up of the *Oosterland* GIS, using ArcView and Arc/Info software.

It should be noted that the purpose of this project is not to undertake a complete spatial analysis of the artefacts recovered from the *Oosterland*. Instead, the analyses presented here are merely a means of making preliminary observations on spatial distribution in an effort to test the viability of the system. The aims of the study do not include making conclusive spatial analytical arguments. The results presented here are part of the process of testing the viability, validity and significance of the system. The results of the questions asked of the system, although interesting, cannot be seen as being definitive in any way for a number of reasons, including the fact that the site has not been fully excavated to date and as more artefacts are recovered, updated data may show different results to those offered here. What the results will hope to show is that the system created can be used to do meaningful spatial analysis on a wreck site. Finally, Chapter 3 will give a brief summary of how the GIS might be used in the future. Some suggestions will be made regarding ways in which it could be improved and ways in which it can be adapted for use on other archaeological sites both in South African waters and abroad.

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1. GEOGRAPHICAL INFORMATION SYSTEMS

Many of the daily decision-making processes that face humans are related to space and the interaction that take place with and within that space. In an effort to deal effectively with a complex world of which very little can be physically seen, humans have developed a system by which data relating to the world around them can be represented symbolically in a simple, universally understandable manner. These representations are called maps. They contain varying amounts of detail or data regarding features that exist in the environment and assist in daily decision making related to the world around us.

Data elements represented on maps are commonly called spatial data. Each element has the distinction of occupying a unique location on the earth's surface. Each of these locations can be defined using co-ordinate systems, such as latitude and longitude, distances, depths and heights. Over time, humans have created increasingly complex and accurate means of measuring the co-ordinates of objects on the earth's surface. The scientific advances in geodesy and surveying have meant that any part of the globe's surface can be located to within an astounding degree of accuracy (Peuquet & Marble 1990:1). Following the development of more accurate measuring systems is the practice of creating more accurate and detailed maps. Maps have moved out of the realms of being merely a means of locating an item or finding a direction into the terrain of analytical use. Maps can be used for determining land ownership, environmental assessment, military applications and other commercial and governmental purposes (Peuquet & Marble 1990:2). It is unfortunate, however, that many maps contain only limited data sets, such as roads or vegetation types, which are dictated by the specific purpose for which they are produced. Few maps contain complex series of different data sets, one over the other, for the simple reason that each set would obscure something of the set below it. This problem is easily managed with smaller and fewer data sets, but as the questions being asked of the map become mere complicated and more varied, it becomes less and less elementary. Analogue maps, those maps which are represented on paper rather than on a computer screen, also make spatial analysis a time-consuming and difficult task. For example, if an organisation wanted to build a large building on flat ground, close to a road system in a mountainous area, it would have to build up two data systems. One would have to show the size and distribution of the potential sites, i.e. the flat areas. These would have to be individually examined in order to locate the sites that could support a building of the size required. Secondly, a data set that incorporates the proximity of the roads to the site would have to be created. This would also have to be studied in order to locate roads that fall within the required distance of the sites that could be used. Only after this could a site be selected. This is only a basic example but it does illustrate the types of problems that may arise in such spatial problem-solving. The example also illustrates how this type of spatial analysis takes place on a day to day basis (Peuquet & Marble 1990:2).

Over the past twenty years, technological advances have allowed new types of computerised spatial data handling systems to be developed. These systems are known as Geographic Information Systems (GIS). These systems have developed considerably since their inception in the mid 1960's and have become powerful tools in the analysis and interpretation of the earth's surface and the spaces in which people live (Peuquet & Marble 1990:3). These systems make the analysis of complex spatial data both an attainable objective and accurate. GIS have enjoyed massive growth and increasing popularity and have become an important tool for many people: from planners and explorers, to the business community and financial analysts. GIS represent a new field, the potential of which has not been fully explored. Because of continuous development it has been impossible for its users to agree on any definition of a GIS. Despite this, several textbooks on the subject have been written, but these cannot incorporate the rapidly changing aspects of these new analytical tools (Maguire, Goodchild & Rhind 1991:5).

1.1 TOWARDS DEFINING A GEOGRAPHICAL INFORMATION SYSTEM

The use of computers in the handling of geographical data has been allowed to advance as computer technology itself has advanced. The impetus for the move from the analogue handling of spatial data into the digital world has experienced a "push and pull" effect (Peuquet & Marble 1990:5). The fact that large amounts of computer based geographical data can be easily stored and quickly retrieved with mechanical accuracy, has had a push effect on the development of this kind of mapping system. Furthermore, the physical storage space of the digital map is small when compared to that of the analogue map. The use of computerised maps also allows for the performance of quicker and more complex analytical operations. For example, the computer can handle many large data sets at once without the problems of overlay distortions and masking. Computer or digital maps also have an advantage over their analogue counterparts in that they are cheaper and easier to update when new information becomes available (Marble 1990:9). At the same time, there has been a pull towards the handling and analysis of geographical data with the use of computers because most of the new data available are collected in digital form. Advances in data capture techniques, such as the development of remote sensors, means that raw data are collected digitally and can be directly accessed via computer (Peuquet & Marble 1990:5). The popularity of the GIS has also been increased because of its capability of linking attribute or reference data that could not be displayed on an analogue map to a specific feature. The feature can take the form not only of a Cartesian point i.e. a location referenced to latitude and longitude, but also an area or polygon such as a town or landscape which encompasses other attributes. Having locational data implies that each separate location can be linked to others. In a world in which temporal size is continuously diminishing, it is important that data sets can be compared and tested over regions that can be associated to one another in this way (Maguire 1991:14). Remote sensing, market and population surveys, topographic surveys and other advancing data collection techniques are adding to our culture and environment every day. The development of GIS and locational attributes means that all these data can be stored, retrieved and used in ways that were not previously available.

The Geographical Information Systems have been created out of this move from analogue towards digital mapping systems. Although a GIS can be both manual and digital, modern technology has ensured that most are now in the digital or computer format (Maguire 1991:10). Defining exactly what they are, however, is problematic. In order to describe what a GIS is and how it can be used, it is perhaps necessary to look at information systems in general and then examine how GIS is different from the others.

If information systems could be defined by task alone, it would be possible to divide them into two distinct groups. The first of these groups would contain the information systems used in banking systems or restaurant billing systems. These types of information systems are transaction processing systems (Maguire 1991:10). The second type of information systems are those involved with decision support. Here the emphasis is on manipulation, analysis and modelling of data to support decision making. The system needs to be retrieval orientated and flexible. The applications of this type of system range from tactical warfare to civil engineering. Geographical Information Systems make use of both types of information systems but are more firmly based in decision support.

There have been many attempts at defining GIS. Most of the definitions depend largely on the user and what he or she is trying to apply the system to. Table 1.1.1 below gives some examples of the many definitions in existence.

Table 1.1.1 Definitions of a Geographical Information System. (After Maguire 1991:11)

A system for capturing, storing, checking, manipulating, analysing and displaying data which are spatially referenced to the earth (DoE 1987).
Any manual or computer based set of procedures used to store and manipulate geographically referenced data (Aronoff 1989).
An institutional entity, reflecting an organisational structure that integrates technology with a database, expertise and continuing financial support over time (Carter 1989).
An information technology which stores, analyses and displays both spatial and non spatial data (Parker 1988).
A special case of information systems where the database consists of observations on spatially distributed features, activities or events, which are definable in space as points, lines or areas. A GIS manipulates data about these points, lines and areas to retrieve data for ad hoc queries and analyses (Dueker 1979).
A database system in which most of the data are spatially indexed, and upon which a set of procedures is operated in order to answer queries about spatial entities in the database (Smith et al. 1987).
An automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation and display of geographically located data (Ozemoy, Smith and Sicherman 1981).
A powerful set of tools used for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world (Burrough 1986).
A decision support system involving the integration of spatially referenced data in a problem solving environment (Cowen 1988).
A system with advanced geo-modelling capabilities (Koshkariov, Tikunov and Trofimov 1989).
A form of MIS [Management Information System] that allows map display of the general information (Devine and Field 1986).

In their attempt to define GIS and separate them from other types of information systems, the above definitions tend to gravitate towards four different views or approaches to GIS. The first of these is a function- or process-orientated approach. This focus tends to highlight the information handling properties of the GIS. A second view or approach to defining the systems is an application approach. This focuses on the applications of the information systems and the problems they attempt to solve. In other words, a GIS is different from other information systems only in its problem solving capabilities. One of the most widely used approaches to defining GIS is to look at and emphasise the generic aspects of the system or what the system can do. This is known as a toolbox approach. Finally, there exists a database orientated approach to defining GIS. Definitions given by Smith et al. and Dueker above are illustrations of this type of approach. This is the most popular method of describing GIS because of the close links between other database systems and Geographical Information Systems (Maguire 1991:11).

Although the above approaches highlight the differences between aspects of function and user needs, they do all contain a common thread that makes a GIS unique from other information systems, namely that a GIS deals with geographical data. Geographical data can be divided into two data elements. The first of these, physical geographical data elements or locational elements, are the tangible elements in the landscape such as roads, rivers, enclosed areas etc. They can be defined as points, lines and polygons. These act as reference points for a second data element, the attribute, statistical or non-locational element (Maguire 1991:11-12). These second data elements contain further information about the physical geographical elements. For example, boundaries could be used to contain vegetation types, lines could be used in the examination of traffic flow along roads and points could be used as references in the inspection of elevation. In GIS, the physical geographic data elements are seen as more important than the attribute elements and it is this fact that goes some way to separating them from other information systems (Maguire 1991:12). It should be noted, however, that the attributes of the feature, or the non-locational elements, are not ignored and are often used in the analysis of geographic data.

Further problems in defining GIS arise out of the fact that many systems that do not contain the properties needed to be a true GIS are often proposed as being so. For example, Computer Aided Design or CAD, database management, remote sensing and computer cartographic systems are often called GIS. All of these, however, lack certain elements. Although CAD has been designed to create and define objects in space, its analytical power is limited and it has poor links with database systems. CAD can work only with relatively small data sets and has little ability to assign user defined symbology automatically to a given field. The same can be said for computer cartography. Although these systems have outstanding display capabilities, they possess little in the way of analytical tools (Maguire 1991:12). Database Management Systems (DBMS) are powerful tools in data capture, storage and retrieval but lack the display powers and analytical capabilities that are needed in GIS. The same is true for the remote sensors. Although this system is the closest to GIS in that it has the ability to collect, store, retrieve and graphically spatial display data, it has difficulty handling data not in the raster format (see Table 1.1.2.) Since analytical examination of spatial data tends to take place in the vector format (see Table 1.1.2), remote sensing falls down in its analytical capabilities. It should be noted, however that all the systems mentioned above predate the GIS and that GIS have evolved from these systems (Maguire 1991:13).

Table 1.1.2 The difference between Raster and Vector data (After ArcView Spatial Analyst, ESRI 1996:36).

Vector data represents geographic features and variation as point, line or area objects that that specify location or boundaries and stores information about the objects.	Raster data represents geographic features and variation by dividing the world into discrete squares, called cells, for which a value is stored. Each cell knows its location implicitly from the origin point and its location relative to this origin. The exact location of each cell is not stored, just the origin, cell size and number of cells from the origin.

Examining what these other information systems posses and what they lack makes a definition of GIS easier. The GIS must contain the features mentioned above and also something extra. Data display and capture are not the only defining characteristics of GIS. A powerful and easily defined analytical component must also necessarily exist within the system and this is the most prominent omission from the other systems mentioned here. For some users it is only the ability for spatial analysis that separates the GIS from other information systems (Maguire 1991:13). If the other systems are examined and compared both with each other and with the GIS, it is possible to note that all features are shared between at least two of the systems, except for the spatial searching, overlay and analytical features which are unique to the GIS (Maguire 1991:13).

There are three different views on the way in which GIS can be defined. This is supported by the definitions presented in Table 1.1.1 These three elements have all been suggested as being the defining components of the GIS. They are: mapping, database and spatial analyst views (Maguire 1991:14-15). It should be noted, however, that none of the practitioners of these views sees them as mutually exclusive. Instead, they are defined by the user and the needs and outlook of the user. Different views can be adapted or combined to suit each individual project.

GIS need four basic units to operate. These elements are hardware, software, data and a user (Maguire 1991:15). As GIS packages have been refined, hardware has become more varied. It is now possible for GIS to operate on all computers, from PC's through workstations to mainframe computers. Peripheral hardware that may be required for the establishment of a GIS include scanners, digitising equipment, printers and plotters. These may not be essential to the operation, manipulation and analysis of data, which takes place at the computer itself, but are often needed for data input and output.

There are several different types of GIS software available. These packages fall into three main design areas, namely:

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File processing designs such as IDRISI, which store each data set and function separately and link them only during analytical operations.

Hybrid designs such as ARC/INFO, which store attribute data in Database Management Systems (DBMS) and use separate software for geographical data and analytical functions.

Extended designs which store "...both geographical and attribute data in a DBMS which is extended to provide appropriate geographical analytical functions" (Maguire 1991:15). Examples of this type of design include SYSTEM9 and TIGRIS.

The third important operational building blocks of GIS are data. Data collection can take the form of remote sensing, physical measurement, surveys or any other means that gives the data some kind of geographical or spatial positioning, be it a point, a line or an area. This aspect of GIS is often the most expensive part of the overall process. The collection of data may involve a large part of any projects budget. It is often time consuming yet essential to the operation. The energy spent on this part of building a GIS is often overlooked in the planning stages (Maguire 1991:16).

Finally, there is the user; the person who designs, implements and uses the GIS. It is unfortunate that, although the potential of GIS has been recognised, there are few people trained in its use. The user is the vital link between the three other building blocks. He or she regulates and controls the GIS as well as creating questions for it to answer and problems for it to solve (Maguire 1991:16).

In order to create a definition of Geographical Information Systems it is necessary to look at the components vital to its makeup and thus it is essential that the above be borne in mind when creating that definition. In searching for a definition it is also necessary to look at its applications. These will be discussed briefly here and illustrated with hypothetical examples. A more detailed examination of GIS applications will be considered later in this chapter.

There are six basic questions that can be asked of the GIS:

Location: this asks the question "what is at...?". For example, it would be possible to ask the question: "what is the density of schools in a given area?". This queries the types of features that occur at a point, along a line or within an area.

Condition: this looks at the problem in reverse. For example, the question would state: "where is all the housing that lies within 5 kilometres of a school?". This question revolves around "where is it...?"

Trend: this asks the question: "what has changed...?". It examines changes that occur at any given location over a period of time. In the school example used above, this type of question might examine the changes in numbers of pupils at the schools from year to year.

These are the simpler questions asked of a GIS. They examine static features in the environment and do not require any complex spatial analysis. These questions tend to ask the GIS about attribute data of specific locations, both of themselves and within larger locations (Maguire 1991:16). The questions related to trend tend to become more advanced. This occurs when the element of time is added. The questions can become more complex and extend to include: "where and when did change occur?", "what types of change occurred?", "what is the rate of change?" and "what is the

In 1984, Crain and Macdonald developed a threefold theory of the evolution of GIS (Crain & Macdonald 1984). They believed that the initial drive in the creation of GIS was to answer questions about the inventory of the data sets contained in the systems, rather than to do any true spatial analysis on those data sets. For example, an inventory of land use could be created to include forests, farming land, towns, scrub, etc. Users would ask the GIS questions of location and condition such as: "what is the size of the area that can be used for farming?" or: "what land falls within 1 kilometre of a river?". Phase two of the evolution saw the user begin to ask more complex questions such as about the suitability of land for a specific purpose. These questions take in the more complex areas of condition and trend as discussed above. They require access to several layers of data and rely on statistical tools and spatial analysis. The final stage of GIS evolution makes use of Rhind's routing, pattern and modelling questions. These advanced types of GIS are used in decision making processes and decision support. They allow the user to take into account a variety of factors affecting the outcome and, in turn, allow the user to make certain hypothetical predictions of change and factors that may effect a particular outcome (Maguire 1991:17). A summary of this evolution is given in Table 1.1.3 below.

Table 1.1.3 Three stages of GIS evolution (after Langran 1993:5)

Stage	Input	Analysis	Output
First	ad hoc, in house digitisation	none; stores and retrieves digitised maps	hardcopy; goal is to replicate existing products
Second	centralised data capture, data exchange	single state analysis, static modelling	interactive softcopy graphics; successful replication of existing products
Third	incremental updates, dissemination of change data	multi-state analysis, dynamic or predictive modelling	animated graphics, multi-temporal maps, new product designs

In summary, a GIS has to be able to perform a variety of fundamental functions. It must be able to store a complete overview of the location under investigation, as well as all the features within that location i.e. it must be able to keep an inventory. Together with this, it must be able to cope with changes in the physical world and in computer storage. Secondly, it must be able to perform functions that can explain, manipulate and forecast outcomes that result from processes in any particular study area. In other words, it must be able to perform analysis. A GIS must also be able to cope with updates of out-moded information with new information. Fourthly, through quality control, a GIS should be able to determine whether new information is consistent with existing data states or versions. A GIS should be able to schedule database states which trigger a predefined system response. Finally, a GIS should be able to display data through static or dynamic maps or tabular summaries that reveal processes, activities taking place in, and information about the study area (Langran 1993:5-8). These functions are only performed in the most advanced stage of GIS evolution as defined above.

It is now possible to create a definition of a GIS. A Geographical Information System is an information system that includes mapping, database and spatial analytical links and tools. Although many of its components overlap into other types of information systems, such as CAD and remote sensing, it includes powerful spatial analytical features and tools that are unique to GIS. It can answer various types of question involving location, condition, trend, routing, pattern and modelling. The ability to answer these questions depends largely on the stage of evolution of the GIS. The more fully evolved the system, the more complex and analytical the tasks. A GIS needs four basic "building blocks" in order to exist. These are hardware, software, data and a user. A GIS needs to perform certain functions including inventory, analysis, updates, quality control, scheduling and display. Most importantly, it must be based geographically, i.e. it requires a locational reference.

Marble (1990:10) realises the vast potential application of GIS. He states that despite the diversity of the applications, from forecasting potential market areas to gathering oceanographic data off the Newfoundland coast, all the GIS have certain characteristics that are shared. He summarises the major components as follows:

A data input subsystem which collects and/or processes spatial data derived from existing maps, remote sensors etc.

A data storage and retrieval subsystem which organises the spatial data in a form which permits it to be quickly retrieved by the user for subsequent analysis, as well as permitting rapid and accurate updates and corrections to be made to the spatial data.

A data manipulation and analysis subsystem which performs a variety of tasks such as changing the form of the data through user-defined aggregation rules or producing estimates of parameters and constraints for various space-time optimisation or simulation models.

A data reporting subsystem which is capable of displaying all or part of the original database as well as manipulated data and the output from spatial models in tabular or map form. The creation of these map displays involves what is called digital or computer cartography. This is an area which represents considerable conceptual extension of traditional cartographic approaches, as well as a substantial change in the tools utilised in creating the cartographic display.

(After Marble 1990:10)

Marble argues further that all of these four criteria must be met and performed efficiently if any software system is to call itself a GIS.

1.2 THE DEVELOPMENT OF GEOGRAPHICAL INFORMATION SYSTEMS

It is possible that the manual predecessors of the computer based GIS had been in place for at least one hundred years before the first automated versions appeared in the 1960's. Unfortunately, little research has been carried out as to the origins of the Geographical Information Systems. Although a thorough search of government archives and the examination of the records of organisations involved in the production of GIS would probably yield a great deal of information on the subject, no-one has yet attempted such a project and at least one of the major GIS producers will not allow any outside research into its records (Coppock & Rhind 1991:21-22). Further problems with the study of the history of GIS arise in the fact that the earliest users and developers, such as people involved with government agencies and the military, tend not to be the types of people who would write books or articles documenting their successes and failures. Even the academics involved in the earliest developments in GIS were often not mainstream academic staff and had little time for the publication of results. It was not until 1974, when the first GIS specialist conferences were held, that information began to become more accessible. Even so, information concerning GIS was difficult to come by, particularly as many of its developers opted to "go it alone" rather than join with others and share information (Coppock & Rhind 1991).

The study of the origins of GIS is also hindered by the definitions of a GIS. As discussed previously, many ideas differ substantially. The importance of the spatial analyst capabilities of the modern systems can also be misleading. Early GIS would not have had much in the way of analytical power. In fact, it was not until the 1980's that true spatial analysis could be effectively performed using computer systems. Because of these definition problems at the early stages of development, it is perhaps better to define a GIS as "any system for handling geographic data" (Coppock & Rhind 1991:22), for the purposes of this historical examination.

In order to understand the growth and development of GIS, it is necessary to look briefly at the predecessors of the system. Because so little was written on them at the time, the earliest developments towards a true GIS are difficult to determine. What is clear, however, is that certain factors forced or inspired the development of GIS. These factors are far ranging and cover all aspects from academic curiosity with new data handling techniques, through the desire to speed up and automate operations performed on spatially referenced data, to a necessity to complete tasks that without the help of computer based systems would not be possible (Coppock & Rhind 1991:23). An example of the latter was experienced by the publishers of the Atlas of Great Britain and Northern Ireland (Bickmore & Shaw 1963 in Coppock & Rhind 1991:23). By the time the atlas was made available, it was criticised for being not only difficult to handle but also to be out of date. The enormous expense of producing such an item and the great length of time taken to gather, consolidate, analyse and display the data meant that an alternative production method needed to be found. This method of producing maps needed to also contain the ability to check, edit and classify information, as well as being able to model and experiment with spatial situations (Coppock & Rhind 1991:23). As a further example of the logistical problems facing the analogue map makers, it is possible to examine the situation faced by Canadian government agencies in 1965. It was estimated that it would take three years, 556 technicians and $Can 8 million at 1965 prices to overlay the 1 : 50 000 scale maps of the Canada Land Inventory. From this type of example it becomes clear why GIS development was forced to evolve (Coppock & Rhind 1991:23).

From the 1960's until the 1980's, most of the major developments took place in North America (Coppock & Rhind 1991:23). When IBM introduced a computer that had a memory 23 times greater and a speed 400 times faster than its predecessor, the developers of information systems could take a giant leap forward. Although this type of technology was only available in academic and government institutions, it allowed people to recognise the power of computer aids in the management of land use and land title data. This is noted by Cook and Kennedy, who saw that by 1966 the District of Columbia had already established a land data bank and that Nassau County in New York was developing the first fully automated access to records of land ownership (Cook & Kennedy 1966 in: Coppock & Rhind 1991:26).

The government impetus and interest in the design of GIS predecessors was doubtless a means by which the technology could be advanced. The US Bureau of Census, for example, had designed an automated system (DIME) that matched address data to geographical data in order to make locational sense of the information that was being gathered by census surveys (Coppock & Rhind 1991:26-27). While government approached the problems that faced them as administrators, universities, who were gaining access to more powerful computers, were making advances in the field of academic geography including the new field of spatial analysis (James & Martin 1978; Hudson 1979 in: Coppock & Rhind 1991:27). Spatial analysis was beginning to gain popularity because for the first time geographers could model spatial data and treat them statistically. These were, of course, abstract concepts. The graphic display abilities of computers were limited, although attempts at using plotters to display data were made. It would not be until the middle to late 1980's that spatial statistics could be coupled with geographic displays. Because of the problems encountered with graphic display, many of the early developments were merely attempts to make computers mimic manual processes such as drawing maps. These were very successful in their purpose and produced maps almost indistinguishable from their manually produced counterparts. (Coppock & Rhind 1991:30).

The need for better display capabilities that came with research into computer mapping in the 1960's led to the creation of the Harvard Laboratory for Computer Graphics in 1965. Here, graphic capabilities of computers were expanded to include the use of line printers as a means of displaying maps generated by computer. This meant that advances such as the overlaying of maps could follow. The Harvard Laboratory for Computer Graphics was undoubtedly the influencing factor behind many of the long term GIS developments that would follow.

It was at about the same time as the inception of the Laboratory that Tomlinson, the father of GIS, began the development of the first true GIS: the Canada Geographical Information System (CGIS) (Coppock & Rhind 1991:28; Bernhardsen 1992:27). The CGIS was initiated when the Canadian government realised that the land resources of Canada were not limitless. Growing rural populations forced the government to set up a committee to study land use in Canada and pass what would eventually become the Agricultural and Rural Development Act (Tomlinson 1990:18-19). The problem that then faced the government was re-mapping Canada and all the various types of land use. In order to acquire sufficient detail on these maps so that they would be of use, both nationally and regionally, meant that they had to be of scale between 1 : 20 000 and 1 : 250 000. As mentioned above, the cost of producing maps and the time expended on the process would be enormous were the government of Canada to follow conventional map making practices. Tomlinson also points out that in a country the size of Canada it would take about 200 maps at 1 : 250 000 scale and 3 000 maps at 1 : 50 000 scale to cover the area (Tomlinson 1990:19). Clearly some alternative had to be found.

At this time, advances in computers meant that they were becoming faster, more reliable and capable of storing more data. Developers at IBM were also beginning to develop methods of digitising aerial photographs and were therefore interested in the problems that faced Canada in putting maps into a computer or numerical format (Coppock & Rhind 1991:29). Although the concept of numerical expressions of lines and the digitising of maps was not new, the concept of linking different sets of map data was (Tomlinson 1990:19). Once these links had been made, the computer could analyse the data on natural resources for a country or even a continent and help make meaningful decisions for strategies for the management of the natural resources.

Tomlinson was faced with numerous problems. The computers that were available were slow, extremely expensive and peripheral hardware, such as digitising tools and scanners, were inadequate. Storage capabilities were limited, tape being the preferred medium. Technical experience and knowledge of creating digital maps was limited and many of the programmers, working with extremely cumbersome computer languages, were employed by the computer companies themselves. "No one was trained in digital spatial data handling" (Tomlinson 1990:20). Despite these setbacks, by the end of the 1960's, the CGIS was operational and able to perform everyday tasks efficiently and accurately. Methods were developed so that attribute data could be quickly entered into the system and stored separately from the line data, efficient raster-vector conversion techniques were created and "automatic topological coding and methods for detecting topological errors in the polygons were [assembled]" (Tomlinson 1990:20). The system allowed users to link together smaller maps to build up a complete, edge to edge, map system of the entire country. This linking included the attribute data associated with each map (Tomlinson 1990:20-21). The CGIS had almost all of the traits seen in a modern GIS but experienced several setbacks. Graphic display was poor, a problem associated with hardware available at the time. The system was also limited in its ability to handle lines and points and lacked interactive capabilities (Tomlinson 1990:21).

It should be noted that the CGIS was not the only development taking place at the time. The US Bureau of Census continued the development of it's DIME system, as discussed above (Tomlinson 1990:21). Developments were also being made in the United Kingdom and continental Europe. For example, pioneering work in automatic cartography, such as the Oxford Cartographic System's AUTOMAP, was revolutionising map creation. As the potential of automated mapping systems and GIS began to be realised, governments took greater interest in their development. The high cost of entering the field meant that most of the universities could not compete or did not see the need to compete. There were, of course, a few exceptions including the Harvard Laboratory of Computer Graphics, the Experimental Cartography Unit at the Royal College of Art in London and the University of Michigan's Geography Department. Despite high costs, the scientific community began to take a more active interest in GIS and in 1968 the International Geographic Union established the Commission on Geographical Data Sensing and Processing. This body played a major role in the dissemination of knowledge and information about GIS throughout the next decade (Tomlinson 1990:22).

In the 1970's, cheaper, better computers and associated hardware became available to a larger number of people. GIS moved from being solely the domain of central government into local governments, universities, and other research agencies. Together with this increase in the potential markets for computers and GIS, governments had begun to realise the importance of land management to a degree that had not been seen before and, as a result, began passing legislation regarding management. This meant that there were practical advantages to creating, developing and running GIS applications (Tomlinson 1990:22-23).

Commercial companies such as ESRI, GIMMS, Synerco, Systemhouse and others began to produce off-the-shelf software that was well-supported. These packages and their analytical functions, however, did not expand on what had been produced in the 1960's. Despite advances in hardware, software underwent consolidation rather than innovation during the 1970's. It was a decade of increasing the numbers of trained personnel and university students who were computer literate (Tomlinson 1990:23).

During the 1980's and 1990's, the demand for GIS capabilities continued to grow (Tomlinson 1990:24). The systems moved out of the arena of governmental and research application and into business. They have spread and continue to be developed all over the world, from the USA to Europe, Africa and Asia. Coupled with this increase in demand for spatial analytical capabilities are the developments in computer hardware and software. Despite these advances, there are still problems associated with GIS, such as converting graphic data to machine readable formats but as technologies advance, steps are being taken to overcome these obstacles (Tomlinson 1990:25).

1.3 GIS AS ARCHAEOLOGICAL TOOLS

GIS have been used for a number of years in archaeology. Work has, however been concentrated in terrestrial applications. Maritime archaeology has also made use of the system but to a much smaller degree. There is no lack of interest from the maritime archaeological community in GIS as an analytical tool and the apparent dearth of information should not be viewed as an indication that little work has been done using the system. It merely means that very little of the results have been published or made publicly available. Because spatial distributions of artefacts is one of the central themes of archaeological analysis, GIS are perfectly suited for use in the field. The problems associated with manual spatial analysis and the time consumed in doing so can be greatly decreased with this new technology and the study of inter-relations between sites and the artefacts that they contain can be accurately assessed and processed. In the following section some of the GIS applications that have been used in archaeology will be discussed. An examination of as wide a range of applications has been selected in order to illustrate the power of the systems and the variation that can be achieved.

1.3.1 GIS IN TERRESTRIAL ARCHAEOLOGY

GIS are well suited to archaeology in that they can process large amounts of similar and different data from smaller individual data sets. They have been used in various ways in terrestrial archaeology. On one level, they assisted Cultural Resource Management (CRM) and site management. These applications include predictions of site locations through the development of regional or even national GIS and related databases (Allen 1990:197). On a second level, GIS have been used in a more theoretical manner to create models and simulations of processes occurring on sites (Allen 1990:197). Hereafter, several of the terrestrial archaeological projects in which GIS have been used will be briefly examined.

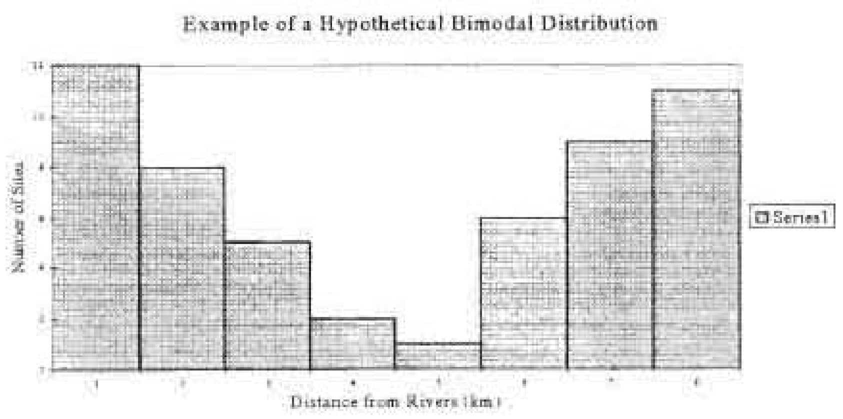
In the American Mid-West, the Illinois State Museum created a GIS for the Shawnee National Forest in the 1980's, that attempted to make predictive models for the location of archaeological sites. The project members noted that sites tended to occur under similar environmental conditions. The predictive modelling that this study aimed to undertake made the assumption that people in the past tended to be strongly influenced by the environment when selecting a living area. It also assumed that modern maps would partially reflect past environments. Because of these assumptions, it had previously been necessary to examine large amounts of geographical, environmental and archaeological information time and again in order to predict the locations of archaeologically important sites. With the advances in spatial modelling capabilities in computers, this task had become easier and, as a result, it became possible to process large data sets much faster. In addition, it became possible to make predictions from small data sets as well (Warren 1990:201).

The study examined environmental data such as slope, aspect (the direction that the site is facing and its relation to prevailing environmental conditions), proximity to resources, soil types and vegetation. The abstraction was that people would have selected the best possible areas for settlement and would thus selection would focus on those areas that contained the most favourable environmental features. This also implied that areas that contain few or none of these preferred environments would show low or no frequency of settlement. In order to predict the presence or absence of sites, it was necessary to make a statistical classification that could measure environmental differences between the two cases (Warren 1990:202) and then to examine these differences over a landscape in order to predict where sites might exist. This method of landscape evaluation tended to look more at land parcels than at specific points or sites. In other words, the area of study examined areas where settlements might be present rather than looking for the sites themselves.

The type of project described above has three main implications for archaeology. Firstly, it shows archaeologists patterns of distribution of sites which suggests the existence of a process of environmental favouritism that would have effected the selection of a settlement's location. Secondly, it indicates the value of the use of GIS as a tool for developers in their selection of areas for building in that it can indicate areas where archaeological sites are most likely to occur and thus allow developers to participate in the protection of these sites. This protection is required by U.S. state laws and a GIS of this nature helps in lowering costs involved in the locating of sites and the subsequent avoidance thereof. Finally, predictions of this nature can show up areas that are most likely to contain non-sites and therefore construction in these areas is least likely to effect cultural resources (Warren 1990:202).

Problems encountered by the Shawnee Forest study included the production of poor or crude contour models. Three-dimensional renderings of the landscape tended to produce stepped slopes rather than the smooth slopes that existed in reality. This problem could be overcome by shortening the intervals entered for the contours (Warren 1990:210-211). Further problems arose with the statistical classification of environmental data. Users had to be aware that site presence probability could be multi-modal. For example, sites appeared to be situated both near and far from streams and rivers, but not as frequently in the interim distances. The bar diagram below illustrates a bi-modal distribution (Figure 1.3.1.1).

Figure 1.3.1.1 Example of a bi-modal distribution



the process of identifying these sensitive areas. This investigation made it clear that a need for detailed testing of GIS as long range management tools exists, and that pre-development field surveys are still a vital part of Cultural Resource Management Despite this, this type of modelling appears to be extremely useful and largely accurate. Even at developmental level, the project could accurately predict areas that were sensitive and should thus be avoided (Carmichael 1990:223-224).

The United States military were also involved in a joint venture that incorporated both army and civilian personnel at Fort Hood. This project, however, used not only GIS but also Exploratory Data Analysis (EDA) to locate sites clustered around zones possibly associated with ancient agriculture. EDA is a process that involves searching for patterning in the larger data sets in order to gain some insight into the causes for the data structures (Williams, Limp and Briuer 1990:243). The results of this project showed that these agricultural zones showed little clustering, suggesting rural rather than urban settlement patterns (Williams, Limp and Briuer 1990:268-269).

Altschul argues that archaeologists do not need to use predictive modelling to discover where sites exist or do not exist (Altschul 1990:226-227). He feels that there are enough data already available to archaeologists to predict area sensitivity without the use of computers. Instead, he concludes, it is important to determine the whereabouts of what he terms as "red flag" sites. These are sites that would be both expensive and time consuming to excavate and document (Altschul 1990:227). "Red flag" sites are also those anomalous sites that occur in areas not usually associated with settlements (Altschul 1990:235-236). An hypothetical example of this would be habitation sites discovered on a steep slope on the south side of mountains, a characteristic that contradicts the occurrence of the majority of sites found on more favourable north orientated, gentle slopes in a specific area. These sites are important because they reveal something new about the past, something that is not already known (Altschul 1990:228). Previous models, as discussed above, tended to show only those areas that were known to contain remnants of past communities on the basis of identified characteristics which influenced decision-making in the past.

Altschul used the technique of overlaying favourable zones, or places where people were most likely to have lived, with actual site data. The results of this were then inspected to determine the number of sites that fall outside the normal patterns and to discover if there was any correlation between the irregular encampments (Altschul 1990:234). Unfortunately, Altschul could not find any conclusive single variable or group of variables that linked these sites. He does believe, however, that, once refined, this GIS should prove extremely useful for the archaeological examination of areas that fall outside of normal habitation patterns (Altschul 1990:235-237).

Jackson maintains that the type of study undertaken at Fort Hood, as mentioned above, goes a long way in the development of GIS (Jackson 1990:274-277). Although the topic has not been fully discussed here, studies of this nature have shown also that the levels of time, money and effort can be curtailed by moving away from the analogue mapping method that makes use of overlay maps and into the digital mapping world which can not only make overlays automatically, but also predict within a good level of accuracy the location or distribution of sites (Jackson 1990:274-275). The GIS can also handle large amounts of data with a degree of accuracy that hand drawn counterparts cannot hope to achieve (Jackson 1990:272).

Hasenstab and Resnick corroborate these observations. They identify the importance of having a relatively simple system that can predict and identify sensitive areas that may contain archaeologically important sites. They believe that GIS afford such systems that can test hypotheses which can be verified through subsequent field survey. They conducted a project at Fort Drum in New York State, USA. In accordance with Cultural Resource Management laws, agencies working for the US Army contracted the development of a predictive modelling GIS that could again identify areas rich in cultural resources (Hasenstab & Resnick 1990:284-285). This study examined settlements established after the American Revolution through to the early 20th century (Hasenstab & Resnick 1990:286). The project looked at environmental data, historically mapped site locations and modern ground disturbance surveys. These were digitised into a GIS map (Hasenstab & Resnick 1990:289). Once sensitive areas had been identified, field tests were carried out to check the reliability of the system. These physical field surveys proved invaluable in that they identified problems with the predictive models. Firstly, the maps that were produced proved to be too coarse to properly identify the exact locations of sites. The cells that were identified to contain archaeological remains were too large to be of value. It was not possible to identify the exact location of sites within these cells by means of using GIS. Secondly, sites were identified in areas that the GIS had shown to be low in cultural residue in it's initial predictions (Hasenstab and Resnick 1990:293). This meant that "favourable environmental conditions" had to be re-evaluated in order to include those that contained the new sites. Hasenstab and Resnick concluded that GIS can still be viewed as important tools in effectively forecasting site location and in the examination of areas marked for development. Despite the fact that there are flaws in GIS, they believe that there is great scope for refinement and use in archaeological projects (Hasenstab & Resnick 1990:304).

Predictive modelling with GIS was again used in an attempt to determine the processes of settlement along a frontier. Zubrow endeavoured to determine limiting factors of growth and migration and examined the advantages and disadvantages of certain models and their subsequent outcomes (Zubrow 1990:308). Based on historical evidence, it was assumed that people followed waterways during migration. This was done, not only because transport along waterways is favourable, but also because waterways facilitate trade and contact. Zubrow used ARC/INFO to digitise a base map that contained hydrological data of New York State, USA (Zubrow 1990:309). Populations were placed at various points along the waterways and all possibilities of flow away from these points were examined. In other words, it was assumed that people could follow different routes at different times resulting in the population of the State. Zubrow used a technique that opened different pathways at different times in order to investigate the arrival of people at historically documented locations. Paths of travel could easily be traced along rivers and streams. The outcome of this project showed that restrictive resistance, such as cost, limited initial settlements to areas near or on the smaller tributaries before large settlements on the main channels could grow. The project was also of interest in that it exhibited migration patterns that were different to those that had been suspected in earlier historical models.

The hydrological features of New York State were used by Allen in an effort to determine the extent of trade between Native Americans and early European settlers between 1550 and 1750. This model was based on known settlements, historic forts and trading posts (Allen 1990a:319-328). Although this design was simplified in that it allowed trade goods to have an equal chance of flowing in any direction along river routes when a decision between two or more directions had to be made and did not take resistance in the form of hostile territory etc. into account, it was successful in showing the spread of trade in an ideal situation. With refinements and added data that would take these resistance factors into account, this GIS could become a powerful tool in the examination of the spread of trade, populations, cultural resources, agriculture and even abstract ideas, such as language, in the near future.

In trying to model a late archaic social landscape of the Savannah River Valley of Georgia and South Carolina in the United States, Savage located base camps and base camp areas (clusters where more than one base camp occurred in close proximity to one another) over his study area (Savage 1990:331-332). He then created Thiessen polygons, polygons which divide the landscape by taking the maximum divided distance between two base camps, which divided the landscape between different bands (Savage 1990:344). Following this, he calculated the size of populations by inspecting the range needed for different population sizes and the historically estimated population densities of the region (Savage 1990:349-350). The study concluded that there was indeed cultural exchange and interaction between bands and that these boundaries acted both as centres for cultural and social exchange (where clusters of sites appeared close to both sides of territorial limits), and as edges (where sites were not present near the borders) (Savage 1990:351-352).

In Europe, similar activities have been undertaken. S.W. Green, in collaboration with M. Zvelebil of the University of Sheffield, England, began a project that used GIS to look at initial colonisation and subsequent development of agricultural societies around Waterford Harbour on the south-east coast of Ireland (Green 1990:360). GIS were first used as a mapping tool to outline, describe and position the area of study. Data from field collections that had been carried out in the area were added to the database as those data became available. From this type of research, the GIS could calculate artefact densities on specific sites, as well as site distribution and density (Green 1990:362). It also became possible to examine the distribution and movement of raw materials and the interaction between the natural and cultural landscapes.

The interaction between the cultural and natural landscapes was also studied by Madry and Crumley in the Arroux Valley in Burgundy, France (Madry & Crumley 1990:364). This project linked GIS analytical tools with remote sensing tools and "old" survey data that had been collected since the 1970's. Using Landsat MSS and SPOT satellite imagery, the team was able to define the landscape to with 10 to 20 metre accuracy. Although the results of this example were tentative at the time of publishing in 1990, it indicated a great scope for research using GIS and its potential to map model and interpret landscapes (Madry and Crumley 1990:364).

1.3.2 GIS IN MARITIME ARCHAEOLOGY

Despite an identifiable interest in the use of GIS in maritime archaeology, very little has been published on the subject. The early endeavours that were undertaken on the *Oosterland* project seem to be among the first of their kind anywhere in the world and inspired by this project, E. Breitenmoser created a system that could plot wreck sites around the Cape Town coast line and relate relevant attribute information concerning those wrecks to each site for comparative studies (Breitenmoser 1991:1-43). On a finer level, this pilot GIS project was used to plot artefacts on specific maritime archaeological sites whereby the results of the first excavation season on the wreck of the *Oosterland* served as a test case (Breitenmoser 1991:29-32). At the time, however, the system was not designed to perform any detailed analysis on plotted artefacts. The reason for this was that Breitenmoser was trained as a surveyor and only aimed at providing a framework for a future, more complex system and, at the time, only limited on-site observations had been made. As a result of this, the initial database was limited. Since that time, however, the project has been updated and redesigned to incorporate more complex archaeological analysis, as will be discussed in this thesis.

Elsewhere in the world, other efforts have been made to apply GIS to maritime archaeological sites. At Cape Hatteras, North Carolina, work is currently underway to set up a GIS for the wreck of the *Monitor*, an ironclad vessel built for deployment in the American Civil War (1861-1865) and launched on 30 January 1862. The vessel was involved in skirmishes with Confederate forces in Hampton Roads, Virginia, including the ironclad *Virginia*. On 31 December 1862, the *Monitor* sank in a gale off

Cape Hatteras while under tow for repairs. Although the wreck site had been discovered earlier, it was not until 1974 that the ship was identified. It was lying in 230 feet of water, about 16 miles from the coast (*Monitor* 1994:9). During subsequent survey and monitoring, it was recognised that the wreck was deteriorating rapidly and that a plan for long term management and conservation had to be found. As part of this management plan, it was decided that an accurate, interactive GIS database should be created that would help with long range understanding and research of the site (Charting 1996:7-8).

The *Monitor* GIS combines photographic images, computer aided design, GIS coverages and data files. The system is interactive, allowing the user to select features present on the site and retrieve relevant data concerning their attributes. The system has been designed in such a way that it is updatable and can be used as a reference and spatial control for activities taking place on the site. It also serves as a tool for assessing and monitoring the physical state of the wreck, as well as making data available to researchers and the public. The creation of the *Monitor* GIS is still in its infancy but promises to yield some exiting results (Broadwater, J. 1997 *Pers. Comm.*).

The late Pleistocene-middle Holocene site, Little Salt Spring (8So18) in Florida dates to between 12500-6000 years BP. Work undertaken in the late 1970's revealed extensive material remains in the parts of the spring that lay between the surface and 13 meters depth. New excavations were completed between March and June 1992 (Gifford 1993:167). It was decided that 8mm videography and GIS map-making abilities would be combined to record as many data as possible. A calibrated scale was included in all video images of the site so that they could be integrated into the Map Image Processing System (MIPS) GIS (Gifford 1993:169).

One meter video squares were produced and integrated into the system. By creating mosaics of the images it was possible to create a co-ordinate system that used the south-west corner of the mosaic image as point 0,0. By moving the cursor over the screen, relative x and y co-ordinates could be established for the parts of the site covered in this way. The images created gave an accuracy of approximately 0.07 meters. Despite the fact that only a few of the routines available on MIPS GIS were used, the excavators realised the importance of the GIS as a storage, imaging and data manipulation tool and believe that more work can be done to maximise this as an archaeological device (Gifford 1993:171-172).

Besides the above mentioned, some other projects have been undertaken which have made use of computer mapping tools. One such project was described by Arnold, Landry, Roseberry and Hauser (Arnold *et al.* 1994:109-113) who used simple mapping techniques to survey the Canary Creek wreck in Matagorda County, Texas. Although this project was set up as an initiative to involve recreational divers in archaeological activities, computers were used as a means of plotting surveyed material. Computer mapping images were also used in a project describing prehistoric and historic shorelines of the Southern Argolid Peninsula in Greece. This undertaking resulted from sub-bottom profiling and side scan sonar imaging (Van Andel & Lianos 1983:303-304). The aim of this project was not, however, to set up a system by which results could be analysed using computers, although extensive use was made of these machines as a means to collect and store relevant data.

During a sub-bottom acoustic survey of the area off Tofino on Vancouver Island, British Columbia, Canada, computer maps were again generated. Once more, the results of this project were not intended as a GIS and little or no work was done whereby data were analysed and manipulated to allow for archaeological interpretation. Nevertheless, the latter two projects mentioned here rely on computer mapping systems and computer navigation systems as a means of displaying recorded data (Schurer & Linden 1984:305-309). It should be noted, however, that computer aided mapping of the nature referred to in the above, can, in due time, result in the establishment of a GIS proper for such projects.

It seems clear that, to date, GIS have been used only occasionally in maritime archaeology and then primarily as a mapping rather than an analytical tool. This is not to say that GIS analytical work has not been undertaken, but rather that the utilisation of this tool is only at its earliest stages of development. Most of the work that has made use of the system is in its infancy and little has been published in terms of results, although it should be noted that those that have used GIS as an archaeological aid seem to have realised its potential as an analytical device.

2. THE *OOSTERLAND*

The seventeenth and eighteenth centuries saw the growth and empowerment of a Dutch trading empire that was arguably the greatest commercial endeavour the world has ever seen (Israel, 1991:12). This empire, the United Dutch East India Company or *Verenigde Oost-indische Compagnie* (VOC), was established in 1602. The unification of smaller trade companies, which had already been established towards the end of the 16th century, was imposed through governmental intervention (Gaastra, 1991:19, Davies 1961:70, Boxer 1988:25). This was done to combat the erosion of Dutch influence as a world trading power, that was taking place due to competition between these different groups (Gaastra 1991:19). The unification allowed the formation of a trade monopoly that overwhelmed even the greatest of the seafaring countries at the time, Portugal and Spain, in their endeavours to gain footholds in the world markets (Davies 1961:51).

The VOC was headed by seventeen directors, the *Heren XVII*. These men represented the six chambers or regional offices. Because the Amsterdam chamber had the majority share in the company, it held eight of the seventeen seats. The remaining nine seats were shared between Zeeland (four seats), the North Quarter: Hoorn and Enkhuizen (two seats), and South Holland: Delft and Rotterdam (two seats) (Bruijn, *et al.* 1987). The seventeenth seat was held on a rotational basis between Zeeland and the four smaller chambers. This seventeenth seat was added to stop the Amsterdam chamber from gaining overall control of the VOC. If it controlled half the votes it could, in effect, hold the voting to a tie and jeopardise the decision-making processes of the

Company (Israel 1991:69-70). The charter of 1602, which laid the foundations for the Company, was devised in an attempt not only to create a monopoly of trade east of the Cape of Good Hope, but also as a way of ensuring a military power-block against other trading nations such as the Portuguese and later the French and English. The Company was granted enormous power but remained answerable to the States General, who could revoke the VOC's charter (Bruijn *et al.* 1987:6). Investors in the Company were concerned about its expenditure, as they believed that this power was given to inflict damage to Spain and her ally Portugal during the Dutch Revolt, or Eighty Years War, between 1568 and 1648 (Boxer 1988:26-29). This meant that funds going into the company were being diverted from trade into national political advancement. These fund diversions did, however, prove to be of value in that by 1605, the VOC had repelled the Portuguese and taken exclusive control of the legendary "Spice Islands" of Amboina, Tidore and Ternate (Israel 1991:73). The Dutch had, in only three years, gained a strong foothold and extensive power in the East.

From 1602 to the 1680's the VOC has been identified as going through a period of maritime expansion (Gaastra 1982:53 in: Werz 1997:227). The Dutch made enormous advances in maritime technology, including ship building, navigation and the transport and storage of cargo. The Dutch also began to increase their production of new ships drastically and expanded their sphere of influence all over Asia (Werz 1997:227).

The surge of wealth and public confidence in the VOC, which characterised the greater part of the period of maritime expansion, could not maintain at its peak. The French invasion of the Dutch Republic in 1672 caused financial panic and the VOC shares plummeted to record-breaking lows. Despite the market crashes and war flaring up between the Dutch and the French, who were also trying to get a foothold in the East between 1672 and 1674, the VOC still managed to maintain supremacy. Humiliating defeats incurred by the French prompted Louis XIV to proclaim never to launch such large scale offensives against the VOC again, notwithstanding the fact that the French managed to retain a fort at Pondichery until 1693. Shortly after this, however, peace talks forced the VOC to return other strongholds to the French and evacuate the Asian south-east coast. This signalled the beginning of the decline of power of the Company (Israel 1991).

The mid-1680's saw the VOC's culmination as the dominant trade power in Asia. The Company had amassed some 8000 troops in sixteen major garrisons along the Asian south-east coast and had an almost monopolistic hold on the spice trade with Europe. It should, however, be noted that the spice trade saw a major drop from the 1650's to 1700. The Dutch had dedicated almost two thirds of their total trade value to spices in the 1650's but by 1700 this proportion had dropped to only 23 percent of total commodities value (Israel 1991:335-336). The spice trade was replaced by cargoes such as tea, textiles and porcelain, which, by 1700, made up 53 percent of trade value (Glamann 1958:126). Again the VOC had a stranglehold on these commodities, removing both European and Asian rival trading companies and trading powers by force and political efficiency. Despite a decline of power in the last decade of the seventeenth century, the VOC managed to sustain supremacy in the East until well into the eighteenth century. It is out of the above political and economic climate that the trading ship *Oosterland* was to emerge.

2.1 HISTORY AND WRECK

The first mention of the *Oosterland* is found in the minutes of the meeting of the *Heren XVII*, dated Saturday 24 June 1684. In this meeting, the directors commissioned the construction of eight new ships, including a 160 by 39 foot *retourschip*, the *Oosterland*, for use by the Zeeland chamber of the VOC (Werz 1997:229). Soon after the June meeting, preparations began and materials were made available for the commencement of construction of the ship at the Company's shipyard in Middelburg, under the scrutiny of master shipwright Penne (Werz 1997:229). On 24 July 1685, the *Oosterland* was nearing completion. The *Heren XVII* commissioned the Zeeland chamber to complete, outfit and prepare the ship for the voyage to Batavia in time for the departure of the annual Fair fleet that usually sailed in September (Werz 1997:230). The Zeeland chamber accumulated the necessary finances to complete this work, the ship was once again inspected by the master shipwright, and the process of nominating and recruiting the 240 people who would sail with the *Oosterland* began. Finally, on 6 October 1685, the *Oosterland* left the shipyard to prepare to sail to the East on 25 November that year (Werz 1991a:5-6; Werz 1997:231).

During the twelve years that the *Oosterland* remained in service, the vessel undertook four major voyages. Her first voyage had a stuttering, but not uncommon start. After an attempt to leave the Wielingen roads on 25 November 1685, bad weather forced the ship to return to safety and await favourable conditions that would allow the vessel to set sail. The complement of 164 sailors, 98 soldiers and 14 passengers, under the command of Karel de Marville, had to wait out the weather for nearly two months

(Werz 1997:231). On 2 or 3 February 1686, the *Oosterland* left the Dutch coast and set sail for Batavia. She arrived at the Cape of Good Hope on 17 May and stayed until 8 June. A month-and-a-half later, on 31 July, the *Oosterland* arrived in Batavia with 262 people out of the 276 that had left Holland. Of the missing fourteen members only two had died, a soldier and a sailor. The remaining twelve had left the ship, either legally or illegally, during stopovers on the voyage. After a four-and-a-half month stay, the *Oosterland* began the homeward voyage. She left Batavia on 13 December 1686, and after a month long stop at the Cape of Good Hope, from 20 March to 20 April 1687, returned to Zeeland in August 1687 (Werz 1997:231-232).

The first leg of the *Oosterland's* second voyage passed uneventfully. Under the command of Karel van Maarseveen, 148 sailors, 144 soldiers and 33 passengers boarded the ship bound for the Cape of Good Hope and Batavia. The ship began the outward-bound voyage on 29 January 1688 and arrived in Batavia on 19 July that same year. 29 of the passengers, three sailors and four soldiers were left at the Cape during the stopover in Table Bay, between 25 April and 15 May (Werz 1997:232-233). On departure from the Cape of Good Hope, sixteen new passengers, five sailors and three soldiers had joined the ship's company. On the second leg to Batavia, four people died, leaving 309 people by the time the ship reached it's destination. After nearly five-and-a-half months in the East, during which time she was probably involved in inter-Asiatic trade, the *Oosterland* left from Java on Christmas day 1688 and began the homeward voyage under the command of Aarnoud Scheiteruit. After stopping at the Cape of Good Hope, between 17 March and 17 April 1689, the *Oosterland* reached the Dutch coast on 9 August 1689, with a cargo destined for the Zeeland chamber of the VOC (Werz 1997:233).

The *Oosterland* once again left the Wielingen roads on 8 February 1691. Having been in service for over five years, she had probably been overhauled in the five months before her third outward-bound voyage (Werz 1997:233). Aarnoud Scheiteruit commanded the 300 people who made up the compliment on board. The *Heren XVII* had ordered the fleet to steer a course to the north of Scotland, in an attempt to avoid French fleets with whom the Dutch were at war. The voyage to Batavia proved costly. 35 sailors were lost on the first leg to the Cape, where the ship stayed from 17 June until 20 July, and a further 42 lives were lost before the *Oosterland* reached her destination in the East on 26 or 28 September. The ship was once again involved in inter-Asiatic trade, eventually arriving in Ceylon, from whence she began her return voyage on 28 February 1693. After a short stop at Table Bay, from 20 May to 12 June, the ship reached the Dutch coastline on 3 October that same year.

TABLE 2.2: Summary of the first voyages of the *Oosterland*. (Dates and figures from Werz 1997:231-234).

	FIRST VOYAGE	**SECOND VOYAGE**	**THIRD VOYAGE**
DEPARTURE FROM HOLLAND	2 or 3 February 1686	29 January 1688	8 February 1691
TOTAL PEOPLE ON BOARD	276	325	300
STOPOVER AT CAPE	17 May to 8 June 1686	25 April to 15 May 1688	17 June to 20 July 1691
ARRIVAL AT BATAVIA	31 July 1686	19 July 1688	26 or 28 September 1691

TOTAL OF DEATHS	2	4	77
TOTAL PEOPLE ON BOARD	262	309	223
DEPARTURE	13 December 1686 (from Batavia)	25 December 1688 (from Batavia)	28 February 1693 (from Ceylon)
TOTAL PEOPLE ON BOARD	Unknown	84 soldiers plus others	About 140
STOPOVER AT CAPE	20 March to 20 April 1687	17 March to 17 April 1689	20 May to 12 June 1693
ARRIVAL IN HOLLAND	August 1687	9 August 1689	3 October 1693
TOTAL CARGO VALUE	Fl.515 385:2:1:-	Fl.158 049:6:8	Fl.492 821:13:-

During the spring and summer of 1694, the *Oosterland* was fitted out to join a 21 ship strong fleet headed to the East. With a total of 342 people on board, the ship set sail on 16 July 1694. She arrived at the Cape of Good Hope on New Years Eve that year, stayed until 3 March 1695 and then departed for Batavia. The *Oosterland* arrived in Batavia on 11 June with only 181 people on board. While 52 soldiers and sailors had disembarked at the Cape along with all four passengers, 111 soldiers and seafarers had died on the voyage (Werz 1997:234). After a short stay at Batavia, the *Oosterland*, along with five other ships, set sail on 19 July 1695. The voyage was undertaken both as a trading assignment and to drive French merchant ships out of the area (Werz 1997:235). The fleet spend eight months trading along the western and northern Indian coast and by 10 March, it had returned to Goa, having lost only four men in combat with French trading vessels.

The fleet was joined by a second group of vessels at Goa. Part of the fleet, including the *Oosterland*, set sail around 19 March and headed north to Surat. On arrival in

Surat, on 27 April, the fleet encountered the French ships that had fled from the earlier encounter at Vengurla and again drove them off. By 1 June, the fleet had sailed south to Tuticorin. After a short stay, the *Oosterland* sailed to Ceylon where, after arrival in the port of Billigam, present day Weligama, some time after 22 August 1696, it was decided that she should be fitted out for the return voyage to the Netherlands. The vessel arrived in Galle some time between the end of August and 3 November that year to be loaded with trade goods and manned for the voyage to come (Werz 1997:237-239) (See Figure 2.1.1 and Figure 2.1.2).

By 15 February 1697, the six ships for the return fleet were prepared for departure. The cargoes included Cowrie shells, indigo and tropical hardwoods, saltpetre, spices, including cinnamon and pepper, shellac, sealing wax and textiles. Although the records do not reflect the way in which the total cargo was divided between the ships in the fleet, it is known that the *Oosterland* carried goods amounting to a total trade value of Fl.372 691:14:- for the Amsterdam chamber of the VOC. Although the *Oosterland* belonged to the Zeeland chamber of the Company, the fact that she was probably fitted out for this voyage by the Amsterdam chamber meant that she would carry goods for the latter. This was the second most valuable cargo in the fleet, the *Waterman* being the only ship with higher trade goods value. The six ships together carried cargo worth Fl.1 444 956:4:8, of which Fl.496 122:1:8 was destined for the chamber of Zeeland and Fl.948 834:3:- for the markets of the Amsterdam chamber (Werz 1997:239-241). No mention is made of cargo being loaded onto the galliot *de Snoeper*, nor is there any record of it entering Table Bay with the rest of the fleet, suggesting that it sailed to other Asiatic ports rather than making the voyage home (Werz 1997:322).

Figure 2.1.1 The *Oosterland* in Asia (I)

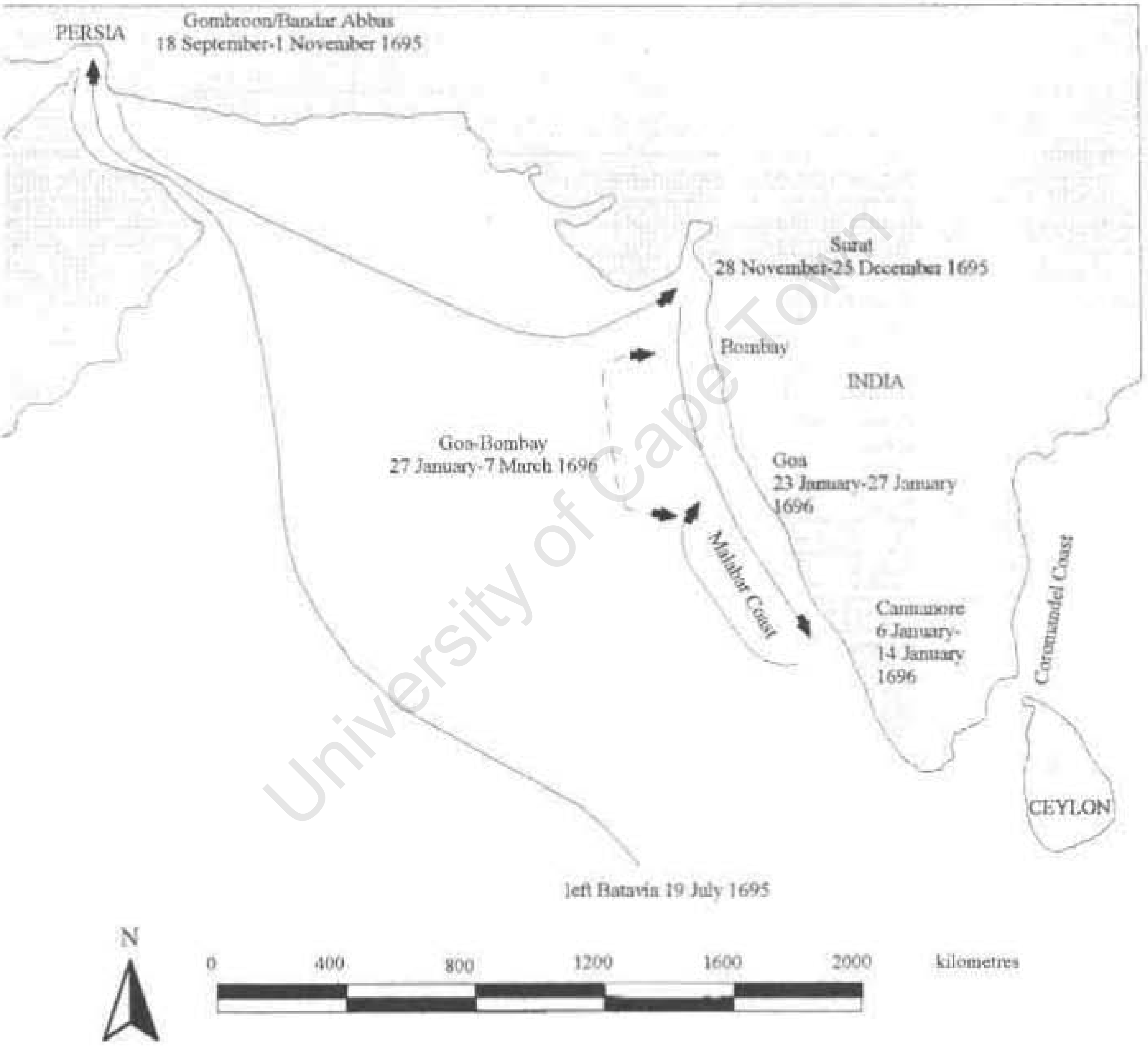
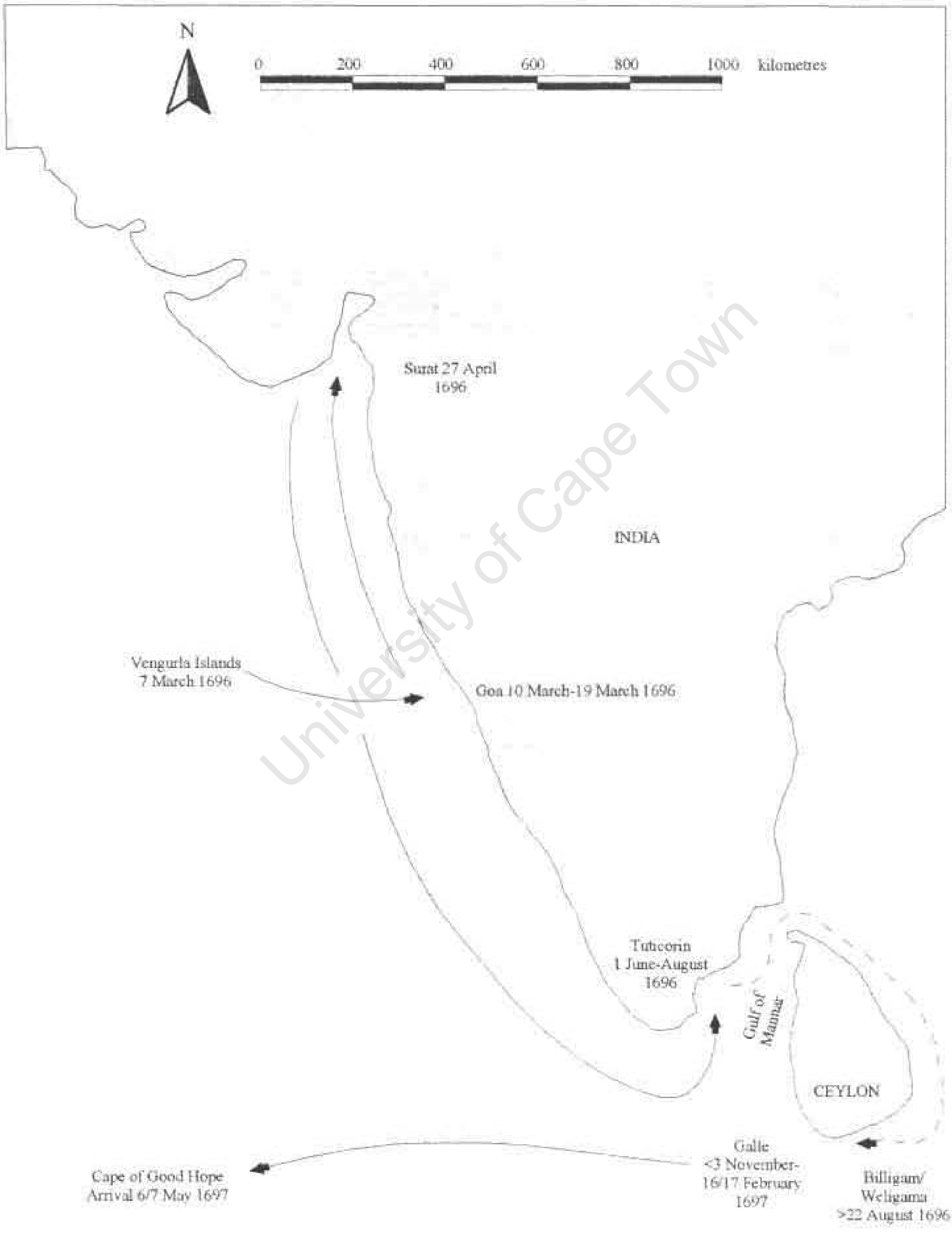


Figure 2.1.2 The *Oosterland* in Asia (II)



On 16 or 17 February 1697, the *Oosterland* with 146 people on board left Galle along with the rest of the fleet and set a course for the Cape of Good Hope. The journey was rapid and on 6 or 7 May 1697 the fleet dropped anchor at the roadstead in Table Bay. On arrival, the *Oosterland* reported eleven dead and 35 men sick. Those who were sick were probably taken ashore for treatment at the hospital. It is also probable that some of the higher ranking officers went ashore to report to the governor, Simon van der Stel, and his staff. This meant that close on 100 people remained on the ship while it was anchored in the bay, where they received fresh food and water supplies (Werz 1997:241). The Ceylon fleet was later joined by a twelve strong fleet from Batavia which included the ship *Waddinxveen* (Werz 1997:242).

On Wednesday 22 May 1697, the wind was blowing from the south-west. During the night, however, it swung around to blow north by north-west, causing a marked rise in the swells. The wind increased during 23 May, causing the turbulent sea to become even more ferocious. At about 8:00pm, three distress signals were fired from the fleet anchored in the bay. The *Stad Ceulen* had broken free of her anchor cables and drifted towards the *Kattendijk*. In an effort to avoid collision, the latter cut free of her own cables and began to drift. In the early hours of the morning of the 24th, the *Kattendijk* passed close to the *Oosterland* and in the process one of her anchors caught the anchor cables of the *Oosterland*. The result was that the *Kattendijk* was pulled in to the stern of the *Oosterland*, where she struck and caused damage. In an effort to avoid further damage, the crew of the *Oosterland* decided to cut free their ensnared cable, resulting in all three ships drifting freely. Some time later, however, all three ships managed to drop additional anchors. At approximately 9:00am during the morning of

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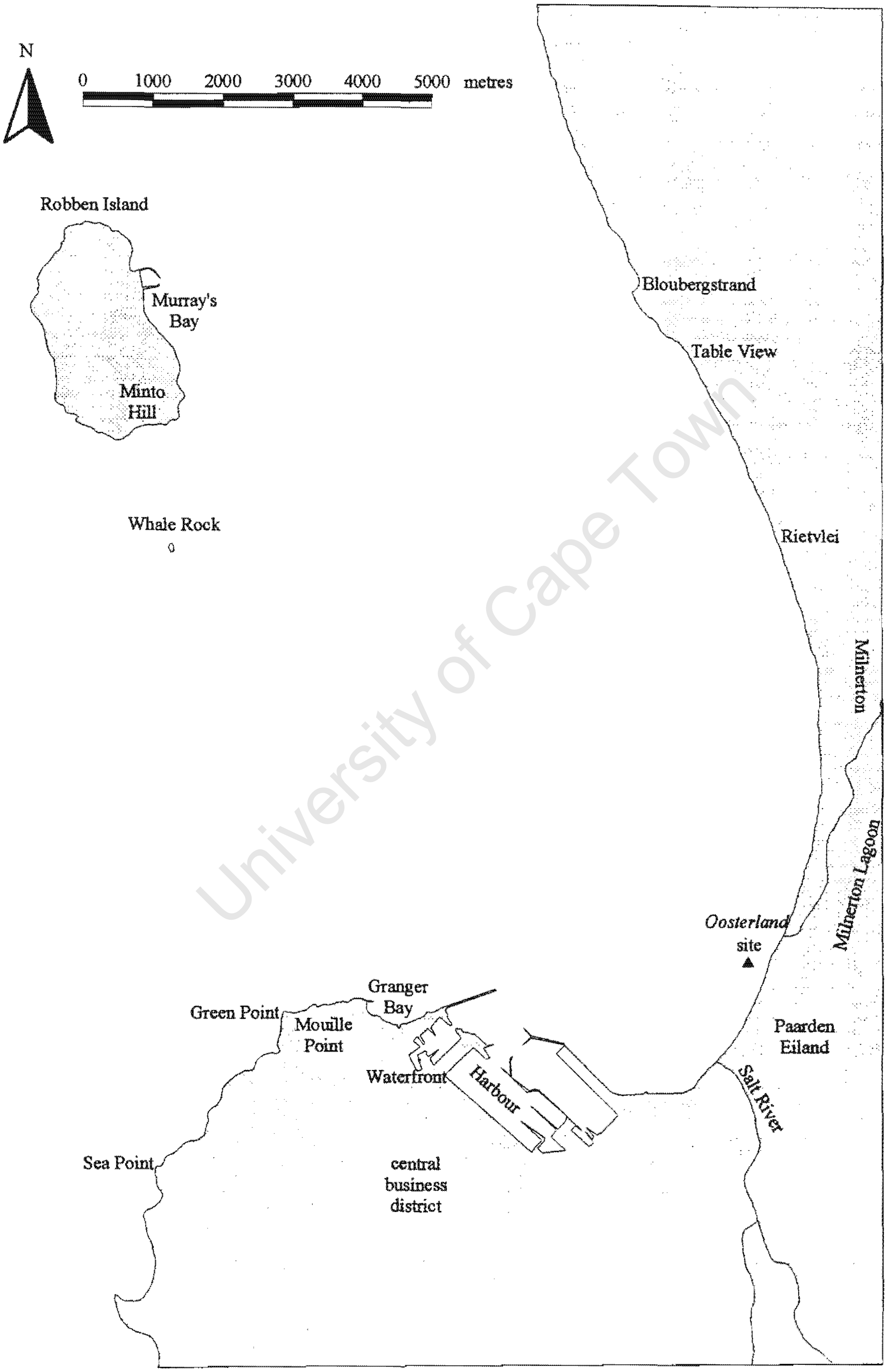
What could be salvaged from the cargo was taken to the Castle. The manner in which the ships had broken up meant that a large proportion of what had been on board was washed up on the beach along Paarden Eiland. Further salvage took place in the weeks following the catastrophe, but much of what was recovered had been damaged. What could be recovered was sent to the Netherlands on the returning vessels in the months that followed and distributed amongst the various chambers of the VOC (Werz 1997:245-246).

2.2 DISCOVERY

In December 1988, Graham Raynor, Christopher Byrnes and Michael Barchard, three sport divers searching for wrecks in Table Bay, discovered an assemblage that included blue and white porcelain shards and a number of cannon opposite the Paarden Eiland beach (Werz 1989a; Werz 1989b:14-15; Werz 1990a; Werz 1991b:1; Werz 1991c: 21; Werz 1992a:85; Werz 1992b:59; Werz 1993a:25 Werz 1993b:33; Werz 1993d:242; Werz & Klose 1994:522). Realising the historical importance of this wreck, they reported their find to Dr Bruno Werz, maritime archaeologist at the University of Cape Town. Werz in turn reported the find to the National Monuments Council. The wreck was situated close to the south-eastern shore of Table Bay, just off Paarden Eiland beach, south of the present-day mouth of Milnerton Lagoon (Werz 1997:246). (See Figure 2.2.1). The divers expressed their compliance to scientifically excavate the wreck and assist in the process of recording and documenting any finds. With this, they lodged an application for a permit that would give them the sole rights to salvage activities on and around the site itself (Werz 1997:246).

Werz then began the task of identifying the wreck. Working on the assumption that the type of material observed in the preliminary investigations on the site indicated it to be a homeward-bound vessel, he had a starting point from which to conduct further investigation. Inscriptions showing that cannon, which had been retrieved previously, had been cast in 1685 gave an indication of the time range in which the ship would have operated. Werz took an arbitrary "end point" of 1730, based on the conjecture that after forty five years in service any ship would have either been sunk or taken out of commission and guns of this age would have been replaced by more technically advanced equivalents. Following this, an investigation of historical and archival material took place which narrowed down the candidates to seven homeward-bound vessels. These were the *Stavenisse*, discounted because it had been wrecked in Kwazulu/Natal; the *Bennebroek* and the *Sakensburg*, both discounted because they were wrecked near Cape Agulhas; the *Goede Hoop*, the *Oosterland*, the *Hogergeest*, and the *Waddinxveen*. The discrepancy between the time that the *Hogergeest* and *Waddinxveen* were built, 1681 and 1691 respectively, and the date given by the cannon was too great, and these two were also discounted. The records describing the events surrounding the wreck of the *Goede Hoop* and its subsequent salvage, also made it an unlikely candidate for being the wreck discovered in this case. This meant that the ship being investigated was most likely the *Oosterland*. This has since been further supported by artefacts that have been recovered and their relation to the final voyage of the ship (Werz 1997:250-252, Werz 1992:86-87). On the basis of this evidence it was thus concluded that the wreck is, in all probability, that of the *Oosterland*.

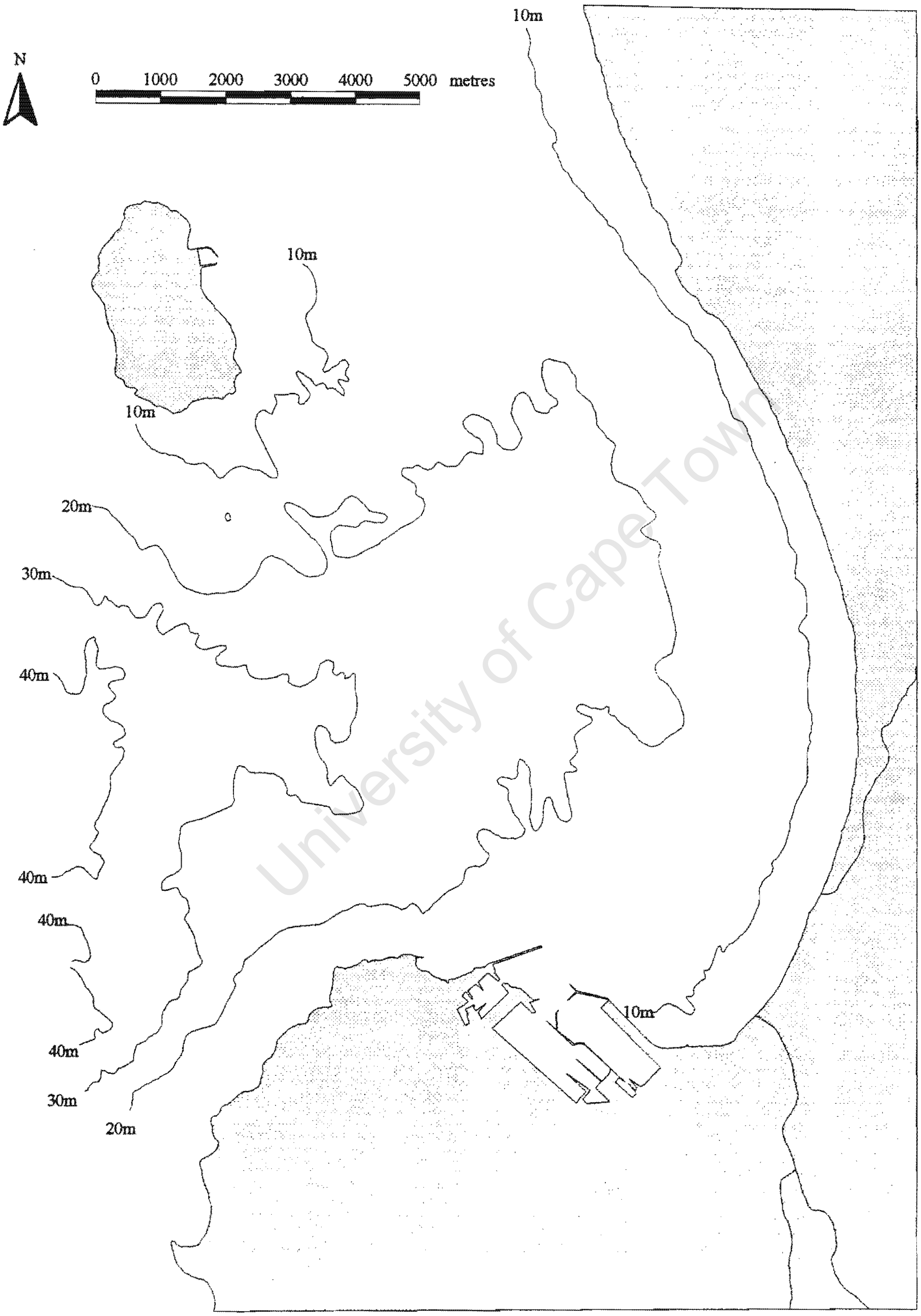
Figure 2.2.1 The *Oosterland* wreck site



2.3 PROJECT PLANNING AND FIELDWORK

An important motivating factor behind the application for a permit allowing the excavation of the *Oosterland*, was to set up an initial standard for maritime archaeology in South Africa. Because this was to become the first fully scientific excavation of a maritime archaeological site in these parts, the project could act as a test case where archaeological methods could be tried and improved (Werz 1997:253, Werz 1993:39, Werz 1990:121). A further aspect was the fact that the site was threatened, not only by illegal salvage activities but also by natural processes. These problems were compounded by the fact that the *Oosterland* site is at a depth of between only 6 and 9 meters (see figure 2.3.1). The exposure of the site meant that it was vulnerable to corrosion, artefact de-contextualisation by currents and wave action and damage to features and artefacts (Werz 1997:254). This meant that urgent action needed to be taken to stabilise the site or, failing that, to rescue what information could be recovered before such information was lost. In addition, the project signified the first true co-operation between private individuals and academics in these waters. To this end, an agreement between Werz, the discoverers of the wreck and the University of Cape Town, which would assist by providing facilities for the conservation and storage of recovered material, was drawn up. It was agreed that Werz should be the permit holder. This would ensure the scientific integrity of the project by making a withdrawal of legal rights to the wreck possible if any contravention of the regulations were to take place. It should be noted here that all academic involvement throughout this project has been undertaken purely in the interests of the advancement of maritime archaeology. No monetary incentive exists and none shall be offered (Werz 1991b:21).

Figure 2.3.1 Bathymetry of Table Bay



The agreement also gives researchers the right to delay the dispersal of artefacts by the discoverers of the wreck until such time as full analysis of all items can be completed. The agreement was contained within the research proposal that was issued with the application for an excavation permit.

From an historical point of view, this site proved of interest and value. Although some 25 VOC shipwrecks had been discovered world-wide by this time, little was known about the ships themselves and how they related to the VOC and the regions with which they were in contact. Added to this was the fact that most of the wrecks that had been excavated were of outward-bound vessels and therefore carried a very different type of cargo (Werz 1997:254). Furthermore, of the homeward-bound wrecks that have been examined, only two, the *Mauritius* and the *Witte Leeuw*, were scientifically excavated, the rest being salvaged for profit (Werz 1997:255). As a result, very little information is available.

TABLE 2.3: Summary of objectives of the *Oosterland* project. (From: Werz 1997:256; Werz 1990a; Werz 1992b:85-86)

OBJECTIVES OF THE *OOSTERLAND* PROJECT
Undertake research on an inter-disciplinary basis.
Collect and process information gathered through pre-disturbance surveys, excavation and relevant research.
Creation of a field school where interested parties can learn and gain excavation experience.

Development of a standard for the excavation of historically significant wrecks in southern Africa.

Following the research objectives and the agreement that had been drawn up, the NMC granted a permit for the disturbance and excavation of the *Oosterland* in September 1990. The discoverers of the wreck were to contribute all finances, equipment and labour; Werz was to manage and direct the archaeological aspects of the project; and the University of Cape Town was to provide for storage and conservation of artefacts. In addition to this, academic departments at the University such as Geology, Archaeology, Surveying and Geodetic Engineering, Chemistry, Materials Engineering and Oceanography would assist in the analysis and recording of the site and artefacts. Co-operation was also obtained from the Groninger Museum in the Netherlands, the Ashmolean Museum in Oxford and the Victoria and Albert Museum in London (Werz 1997:256).

Preparations for excavations were immediately initiated and fieldwork on the *Oosterland* site began in late December 1990. By mid-1997, four excavation seasons had been completed. Most of the information given here has been retrieved from the Diving Record Sheets, Excavation Record Sheets and Finds Lists that were compiled during excavation and reflect the fieldwork undertaken and fieldwork notes that were produced.

Table 2.3: Duration of Excavation Seasons.

SEASON	DURATION
1991	27th December 1990 - 22nd April 1991
1993	9th October 1992 - 5th April 1993
1995	19th November 1994 - 14th May 1995
1996	3rd November 1995 - 8th May 1996

Excavation possibilities, as with any underwater site, were dictated by weather and sea conditions. Although for the most part adverse conditions did not stop the progression of work, there were occasions when visibility was so poor or weather conditions so bad that continuance of work would have led to inaccuracy or even loss of information. At these times work was called to a halt.

The *Oosterland* site is located in the south-eastern section of Table Bay, opposite Paarden Eiland beach and about 500 meters south of the mouth of Milnerton lagoon. The site co-ordinates have been recorded as being about 33°53'36'S and 18°28'43"E (Werz 1997:257). It is about 280 meters off shore from the high-water mark and ranges in depth from about 4.5 to about 7 meters. The greater part of the site has not been entirely excavated to date and materials are dispersed over a large area. Deposits, from seabed to bedrock, range from featureless fine sand through increasingly large pebbles and rocks to the Malmesbury Shale bedrock. There are clay lenses in certain parts of the site, but this is not a feature that extends throughout.

The size of the site is difficult to determine. The ship itself was roughly 45 meters long by 11 meters wide. When it broke up, however, artefacts were dispersed over a much larger area. It has been determined that the ship is lying in a roughly north-south direction more or less parallel to the beach. Added to that it is known that artefacts have washed out on to the shore at Paarden Eiland beach. This means that the wreck site covers an area of at least 280 meters by 50 meters. This does not take into account any artefact dispersion to the seaward of the site or any north-south dispersal. These are, as yet, unexplored areas (Werz 1997:257).

With the help of the Department of Mineral and Energy Affairs' Geological Survey/Opname section (GSO), a pre-disturbance survey of the wreck was undertaken in 1990 in an attempt to determine its extent. Nine runs were made over the site using side-scan sonar. The only feature that was visible from the nine passes was a large mound of metal conglomerate that had been observed during earlier diving investigations on the site, the rest being covered by sand (Werz 1997:258, Werz 1993:35, Werz 1992:88).

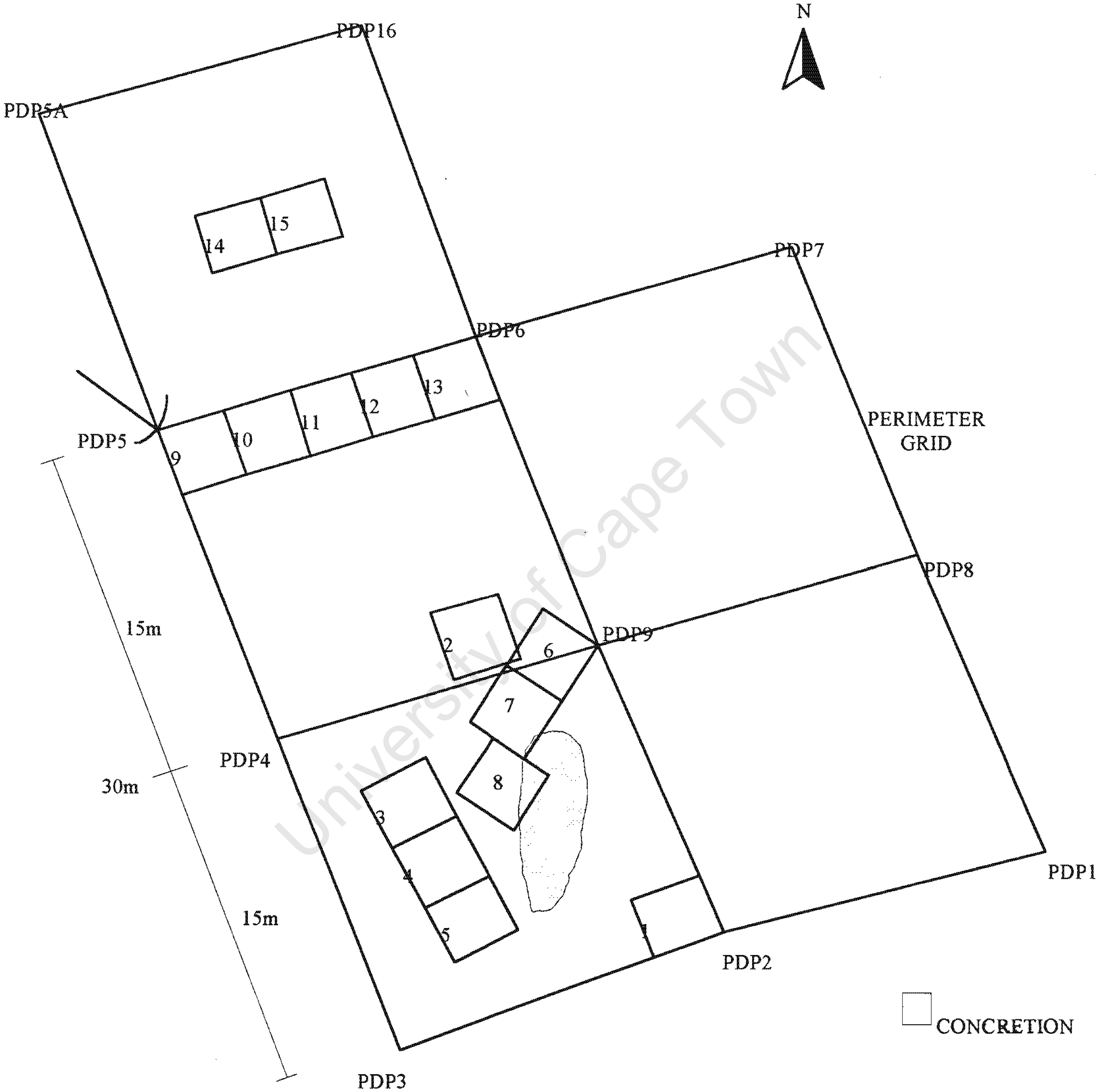
On completion of the pre-disturbance survey, it was decided that a control area should be demarcated. This area would act as a network from which any underwater survey measurements could be taken. This would also allow research to be contained and controlled. To that purpose, a grid was created on the sea bed using concrete filled car tires. The grid measured 30 meters by 30 meters and was divided into four squares, each one being 15 meters by 15 meters as shown in Figure 2.3.2. The tyres at each intersection acted as fixed datum points and were called Perimeter Datum Points or

PDPs. They were numbered from one to nine in a sequential, clockwise direction. PDP 5 is represented by a large anchor. This feature was chosen as a corner point because of it's size and because, as a datum point, it would remain in position.

The PDP points that had been established were measured into the national grid system on 10 March 1991. Members of the Department of Surveying and Geodetic Engineering at the University of Cape Town assisted in this process by taking theodolite readings from the shore (Werz 1992:88, Werz 1993:34 Werz & Martin 1994:9-11, Werz 1997:295).

During the first two seasons (1991 and 1993), smaller, rigid grids (Numbers 1 - 8) were incorporated into the system. These grids represent a finer level of control on the site. Once the rigid grids had been set and levelled on the sea floor, each datum point or DP on these grids was measured into the PDPs in the perimeter grid by trilateration. In addition to this, the DPs were checked against on another by taking internal measurement observations to between seven and fifteen other DPs on the grids (Werz 1997:261). Excavations continued during the 1995 and 1996 seasons. More grids were laid down in the north-western quadrant of the perimeter grid and later a the new section of perimeter grid added during the 1996 fieldwork season.

Figure 2.3.2 Approximate positions of grids laid out on the *Oosterland* site



3. THE APPLICATION OF GIS TO A MARITIME ARCHAEOLOGICAL SITE: THE *OOSTERLAND* PROJECT.

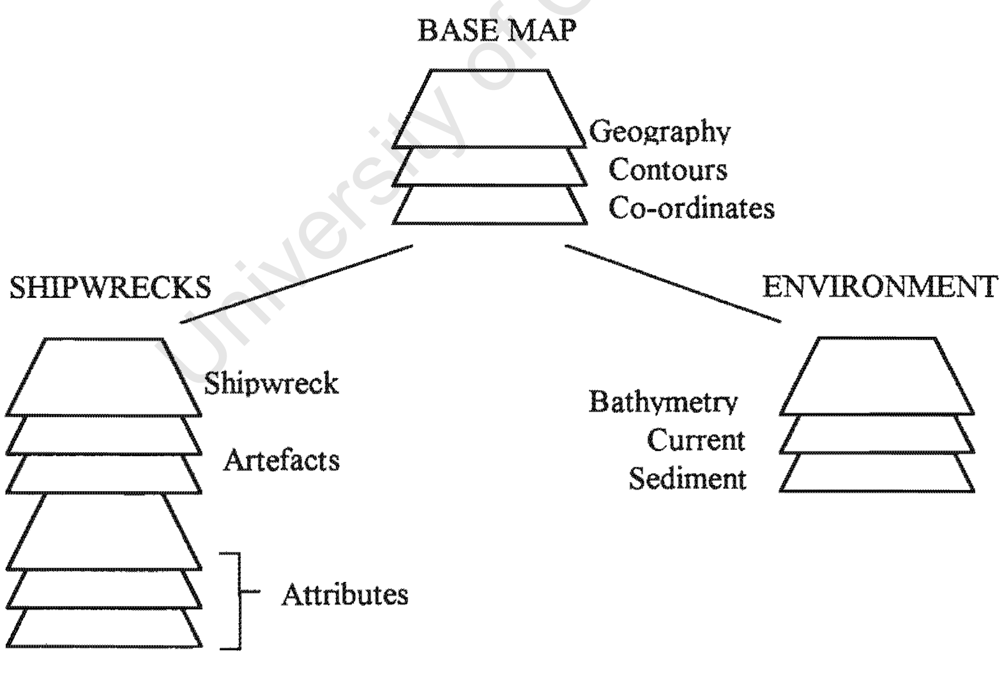
It has already been acknowledged that very little work has been done to date to apply GIS to maritime archaeological projects. Because GIS have not been specifically designed for use by archaeologists, there are several functions that need to be performed outside of the system before data can be entered. These range from the manner in which information is collected on site to the creation of particular programmes that can transform data into a format that can be read by the GIS. Once data have been manipulated and entered, it is possible to test the spatial analytical powers of the GIS by asking several archaeological questions that relate to the spatial distribution of artefacts recovered. When such tests have been completed, it will be possible to make some preliminary comments on the future of the *Oosterland* GIS, how it can be adapted to incorporate further maritime archaeological research and how GIS in general fit into the future of maritime archaeology. The following will examine these issues by discussing the manner in which a variety of data were captured, the tests that were carried out and the results of those tests. Finally, the future of the GIS and its applications to maritime archaeology will be briefly examined.

3.1. THE ORIGINAL CONCEPT

In 1991, the first steps to creating a GIS for use on the *Oosterland* project were set up. Emile Breitenmoser, a student in the Department of Surveying and Geodetic

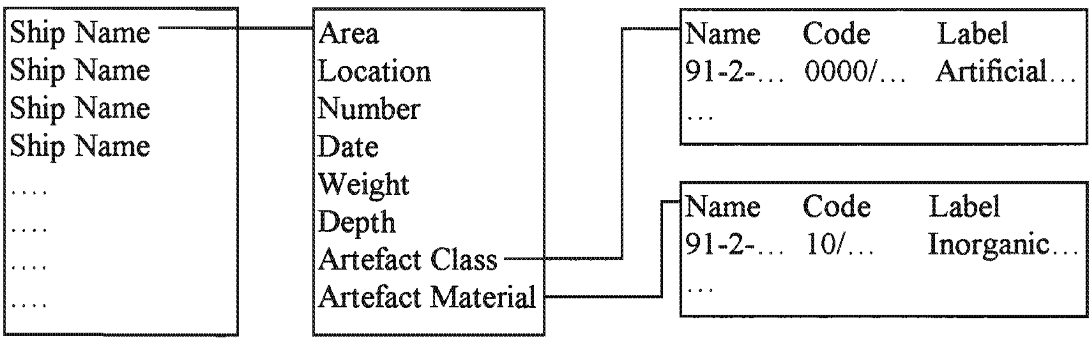
Engineering at the University of Cape Town, took on the responsibility of making preliminary advances in this area. This project was a part of the Maritime Archaeological Project (MAP) of Table Bay, which was created to investigate wrecks found in the Table Bay area. His work was intended as the foundation of a GIS that could incorporate any shipwrecks found in this area as well as environmental data concerning Table Bay (Breitenmoser 1991:1, 33-34). The Table Bay GIS had to combine shipwreck data with environmental data such as currents, winds and geological formations. This was necessary because the database was not restricted to archaeological use, but also catered for geologists, oceanographers, biologists and surveyors.

Figure 3.1.2.1 Overview of 1991 Table Bay GIS (After Breitenmoser 1991:35).



The project intended to develop a set of map overlays for individual wreck sites with attribute and artefact layers. Figure 3.1.2.2 below shows an overview of the database which Breitenmoser hoped to achieve for each shipwreck.

Figure 3.1.2.2: Overview of Original Shipwreck Database Planning (After Breitenmoser 1991:31).



In setting up the GIS it was realised that certain user defined requirements had to be followed and incorporated. These included access to artefacts and their related data and the ability to map selected artefacts and examine their spatial relations to one another (Breitenmoser 1991:29). In order for these requirements to be fulfilled, it was necessary to design the database as comprehensively as was possible at the time while allowing for future expansion, before commencing data capture procedures. This ensured that the required layers would be correctly identified and designed so that individual artefacts could be easily accessed (Breitenmoser 1991:30). User needs and possible archaeological questions had to be incorporated into this design. Artefacts had to be classified in such a way that most, if not all, of their acknowledged associated attributes could be examined and groups of artefacts could be identified and compared. It should be noted, however, that the original concept was not aimed primarily at analysing spatial data but rather to create an inventory of shipwrecks and artefacts that could be quickly and easily updated and plotted. Associated information such as the history of individual ships, their size and contents were to be added to the database.

This information also included a rough position of wrecks detected from archival and historical sources, where exact location was not known.

With the unfortunate death of Breitenmoser, much of the system became unusable. Data that had been entered originally were often not saved and, where they existed, were not properly classified or explained. This meant that a new system had to be created, using only a fraction of the information that had been previously entered. Artefact data had to be reclassified and manipulated for entry into the new system since some programmes, written for conversion of survey data to map co-ordinates, were mostly unusable. In addition, no explanation of the format of data entry was given. As a result of these unfortunate circumstances the possibility of continuing the establishment of a GIS for use on the *Oosterland* project seemed to have fallen away, until in 1994 the author took on the responsibility of continuing the work, as suggested by Bruno Werz, as an honours project.

The project that was undertaken in 1994 was similar to that produced by Breitenmoser in 1991. The final results did not show any analytical work and the GIS, once again, was only used as a mapping tool. The project did, however, make advances on previous work in that it allowed for the plotting of all artefacts recovered up to 1994. It also reclassified artefacts in a manner that made them easier to identify and examine. Information regarding data entry and programme use were also included so that future users can build upon the system. Although the final product was simple and its use limited to mapping, it did form the base from which further work can be undertaken.

3.2 DATA CAPTURE

The process of data capture for this project took a three-fold approach. On site data, as captured by divers and archaeologists in the field, were recorded and this was followed by data classification and manipulation. Finally, the information was entered into the Geographical Information System which allowed for further processing and analysis.

In order to examine on site data capture, it is perhaps necessary to first look at the manner in which the *Oosterland* site is laid out. In 1989, when the wreck was first discovered, most of the overburden which normally covers the area had been scoured away by currents. As a result of this, wreckage was clearly visible on the sea bed. Unfortunately, the delays which occurred with obtaining an excavation permit meant that by the time a full examination of the site could be undertaken, it had been covered by sand overburden once more. This meant that an opportunity had been lost to collect any photographic or survey data that could have helped with excavation planning. It was therefore decided that a pre-disturbance survey with side scan sonar should be conducted in order to establish a starting point for excavation. This survey achieved limited success but did show the location of a concretion mound that would later act as a starting point for the archaeological survey. As discussed previously, the concretion mound was incorporated into an initial thirty by thirty metre grid during the first fieldwork phase in 1991. This perimeter grid was laid down by divers using concrete filled tyres to demarcate grid corners, with the exception of the north west corner which was represented by a large anchor, in all likelihood originating from the

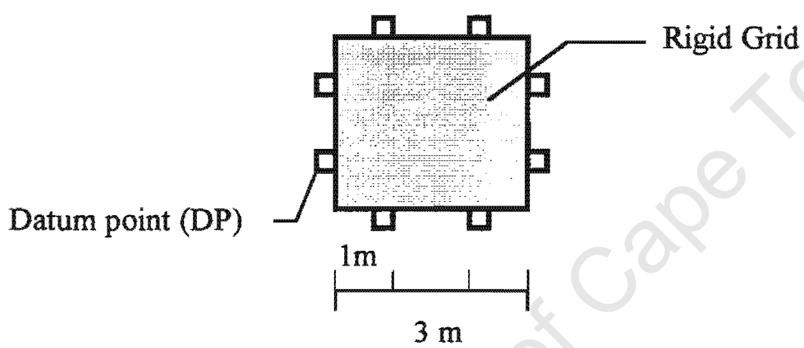
Oosterland itself. Concrete filled tyres were used as datum points because, with the exception of the anchor, there were no visible structural remains or large artefacts, such as cannon, which could have been used for this purpose. The tyres were fixed to the sea bed by hammering metal spikes through the centre and into the underlying sand covered bottom. The orientation of this perimeter grid was determined by underwater compass which resulted in a baseline coinciding with magnetic north, 23.8° west of True North. Each thirty metre side was divided in half and the large grid was thereby sub-divided into four smaller fifteen by fifteen metre squares. This grid is shown in Appendix VII. Datum points on this grid were named Perimeter Datum Points or PDPs. They were numbered clockwise, starting with the south east corner and ending in the centre of the grid. PDPs were, at this time, connected with ropes in order that divers could orientate themselves on the site and easily move from one PDP to another. Orientation was essential at the initial stages of work because poor visibility, often less than one metre, and strong currents that often washed divers off the site made work difficult.

With the help of the Department of Surveying and Geodetic Engineering at the University of Cape Town, the PDPs were surveyed into the South African national grid system. Buoys were attached to each PDP and two theodolite readings were taken simultaneously from fixed points on the adjacent beach. To accommodate for the shifting of buoys due to wave action, an average of at least ten readings for each PDP was taken (Werz 1997:259; Werz 1993:35; Werz 1992:86; Werz & Martin 1994:9). In addition to these readings, divers surveyed the datum points underwater using tape measures. All datum points were measured to adjacent datum points, with the exception of the distance between PDP9 and PDP3 as the height of the concretion mound prevented direct measurement. This was later rectified using rigid grids between PDP3 and PDP9, whereby readings were taken from one PDP to the grid and then to the other PDP (Werz 1997:259). A comparison of survey results taken by theodolite and through underwater measurement showed that the latter form of survey was more accurate than the former. This can probably be associated with the problems encountered with the movement of the buoys on the surface during observation.

In order to reduce the lengths of underwater measurements and thus to increase survey accuracy, the site was further divided using three by three metre rigid grids. These consisted of metal constructions with legs that could be sunk into the sea floor. The first of these was placed in the corner created by PDP3, PDP2 and PDP9 in 1991. This was followed by the positioning of rigid grids 2 to 5 during the same season. Grid two was placed in the south eastern area of the perimeter square formed by PDP4, PDP5, PDP6 and PDP9. Grids 3 to 5 were aligned along an axis slightly west of magnetic north. They were positioned between the concretion mound and the line formed by PDP3 and PDP4 (See Appendix VII). During the 1992/1993 field season, rigid grids 6, 7 and 8 were added to this system. These grids ran diagonally from PDP9 towards grids 3 to 5, with grid 8 offset slightly to the south of grids 6 and 7, as shown in Appendix VII. In early 1995, rigid grids 9 to 13 were placed to the immediate south of the line PDP5 to PDP6 (Appendix VII). During the 1996 field season, it became necessary to extend the perimeter grid and PDP5A and PDP16 were added to the magnetic north of PDP5 and PDP6 respectively. Rigid grids 14 and 15 were placed in the centre of this new square parallel to grids 9 to 13. The total grid system now covered an area of 1125 square meters. (See Appendix VII)

Each of the rigid grids was further divided along its sides. At one metre intervals Datum Points or DPs were created which consisted of metal hooks (grids 1-5) and bolts (grid 6-15). As a result, measurements could be taken from DPs that were closer to the artefacts and finds than were the PDPs.

Figure 4.1.6 : Division of rigid grids



In order to check the integrity of the rigid grids and for later use in data capture, each DP was measured to all other DPs on the same grid and to as many DPs on adjacent grids as possible. An example of the measurements taken can be seen in Appendix I. In addition, the corners of the rigid grids were tied into the survey network by taking direct measurements to surrounding PDPs.

If it can be assumed that the minimum spread of wreck debris on the sea floor would coincide with the maximum extent of the original ship, then it can be concluded that about 490 square metres would mark the minimum wreck spread, given that the dimensions of the ship were approximately 44.80 by 10.92 metres. Practice has shown, however, that this minimum is far exceeded. Currents and wave action have caused the dispersal of porcelain shards, cowrie shells and even tropical hardwood timbers as far as the adjacent beach, whereas to date it has not been possible to determine the extent to which such artefacts have been moved in other directions, to the seaward and north-south sides of the wreck. As a result, it is difficult to establish exactly the extent of the wreckage on the sea floor but it has been estimated that debris may cover an area of at least 50 meters, the length of the original vessel, by 280 meters, the distance from the wreck to the shore (14000 square meters) (Werz 1997:257). This means that only a small part of the site has been examined since 1991.

Excavation was carried out over diving seasons that coincided with the summer months of the southern hemisphere. Each season during which work was planned, kept divers on standby for approximately five months, from December to April. Diving was undertaken on favourable days during these periods but discontinued when poor weather resulted in adverse sea conditions or poor visibility. Because the site is situated just outside of the surf zone, sea conditions had to be carefully monitored. In addition, recurring mechanical problems with the surface vessel also resulted in regular discontinuation of diving.

Excavation started in a three by three metre area immediately north-west of PDP2, in grid 1. Little in the way of cultural remains were found here. Only an iron cannon and a ceramic shard were recovered. Despite this lack of artefacts, the first test excavation area served as a means of giving the investigators some idea of the conditions under which they would be working. It was found that the site was covered by a layer of sterile sand containing more and more pebbles and boulders with increasing depth. The site itself is interspersed with a wide range of deposits. The initial excavation on the edge of what was thought to be the site, would have given the divers a good idea of how deep they would have to go, the type of material that indicated the site, the time that needed to be spent on each section and the feasibility of different excavation techniques that were to be used throughout the excavation. On completion of this test hole, a second test was carried out towards the centre of the perimeter grid. Rigid grid 2, to the north west of PDP9, marked the boundary area for this second test zone. Following this, excavation continued to the south of grid 2 and to the west of the concretion mound. This area was chosen partly for the purpose of defining the extent of the site. It was determined that, although no clear boundaries existed, a large concentration of the artefact remains was covered by the original 900 square metres enveloped by the perimeter grid. This excavation area once again gave divers a chance to experiment further with excavation and recording techniques. The area around grid 2 yielded some animal bone with cut markings on them and some Ysel bricks, used to line the galley situated in the mid-ships region of the vessel. For this reason it was assumed that the area south of this rigid grid would contain a portion of the contents of the stern of the ship. Further evidence for this assumed position was the adjacent concretion mound. This was assumed to be the ammunition store, located towards the stern. The artefact evidence that these two areas revealed, led Werz to the conclusion that the ship was lying in a roughly north-east to south-west direction (Werz 1997:262).

In order for excavation to continue in the area west of the concretion mound, it was necessary to extend the number of rigid grids. On 21 and 22 February 1991, grids 3, 4 and 5 were assembled and set up on the sea floor. Excavation continued in and around these grids, covering an area of about 45 square meters. Artefacts recovered in this new areas included copper cauldrons and ceramics, interspersed with pepper and cowrie shells.

On site data capture was completed in various ways and for that reason it was required that several forms were filled out by archaeologists and divers during the course of each day. Care was taken to keep detailed records of work undertaken in the excavation areas. The positions of these areas were recorded on a site plan, which had grids and other features marked onto it, and recorded in "code" form. This code included the date and the area of the site under examination. For example, a code such as OS 95-02-28/14-15 S would indicate that excavation took place on the 28th of February 1995, on the *Oosterland* site, in the area south of grids 14 and 15. At this stage of the excavation, an artefact bag was marked with the particular code and a tag would be made for insertion into the bag. This double reference system ensured that if one of the written codes were to be lost or should fade, a second would be available for reference. As excavation continued through the day, records, bags and tags would be updated or renewed accordingly. As artefacts were recovered, they were brought to the surface and immediately placed into the bags that had been prepared for them. This ensured that artefacts were kept together and that tags would be correctly associated with each artefact.

Artefacts that were half complete or more were measured accurately into the grid system. On discovery of such artefacts, the item would be left in the position that it held on discovery while the distance between the artefact and at least three adjacent datum points was recorded, using a tape measure and underwater slate. In practice, one diver secured the end of the tape on the artefact, while another would swim out to datum points and record relevant distances. Although this process was relatively slow, it was found to be remarkably accurate. Standard deviation for artefact positions fell between 0.2 and 0.5 % per point, a degree of error that makes this work adhere to standards met on terrestrial archaeological sites (Werz 1997:261; Werz 1993:35-37; Werz & Martin 1994:9-10). Problems did, however, arise in the measurements of a limited number of artefacts, as will be discussed hereafter. Together with the measurements of the artefacts, a short description of each item was recorded, such as "miniature blue and white vase", and a shortened code that included the date and the number of the artefact in relation to others that had already been recovered the same day. The description on the underwater slate would therefore look as follows:

Miniature blue and white vase 93-02-10 no. 2

PDP5 2.12m

DP12 1.23m

DP13 1.50m

The above short code would be later adjusted to fit with the style mentioned above as each item received a tag with its full code at the end of the day. Once these data had been gathered, the artefact was brought to the surface, bagged separately and excavation continued. Artefacts that could not be conserved or were too large to bring to the surface, such as iron cannon or basket work, were tagged with coded labels and left on the sea bed. Their positions were recorded on the site plan as a means of ensuring that even if tags were lost, the rediscovery of such an artefact would not result in double recording.

The second form to be completed was the Diving Record Sheet (DRS). An example of this form can be seen in Appendix II. During work, all relevant diving data would be recorded onto the DRS. This included the date, the site and the area under investigation. The second section of this form comprised environmental data such as wind and current speed and direction, swell height, sea state, temperature and surface visibility. Also covered in this form was information about diving operations themselves. The names of the supervisors and stand-by divers were recorded as well as data on decompression schedules, if any, and tables used. Lastly, the names of the divers, their dive times, their depths and the code number of the ERS issued to them would be included. Together the DRS and the ERS held all the relevant information on diving operations for each day.

The third daily record form was the Finds List. Again, an example of this can be seen in Appendix II. This list recorded a complete inventory of artefacts recovered during each day. Information that was entered onto the first section of this form comprised of the date, the site code and the name of the "finds recorder". In the second section of the Finds List, the finds recorder would display the type of artefact found, the number or code of the artefact, which included the area in which it was recovered and, in the case of those artefacts which had been surveyed, the ERS number where observations on the artefact could be found. An example of a portion this information is given below:

20 blue and white shards	OS 96-02-18/PDP16 SE	
5 pipe stems	OS 96-02-18/PDP16 SE	
1 pewter syringe	OS 96-02-18/PDP16 SE N4	ERS 1-2-2

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Examples of completed ERS, DRS and Finds lists are given in Appendix III.

The second phase of data capture took place during the post-diving seasons. This period was used as a time to collect, check, store and manipulate data gathered over the field season and was aimed at further description and analysis. Since record sheets were collected from the divers and filed on a daily basis, it was an easy task to examine them. Despite the fact that record sheets were checked during the diving season, additional controls were set up to ensure that all were present. If it was found that a sheet was missing from the collection, divers were contacted and asked for any outstanding data.

Once records had been scrutinised it was possible to extract information for use in the Geographical Information System (GIS). At this stage, it was necessary to complete a Finds Record Sheet (FRS) for each surveyed artefact. An example of the FRS can be viewed in Appendix II. It is divided into eight sections. The first of these contains the date, the name of the record keeper, the find number or code and its cross reference to the ERS on which its survey data are recorded. This section also contains a basic description of the artefact. The second section of this form shows the physical dimensions of the artefact: length, width, height etc.. In the third and fourth parts of the FRS, the artefact is classified as to its function or purpose on board ship and the material from which it was made. It can be observed that each unit of classification in sections three and four is associated with a classification number. These numbers were used to further encode the artefact. It was on the basis of the FRS and the ERS that most data capture in this project occurred. The following sections of the FRS give further detailed information about the artefact, such as where and when it was produced and any inscriptions or marks. The form allows for a detailed description of the artefact and includes comparative studies and related literature. In many cases, the sections dealing with comparative studies and related literature have, as yet, not been completed. Further work still needs to be done in this regard.

Artefact Name or Code (from ERS and FRS)

Distance from artefact to DP (from ERS)

POINT	NAME	DP10	DP11	DP6
201	91-2-21/4EN3	1.00	1.00	3.20

0000,10000, 10, 29

Descriptive Classification Code (from FRS)

Artefacts were measured into the grid system using direct survey measurements, as mentioned above. In order for these measurements to take on meaning and be plotted by the GIS, it was necessary to convert there measurements from grid co-ordinates into map co-ordinates. With the help of Professor Heinz Rüther of the Department of Surveying and Geodetic Engineering at the University of Cape Town, a programme was written using True Basic that could perform the task (See Appendix IV). For this programme to run it was required that data from artefacts be entered into ASCII format. The records for each artefact contained in these files included an assigned previously calculated DP co-ordinates. The artefact code assigned to the DPs was 0,0,0,0. The records produced by this programme were ready to be entered into the GIS . Appendix V contains all of the records created the conversion of tape measurements to artefacts into map co-ordinates.

In the third stage of data capture, data were entered into the ARC/INFO and ARCVIEW systems in three ways. Firstly, digitising was used to enter line or polygon data from maps or scale drawings into the GIS. Many of the illustration maps in this project were created in this manner. Digitising is useful in analysis only if scale is known. Although relatively simple, it is a slow task which requires great care if accuracy is to be maintained. This is particularly apparent when digitising from small maps where even slight errors will distort the accuracy of the coverage produced. This specific project has made limited use of digitising for the creation of grids. Using the conversion programme mentioned above, DPs and PDPs were plotted. Points were then connected by digitising lines between datum points to form the grid outline. Two methods can be used to do this, the first in ARC/INFO and the second in ArcView. Digitisation was also used in the creation of the base map onto which an outline of the ship was plotted. The ship model presented here has been digitised from the outlines constructed by Gawronski ((ed.) 1987:56).

Secondly, data were also entered into the GIS manually. In this instance it was possible to create tables in ARCVIEW that contain information about each artefact and this method has been extensively used for the *Oosterland* GIS. Artefact names and numbers were used as a reference, followed by the X and Y co-ordinates generated through conversion from grid measurements to map co-ordinates. Once artefacts had been plotted, it was possible to add information pertaining to those items. This included the addition of the classification code, as discussed above. Four separate columns were created to incorporate the material from which the artefact was made, whether it was organic or inorganic, whether it was natural or artificial and what its function or purpose on board ship was. These columns were updated to contain words rather than code numbers at a later stage of the project as it was felt that this would make the system more user friendly and easier to decipher. Finally, a column containing a short description of the artefact was included. Appendix VI contains tables created from the surveyed artefacts of the first three seasons, all the PDPs and DPs and some examples of "Attributes of..." tables that were created using ArcView, as will be explained below.

This process also made use of the third data entry technique, entering information from file. It was possible to import co-ordinate information directly from files created during the output of the conversion. This output contained the artefact numbers and their X and Y co-ordinates. Although the classification codes were also contained in this output, it was decided that numbers represented in the code should be substituted for word strings associated with those numbers. It was felt that descriptions would make tables more user friendly and easier to handle. The use of these tables also makes it easy to check data. Once the artefact number and its co-ordinates had been entered, it was possible to immediately plot those artefacts into Views, a feature of ArcView. With the help of the Autolabel tool in Views, it was possible to determine the position of each artefact in relation to all the others. This meant that the number of any artefact that was obviously misplaced would be displayed and could thus be re-examined and data pertaining to that artefact corrected. This particular problem will be discussed hereafter. The advantages of tables can be seen largely when changes to the database are made. In the case of manual digitisation, it becomes necessary to retrace lines or polygons that have been incorrectly entered, while tables will automatically update the View when changes have been made.

Once data had been captured and corrected, it was added to the View window of ArcView. This is done using two commands from the View drop-down menu, namely Add Theme, to place digitised coverages or other images into the View, and Add Event Theme, to convert data included in the tables that contain geographic locations but are not in a spatial data format (ArcView 1994:43). The latter contained the bulk of the data that was used in this project. One digitised image and four primary tables were included in the first View of the *Oosterland* GIS. The base map of the ship was the first to be plotted, followed by the table containing data regarding to positions of the Perimeter Datum Points and the grid that they created. Finally, three tables that hold the data concerning the three fieldwork seasons and surveyed artefacts have been added. Secondary event tables that are included are the tables that carry co-ordinate data about the position of the datum points on the smaller rigid grids. The above tables contain all of the necessary information needed to perform spatial analysis on the artefacts.

The View window contains two work spaces. The first of these is the Table of Contents. This column displays all of the themes that have been added to the View. From the contents it is possible for the user to manipulate the style of the theme displays. For example, if the theme contains a set of points, it is possible to change the style of the point from a round dot to a star, change the colour of the points or create colour ramps. Colour ramps may be used when a field in a theme attribute table contains values that are better understood when teased apart. In the *Oosterland* GIS, colour ramps were used to separate artefacts that were classified differently. By using the colour ramp it was possible to display Tools Utensils, Stores, Cargo, Personal Belongings etc. as unique symbols and thus make the examination of the different groups easier. The table of contents allows theme displays to be switched on and off and different themes to be plotted over or below one another. This is an important feature when dealing with many point coverages in that certain points are bound to obscure others.

The second area of the View window is the display area. This window displays all of the themes that have been switched on and can be used to add text, draw images, select objects and, most importantly, view coverages and themes.

Once tables had been entered into Views it was possible to use the Query Builder tool to select relevant records from all of the themes. To use the Query Builder, the theme that is being examined must be active. To make a theme active it is necessary only to click on it in the table of contents of the View window. When accessed, the Query Builder displays a pop-up window with four display areas that are used to create the query. A list of all of the fields within the theme's attribute table is displayed in the first area of this window called the "Field" text box. In the case of the *Oosterland* GIS, this area lists fields such as Classification, Description, Number, x and y co-ordinates, artefact Name etc., in other words, the headings of all of the columns of the table being queried. Once one of these fields has been selected, all of the record or value categories that appear in that column of the table are displayed in a second box in the pop-up window. For example, if the Classification field has been selected, the Value box will contain records such as Tools Utensils, Stores, Cargo and the other classification groups that were established during the manipulation of artefact data as described already. Between these two boxes is an area that displays conditions of selection or operator features. This area includes mathematical conditions such as +, =, >, < , and logic operators such as "and", "or" and "not". By double clicking on the required field, followed by the operator that best suits the query and finally, the value that is being examined, it is possible to automatically select all of the records in the theme being queried that adhere to the conditions specified. By default, the information that is selected is displayed in the text box of the Query Builder window. For example, if the user wished to select all of the artefacts that had been classified as stores, he or she would enter the following query:

```
([Classification]=Stores)
```

Once a selection has been made, simply clicking on the New Set button on the right of the pop-up window will make the system select all records classified as "Stores" and create a temporary data set that contains only the selected records. It is possible to add more data to the selected set by re-accessing the Query Builder and using the Add To Set button after creating a new query. More complex queries can be built by using the "and", "or" and "not" operators:

```
([Classification]=Stores) or ([Classification]=Cargo)
```

This will automatically select all of the records in which artefacts have been classified as stores as well as all the records in which artefacts have been classified as cargo. This method of data selection was used extensively to select records that had been classified as possibly belonging to two or more groups. For example, many of the artefacts were classified as being either Personal Belongings or Tools Utensils. The record in this case contained both of the options. Because of this, it was necessary to select more than one value when examining personal belongings. A query:

```
([Classification]=Personal Belongings) or
([Classification]=Tools Utensils/Personal Belongings)
```

allowed the system to select records all of the records containing either of the two classification values.

Having selected the relevant data sets, it became possible to create a new file that contains only the data that has been selected by the query. The theme must again be active to perform this operation. By using the Convert to Shapefile option in the View drop-down menu, the system is instructed to create a new shapefile that contains relevant records. An ArcView shapefile is a non-topological format for storing the location and attributes of geographic features (ArcView 1994:43). When this command is used, the system will automatically prompt the user to name the new shapefile and ask whether it should be included in the current View. Once the shapefile has been added to the View it is possible to switch it on and display the information that it contains. It is also possible to create new table that hold the attribute information of the shapefile. These tables are called "Attributes of `[FILENAME]`" when displayed in the table of contents of Tables. Comprehensive use was made of these functions during the course of this project as will become clear later.

3.3 PROBLEMS AND SOLUTIONS IN DATA CAPTURE

The excavations on the *Oosterland* made extensive use of a "mailbox" or "blower" to remove sand overburden from above the site. This tool creates an artificial current on the site by deflecting the propeller wash of the surface vessel vertically onto the sea floor. This method of excavation has often been condemned by archaeologists as being destructive and inaccurate but, in the case of the *Oosterland* project, it was the only method that could effectively removed the sand overburden and expose the site. The sterile deposits above the site reached depths of up to three meters and currents running across the excavation areas meant that sand was quickly back-filled into exposed sections. Although airlifts were used to a limited extent, they proved to be ineffectual in removal of overburden. Although the use of the propeller was as an archaeological tool has often been slated, it should be noted that, if used in the proper context and in the proper manner, it can be an effective tool in uncovering wreck sites. In the context of uncovering the *Oosterland*, the propeller wash was used at a relatively high power to clear sand from the wreckage. As soon as the rock-containing layers indicating the presence of the site wee reached, the propeller wash was turned down until it acted only as a means of slowly "peeling" away the sand. Even small pebbles and peppercorns were observed to remain *in situ* while the propeller wash operated at these levels.

Several problems were encountered in data capture and in adapting the GIS to suit archaeological purposes. As has been discussed above, the immediate problems of converting distance data gathered from tape measurements taken on the site to map co-ordinates was apparent early in the development of the *Oosterland* GIS. It is clear that manual conversion of more than 200 artefact positions would have caused a problem as it would be too time consuming to calculate triangulation solutions for so many artefacts. It would also be impractical to plot the artefact positions on graph paper by drawing distance intersection arcs with a compass from PDPs. Conversion programmes served as solutions to this problem. Although Breitenmoser created such programmes in 1991, they proved difficult to decipher because of the author's limited understanding of True Basic and because data input methods and formats were not recorded. Instead, a conversion programme written by Heinz Rüther was used for the *Oosterland* data.

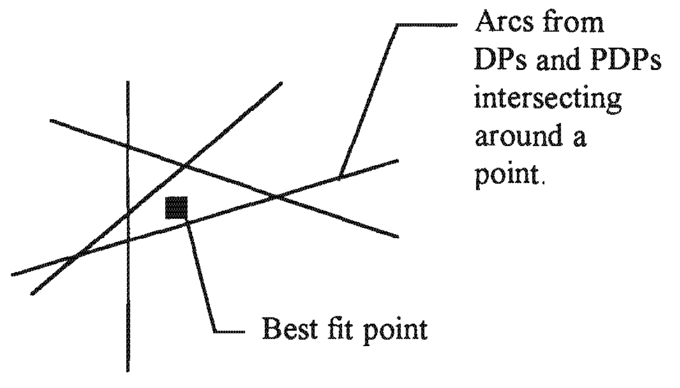
Once the conversion programme had been created, the process of adding data to be transformed began. Problems were encountered at the early stages of this process in that large data sets that included names, codes and distances were often found to contain errors. These errors crept in because of the time spent entering the data. As the author tired, mistakes became more abundant. This problem was often only realised when the conversion program was run and incorrect distances would result in either incorrect co-ordinates or program crashes. The program would crash if tape measurements were too short and no intersections could be achieved. This particular problem was solved by having a second party, in most cases Werz, check records that had been created. This process meant not only checking of distances, but also names and descriptive codes and although it was often time consuming it meant that all data entered were checked at least twice.

Artefact names needed to be changed to suit the GIS. In the ERS, Finds Lists and FRS, the artefacts had all been associated with a description including such information as where they were found on the site and what other artefacts had been recovered in the same day. It became clear that this information would not be contained in the GIS at this stage of development and that artefacts had to be named in such a manner that each could stand on its own and still contain relevant facts on its position, number etc. It became necessary, therefore, to create a naming system that contained all of these data. Werz and the author created such a system, as has been described above. This meant that during analysis it would be possible to examine each artefact by itself before relating it to others. It also meant various bits of information concerning each artefact could be determined at a glance.

Several difficulties were encountered with measured distance data between DPs, PDPs and artefacts. Most problematic were those instances where tape measurements were too short. This problem may occur during underwater measurement for several reasons. The most frequent reason appears to have been that divers measured distances from different points on the artefact. For example, if the artefact was a miniature vase, one of the measurements may have been taken from the base of the vase and another from the lip. This would mean that a discrepancy of the length of the vase, in this case about 5 centimetres, would occur in the data. As with data entered incorrectly, the conversion program could not create intersections of arcs and could therefore not calculate the artefact co-ordinates. Although it is possible to program the computer to deal with these instances using least squared adjustment, this was not done here. It was decided rather that all the distances used in those artefacts that experienced this problem should be extended by a maximum of 5 cm. This adjustment slightly lowered the accuracy of plotted data and means that the accuracy of the co-ordinates used in this GIS and on site plans as a whole will be within 0.05 meters. It is felt that this degree of accuracy over a site of this extent and nature is acceptable.

Measurements that were too long also created some problems. If they were taken over long distances, the possibility of inaccuracy was increased. Currents that moved over the *Oosterland* site tended to cause tape measures to bow in the water, which meant that distances were increased. This was compounded by that fact that obstacles and irregularities on the site snagged the tape measures and again increased distances. Although great care was taken to keep these problems to a minimum, they did occur. The conversion program was specifically designed to take this occurrence into account and hence the use of at least three distance measurements. The first two measurements are used to find an intersection and the third and subsequent measurements as a control. This method of data adjustment is called "cocked hat" adjustment and it creates a point that has the best fit within the measurements. An example of how this works is shown in Figure 4.1.3.1 below.

Figure 4.1.3.1 Creating a best fit point using cocked hat placement.



Problems, however, occur when distances are very long because the enclosed polygon which is formed by the arcs and which would contain the "best fit point" tends to be too large. Again the program is specifically designed to handle this and so all points are created in a manner that is accurate and acceptable.

Data had to be entered into the system in a specific way for the program to be effective. Because the intersection between the arcs formed by the first two distances on the data set are used to determine the area in which the point will be positioned, it is necessary to take two things into account. Firstly, the datum points that are used should not be opposite each other as this results in two intersection that are situated close to each other. A third intersection may lie between these two and the system would not be able to choose between which is correct. This could mean that it chooses an incorrect value and the point will have inaccurate co-ordinates. This means that, when creating records to be converted, care should be taken to make sure that the order in which data are entered takes the above problem into account. Secondly, distance measurements should not be taken from datum points that exist along the same line. This results in two co-ordinate possibilities either side of that line and the system may choose to calculate the wrong one. This problem was solved in the early excavation stages of the project when divers were instructed to take measurements from adjacent sides of the grids.

Measurements that were taken to grids during the 1995 fieldwork season were found to be producing consistently poor results. In an effort to discover the problem that was associated with these inconsistencies it was decided that a re-evaluation of the entire grid system should be made. The process of evaluation worked from the measurements taken to the artefacts themselves back through the measurements taken to the rigid grids and finally to the PDPs and the perimeter grid. It was not until the PDPs were examined that the problem was solved. Measurements had been taken between the PDPs during the course of the season and during the process of laying down the rigid grids. The measurements between PDPs was recorded in the ERS. Since PDP5 is the most stable of the datum points, it was chosen as the base from which the re-examination would proceed. Measurements taken from this PDP and others which had remained in place were used to convert the distances between the datum points to map co-ordinates once again. As conversion progressed, it was discovered that PDP4 had shifted from its original position to an locality approximately one meter north west. The position of this was entered as data in the conversion problem and the point was called new PDP4 or PDP4N. All of the records that used PDP4 as a datum point were changed to use PDP4N. This change resulted in accurate and consistent conversion results.

Other problems were associated with the grid themselves. Firstly, it was difficult to maintain any depth control over the site because of the distances between rigid grids be surveyed again at a later stage before the position of these artefacts can be properly established.

Finally, the descriptive codes that were created and used in the 1994 version of the GIS were found to be inadequate. It was realised that users would have to have access to FRS or explanatory information if they were to decipher what each number in the descriptive code meant. Instead, it was decided that these codes should be converted into words. It is believed that this will make it easier to use the system in the future and that any future updates will be less complicated to complete. In addition to this, a short description of each surveyed artefact was given.

3.4 ARCHAEOLOGICAL QUESTIONS

It has already been indicated that this project has not been set up as a means to creating a complete GIS for the *Oosterland* excavation. This would serve little purpose because only a relatively small part of the site has been excavated to date. Instead, this project is aimed at laying the foundation for a GIS that can be used for analysis during excavation and once the site has been completely excavated, and has been tested by making preliminary analyses on artefacts that have been recovered so far. For these reasons it should be recognised that any conclusions drawn from this research are tentative and may have to be modified at a later stage as more data become available. Questions that will be asked of the GIS in this context should, therefore, be seen more as a means of evaluating the viability of the system rather than as an end product. It should also be noted that certain questions may change over time and future research and new finds may result in further questions being asked.

Within the context of this section on archaeological questions, artefacts will be examined in groups or individually and the relations between artefact types will be explored. The first question that will be asked relates to quantities of particular artefacts and looks at individual groups of artefacts in isolation. Items such as lice combs, shoes, navigational equipment, buttons, musket plates, clay pipes and spoons will form the basis of this line of questioning. Historical documentation as contained in the VOC archives and experience gained on other projects indicates that certain numbers of each of these items should be present on the *Oosterland* site. For example, it can be assumed that each person on board the ship would have had at least one lice comb, one spoon, one pair of shoes and several clay pipes in his possession. Spoons have been taken as a specific example because they are amongst the very few utensil that indicate usage by specific numbers of individuals. One spoon represents one individual on board (Van Rooyen 1987: Appendix 9; Van Holk 1997:114). If the number of spoons is examined as a percentage of the number of people on board, it will be possible to provide an indication for the extent of excavation to date. Questions that follow from this point will determine which items can be most closely related to recovered spoons. This line of questioning uses neighbourhood examination to determine related objects. Answering this question may indicate specific ownership of spoons or at least give an indication of the status of the person who might have used this utensil.

Items such as navigational equipment, musket plates and pewter utensils are also specific to certain groups of people living on the ship. It can safely be assumed that only the officers, passengers and possibly non-commissioned officers would have used pewter plates and that the crew would have eaten from wooden bowls. This implies that pewter plates would be limited to specific areas within the ship, namely the stern. The same can be assumed for navigational equipment, which would have been used exclusively by navigational officers. It may be assumed that these items would also be found only in the stern of the ship. Although parts of the navigational items, such as sounding weights, may have been handled by sailors in different areas of the ship during a voyage, the *Oosterland* was at anchor and shortly before these items would probably have been stored. Storage could have been in the stern of the ship or further up front along the rail. This assumption is compounded by the fact that loose objects such as these would have been packed away when poor weather was expected. In the case of the *Oosterland*, the ship had experienced several days of stormy weather when lying at anchor. Another category, musket plates, may have been represented in two areas of the ship. These areas would be the officers quarters and the master gunner's room, in the stern, and the soldiers quarters in the lowest parts of the bow of the ship. A further category, the provenance of which is difficult to establish, is buttons. It would be troublesome to determine whether they are from items of clothing belonging to a member of the crew, passengers or officers and worn during the foundering of the ship, or from clothing which was kept in luggage. GIS will be used to examine the nature and numbers of such items that have been recovered and look at these as a percentage of the total number expected. This type of analysis is again useful in partly determining the extent of the site that has been excavated to date, assuming that the ship sank with its inventory complete and that, subsequently, no artefacts have been removed from the site through natural processes or salvage and treasure hunting activities.

This project will ask further questions relating to artefacts that can be found in ship inventories. The position of groups, or categories, of artefacts will be related to one another, which may go some way in explaining the way in which the ship is lying on the sea bed and how the wreckage was dispersed. The GIS will be used to examine the position of the concretion mound in relation to navigational equipment, galley bricks and barber surgeon equipment. The same application will be applied to the relation between navigational equipment, barber-surgeon instruments and utensils from the stern. Because the positions of these artefacts on board a working ship are to some extent known from historical documentation, it should be possible to determine how far from their original positions they have strayed. The inspection of these artefact groups and their relations to one another may also explain why certain concentrations of artefacts occur where they do on the site and what factors possibly had an effect on site formation. Statistical analyses such as nearest neighbour analysis will then be used to relate these artefacts to people on the operational ship. This may also be useful in determining areas that still need to be excavated and how excavation might proceed.

An attempt will also be made to determine ownership of personal items. By relating certain artefact groups such as galley utensils, navigational instruments or barber-surgeon equipment to their neighbours, it may be possible to determine the validity of attaching ownership to specific groups of people or individuals. Clusters of personal items and inventory, if observed, may show proximity significant enough to relate one to the other. This question will have to take into account the way in which the ship broke up and the way in which the vessel is orientated, as determined by the queries previously stated. If, for example, it were possible to note that all of the barber surgeon equipment recovered was to fall within a specific area, it might be possible to resolve whether the personal items within that area could be related in any way to the same user group. This type of analysis will take the form of a twofold nearest neighbour statistic. First, the barber-surgeon instruments would have to be related to one another in order to ascertain their distribution and, secondly, they have to be related to personal items.

A further exercise that can answer questions regarding the position of the ship and the way in which it has been dispersed concentrates on the positions of cannon that have been uncovered to date. Because of the weight of these items it would seem likely that they have not moved extensively on the sea bed. In looking at where these cannon lie in relation to each other, the presence or absence of lighter artefacts may prove useful. If the cannon are found to be situated away from other deposits and have only small or no quantities of artefacts around them, then it may be assumed that a large degree of post deposit movement has taken place. If, however, they were to be surrounded by artefacts, it may be possible to determine the position of the cannon on board ship. This particular question is, however, a cautious one because many of the cannon from the *Oosterland* have not been found as yet. If those that have been located were to show some kind of patterning, this may be beneficial in determining where other cannon may lie, giving yet another clue to the layout of the wreck.

As mentioned previously, these questions do not pretend to explore all spatial relations between artefacts recovered from the site to date, far from it. They are merely a means of testing the feasibility of applying a GIS to the *Oosterland* project and its *archaeological capabilities and short-comings. It should be noted that a non-result in* these cases is as useful as a result. Showing that some artefact groups or individual items are not related in the first parts of any of these questions will possibly indicate something of the deposit processes and how they occurred.

3.5 ANSWERING QUESTIONS RELATED TO SPATIAL DISTRIBUTION

In order to answer questions that are related to the distribution of artefacts around the site, it is necessary to examine a blueprint that gives an indication of how the artefacts may have been distributed while the ship was operational. This will help not only in determining expected artefact assemblages, but also in determining the extent to which items that were not recorded as being present in the blueprint are visible on site. For this reason, the following section will offer a brief examination of the internal organisation of a Dutch East Indiaman and the types of artefacts that may be associated with divisions within the structure.

for contravention of rules and regulations. The record may also become inaccurate because of subjective reporting. Finally, no complete contemporary building plans of VOC vessels exist. In an archaeological context, it is therefore necessary to examine anomalies such as the differences between what is found in the archaeological assemblage and the historical record. It is necessary also to discover why these anomalies occur. Looking for and interpreting deviations, however, demands a knowledge of the mean or blueprint.

Since this project does not deal specifically with the inventories of Dutch East Indiamen, but rather with the use and application of GIS on wreck sites, it is not appropriate to give lists of all provisions, stores, utensils and equipment that would have been present on board a 160 foot VOC ship, nor does the scope allow for an extensive description of the locations of these items on a fully equipped vessel. Instead, this chapter will give a more general overview of a typical seventeenth century Dutch East Indiaman and its internal organisation. Some examples of the types of artefacts that would have been located in each area will be given to create a basic understanding of the organisation of the ship. For a more complete record of artefacts found aboard such vessels see Gawronski, Kist & Stokvis-van Boetzelaer 1992.

As has already been indicated above, this project concerns itself with trading ships and in particular those of the VOC. By the 1650s, larger square Dutch ships had been divided into two distinct groups, the warship and the *retourschip* or East Indiaman. Because of the dangers associated with trade in the east, such as privateers, pirates and rival East India Companies, VOC ships were built, fitted and manned in a similar manner to the men-of-war used by the navies. It is thus reasonable that, when describing a merchantman of this calibre, some associations with warships can be made (Bound 1995). The VOC, in its efforts to turn a profit from trade in the East, would also have tried to maximise the productivity of a single ship. In other words, the directives given in ship building and the interior organisation would have been devised on the basis of using the confined space to its maximum potential. With constraints on volume and capacity of ships, and bearing in mind that a ship also had to be self sufficient, space had to be carefully planned and utilised (Muckelroy 1978; Gawronski *et al.* 1992:22).

To examine the internal organisation of a VOC *retourschip*, this section has been divided into three parts. These discuss the back or the stern, which in this context will include that area to the stern of the mizzen mast; mid-ships and cargo hold, assigned here as the area between the mizzen mast and foremast; and the bow, the area forward of the foremast. Although certain compartments of the ship overlap the sections as described above, the mast areas have been chosen to demarcate these areas because they form rough physical boundaries within the ship's structure. They may also have indicated social boundaries dividing various groups of people, as will be discussed later (Werz 1997:31-32).

1 captain's cabin (*schipperskamer*)
2 captain's bedroom (*schippersslaapkamer*)
3 cabins for officers (*hutten voor stuurlieden*)
4 surgeon's cabin (*hut voor oppermeester (chirurgijn)*)
5 cabin (*kajuit*)
6 constable's room (*constabelskamer*)
7 cable tiers (*kabelgat*)
8 cartridge lockers (*walegang*)
9 bread & sailrooms (*broodkamers en zeilkooien*)
10 powder room (*kruitkamer*)
11 pumps and pumpwell (*pompen in pompzoo*)
(12) quarterdeck (*halfdek*)
(13) upper deck (*verdek*)
(14) poopdeck (*campanjedek*)
15 capstan (*kaapstander*)
16 ventilator (*ventilator*)
(17) gundeck (quarters for crew) (*overloopdek*)
18 galley (quarters for cook and assistants) (*kombuis*)
19 steward's room (quarters for steward and assistants) (*bottelarij*)
20 mastwell (shotlockers) (*mastzoo*)
21 water and victuals hold (*water en spijsgat*)
22 main hatch (*grote luik*)
23 hold (*ruim*)
24 waterhold (*watergat*)
25 ropework store (*bergplaats voor licht touwwerk*)
26 cable tiers (*kabelgat*)
27 manger (*voorhel*)
28 bitts (*dekknechts*)
29 waist (*kuildek*)
30 forecastle (quarters for crew) (*bak*)
31 anchorbitts (*ankerbetings*)
(32) forecastle deck (*bakdek*)
33 beak (heads for crew) (*galjoen*)
34 sailroom (*zeilkooi*)
35 passageway to constable's room (*loopgang naar constabelskamer*)
36 area for consumption of food and drink (*plaats voor consumptie van voedsel en drank*)
37 backhatch (*achterluik*)
38 cook's hatch (*koksluik*)
39 forehatch (*voorluik*)
40 transom gallery (officers' heads) (*galerij*)

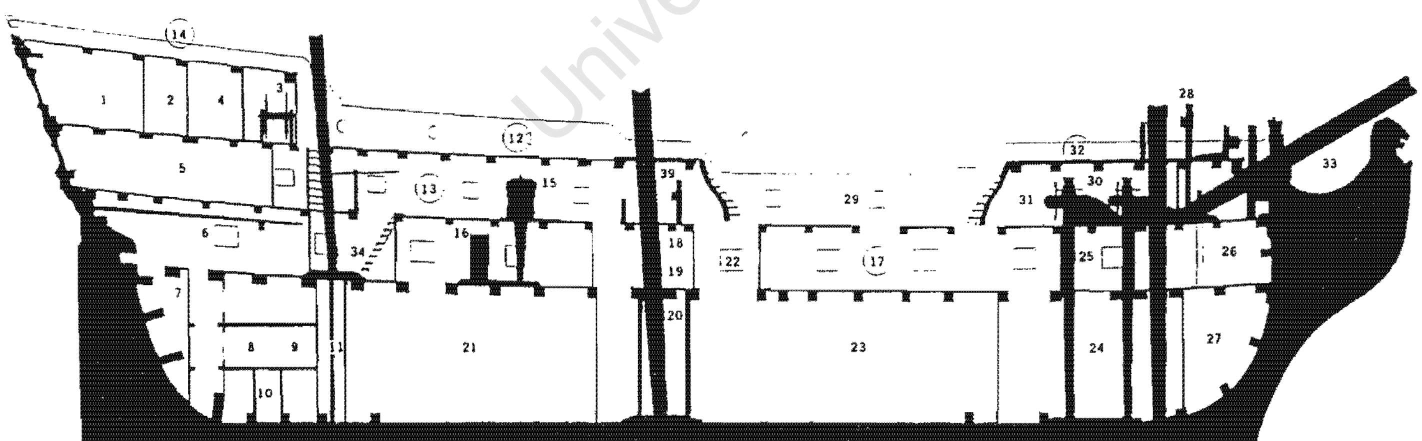


Figure 3.5.1.1 Layout of a Dutch East Indiaman (Gawronski 1992:23)

3.5.1.1 THE STERN

The stern, which is situated at the back of the ship, is probably most detailed in terms of organisation. Five decks divide the stern horizontally. The uppermost deck, exposed to the open air, is called the poop deck and contained small enclosures such as chicken coops. Swivel guns, used in close combat, could also be attached to the thick planking of the gunwales of this structure (Gawronski (ed.) 1987:55). As mentioned above, the perils of East India trade meant that the ships had to be well armed and organised in a manner similar to the man-of-war. Artefacts that may be recovered from this area in terms of official VOC policy might include: swivel guns, perhaps the remains of temporary enclosures or structures added to that of the ship i.e. remains of planking, wire, nails etc. and possibly even organic remains of the animals kept in that area. Being exposed to the elements, it is unlikely that any "loose" artefacts would be associated with the poop deck. Anything that was not firmly attached to the ship would have been hazardous in rough seas and susceptible to weathering and, therefore, stored elsewhere.

Situated below the poop is the quarter-deck. This deck is of equal height to the forecastle, the highest point at the bow. Although the quarter-deck itself extends to forward of the main mast, the deck only supports enclosed cabins in the area behind the mizzen mast. The quarter deck extends quite a way into the section in front of the cabins. This area would probably have been utilised by the officers and passengers as an area for relaxation. It was also utilised as a command post, for manoeuvring, rigging and de-rigging of the ship (Ketting 1979:63-64). It would be unlikely that any artefact remains could be specifically associated with this area. The quarter deck forward of the mizzen mast may, however, have been utilised as a storage area in this mid-ships region as it has the spatial capacity to support a large permanent or semi-permanent structure.

The allocation or use of the cabins on the quarter deck followed a very specific order. The large cabin at the back was the master's "working" cabin. It would have contained charts, log books, crew lists, cargo lists etc. as well as most of the master's furnishing, utensils and personal belongings. Forward of this cabin were smaller cabins. These served as sleeping quarters for the master and the first mate (Figure 3.5.1.2) (Gawronski (ed.) 1987:56). In the 17th century *retourschip*, the large stern cabin was proceeded by one cabin, as shown in Figure 3.5.1.3 which represented a "communal" cabin for the officers of the ship (Kamer 1995:158). Other people that would have been present in this section are the barber-surgeon and possibly some passengers. The ships steering mechanism was situated in front of the second cabin. As a result, items associated with the two cabins, such as personal belongings, can possibly be found in association with items that formed part of the steering or navigational equipment, such as sounding weights and compasses.

Artefacts that may be associated with the stern quarter deck area include navigational equipment like sounding weights and dividers, lamps, high quality dining utensils, officers weapons, such as swords and other side arms, furniture such as tables or sea-chests, brass fittings etc. The barber surgeons instruments would also be present in this area. These may include syringes, ointment jars and medicines. It should be noted, however, that the barber surgeon equipment was often kept in the master-gunners room underneath the quarter deck, and not in his cabin (Leuftink 1991:57).

Figure 3.5.1.2 Outlines and compartments on decks of East Indiaman (after Gawronski 1992:24-25)

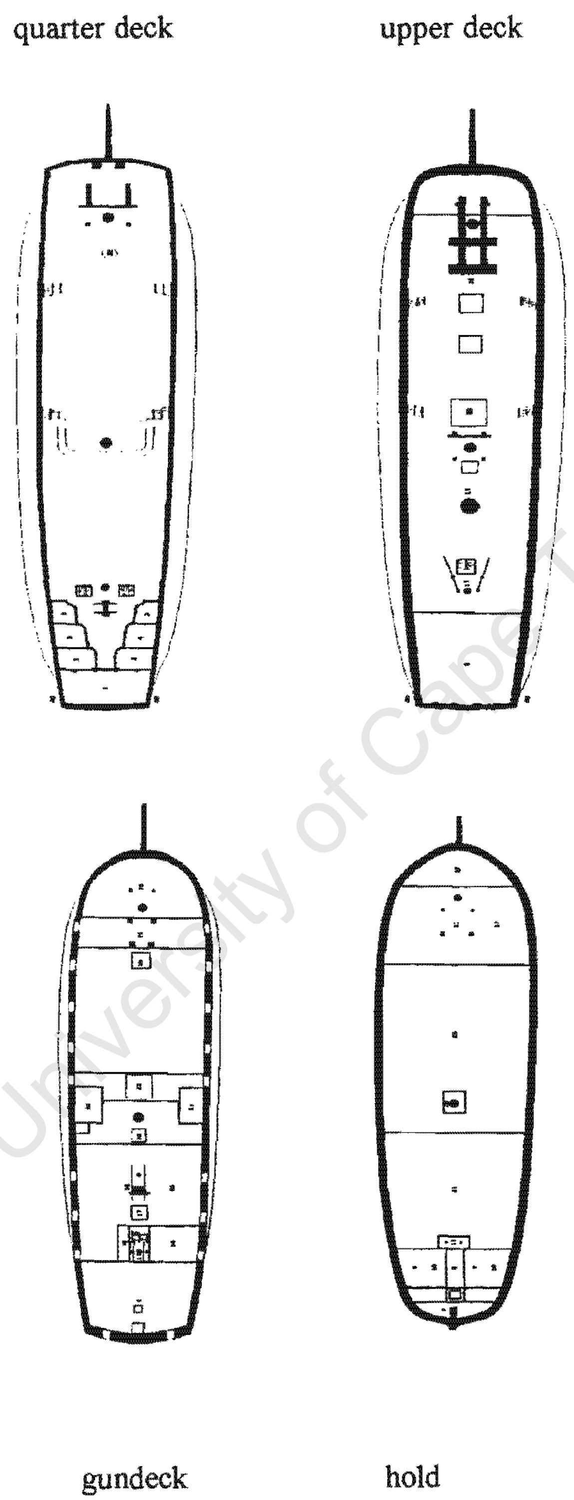
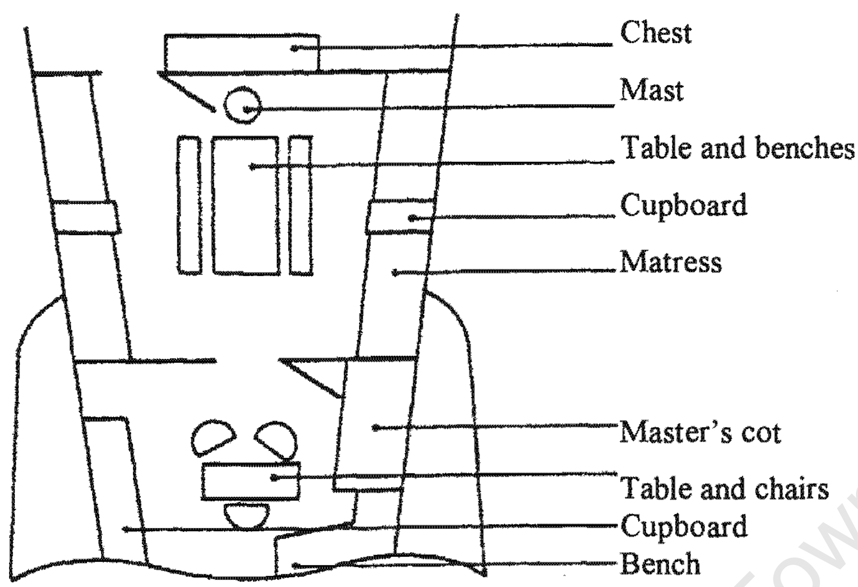
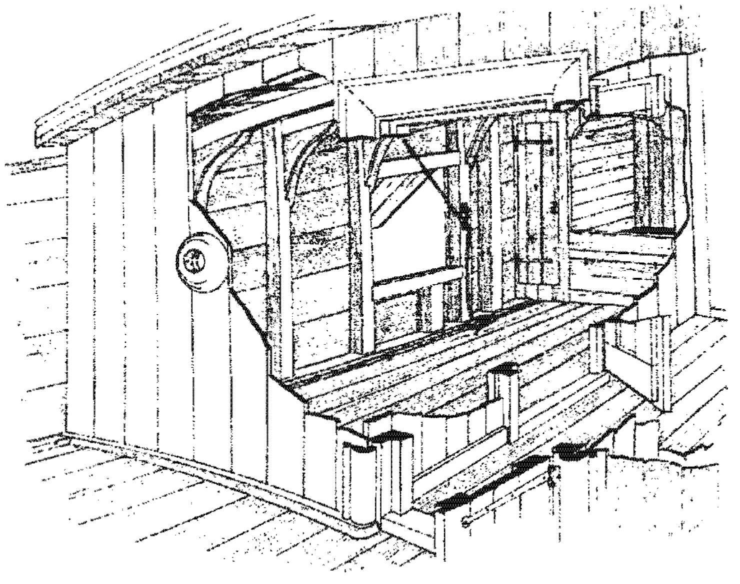


Figure 3.5.1.3 Stern section of a 17th Century Dutch East Indiaman (Kamer 1995:158)



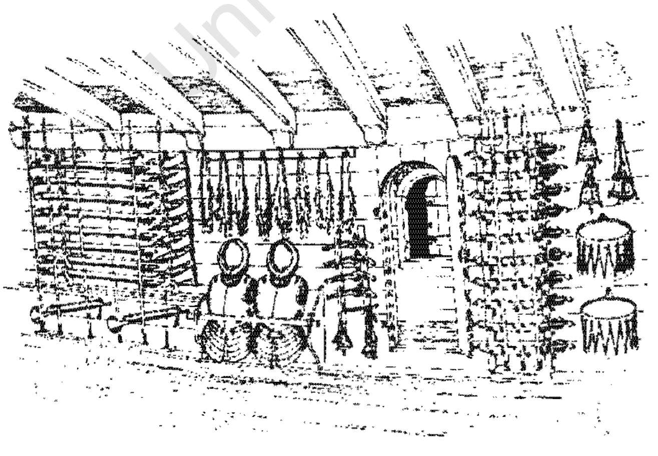
The upper deck was situated below the cabins of the stern. This is the highest deck that runs over the entire length of the ship. At the stern of the ship, below the masters quarters of the quarter deck, the upper deck supported a large cabin. This cabin took up the entire stern area. The cabin would have housed some of the small armament (Figure 3.5.1.5), the less important passengers or if there were no passengers could have been used as a store room. It would be interesting to know whether officers and crew shared this space for personal storage or whether there was some kind of hierarchy in space allocation. Artefacts that could possibly be associated with this area thus include personal belongings such as jewellery, luggage chests and perhaps porcelain and other goods that people were taking back to Europe on the homeward-bound voyage. The items would be similar for both the passenger or storage situations, perhaps differing slightly in volume without the added space consumption of people. In the example of the *Oosterland*, all porcelain recovered, with the exception of some of

Figure 3.5.1.4 The passenger and officer cabins (Ketting 1979:67)



The lowest deck of the ship was the gun deck. This was below the main deck and accessible only through the hatches that led from the upper deck. This is the first fully enclosed deck on the ship.

Figure 3.5.1.5 Arms Stored in the General Cabin (Ketting 1979:66)



The area towards the stern of this deck was occupied principally by the *constabel* or master-gunners room. This large cabin contained part of the small weaponry of the ship. With the exception of some cutlasses and firearms that were kept in the main cabin, gunners tools and equipment, handguns, armour and other weapons, with the exclusion of the cannon themselves, would have been kept in this room. This area would have been heavily guarded to ensure against crew members acquiring weapons that could be turned against the officers. The steering gear passed through this room, from the steering mechanism on the quarter-deck to the rudder itself. Artefacts that may be associated with this area would then include mostly small arms and gunnery equipment. The steering gear found here could also play a part in the identification of this area of the ship. Barber-surgeon equipment, that was often kept in a chest in the master-gunners room could be useful as an indicator of this area, but care would be needed to distinguish this particular set of equipment from its counterparts that could possibly be found in the barber-surgeons sleeping quarters on the quarter deck.

The cargo hold is the lowest and biggest enclosure of the ship. In the stern section the cargo hold was divided into smaller compartments covering the area from the mizzen mast to about half the distance to the *agterstevenbalk*, connecting the stern structure to the keel. At the very stern of the ship was a cable well. The tiers would have been used as storage areas for cables, bread and sails and other supplies. They also acted as cartridge lockers and contained the powder room surrounded by bread rooms. Forward of these sections was a pump-well that surrounded the mizzenmast and was connected to the bilge pumps above. Material that may be associated with this area would include cables for anchors, sails, stores such as shot, nails, carpentry tools etc. In the identification of this section of the ship, it may be useful to make note of the fact that copper sheeting, hinges and nails would have been used in the powder room and adjacent areas to create a spark free environment. Large quantities of these materials could point to this space. Again this area would have been heavily guarded and items associated with soldiery may be present in small quantities.

3.5.1.2 MID-SHIPS AND CARGO HOLD

As mentioned above, the quarter-deck and forecastle overlap with the mid-ships section, as defined in this project, and are on the same horizontal plane. The sections are, however, not joined and they are open in the centre revealing the upper deck. In other words, the upper deck, the first full deck on the ship, is situated below the quarter deck and forecastle deck. In the area at the stern that is covered by the quarter-deck, the upper deck houses the capstan (Gawronski (ed.) 1987:57). The capstan is a lifting device used to move heavy objects such as anchors, ship's boats, cannon, etc. (Figures 3.5.1.6 and 3.5.1.7). Although it would have been necessary to keep this area relatively uncluttered, it may also have been used to store livestock such as pigs (Gawronski (ed.) 1987:57). Once again the ships fittings, in this case the capstan, would give a clue of the area being examined. Little in the way of artefact remains would be found in this area except for possibly animal remains and personal items belonging to the crew if the area was used for sleeping or other activities. Most of the crew were, however, accommodated on the lower gun deck. The portion of this deck that was uncovered, was used for the storage of the ship's boats. The section covered by the forecastle housed part of the crew. The boatswain and watchmen could have used this area for shelter in rough or unpleasant seas. The anchor bitts were also stored in this part of the ship. Because of the accessibility and situation of this deck, it could be used also as a place to tend to the sick during calm weather. Being uncovered and thus aerated it would have been more hygienic and pleasant in this regard. Activities of this kind would not, however, be reflected in the archaeological record because ship

Figure 3.5.1.6 Pulling up of Anchors (Ketting 1979:61)

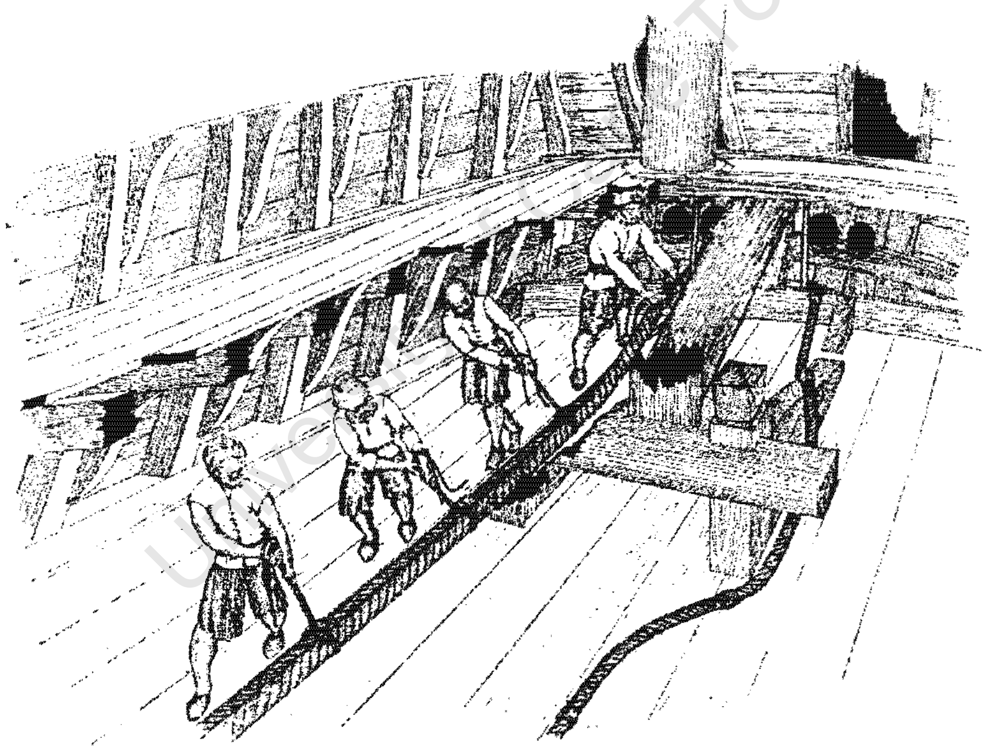
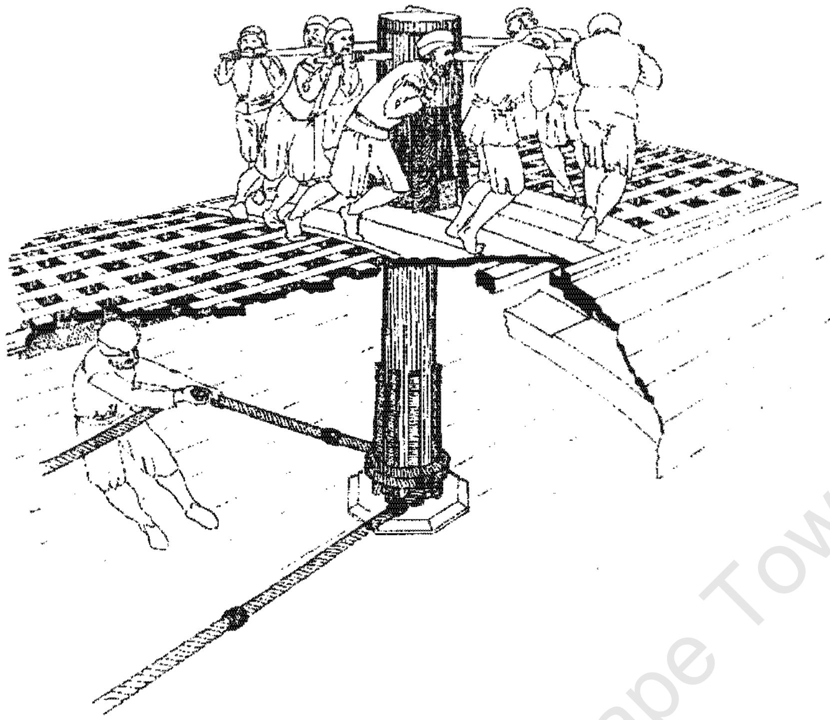


Figure 3.5.1.7 Working the Capstan (Ketting 1979:62)



wreck accidents did not usually occur in good weather. The smaller cannon, mainly six pounders, of the ship would also have been situated on this deck and would also thus be reflected in the archaeological remains. In addition, there was the small boat equipment, personal items of the crew and items associated with livestock maintenance. This area may also contain small quantities of other items such as medical equipment left by the barber-surgeon perhaps giving emergency medical attention to injured personnel during a disaster. Although this is an unlikely occurrence, assumptions like these are important when excavating a wreck in that they may solve confusion created by items that seem out of place.

The lower gun-deck was situated below the upper deck and was accessible through hatches and a small passageway leading from the gun room. This deck housed the main ship's armaments and the crew's quarters. The stern area on this level was used as a sail room where spare sheeting, ropes and rigging tackle would have been stored. Forwards of the sail room were ventilation shafts that opened up just behind the capstan. A large bellows was situated in this area to accommodate ventilation of the crews quarters and lower compartments of the ship (Gawronski (ed.), 1987:57). The heavy armament of the ship, i.e. large cannon were situated from this point forwards.

The East Indiamen, although carrying fewer guns, were armed in a similar fashion to the war ships. Ships were sometimes armed differently on each voyage (Brown 1992, in: Bound (ed.) 1995:114). The different types of ordinance depended on factors such as resolutions of the VOC governing weaponry, war and other political circumstances of the time. This once again shows the importance of the correlation between the archaeological records and the historical sources for each voyage. The number of guns present on the ship would not only affect the numbers of trained sailors needed to work the guns, thus affecting the space constraints on board, but also the internal organisation of the ship to accommodate the guns present and their related equipment.

Most of the crew stored their sea chests around the cannon and daily life on board ship advanced in this area. The steward's room and the galley were situated to the port and starboard of the main mast on the lower gun deck. These were the areas where the preparation of hot food took place and the crew received its refreshments rations. The galley was a brick lined area that contained fires necessary for the preparation of food. The bricks ensured that the fire was controlled and did not spread to the rest of the ship. Towards the bow, this section of the ship accommodated another store room used mainly for storage of rope work.

Artefacts that can be associated with the lower gun deck of the ship are varied. Firstly, and most noticeably, are the cannon. Where salvage operations could not retrieve the cannon after the ship had been wrecked, it may be assumed that a large number of cannon can still be found in the lower gun deck area. Related to the cannon are items such as shot, used in the operation of the guns. Items belonging to crew members can also be found here. The contents of sea chests, including tobacco pipes, footwear, lice combs etc. should be visible in the archaeological remains in many instances. Items such as clothing that were contained in these chest are unlikely to survive, although leather and buttons can be reflected in the archaeological record. Personal items and part of personal trade goods were also stowed in these chests, out of sight of the officers and other crew members. The size of the chests would, however, restrict the volume of such items. Artefacts associated with the galley and stewards room, such as bricks, copper cauldrons, pots and cooking utensils should be highly visible in this area. As a result of the durability of such items, together with their unique size and shape, they can be excellent indicators of the lower gun-deck and its associated compartments. This section of the ship would also be the most difficult to investigate, considering the possibility that unofficial goods were kept here. This again would be an area where the archaeologist would have to draw in the historical records in order to decipher the official ship's equipment and fitting issue from the informal items taken on board. It is this area that would probably give the most information regarding everyday life on board ship.

Below the gun deck was the main cargo hold (Figures 3.5.1.7 and 3.5.1.8). To discern this section from other areas with absolute certainty it is necessary to know what cargo the ship was carrying at the time. Once again, investigation of the historical documentation together with archaeological evidence might show what types of artefacts can be associated with this enclosure. There were, however, divisions present in the hold that may give additional clues as to its identity. Towards the stern of the hold were water and victual stores. These contained fresh drinking water and alcoholic beverages, as well as provisions (Gawronski (ed.) 1987:57). A smaller provisions store was situated towards the bow of the ship, the two being separated by the main cargo hold. The area around the main mast was used as a storage space, or well, for the majority of cannon balls (Gawronski (ed.) 1987:57).

It is possible to recognise this part of the ship, therefore, without knowing the specifics of the cargo being carried although large quantities of items such as peppercorns, fennel, cowrie shells, tropical hardwood and indigo, all found on the *Oosterland*, could give a good indication. Artefacts, ships equipment and stores that can be allied to this part of the ship would include barrels and casks used for the storage of liquids such as water and alcohol, other containers such as baskets used for the storage of provisions, lead shot and cannon balls. If the cargo of the ship is known, this section of the ship will be even more easily recognisable. For obvious reasons, the cargo hold would be relatively free of artefacts associated with life on board, although it might well contain illicitly transported private goods.

Figure 3.5.1.7 The hold looking from mid-ships towards the stern (Ketting 1979:72)

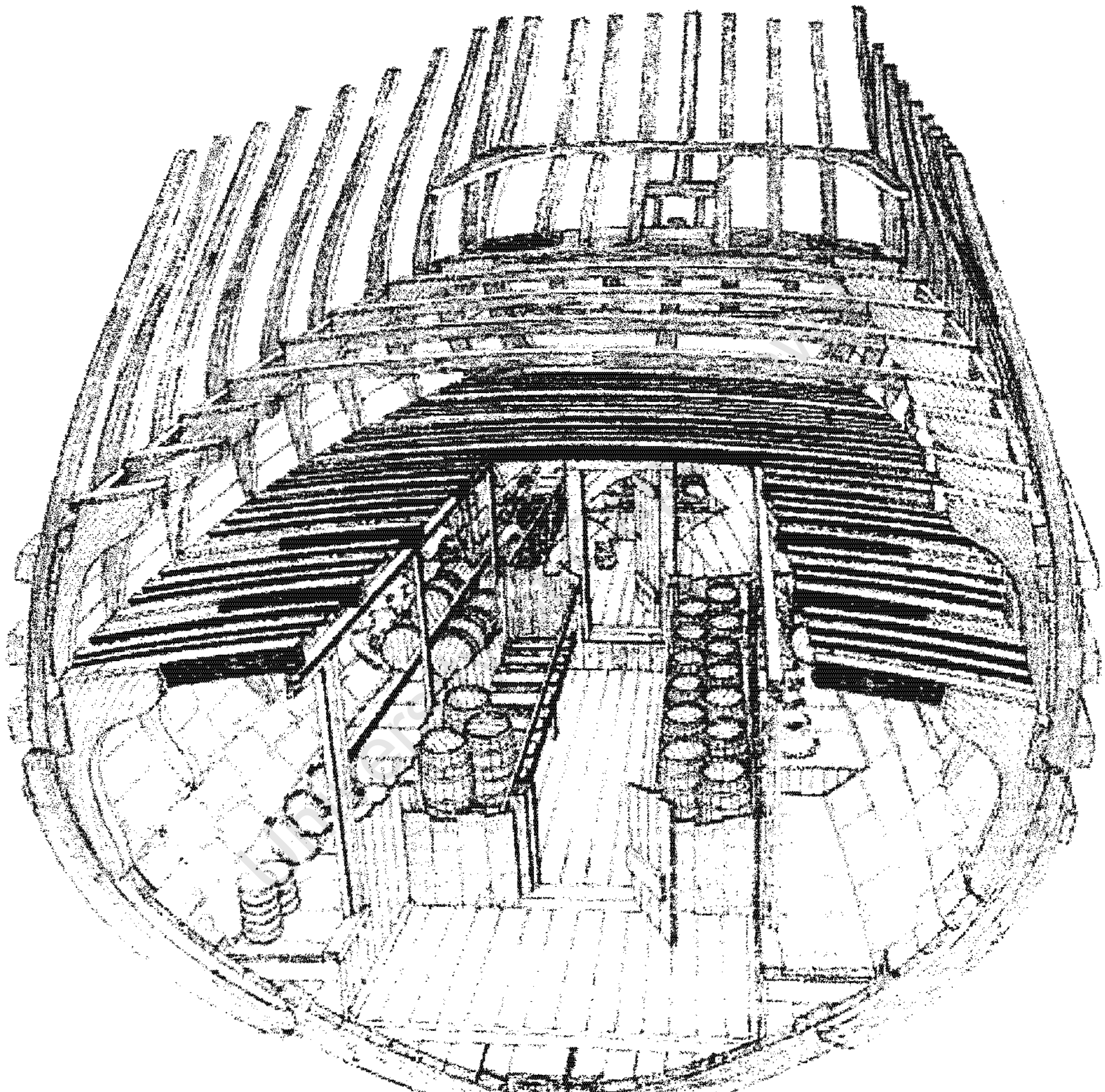
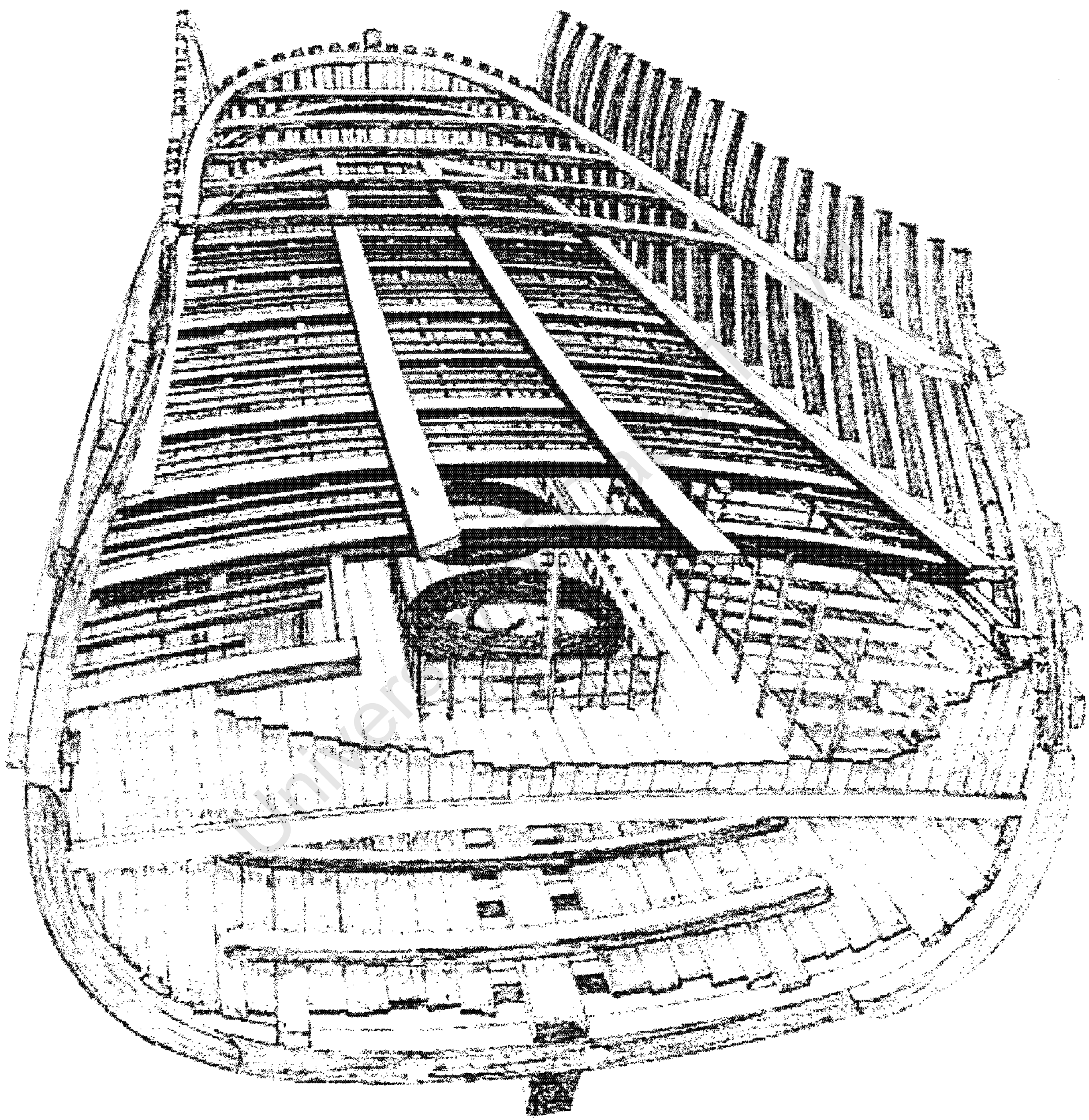


Figure 3.5.1.8 The hold looking from mid-ships towards the bow (Ketting 1979:73)



3.5.1.3 THE BOW

The bow area, in front of the foremast, included the forecastle deck and the upper deck which were taken up largely by the fittings of the bowsprit. Below the bowsprit on the gun deck were cable banks used for rigging etc. There was a manger in the hold and on the beak of the ship was the crew's head. What may remain are artefacts allied to livestock maintenance and rigging. The actual ship structure in this area is relatively solid and densely fitted. It may be that ship fittings and perhaps even decorative paraphernalia, such as the figurehead which was attached to the bow, are preserved due to these conditions.

Soldiers and sailors were also accommodated in the lower parts of the bow structure. This would indicate that many items associated with these people can be recovered from excavations in this part of the ship. Finds would include weaponry, such as brass musket plates; personal belongings, such as lice combs, spoons and other items that may have been stored in the sea chests; and possibly personal trade goods. Buttons and other metal items that were used on soldiers uniforms could also be associated with this area. Because soldiers were comparatively inactive during a voyage, artefacts such as gaming pieces and other devices that may have kept people occupied may be found in the bow of the ship, although such items would obviously also be present in the crew's and officers' quarters.

It can be assumed that certain structural features determined and restricted spatial organisation within the ship. For purposes of this research, it is therefore useful to examine parts of the ship that most likely to survived over long periods of time. For example, the location of the keel would be a good indicator of the direction in which the ship was deposited on the seabed and therefore where certain artefacts can be expected during excavation. Inversely, the location of an unidentified object can possibly be linked to a structural component that can provide a clue as to the artefact's original location on board the working ship. This allows the archaeologist to begin to relate this artefact to people on the ship and its past use or significance. As it is not practicable to look at each component of the ships structure in detail in the context of this study, only a few examples or the more durable components will be given hereafter to illustrate this assumption.

As suggested above, the keel together with the aft and fore stays, determined the length of the ship. These stays are important parts of the ships structure. In a spatial sense, they indicate the bow and stern of the ship and are also significant as indicators of a ship's total proportions, as these seem to have been dependent on the height of the fore and aft stay. As structural components, stays were vital. The fore stay was used in the attachment of hull planking to the ship skeleton. The aft stay not only supported outer planking, but also needed strength to support the wide stern structure and the pressures put onto it by the mizzen mast (Ketting 1979:17-18). Because of these stress factors, the stays would have been heavily built and thus possibly survive in the underwater environment for a long time. An example of this is provided by the remains of the VOC ship, *Batavia*, wrecked on the Australian west coast. They are important as an archaeological reference in determining the bow and stern sections of the vessel, the direction in which the ship is positioned, and the size of the ship (in the absence of the complete keel). Once the lie and size of the ship has been determined, certain determinations can be made concerning artefact dispersal. Artefacts and an examination of their positions in relation to the structural remains would show how the ship broke up or how a shifting seabed affected the wreck and its contents. The position of artefacts and their relation to the structural elements could also give some sense of life on board the ship. Artefacts that seem out of place from their location as given by official or historical documentation could be identified with this analysis and show something more about they way people organised themselves and interacted with each other while living on the ship.

Other structural remains which can serve as indicators for the layout of a wreck site are the masts. Although the tops would be easily put out of place during the wrecking process, the bases of the masts would stay *in situ* as a result of their size and their strong connection to the keel, due to the support required for the immense sail area that the ships needed for propulsion. The galley, mid-ships on the port side of the gundeck, is another structural component that is very visible to the excavators. Because it is brick lined to avoid fire spreading to other areas of the ship, and because these bricks will survive the damages of time, it is likely that this part of the ship will be easily discernible. Such bricks have been recovered from the *Oosterland* site and can be associated with cooking pots and utensils. The galley compartment is associated primarily with the gundeck and crews quarters. It contains certain unique items, such as the utensils used in preparation of food which will be discovered in no other area on the ship. Therefore, the archaeologist could expect to find the regulation items issued by the VOC in this area. It may be an interesting problem to decipher the relationship of unofficial items found in association with the galley. In such an instance it may be that, due to the close proximity of the galley with sleeping quarters, artefacts belonging to crew other than the cook or his assistants, have been mixed with galley items on the sea floor.

Finally, there are those structural "indicators" that would fall into the category of ship fittings. These include the capstan, the steering gear and possibly the larger vents and bellows. The capstan, situated on the upper deck between the main mast and the mizzen mast, could well survive destruction. This large, solid circular winch affected the internal organisation to a large degree. Its size and function meant that the area surrounding it would have to be kept clear. Therefore, artefact remains would be rare in its immediate vicinity. Because of its size and strength, the steering gear is also well suited to long term survival. Because the steering mechanism is situated in front of the officers quarters, there would have been a necessity for some sort of adjustment to compensate for its presence. This affect would possibly be on personal belongings if, for example, a temporary structure to house them was built in that area (Werz 1997 pers. comm.) and on the freedom of movement of the officers living around it. This can possibly be shown through spatial analysis. In addition, the mechanisms that connected the steering mechanism to the rudder ran through the gun room, affecting the organisation of this space. Although the rudder did not have an impact on the internal organisation, as it was suspended at the back of the ship, it can be used as a positional pointer during excavation and should, therefore, be included here.

What must be kept in mind is that during excavation, the positions of exposed artefacts or indicators, such as those mentioned above, allow for a prognosis to be made of the approximate position of as yet undiscovered structural remains. If, for example, items belonging to the master of the ship were to be discovered, it could mean that the aft stay and the rudder are in close proximity if they survived on site. The same scenario would be true if structural remains that are difficult to identify were recovered. The fact that certain artefacts are associated only with certain areas on board ship, means that artefacts can be used as a means of distinguishing these structural remains. A case in point would be to find separate beams with pivots on the extremities which were clearly never integrated into the ships structure. If these are found in and amongst gunnery equipment and the remains of small arms, this could well indicate part of the steering mechanism that ran through the master gunner's room.

In conclusion, in discussing the interior of a 160 foot VOC ship it must be assumed that the remaining structure has been altered as a result of wrecking, by contemporary salvage attempts, because of decay or by other environmental factors such as wave action and currents. A further factor affecting both structural remains and artefact assemblages is modern day treasure and souvenir hunting. What might remain, however, are substantial structural features such as parts of the hull and rudder and artefact assemblages which, to a certain extent, reflect the construction and internal organisation of the ship when it was operational.

Although only a very general overview of the official ships layout has been presented here, this section forms an important facet of this research. The concept of space is one of the most fundamental concepts on which archaeological interpretation is based. In the case of maritime archaeological research, and the *Oosterland* project specifically, it may be assumed that relations between artefacts associated with different parts of the ship will provide information about the breaking up of the vessel and the wreck formation process. Depending on the distribution of artefacts from each deck and each area within the decks, it must be possible to determine, at least in part, the nature of the collapse of the vessel on the sea bed. For example, if items associated with the officers quarters on the quarter deck were to be recovered combined with assemblages related to the constable's room on the gun deck, it could be assumed that part of the stern section of the wreck collapsed vertically on to itself. If, however, the same artefacts were found in areas adjacent to each other, it may be assumed that the wreck pitched over onto its side before deposition. An amalgamation of artefacts originating from different areas on the ship may suggest environmental factors, such as wave action, acting on the wreck and moving artefacts around on the sea bed. Further spread distributions could show large scale fracture of the ship's structure on the surface during the wrecking process and subsequent dispersal.

Some of these questions which are related to the internal organisation of the ship will be further examined in the analytical stages of this project, when dealing with specific archaeological questions and answers using the GIS. For example, knowing what types of artefacts can be associated with different areas on the ship, can provide clues as to differences between distinct social groups in terms of space allocation. In addition, artefacts which have been formally recorded can be compared with the undocumented remains recovered, i.e. assemblages of personal items not reflected in the historical documentation, and this will give a more detailed idea of life on board a specific ship in a specific time period. Hereby it is assumed that people's interactions and daily lives will be reflected, to an extent, in the material they leave behind. Examination of the spatial distributions of these residues might show where, how and possibly why such activities took place.

It is clear that a general understanding of the full range and quantities of official equipment that would have been carried aboard is a vital commencement point from which specific anomalies, irregularities, differences and omissions can be measured. Because this research is concerned principally with the use of a GIS on a specific maritime archaeological project, it is not relevant to make a complete list of the enormous volume of material that would have been carried on board a Dutch East Indiaman. Such studies have already been undertaken by, for example, Gawronski *et al.* 1992; Gawronski 1987. In the organisation of artefacts recovered from the *Oosterland* for use in the GIS, however, each artefact recovered has been classified with the historical and official documentation in mind. As the archaeological excavations continue and the assemblage becomes more complete, it will also become possible to identify what is missing from the collection.

3.5.2 CARGO VERSUS TREASURE: THE EFFECTS OF PERSONAL TRADE ON INTERNAL ORGANISATION

It is a generally accepted fact that people on board East Indiamen made use of opportunities overseas to acquire varying amounts of trade goods for personal use or resale on return to the Netherlands and benefited from favourable exchange rates to transfer money for money (Werz 1997:68-69). There are several reasons why these practices are difficult to study. Firstly, sometimes part of the personal trade items that were on board were unofficial and therefore, despite several historical references to the

Another difficulty in examining personal commodities is the fact that these goods were hidden in various places on board the ship or placed in temporary structures. The most prominent place for such structures was in the area in front of the officer's quarters on the quarter deck (see ship plans above). It has occasionally been recorded that the officials on board sometimes set up temporary structures in this area to house personal items acquired in the East or to accommodate themselves if their cabins were filled with personal trade goods (Werz 1995, pers. comm.). If this is the case, then the items that were stored there would probably be mixed with the formal contents of the stern section. This is because during the break-up and decay of the structure, the ship would either collapse onto itself or onto its side. An exception would be when environmental factors cause interspersion between private goods belonging to higher ranking persons and crew, who were accommodated in the mid-ships and bow sections. Other temporary structures could presumably be erected on the poop deck and the upper deck. In the case of the upper deck structure, it would again be the domain of the officers, but artefacts found here could seem to be associated with the crew when the ship broke up. The structures built on the poop deck would be exclusively associated with officers. This relation problem could be solved in a number of ways. If there is a difference between the quality of personal items available to crew and officers, due to financial differences, then it could be possible to sort out the one category from the other to some extent. Quality of items recovered is, however, not a satisfactory means to analysing ownership because individual crew members may have bought one or two expensive items, whereas some officers may have bought large quantities of inexpensive commodities. There would certainly be differences in quantities of personal items because of the space available to individuals of different status and the differences in earnings between officers and crew. It can therefore be assumed, generally speaking, that higher ranking officials transported larger quantities of personal items than individual crew members.

Although the main cabin in the stern of the ship is not an unofficial or temporary structure, it may well have been used as a storage area for the officer's personal goods. In the event that the ship was carrying no passengers, it seems likely that this space would be an ideal area for storage. It is large, easily accessible to the officers and out of sight and out of bounds of the crew. If passengers were on board, then the main cabin would again be a source of unofficial or personal commodities. If passengers were returning from a stay overseas then they would probably be taking part of their belongings with them. This may mean that even items as large as furniture can be found in this area. These larger items could, however, also be stored in the hold, so care should be taken in using these as identifying markers for a particular area within the ship. Smaller personal items, such as jewellery or cutlery, might be found in the cabin area.

As mentioned above, the social hierarchies on the vessel adhered to strict physical boundaries. The sleeping quarters of the higher officers were restricted to the stern of the ship. Only during the execution of their duties would they have moved towards the bow. Passengers would have adhered to similar spatial boundaries. They included merchants, clergymen, newly appointed or retiring governors and others. These people could often be considered passengers if they were solely interested in reaching a specific destination. However, specifically merchants were actively involved in decision making on board ship which makes their status somewhat obscure (Werz 1997:32). The non-commissioned officers would appear to have been of lower social status than most of the passengers. Sailmakers, master-gunners, cooks, stewards, provosts, carpenters and barber-surgeons were, therefore, situated either in the mid-ships or in the lower decks of the stern and close to their working areas. Because of their tasks and the fact that many of them, such as the master gunners, would be needed mainly in an emergency, meant that they needed to be "on call" all of the time and ready to perform their functions immediately and swiftly.

People of lesser status i.e. the sailors and soldiers were housed forward of the main mast. Even amongst these lower status people, there were social divisions (Werz 1997:32). The sailors were situated on the gun decks of the ship, making it possible for them to be close to their area of work. The soldiers, who were considered to be of the lowest status on the ship, lived on the orlop deck in the forecastle and below in the hold at the bow. The reasons for this division were mainly due to function. The soldiers were only active on watch duty, when the ship was engaged in battle or when they were required to assist in loading and unloading of the cargo, whereas sailors were active for the entire voyage.

It may be assumed that the above mentioned divisions are, at least in part, reflected in the archaeological record. There are, however, certain factors that would affect the distribution and, therefore, the analysis of the artefacts that may indicate how the ships were partitioned in terms of people. The most obvious problem is trying to identify the types of artefacts that would show differences between classes. It should be noted that the differences in personal items of the sailors and soldiers would probably have been slight. The difference in pay, as derived from the historical documentation, was small and so the types of items that were available for purchase would have been similar.

Determining separation between soldiers and sailors is further complicated by the manner in which the ship broke up during the wrecking process and it's decay on the sea floor. If the ship collapsed down onto itself it may be difficult to unscramble and assign different artefacts to different people. Further complications relate to the space for storage of personal belongings, which would have been restricted to approximately the same area for both soldiers and sailors. For these reasons the archaeologist can, in most instances, only make reasonable divisions between the people of high rank and the people of lesser status.

Even if items associated specifically with one group or another were to be recovered, the fact that in many instances they would be interspersed with items associated directly with another group complicates the issue. For example, if the ship collapsed down onto itself, the officers personal belongings would be mixed with the items found in the cabin and the gun room. This makes it very difficult for the investigator to determine what belonged to the first mate as opposed to what belonged to the master gunner, assuming that both transported personal goods in their respective areas.

In conclusion, it is clear that the majority of the ship's company would have made an attempt to collect personal items while in the East. These items could take the form of trade goods, for resale in their home countries, or of souvenirs. Added to these items are personal artefacts taken onto the vessel in an attempt to make life during the voyage more comfortable, such as gaming pieces, or as a reminder of home. Even though the VOC tried to curb illicit trade, most people on board seem to have made every effort to acquire the maximum quantities of personal commodities possible, perhaps even through the sacrifice of official VOC issue items. For this reason, space would have been used in a manner to maximise the storage of personal goods. The space available for personal goods is directly proportional to rank or status. There are clear divisions of status groups on board ship and these can possibly be reflected in an analysis of the personal items recovered during archaeological excavations of wrecks.

Because the study of history is about people adapting to and creating their social environments, these items would go some way in reconstructing and interpreting the history of the trade system that was aided by these ships and the people living in their bulks. East Indiamen were amongst the most technologically advanced structures of their time and they played a vital part in historical developments throughout large parts of the world. For this reason, a detailed and thorough study of these vessels is important in recreating aspects of 17th and 18th century history.

3.5.3 RESULTS OF THE *OOSTERLAND* GIS

In preceding sections, some archaeological questions were in an effort to test the use of the GIS system developed as an analytical tool. In the following, an attempt will be undertaken to answer these questions. Before doing so, however, it is perhaps necessary to explain briefly the way in which data resulting from the *Oosterland* project have been organised within ArcView.

Several tables were created in the Tables feature of the Project menu. These included separate tables containing x and y co-ordinates and PDP and DP numbers for different sets of grids. The perimeter grid was plotted first followed by the smaller rigid grids. Grids 1 and 2 form the first set, 3-5 the second 6-8 and 9-13 the third and fourth respectively. These divisions were created based on the fact that the grids in each category are physically connected, except in the case of grids 1 and 2 which form a separate table. Once these tables were created, they were joined to form one table called "Grids" that contains the x and y co-ordinates for all of the DPs and PDPs on the site. Artefact data and positions were contained in a second group of tables created for this purpose. Three tables were created, one for each excavation season. These too were joined to form a table called "Artefacts". This system of tables means that each group of grids and each season of artefacts can be examined separately or as a whole. It was felt that the option of setting up tables in this manner would make the system more user friendly. Artefacts were selected using the Query Builder tool in Views. This tool allows the user to select items from the tables based on the contents of fields in those tables. This is why the classification of artefacts was an important feature of data capture. It was found, however, that searches were most effective if the artefact descriptions were used as a means of selection because several different types of artefacts had the same classifications. For example, the classification Tools and Utensils includes both items associated with navigation and items such as spoons but these two categories may be needed to be examined separately or as a whole, depending on the questions being asked.

Spoons and possibly lice combs represent categories of items that show a one to one ratio to people on board ship in terms of numbers. From historical documentation it has been possible to determine that 146 people took part in the return voyage of the *Oosterland*, eleven of whom died during the journey. On arrival at the Cape, 35 sick and probably some of the officers would have disembarked and been taken ashore. This means that almost 100 people would have been on board the *Oosterland* when she was wrecked (Werz 1997:241). It can therefore be assumed that artefacts recovered would represent these people at an absolute minimum. To examine the numbers of these items and their relation to other artefacts on the site, the "Artefacts" table was selected and inserted into a View. This process makes the data contained in that table available for visual inspection and data query. Using the Query builder tool, spoons and lice combs were selected from the list of artefact descriptions as shown in Figures 3.5.3.1 and 3.5.3.2. Only a minimal number of such artefacts have been recovered to date: three spoons and five lice combs. This means mean that a maximum of eight individuals can be associated with the area covered by these items, if it is assumed that each item belonged to a different person on board ship. It is likely, however, that fewer individuals are present. Figure 3.5.3.3 shows that at least one of the spoons and one of the lice combs could be associated with one individual. Artefacts associated with these items and their relative position on board ship will be discussed later. By examining the numbers of individuals represented on the site to date, it is possible to determine how much of the site has been excavated to date. The fact that a maximum of eight out of almost 100 individuals can be accounted for by spoons and lice combs, means that implies that less than 8% of the total wreck has been uncovered at this stage of excavation. Other evidence that allows for the determination of the amount of the site exposed to date comes from items that are listed in the standard ship inventories of the period. List supplied by Van Yk (1697:276-285) of the inventory of a 154 foot East Indiaman can be examined and comparisons can be drawn between

Figure 3.5.3.1 Spoons recovered from the first three fieldwork seasons of the *Oosterland* excavation from 1991 to 1996 (artefact numbers included)

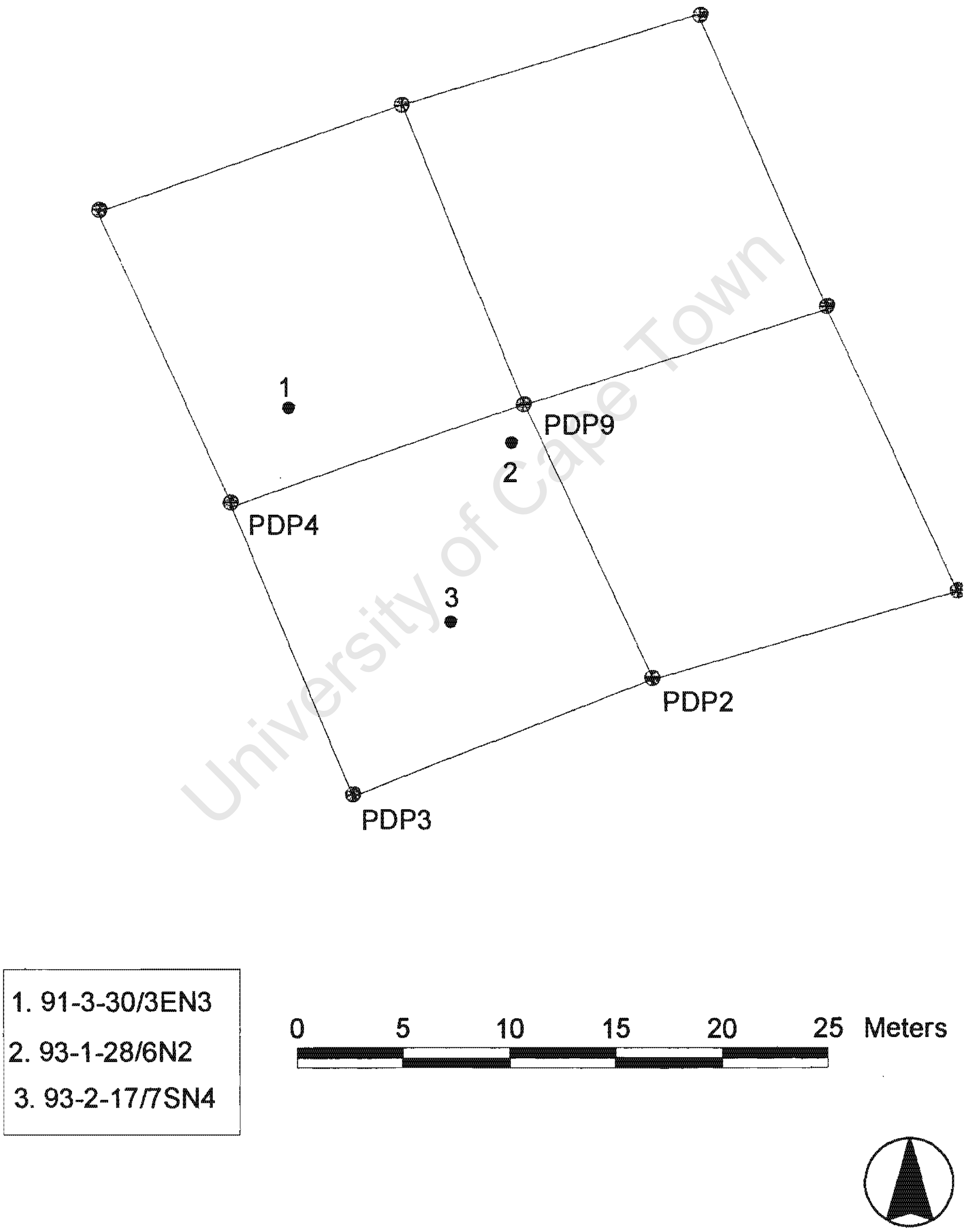
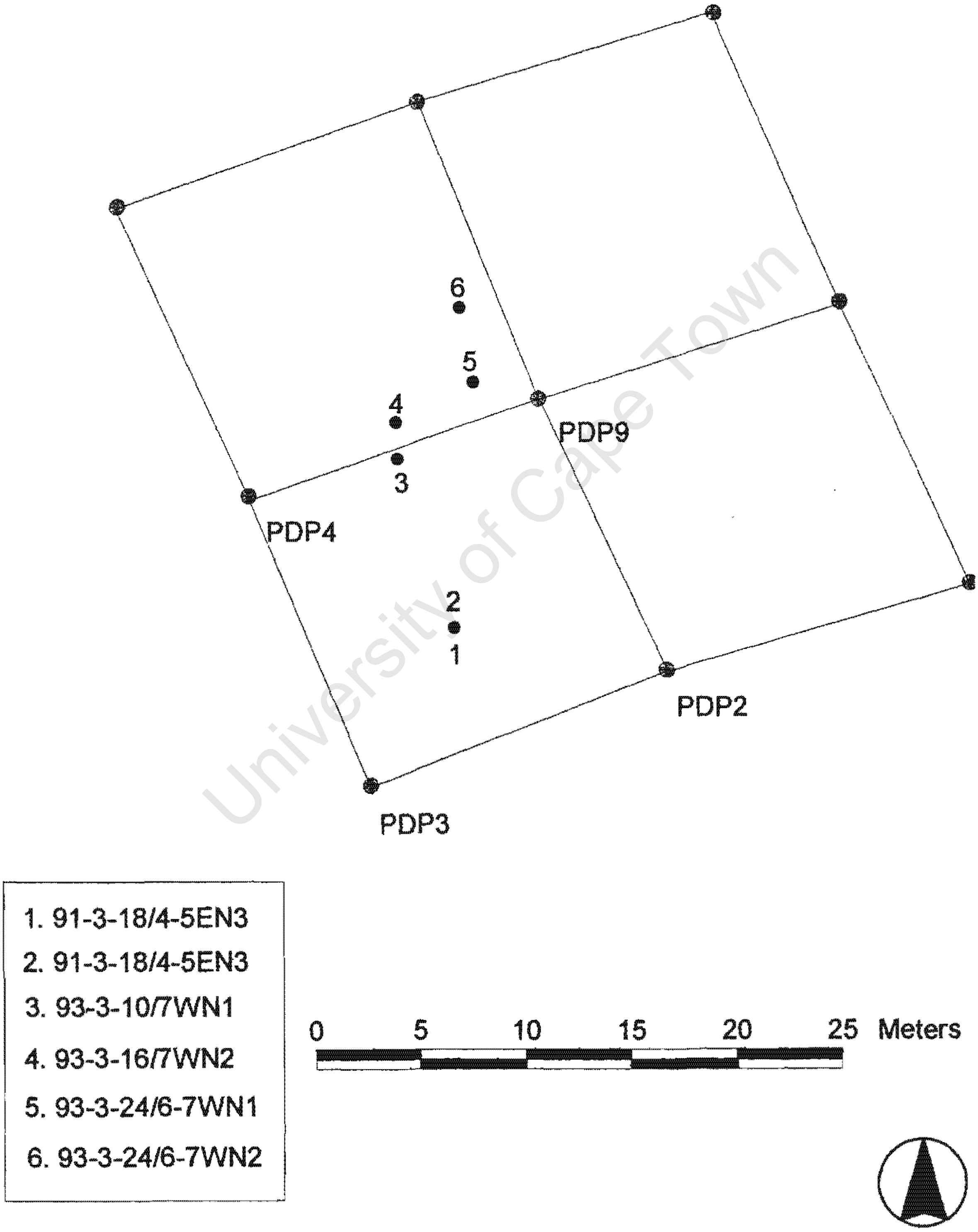


Figure 3.5.3.2 Lice combs recovered from the first three fieldwork seasons of the *Oosterland* excavation from 1991 to 1996 (artefact numbers included)



what has been recovered and what should be present. It should be noted, however, that the *Oosterland* was a 160 foot ship and may have differed slightly, in term of standard outfitting, to the inventories contained in Van Yk. It is possible, however to briefly examine these lists in an attempt to determine the extent to which excavation has covered the site to date. Items of interest include the following:

Table 3.5.3.1 Expected Artefact Finds vs. Actual Finds

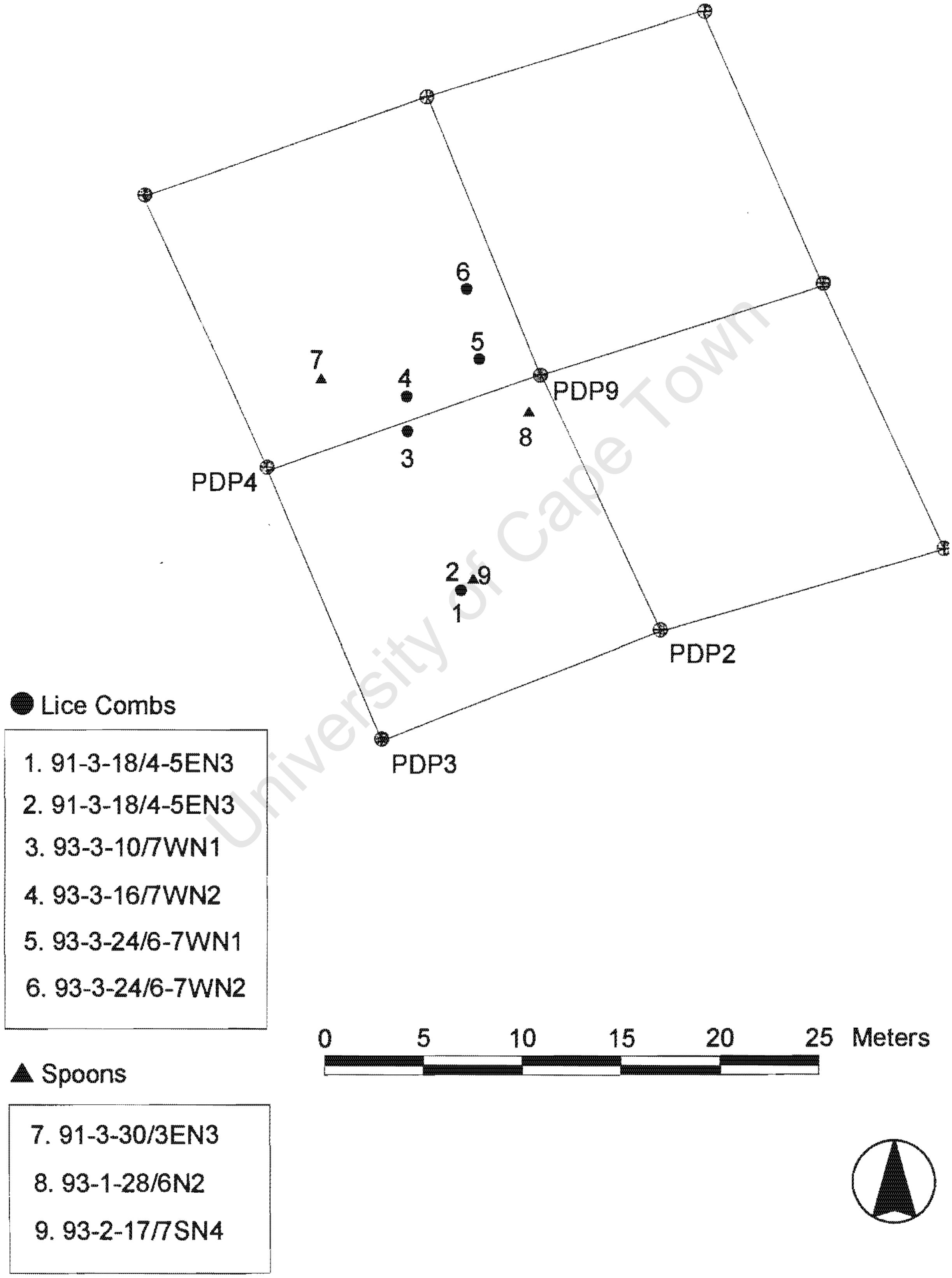
Number of items found in various areas on board ship as indicated by Van Yk (1697:276-285).	**Number of items recovered from the excavation of the *Oosterland* to date.**	**Percentage of total.**
nine anchors and two grapnels	one large anchor and one small anchor	22%
thirty four cannon	five iron and two bronze cannon	20.6%
minimum of four large pewter jugs stored in the stewards room	four large jugs	100%
ten large copper pots and pans	three cauldrons and some pot handles have been surveyed into the grid network.	30%
eight sounding weights	one recovered on site	12.5%
one mortar in the cabin	one mortar recovered (however, the barber-surgeon might well have used one as well).	100% (?)
sixteen pewter plates	three recovered	18.75%

What the above indicates is the degree to which the site has been uncovered. This table does not take into account the artefact groups that are not represented at all. A large proportion of the work that has been undertaken to date, has concentrated in the areas where this type of assemblage would be most visible. A rough estimate of the extent of excavation could, therefore, be put at approximately 15 to 20%.

In order to establish the position of the wreck on the seabed, or rather the direction in which the keel was deposited it was decided to examine artefacts associated with specific areas on board. To this purpose, it was necessary to establish the positions of artefacts groups which should have been present in at least two separate parts of the ship. In this case, artefacts associated with the stern, namely navigational dividers, pewter utensils, and barber-surgeon equipment, and items including copper cauldrons and Ijsel bricks associated, with the galley in the mid ships region, were chosen. Many bricks have been recovered to date but most of them were not accurately surveyed into the grid system and only an approximate position was noted. For this reason, only a general area of the position of these bricks has been indicated here. The assumption was made that these two sets of artefact groups could possibly indicate a line that showed the approximate position and orientation of the keel on the sea floor. From the positions of these artefacts it should thus be possible to overlay a base map of the ship's outline and determine the best fit position of the wreck. Again, it must be noted here that this analysis is based solely on the artefacts recovered to date and that further discoveries may slightly alter the position as established here.

The analysis yielded some interesting results. It was previously suspected that the wreck was orientated more or less in a north-east south-west line and parallel to the beach as shown in Figure 3.5.3.4. If the orientation of the vessel was to follow this line, it would have to be concluded that the ship broke up outwardly because artefacts are positioned in an explosive pattern. By fitting the base ship overlay over the artefacts selected, it appears that a better fit can be gained by a north-west to south-east orientation as shown in Figure 3.5.3.5. This orientation allows more of the

Figure 3.5.3.3 Combined artefact plots of spoons and lice combs in reference to the perimeter grid (artefact numbers included)



selected artefacts to be included in the confines of the ship base map. It also suggests a more plausible solution to the manner in which the ship broke up. It shows an artefact distribution to the east and forward of their original positions, with the exception of the galley bricks which seem to have remained more or less in place. This orientation also includes a greater proportion of the total artefact set as is shown in Figure 3.5.3.6. By placing this overlay onto the artefacts described, it is also possible to determine the "ownership" of artefacts to some degree. Pewter items found in the mid-ships area, between the galley on the starboard side and the stewards room to the on the port side (Ketting 1979:25,69) and west of the stewards room are statistically closer to these two partitions than to the stern of the ship and the officers quarters. By using the Information button on the toolbar of the Views function and mouse clicking on these pewter artefacts it is possible to examine what each artefact is. Four of these six pewter artefacts are jugs, one is a bottle top and the sixth a spoon. These are all artefacts that can be associated with the two above mentioned partitions in the ship. Pewter jugs stored in the stewards room may have been used for dispensing beverages. When these objects are compared with pewter found nearer the stern, it is possible to see some marked differences. Items near the stern include plates, spoons, a sand dispenser used for blotting ink and syringes, all of which would have been used by officers and non-commissioned officers and stored in the stern of the ship. This analysis again supports the probability of the orientation of the ship being north-west to south-east. This is further supported by the copper artefacts found on the site. Copper items associated with the galley and stewards room, including cauldrons, are found in these areas. The only accurately surveyed copper object that is found associated with the stern is a copper coin, quite possibly belonging to one of the officers. However,

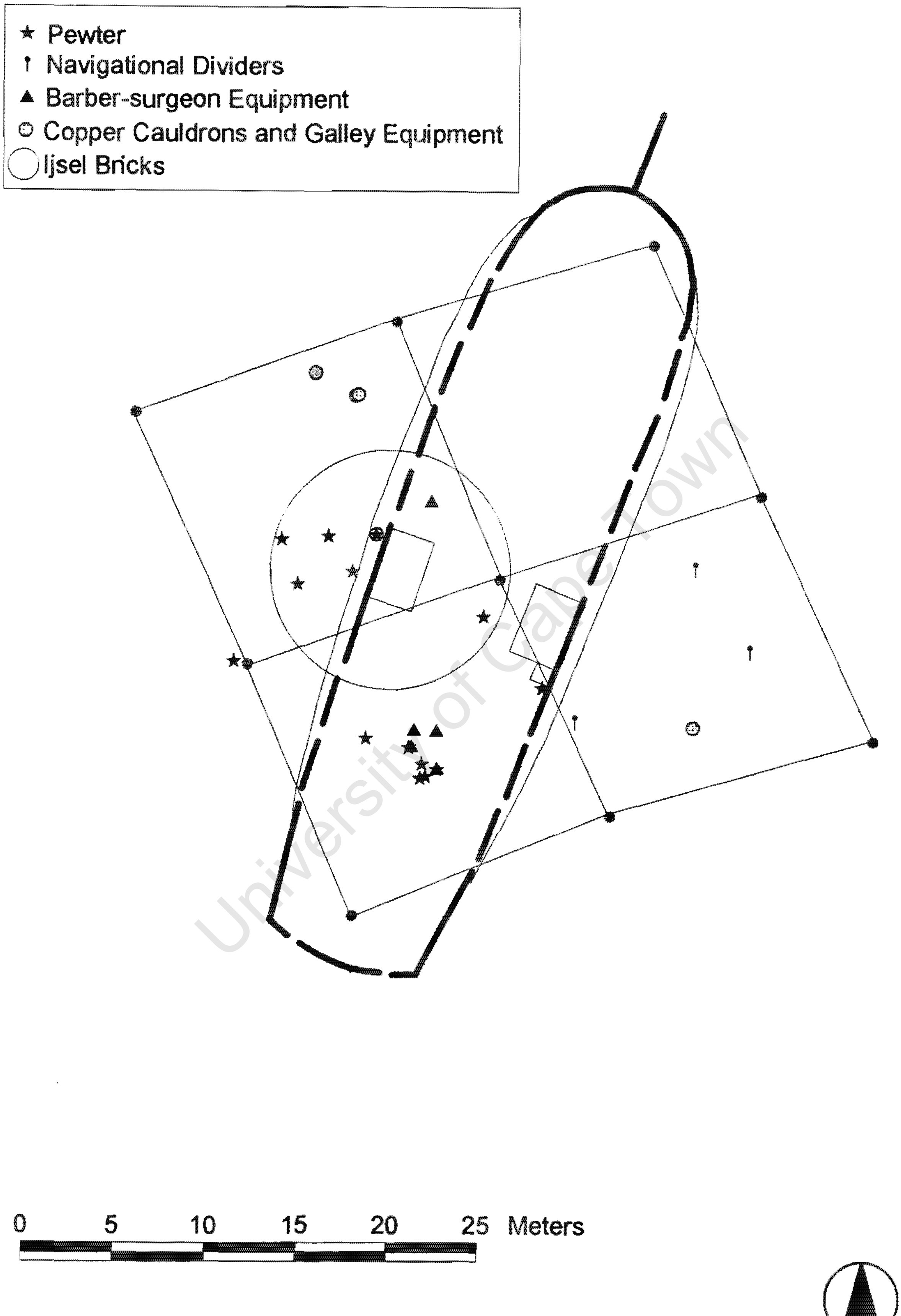


Figure 3.5.3.4 Artefact groups giving clues to vessel alignment in relation to north-east to south-west hypothesis

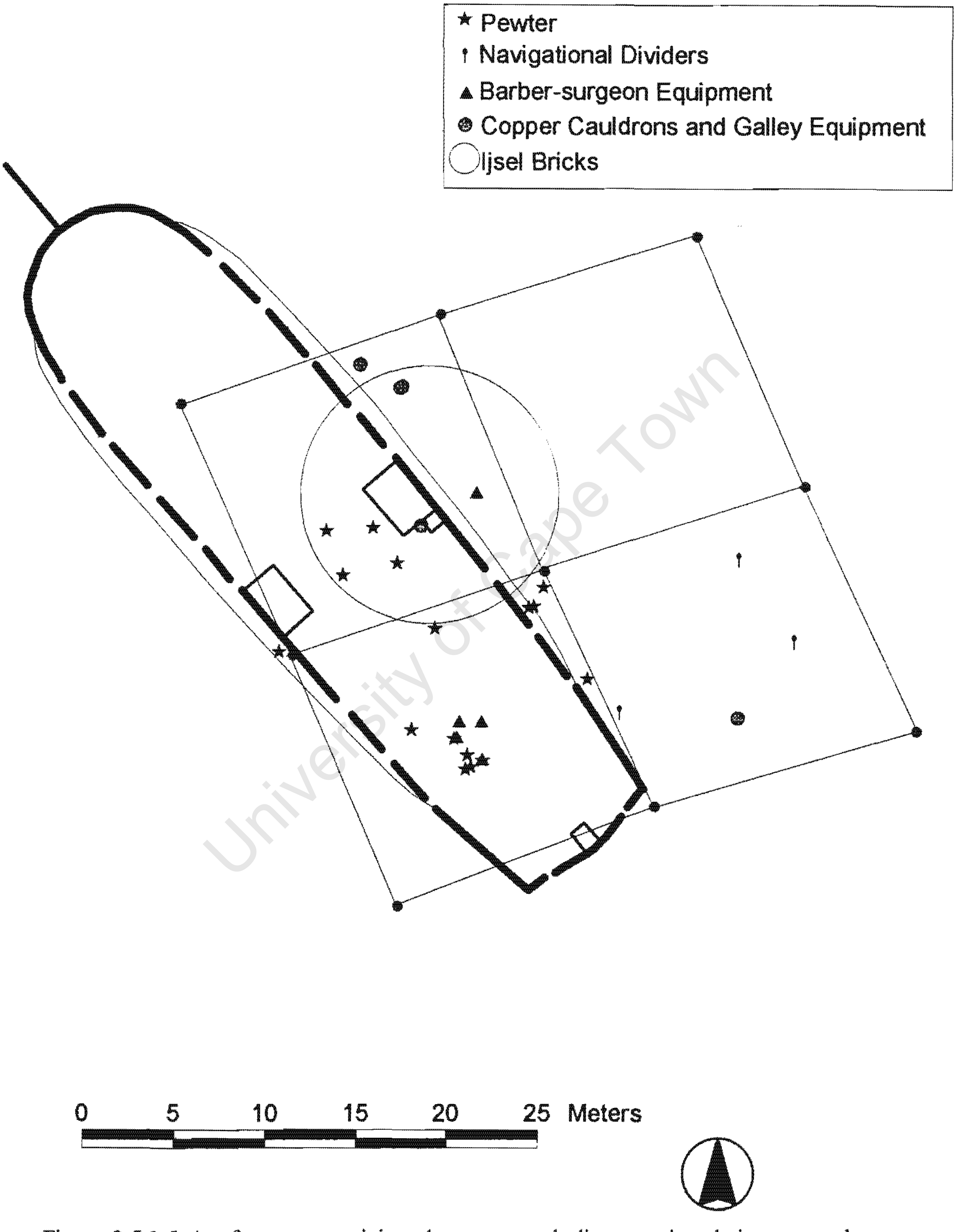


Figure 3.5.3.5 Artefact groups giving clues to vessel alignment in relation to north-west to south-east hypothesis

Figure 3.5.3.6 Plot of all surveyed artefacts recovered from the excavation of the *Oosterland* between 1991 and 1996

remains of copper sheeting and a copper hinge have been found in the same area, probably indicating the remains of the bread and powder rooms. In assigning ownership to the copper coin it is possible to link this artefact to other items whose positions in the working ship are known. Again the artefacts chosen are those associated with specific people and areas in the stern. Nearest neighbours to the coin are navigational dividers. This would suggest that the coin could be tied to the higher ranking officers. It should be kept in mid, however, that the coin and the navigational dividers are relatively light artefacts and would therefore be subject to a greater range of movement on site.

The hypothesis that artefacts were deposited in an easterly and forward direction is supported by the occurrence of navigational dividers to the east of the barber-surgeon equipment and the pewter artefacts in the stern. Navigational dividers would have been stored in the cabin in the top deck of the stern. They would thus have been above instruments associated with the barber surgeon and therefore be deposited further away from the keel line. This can be observed from Figure 3.5.3.5.

Besides the example of the copper coin, other attempts were made to link personal belongings to specific groups of people on board the ship. Again, those artefacts that suggest specific areas on the ship were used as a mean from which to analyse the occurrence and spread of personal belongings. It was thought that if certain of these objects fell within the neighbourhood of official items that some links could be made (Figure 3.5.3.7). Although there appears to be a concentration of personal items near the stern and towards mid-ships, these artefacts could not be linked to specific people on board. There is, however, a high probability that these objects are owned by officers

Figure 3.5.3.7 Personal belongings in relation to artefacts indicating specific area on board ship

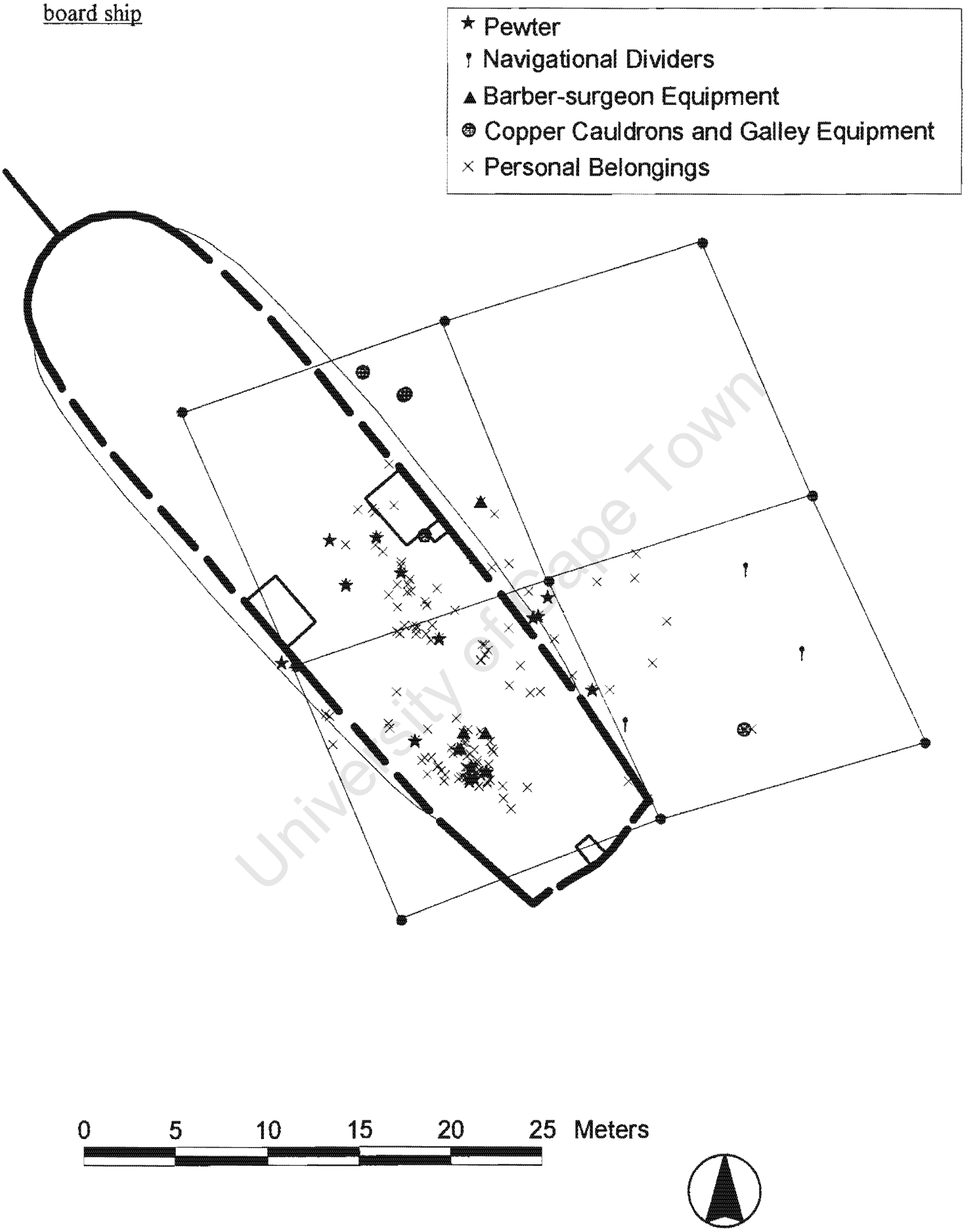
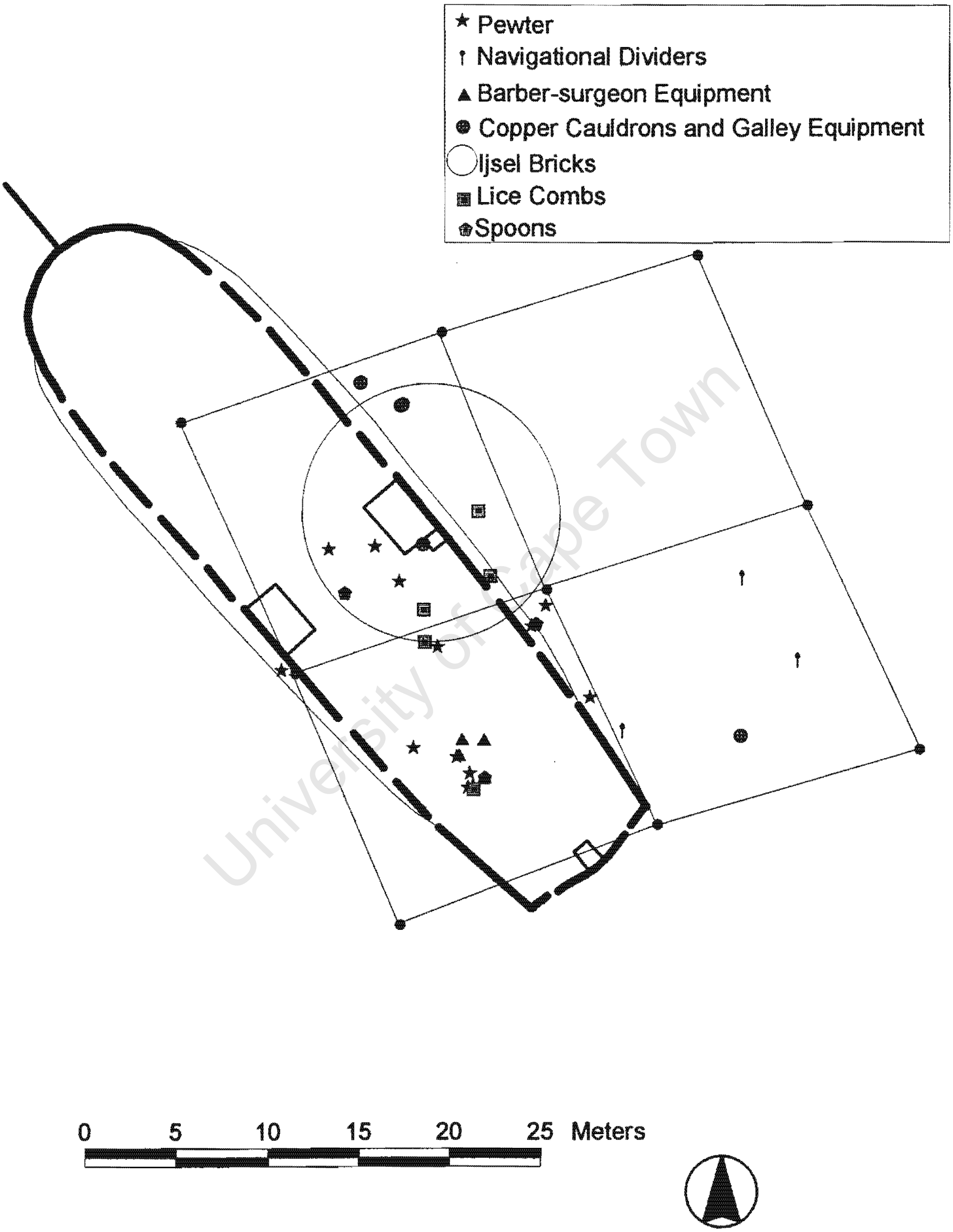


Figure 3.5.3.8 Assigning ownership to spoons and lice combs



described above, the *Oosterland* was one of two ships that were wrecked in the same storm at approximately the same location and other reports of sinkings indicate that anchors from other ships, that were wrecked before or after, could have been located in the same area. For the purposes of this project it is assumed that the anchor is one belonging to the *Oosterland*. Since the dimensions of the anchor are known and an estimate of the weight can be made it is possible to look for examples of similarly aged ships and anchors of similar dimensions. In determining the identity of the anchor, it was necessary to return to the literature on the subject. Ketting gives a description of the anchors used on the *Prins Willem*, an 18th century East Indiaman (Ketting 1979). Historical documentation also gives an indication of the sizes of anchors used for different breadths of ships. From this research it was determined that the anchor is most probably one of the medium day anchors which was stored mid-ships. A second problem associated with this particular analysis is the fact that many of the cannon seen when the site was originally discovered were not measured into the grid system. To date only 5 iron cannon and two bronze cannon, which have been removed from the site, have been located. Cannon which have been located are shown in Figure 3.5.3.9. As can be seen from the Figure, cannon lie in an area slightly south of PDP3 and PDP2 and west of PDP8. Again these cannon fit in well with the theoretical orientation of the ship. Added to this is the location of the anchor which seems to adhere to the assumption that it was one of the anchors stored mid-ships. The position of these heavy artefacts allows some tentative conclusions to be drawn regarding the way in which the wreck took place. It would seem that the ship was pushed towards the shore by the wind coming from the north-west, changing shortly thereafter to south-west, and heavy swell until it touched bottom Werz 1997:243). It is possible that the vessel then keeled over towards the shore to the east, possibly losing some of its cannon in the process. The distribution of the cannon and the anchor suggests that the ship then righted itself after losing some of its weight, possibly swinging back past vertical to deposit more cannon to the west. It could not, however, survive the storm and began to sink and break up. Artefacts from the ship were washed towards the shore by wave action and deposited on the sea floor in a pattern moving from west to east as shown by Figure 3.5.3.6. The heavier articles, such as bricks, were deposited closer to the wreck and the lighter items, some of which were possible packed in crates or chests, were washed inshore. The position of the anchor compounds this analysis. It is positioned about a third of the way from the bow of the ship and in the mid-ships region where it was presumed to have been housed. It would seem that the entire ship did not sink in this area. Cannon and other artefacts have been located inshore and to the north of the perimeter grid and suggest that part of the ship broke away and was washed in towards the beach. This could be confirmed at a later stage when the GIS is fully operational and more survey data have been collected.

A large feature of the site which confirms what has been said above is the concretion mound. This is a large area in the middle and to the east of the grid square formed by PDP2, PDP3, PDP4 and PDP9 (Figure 3.5.3.10). It has been assumed that the concretion mound is made up of part of the armament of the ship, mainly cannon balls. The position of this mound relates well to the orientation of the ship as described above. The gun room was situated in the stern of the ship and the main store of cannon balls slightly in front. The concretion mound is also a good area from which other artefacts can be related. This area would be situated behind the cargo hold and, as a result, artefacts linked to the cargo should be recovered north of the concretion mound. As a test of this, the locations of baskets containing indigo were plotted into the GIS. As can be seen from Figure 3.5.3.10, this is the case. This should, however, be seen in the light of another basket, not shown here, being located in the area north of PDP5. The location of this basket does not discredit the hypothesis being put forward here as it still falls within the area in which cargo might be found.

Finally, it is necessary to examine why certain artefact groups such as musket plates, that should be highly visible on the site, have not been recovered. Musket plates would be associated with only two areas on the ship, the officers cabin and the Master gunner's room in the stern and the soldiers quarters in the bow. It has been assumed that many of the artefacts that would have been found in the gun room have been engulfed by the concretion mound. This would mean that musket plates would not be visible without analysis of this mound and its contents. The area of the site which surrounds the bow portion of the ship has not been extensively excavated to date. The musket plates in the bow area may also be engulfed by concretions formed by the guns and other ferrous metals. Problems encountered with fixing the grid square in this area has meant that it is not possible to plot the artefacts recovered here at this stage. Further excavation seasons will allow the position of grids 14 and 15 to be established with more accuracy and further analysis can be done.

The limited number of lice combs and shoes may be accounted for in a number of ways. Firstly, they are relatively light items and would be easily washed off the site. Shoes in particular are vulnerable to currents and wave action because they often float for a period of time if loose, or removed from the site as people try to swim to the shore. It is clear though that a non-result, as is the case here, is as valuable as a result. Because these items have not been recovered in large quantities, it may be necessary to

Figure 3.5.3.9 Approximate positions of iron cannon located on the *Oosterland* site before 1998

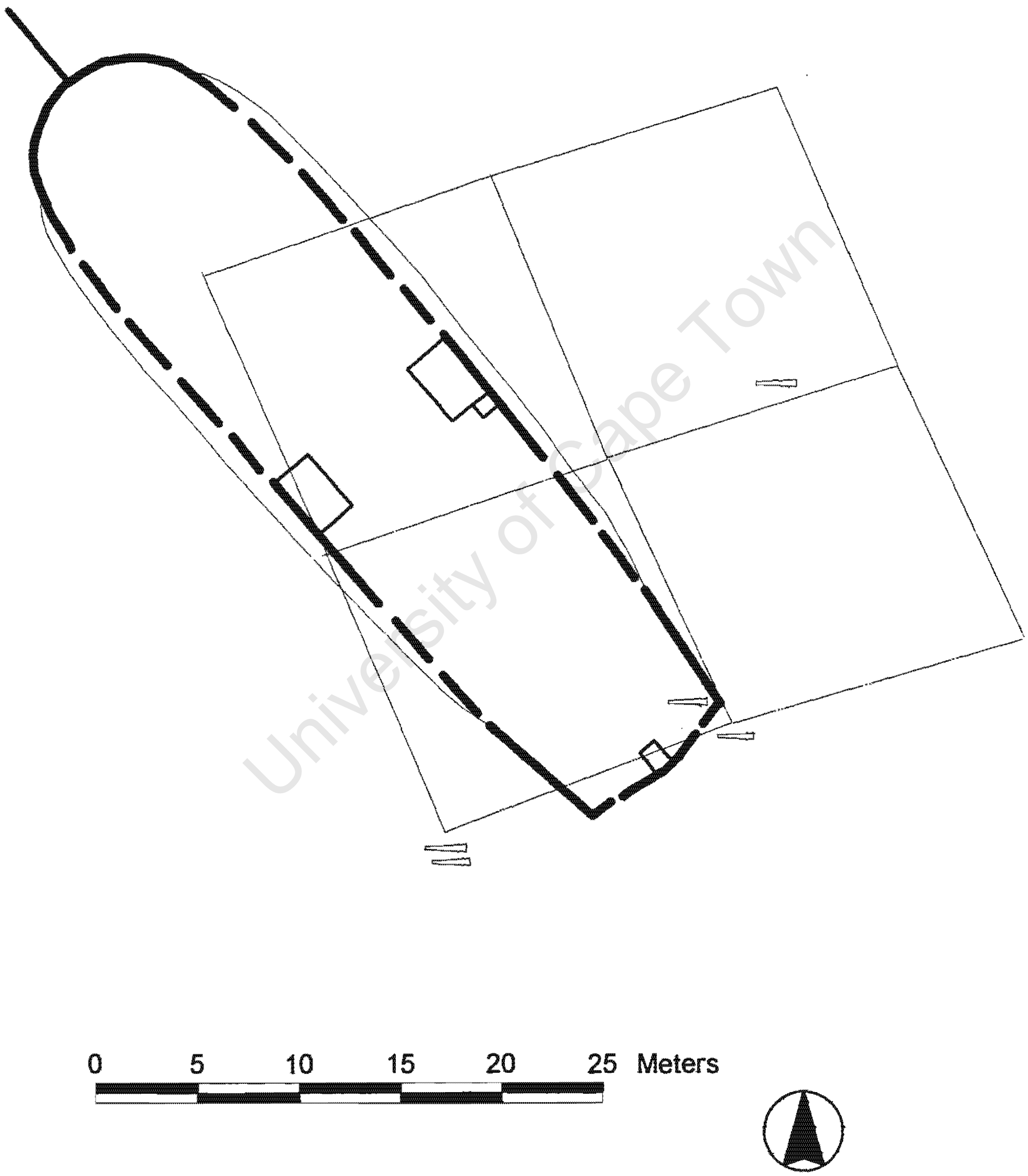
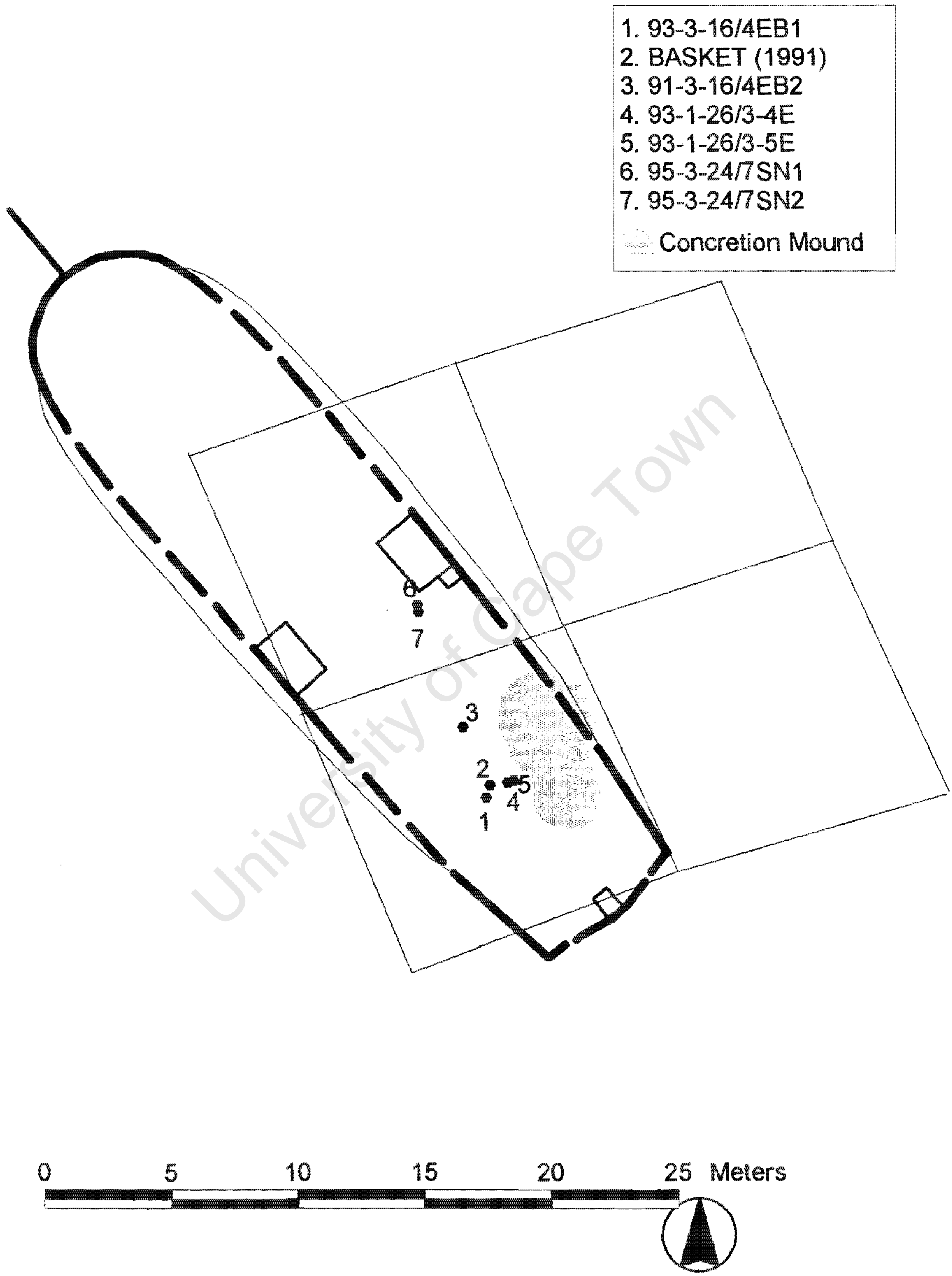


Figure 3.5.3.10 The concretion mound iin relation to cargo carrying baskets



adjust the area in which excavation takes place. As it stands the area west of the perimeter grid has not been fully excavated, although some exploratory work has been done.

The distribution of artefacts also gives a good indication of where other artefacts might be expected and where excavation might continue. Based on the previous assumption that the wreck was aligned along a north-east to south-west axis, excavation was concentrated in areas that would be most likely to fit that hypothesis. This project shows that it is possible that the vessel is orientated slightly differently and future excavation should perhaps be planned to explore this possibility. More extensive excavation in the areas west and north of the perimeter grid may be able to prove this point.

Having examined artefact groups in terms of their relation to the layout of the ship, it is necessary to examine the relationships between the artefacts themselves. Since this project is not a total analysis of all the artefacts surveyed into the grid system, only certain "hot-spots" will be examined here. Figure 3.5.3.11 shows the total distribution of artefacts over the site. It is from this plot that such hotspots will be examined. The first of these is the obvious concentration of artefacts in the centre of the grid square formed by PDP2, PDP3, PDP4 and PDP9.

The area under observation contains four major artefact groups, namely barber-surgeon equipment, personal belongings, cargo/stores and unidentified material. There is also one item of the armament in the form of a breechblock. The area covered is approximately 4.5 by 3.5 meters. An attempt was made to relate artefacts belonging to the category "Personal Belongings" to a specific person on board the ship. Because the only artefacts in this area that can be related to a specific person are those used by the barber-surgeon, it was decided that analysis would focus on attempts to make some links to the tools that he would have used. As can be seen from Figure 3.5.3.12, only four artefacts associated with the barber-surgeon can be found in this area. They are three white porcelain medicinal jars, one of them still containing ointment, and one pewter syringe. The distances between the items range from 0.88 meters up to 2.48 meters. The nearest neighbour for each of the barber surgeons tools was calculated with a cut-off distance of two meters. Two meters was chosen as a conservative cut-off point because the distance falls within the maximum distance between the selected items. Hodder and Orton (1976) used similar methods when plotting the occurrence of Mayan burial sites. A distance was chosen as a maximum has been put in place because only close neighbours are being studied. Although items that may be related to the barber-surgeon are spread over an area exceeding ten meters, a neighbourhood analysis incorporating this range would encompass almost all of the surveyed artefacts. By narrowing the maximum distance to be searched between artefacts and their neighbours will also increase the probability of the relation being true. It is felt, however, that the nearest neighbour of the artefacts under investigation as well as the nearest neighbours of that artefact should be examined. Once this has been done it is possible to create a buffer zone around the original artefact that incorporates the second nearest neighbour. This has been done in an effort to eliminate the possibility of an artefact being associated incorrectly with another. The nature of an underwater site implies a certain degree of movement of artefacts as they come under the effects of currents and wave action. This in turn means that it is possible that some artefacts will be deposited in the same area, even though they are not directly associated with one

Figure 3.5.3.12 Artefact distribution based on classification

another. For this reason, if at least two artefacts do not fall within the buffer zone, then it can be inferred that the association is tentative. This does not eliminate the possibility of mis-attachment completely, as whole groups of artefacts may be moved or many artefacts from different areas of the ship may be deposited by currents in the same place, but it does make the analysis more statistically significant. Figure 3.5.3.13 shows all of the personal belongings that are present within two meters of the barber-surgeon's equipment present in this area. It should be noted that only one other object of this nature, a white porcelain jar, has been surveyed into the site and lies near the east side of the vessel next to the galley. Artefact 1, a pewter syringe, has nearest neighbours of two pewter spoons. These spoons were recovered in the same place as the syringe and have the same co-ordinates. The second nearest neighbour is a leather shoe. Second phase nearest neighbour analysis on the artefacts closest to the original neighbours show that blue and white porcelain items, a porcelain statuette and a Yi-Xing lid, fall within 0.50 meters of the syringe. A white porcelain ointment jar is represented by the point marked 2. Its closest neighbours are a blue and white bowl 0.11 meters away and a Yi-Xing lid 0.13 meters away. Artefact 3 has a nearest neighbour of a blue and white vase, which in turn has a nearest neighbour of a miniature blue and white vase. These two artefacts fall within 0.30 and 0.31 meters of the white porcelain vase. Artefact 4 is another white porcelain ointment jar with some of the contents still contained within it. It has nearest neighbours of two shoes both falling inside of 0.50 meters of it. This close proximity in relation to what has been suggested above regarding the ship's orientation and artefacts distribution suggests a strong probability that these items can be linked with the barber-surgeon or at least the same area of the ship from which the barber surgeon tools originated. Also of interest are those artefacts that fall within two meters of all of the four barber-surgeon items

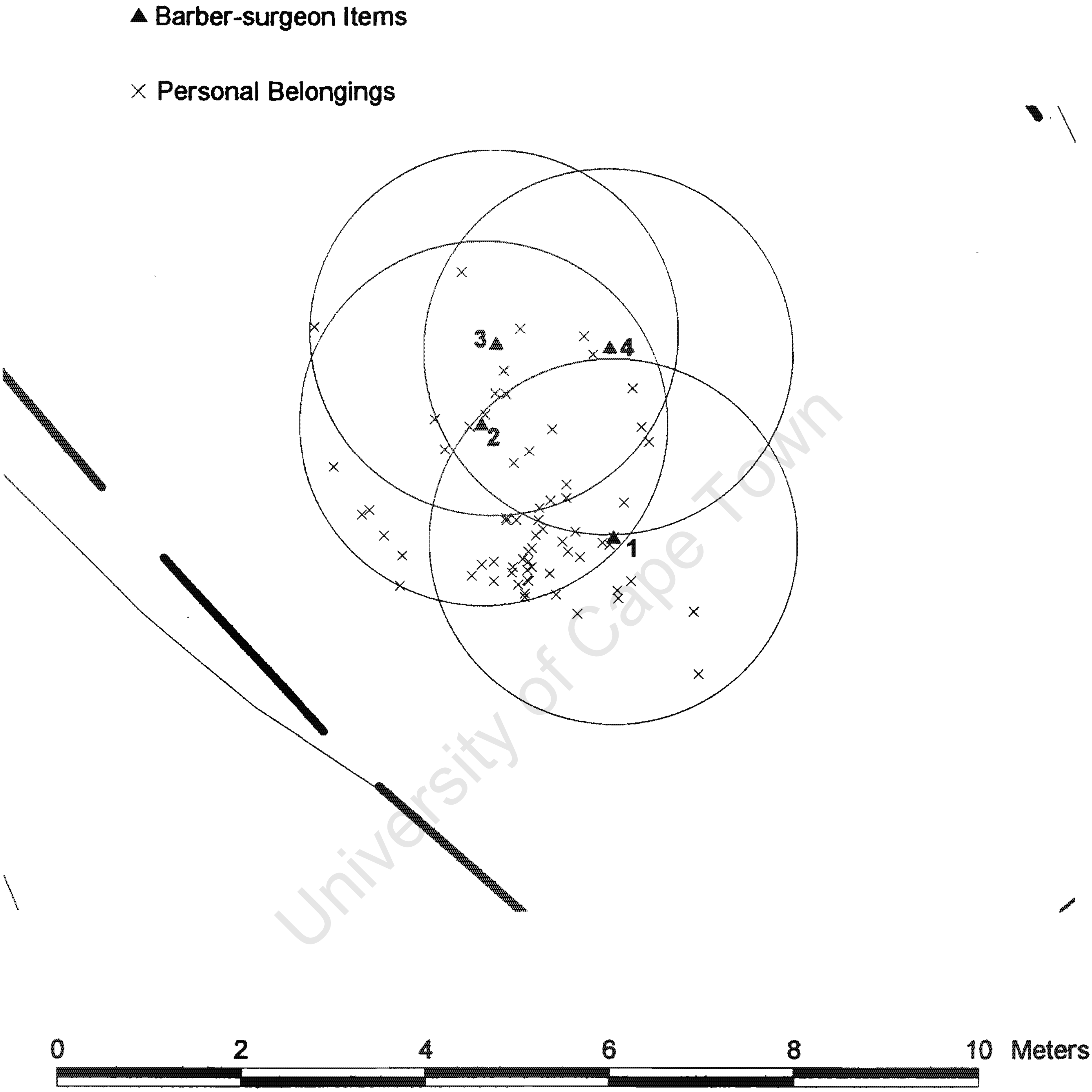


Figure 3.5.3.13 Personal belongings lying within two metres of barber-surgeon equipment

selected. These include seven blue and white porcelain vases, a Yi-Xing teapot and a small duck statuette. Again, they lie within close proximity of artefacts associated with the stern but can not be associated directly with the items selected. This means that it is only possible to assume that the items that fall within half a metre of the tools have a significant probability of originating in the stern and thus being associated with the upper ranks on board ship.

This range of certainty can be tested by examining other artefact groups. As has been discussed previously, two categories of pewter utensils can be found in the artefact assemblage, those associated with the stern and those associated with the galley and the steward's room. These items can be examined in relation to other personal belongings to test whether any valid relation exists between the two. It would be expected that personal belongings can be associated with the pewter found in the stern because of the close proximity to the officers living quarters. The pewter found around the galley and steward's room would be less likely to be linked to personal items because the areas were used as places of work and it is unlikely that many personal items would be stored there. By glancing at Figure 3.5.3.14, it is possible to see that this is true. The pewter found at the stern has a substantially higher proportion of artefacts lying within 0.50 meters of it than that found around the mid-ships area. The same nearest neighbour analysis as was used to determine the significant distance between artefacts associated with the barber-surgeon instruments was used to determine the nearest two neighbours in the case of pewter. In the area of the stern that was examined in the previous example, it was again found that a distance of .0.50 meters represented the maximum distance between artefacts and their neighbours, while the pewter items found near the galley showed only one artefact within that distance. Areas of particular interest have been numbered in the diagram. They represent items that do not conform with what has been calculated and should therefore be more fully explained. Artefact 1 is a pewter sand dispenser, an item that can be associated with the stern of the vessel and the officers with complete certainty and possibly even with the masters cabin. From the plot it would appear that this artefact cannot be said to be significantly linked to any other artefact. In reality there are two blue and white porcelain items that share the same position and can therefore not be seen in the figure. It is however an anomaly that this artefact, which would have been kept in a place where personal belongings were probably most prevalent, does not have more of such items in its immediate vicinity. This may be explained by examining the weight of the artefact and the possibility that the sand dispenser would be less likely to move after being deposited on the sea floor. The point marked 2 in Figure 3.5.3.14, a pewter flagon, is of interest for two reasons. Not only is it not affiliated to any personal belongings, but it has the same co-ordinates as a copper pot handle. This intensifies the argument that the pewter items found in this area of the ship are more closely related to the galley and stewards room than to the stern. A pewter pot is represented by the point marked 3. This point is of interest because it can only be linked to one other artefact in its immediate neighbourhood. The artefact to its east is a spoon of undetermined material, although pewter has been suggested. These artefacts lie in an area approximately half way between the stern and the galley and are an irregularity that cannot be explained in this part of the analysis. Point 4 also appears to be an irregularity. It has been described in the Excavation Record Sheets as being a pewter bottle top. It has the same co-ordinates as a leather pouch with a sheath and strap that may be a part of the armament of the ship or a part of the tools and utensils assemblage. If this is the case then the pewter top may share that classification. In the classification list used in this project, this item has been described as being part of the tools and utensils which may mean that it did not originate from the stern of the ship. The item may well also be the remains of a liquor bottle stored in this area since higher ranking crew and officers were allowed to take alcohol with them.

In order to check the validity of assigning ownership to pewter items recovered from the mid-ships region, they were examined in relation to the types of tools and utensils in their immediate neighbourhoods. It can be assumed that if the items found surrounding the pewter are associated with certain function areas on the working ship model then the pewter items could be assigned to those same areas. Figure 3.5.3.15 shows the artefact plots for items classified as Tools and Utensils and for items made from the material Pewter. Nearest neighbour examination, in this case, took on a slightly different form. Because the pewter artefacts themselves are classified as being tools and utensils, they were allowed to be linked to one another in an endeavour to fix their position on board. This was only done if connections could not be made to other artefacts. The maximum buffer distance of 0.50 meters used previously also needed to be reassessed. The number of items that fall under these classifications are not as extensive as those of personal belongings and so links between artefacts might not be as close.

Although the buffer distance was extended, distances were too long to be considered significant. Apart from the pewter artefacts in the stern area, which could be associated with artefacts such as barber-surgeon implements to within a buffer distance of 1.5 meters, thus confirming the likelihood of these artefacts being kept at the back of the ship, this test proved to be of little value. Three out of the five pewter items surveyed

Figure 3.5.3.14 Personal belongings in relation to Pewter

into the mid-ships region could not be associated with even one artefact within a distance of 2.50 meters. Where couplings could be made such as in the case of the pewter jug labelled 1, they were to objects that could not be fixed into any position on the ship, namely a coconut spoon and a black cup of undetermined material. The problems existed for the pewter pot and spoon marked 2 and the pewter lid to the east of the main concentration and outside of the ship overlay. Each of these items could be linked to one other, a spoon and a leather pouch respectively, but no other tools or utensils are present in those areas. The items mentioned are also not indicators of the position held on board the ship.

Four objects were surveyed into the grid system that have been classified as coins or buttons. Of these, two have been identified as being coins, the other two could be either. In an attempt to analyse the ownership of these objects, several different groups of artefacts were chosen as a means to measure their proximity. By plotting the coins/buttons into the grid system, it was possible to see that they occurred in the stern area of the ship. For this reason, artefacts that could both identify specific parts of the ship and be found in the area where the coins were recovered were chosen; in this case the pewter collection associated with the stern of the ship and the items associated with the barber surgeon. The fact that both of these groups are associated with the stern immediately skews the analysis in favour of that area so a third identifiable group of artefacts was added in an attempt to balance the resolution of the analysis, in this case navigational dividers. Before starting this analysis, it should be noted that the number of coins/buttons present on the site is only a very small proportion of the expected quantities. Although the exact quantities cannot be determined, it can be assumed that at least a few hundred buttons should be present. It is known that soldiers and officers uniforms had buttons attached to them and it is likely that at least part of the crew's clothing would have had the same. The virtual absence of buttons can be explained in a number of ways. Firstly, it may be that officers who went ashore while the *Oosterland* was at anchor may have taken luggage, including clothing, off the ship. The presence of only a few buttons may also be a result of the limited excavation area covered to date which did not include the lower parts of the bow where soldiers were housed. Finally, buttons may have been removed from the site by currents. It is not uncommon for lighter artefacts such as porcelain shards to wash up on the adjacent beach approximately 280 meters away (Werz 1997:257). Buttons are small and light and may also be easily swept away by wave action.

Figure 3.5.3.16 shows the occurrence of the artefacts chosen to determine ownership of the coins/buttons. The two coins/buttons on the left (no. 1 and no. 2) are those that have not been identified either way. They are 0.46 meters apart and 0.59 and 0.79 meters from their closest neighbour, the pewter sand dispenser (no. 3) to the north-west. Their second closest neighbour is a pewter tankard (no. 4) to the east at a distance of 1.91 meters and 2.12 meters respectively. The only other artefacts to fall within this range are three blue and white porcelain items which cannot be related to any definite part of the site. The nearest neighbour in this data set to the silver coin (no. 5) in the centre is 0.91 meters away. It is a basket (no. 6) which possibly held part of the cargo. The nearest neighbour to the basket is a basket lid (no. 7) which lies 1.07 meters from the coin. Using this as a buffer distance, one other artefact is within range of the coin, this is the white porcelain ointment jar (no. 8) containing the remains of its contents. Other artefacts that occur within this buffer zone include blue and white porcelain and Yi-Xing stoneware. Finally, the copper coin to the right of the data set

Figure 3.5.3.15 Pewter items in relation to tools and utensils

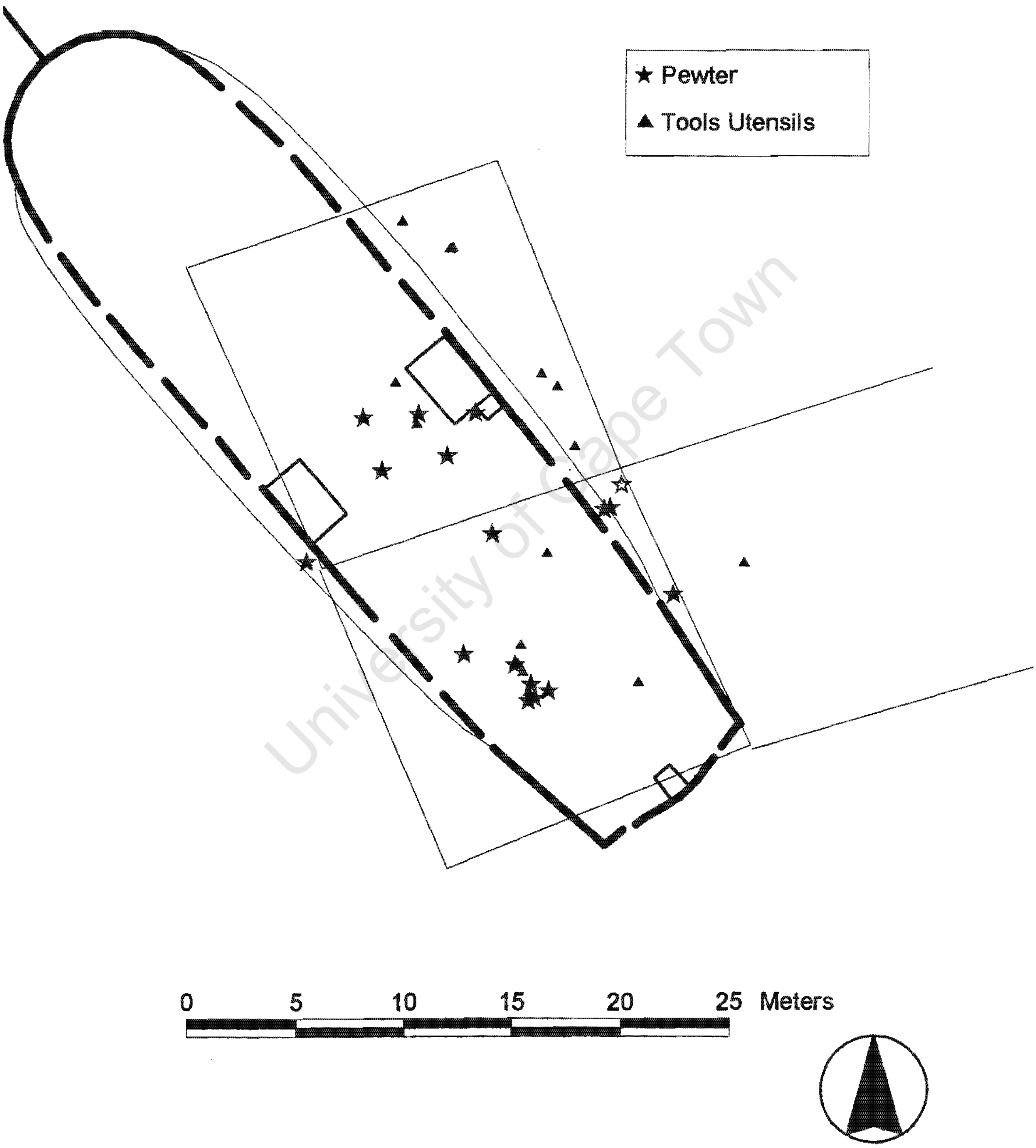
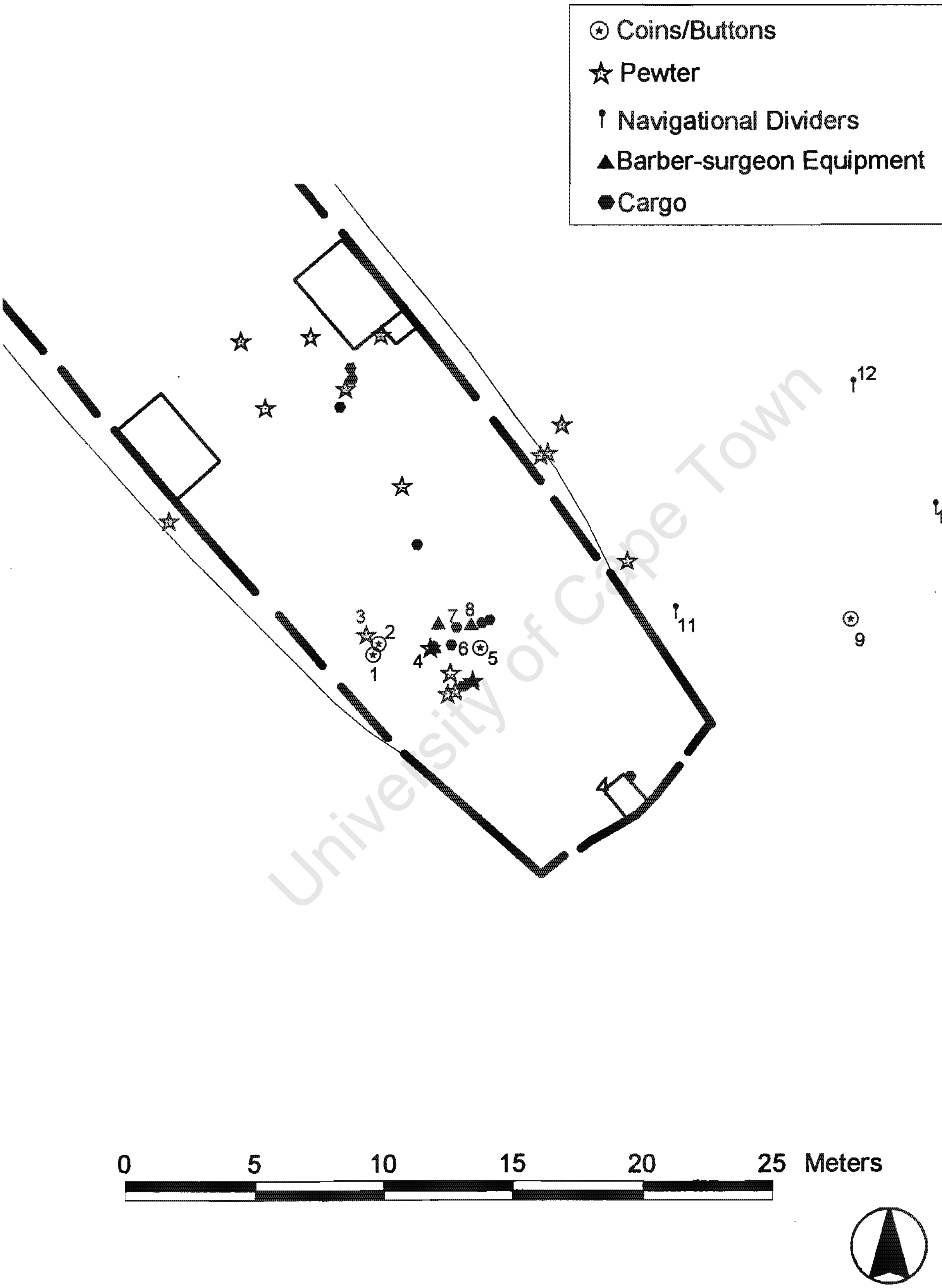


Figure 3.5.3.16 Assigning ownership to coins/buttons



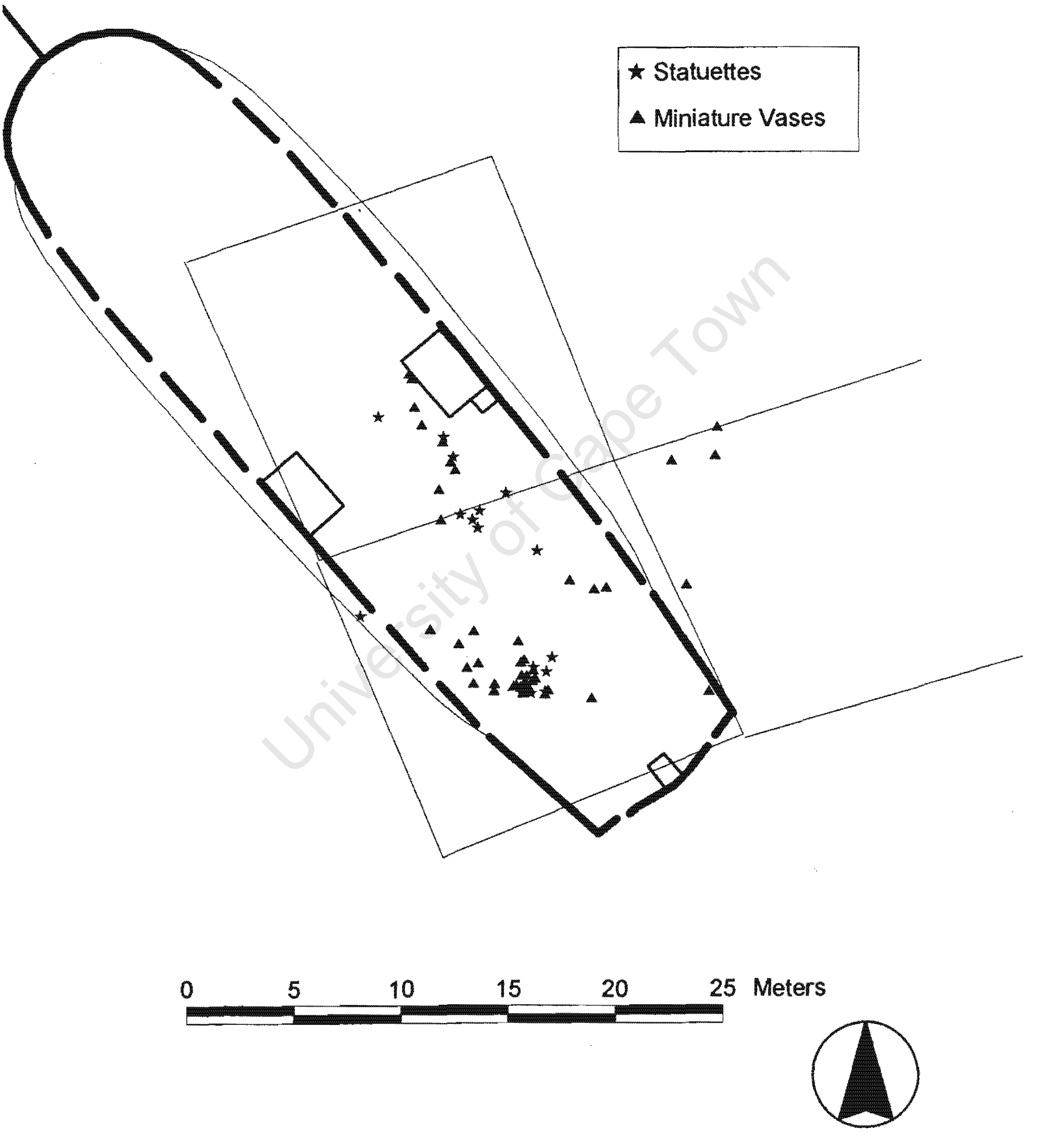
(no. 9) has a pair of navigational dividers (no. 10) as a nearest neighbour 5.13 meters away. Also in close proximity is a fragment of a blue and white vase. From this analysis it is possible only to assign tentative ownership to the silver coin. The artefacts that surround this coin and fall within its buffer distance appear to indicate that the coin originated from someone in the stern of the ship or a crew member living near the mizzen mast above the stern-most part of the cargo hold. It could also be said that the two coins/buttons lie within the area associated with the back parts of the ship as defined by the types of artefacts surrounding them, but this can not be supported using this type of analysis. The same is true for the copper coin. From a logical point of view it would appear that the coin is associated with the stern because the only artefacts to which it can be related derive from that area.

Navigational dividers represent somewhat of a problem in the context of this project. The only items that are situated near the dividers to the far starboard side of the ship overlay are pieces of concretion. Through the examination of the distances between the three sets of dividers it may be possible to offer some suggestions as to what these concretions contain. It is known that this type of navigational equipment would be stored in the masters cabin at the top and stern of the ship. Because the distance between sets of dividers ranges from 5.43 meters to 10.66 meters it can be assumed that any concretion lying within this distance has a medium probability of being associated with these instruments. If this is the case, then several items may be contained within and make up the concretion, such as small arms, kept by the higher ranking officers in the stern of the ship, and ship fittings, such as part of the steering mechanisms and gun mounts. All of these items may form the basis for small pieces of concretion. It is unlikely that heavy iron items such as cannon balls form the greater part of these concretions as they would not be stowed here, particularly during the course of a storm. What is possible, however, is that some cannon balls came adrift of the ship during the wrecking process and were deposited in this area. The location of the concretion mound to the west of the navigational dividers also suggests that matter from the large mound spread out as the ship collapsed on the sea bed.

Many of the surveyed artefacts that have been recovered thus far can be classified as personal belongings or personal trade goods. As has already been discussed, it is difficult to say with any degree of certainty that particular artefacts could be associated with particular people on board. It is, however, reasonable to suggest that a large proportion of the personal items were stored near the stern. As a result of this assumption, it was decided that a test should be carried out on artefacts that might be found in groups. For this purpose miniature vases and animal figurines were used. It is possible that people would have purchased these types of articles in sets rather than on an individual basis. If this were the case then it can be expected that small pockets or concentrations of these artefacts would be scattered over the site. Figure 3.5.3.17 shows the distribution of these items in relation to the hypothetical position of the wreck. It appears that concentrations can be determined from this plot. Pockets of statuettes and miniature vases occur towards the stern, on the port side and around the galley on the starboard side. It is also noticeable that none of these objects are located forwards of the galley. For this reason it might be assumed that personal trade in these commodities was largely the domain of the higher ranking people on board.

In 1991, an egg shaped wooden object, possibly a husk from the east, was recovered near the stern of the ship. What made this object different was the fact that it was hand

Figure 3.5.3.17 Distribution of miniature vases and porcelain statuettes



carved. As a final analytical test, an attempt was made to assign ownership to this object. Previously the popular belief amongst the excavators was that the object could have been carved by one of the soldiers or sailors on board during the voyage. Having set up the GIS to handle spatial distributions and through the examination of nearest neighbours, it is possible to test the theory and determine the most likely person or group of people who owned the object. Figure 3.5.3.18 shows the position of the object in relation to the overlay of the ship. The view shown in Figure 3.5.3.19 gives all of the artefacts found in the neighbourhood of the object. Although there are many artefacts surrounding the object, it is possible only to use those that can be specifically linked to parts of the ship or to other artefacts that show this relationship. At the same co-ordinates as the carved object are two lice combs and a porcelain eagle statuette. These can not be related to a specific part of the ship so the next nearest neighbour was taken. This nearest neighbour to the artefact is an unidentified object 0.25 meters to the north. The nearest neighbours to this object are a pewter plate, a blue and white miniature vase and a Yi-Xing teapot, all 0.05 meters from the unidentified object. Of these objects, the only one that can give an indication of ownership is the pewter plate. This suggests that the object was owned by a person living in the stern area of the ship, i.e. an officer or non-commissioned officer. This hypothesis is supported by the close proximity of a second pewter plate to the west of the object.

The project presented here has met all of the criteria that it set out to accomplish. Firstly, it has shown that GIS and computer mapping act as a good means to storing the large amounts of data that have been gathered over fieldwork seasons on the wreck site. Appendix IV contains the tables that have been created to store the information needed in the analysis of surveyed artefacts. These tables show all of the data

Figure 3.5.3.18 Position of carved egg shaped object in relation to hypothetical ship model

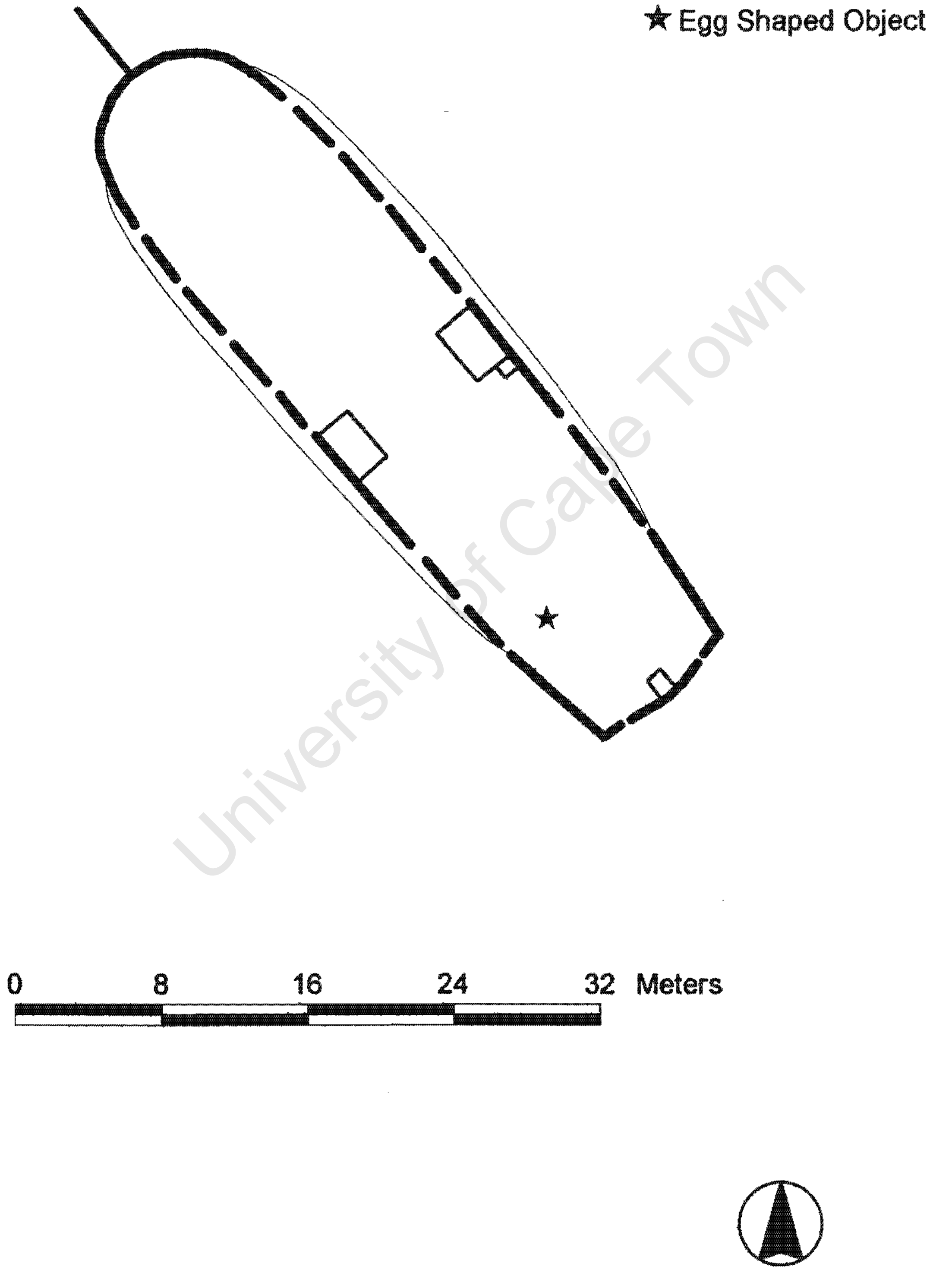


Figure 3.5.3.19 Nearest neighbours to carved egg shaped object

surrounding each artefact in a manner that is easy to examine and easy to interpret. They are easier to handle than the record sheets from which they originated, not only in that they are smaller, but also in that artefacts can be quickly referenced to one another. The record sheets, although thorough, contain information regarding the surveyed artefacts in several different places, while the tables presented here give a complete record in just one line. The records in each line of the data show the artefact number, date, description and general location, information previously contained in the Excavation Record Sheets and Finds Lists, as well as a classification of the artefact in terms of material and function on board the ship, previously contained in the Finds Record Sheets.

Computer based storage of artefact information is not only easy to access, but also more secure than its hard-copy counterpart. Paper copies of such data are much more easily misplaced or destroyed than computer disks. Because of the volume of record sheets it is expensive and bulky to make many copies of them. Computer disks are small, relatively cheap and are more durable, therefore, several copies of the same information can be stored in different locations. It is unlikely that all of the different disks will be corrupted and so a record of data is always available and accessible. Because the size of tables created in this project are also much smaller than the original record sheets, it is possible to make hard copies that are portable and can be carried on site, a feature that original sheets made impossible.

At a later date, more information regarding artefact recovery and diving operations can be added to this database. For example, Diving Record Sheets can be summarised as tables linked to the *Oosterland* GIS. This would allow easy access to diving times, total hours spent underwater, diving conditions etc. Finds List can also be converted to computer based tables. These would allow easy reference to all of the artefacts recovered on site, including their general location and a description of each one.

3.6 THE FUTURE OF THE *OOSTERLAND* GIS

There is much that can still be added to the existing GIS and also more that can be asked of the system. This section will briefly describe some improvements that can be undertaken in future to enhance the GIS as an archaeological and educational tool.

Firstly, there are several cosmetic additions to the system that would make it both more user friendly and educational. These could include the addition of images of artefacts. Existing photographs of surveyed artefacts can be scanned into the system and linked with points displayed in the map window. This addition would make the system more interesting to users with no archaeological background who wish to view retrieved items rather than to analyse them. This would also make the site more accessible to the public. Connected to this is the option to add a brief history of the ship, the wrecking and the subsequent excavation, as has been presented in hard-copy in this thesis. Again, this would make the system more interesting for the lay-person. Making archaeological information available to the public is invaluable to the preservation of historically important shipwrecks. If the system were to be set up in such a way that it held public interest, it could help tremendously in this regard. Awareness of wreck sites and archaeological activity may go some way to creating a general sense of history and the idea that archaeological sites should be preserved as far as possible. The system can partly assist in changing the current perceptions of archaeology as being an indulgence rather than a relevant science. Scanned images can, of course, also be of value in archaeological analysis. They may be linked to artefact data, such as dimensions and weights. Not only would this ensure a more complete record of material recovered from the site but, having information relating to artefacts and the wreck itself close at hand, will assist the archaeologist to answer many questions that may arise.

Adapting the ArcView user interface to display only certain features and menus may be a good method of creating a system that can be used by the public. Knowledge of computers has reached a level that allows most people to operate the machines with basic competency. The use of pop up menus and click-and-view access to different aspects of the site would make the GIS an invaluable educational tool. Although scientifically excavated maritime archaeological sites in South Africa are limited, it will be possible, at a later stage, to link data captured on the *Oosterland* site to others. If this is realised, a series of different levels can be incorporated into the GIS. For example, a map of South Africa could be displayed with various regions available for selection. These regions could then be subdivided into smaller areas and so on until wreck sites and ultimately artefacts represent the finest level of detail. Again this would be of use in archaeological analysis in that sites and/or their artefacts can be compared to one another and areas of research relating to the precise distribution of wrecks, such as likely location of survivor camps, can be examined.

Archaeologically the system will hopefully be improved with the addition of more data in the future. These data will come from continued excavation of the site and relevant research focusing on the ship and the artefacts contained therein. As the system is used to answer questions, more information about the wreck will become available. It can also be assumed that the GIS itself will advance. As this occurs it may be possible to use more and more of the functions being developed in an archaeological context. Archaeology has been fortunate enough to get involved with GIS in their infancy and may, therefore, have some say in the direction of development.

3.6.1 ADAPTING THE *OOSTERLAND* GIS TO OTHER WRECK SITES

The advantage of the *Oosterland* Geographical Information System is that it is spatially referenced. This means that it can be plotted onto any map accurately and completely. This also means that it can be easily adapted to any wreck site anywhere in the world. By correcting co-ordinate data in all of the current conversion programmes, to suit other areas under investigation, it is possible to create a similar GIS for these other wreck sites. This does, however, mean that data capture and organisation would have to be conducted on a similar basis. The conversion programmes make use of data that have been entered using a specific structure. Spacing between parts of the data, the names of artefacts and the names of Datum Points are all specific to this design and may vary from one project to another. In order for other wreck sites to be incorporated or connected to the *Oosterland* project, it would become necessary to follow certain data entry paths. Firstly, data files that mirror those used in this project, as shown in the appendices, could be created for compatible use with the co-ordinate conversion programmes used here. This would create a standardised excavation model for all wreck sites that would be connected to this GIS. Fortunately, on-site data capture methods that were used on the *Oosterland* are standard archaeological practice. Many sites make use of a grid system whereby artefacts are plotted by direct survey measurement from datum points in these grids. These datum points are usually numbered and their positions established as they have been here, this being the easiest and one of the most accurate methods of recording such points. Adapting this project to sites that have been recorded in a similar manner would be merely a matter of formatting data to suit programme requirements.

This project is not, however, restricted to specifically formatted data sets. Because co-ordinates are universal it does not matter how they were calculated, although map projections do play a role in this regard. Co-ordinate data from other wreck sites can be connected to the co-ordinates of this project. The same is true for attribute data recorded on other sites. Descriptions and images of sites and artefacts can be easily incorporated into the system. The only requirement that would be relevant to data that are entered into the system would be that it has to be in a format that is compatible to ArcView. By using ArcView, it is possible to create a world-wide database of shipwrecks. The system has analytical functions that can be applied universally.

Because the standard version of ArcView was used in this project, it will be possible to use its standard functions on other wreck sites as well, even in those instances where different data capture techniques have been used. This is possible as ArcView has the ability to utilise data that have been acquired using several different capture techniques. With advances being made in remote sensing and Global Positioning Systems(GPS), this ability to use other forms of data is vital. As was discussed earlier, data gathered from sources such as video imagery can be used not only as a cosmetic addition to GIS but also in analysis. Images have been used successfully as a means of mapping sites and calculating distances and scale on the sea bed. This new direction has additional advantages in that bottom time and excavation time can be substantially reduced so that work progresses at a more rapid rate (Gifford 1993:167).

It is the view of the author that the *Oosterland* GIS can form an invaluable base for future maritime archaeological research in South Africa and beyond. Even if it is used merely as a mapping tool to start plotting known wreck sites around the coast, with attribute data being linked to those wrecks, it will serve a notable function. Current databases of this nature do exist but only in table form. The addition of a mapping capability will greatly improve the ease with which these data can be used. The system can be easily updated as information regarding these wrecks becomes available and all of this can be stored and accessed from one place.

CONCLUSIONS

The development of GIS as spatial data handling and analysis tools represents a giant lead forward in terms of map making and use. Since its early inception, GIS have made rapid advances and have been put to use in a wide range of commercial and research ventures. The tools have been used by terrestrial archaeologists for some years but have not been extensively adopted in the maritime field to date despite avid interest. Where GIS have been used, very little of the results of the work have been published making research into the area difficult. The current project was set up in an attempt to address the feasibility of the application of GIS to a maritime archaeological site. The main aims of this project were to create the database that encompassed the wide range of data collected from the *Oosterland* wreck site and insert this database into ArcView GIS in an attempt to produce a tool that could be used in spatial analysis of the artefacts distributions. Once data had been captured and entered, a series of test questions were devised to indicate the analytical capabilities of the system and examine the worth of the data entered in the format chosen.

It is felt that all of the aims of the project as described have been explored and fulfilled. The application of GIS to archaeological sites has, for many years, been largely the domain of the terrestrial archaeologist. As the power of the tool has been realised, an identifiable increase in interest in the systems can be identified to exist within the maritime archaeological community. Despite this, very little concerning its application on underwater sites has been made publicly available to date. It is only a small number of applications such as those applied to the *Monitor,* which have been published. The

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Since early steps were taken to create a GIS that could deal specifically with survey data collected on the *Oosterland* site in 1991 by Breitenmoser and in 1994 by the author, substantial advancements have been made in the area of the spatial analytical capabilities of the project. Although Breitenmoser's work appears to have been detailed, his unfortunate death meant that the data types needed for the system and the methods of data entry could not be recreated. For this reason, it was necessary to start the process of data capture from the beginning in order to develop an easily useable format that was well explained and could be continued by future researchers. The author made an attempt to produce such a project in 1994 as part of a BA(Honours) thesis. The project was successful in that the end result was a simple mapping tool that supported certain data queries concerning artefact classification. It could not, however, solve spatial analytical questioning. The current project picked up where the 1994 study left off. Again it was necessary to update the data types and classification in order to change the software format from Arc/Info to ArcView GIS. The system was updated further to include all of the surveyed artefacts recovered from the wreck to date. Problems were associated with the 1996 fieldwork season in that datum points that had been used to reference the location of grids had obviously moved. This meant that the last grids (14 and 15) could not be correctly positioned and the survey data gathered from that grid could not be entered. This constitutes only four artefacts and does not effect the aims of the project, which do not include a definitive analysis of the distribution of artefacts on the seabed. The information regarding these artefacts has not been lost and later excavation will allow an opportunity to measure the position of the grid again and hence find the position of the artefacts that have been omitted. It was also decided that the classification of artefacts should be updated to make the system user friendly and adaptable. The portions of this project concerning data capture and the solutions of problems associated with entry into computer readable tables deal with the adaptation of the earlier work to this style. This constitutes one of the primary aims of this undertaking and it is felt that a good system has been established to deal with the mapping and querying of artefacts and their attributes.

Once the system had been set up its validity was tested by asking several archaeological questions that dealt specifically with the analysis of the distribution of artefacts around the site. Although these questions are simple, they should be seen in the light of being a preliminary trial of the capabilities of the system and a method of making certain that the system, in its current format, works. It is felt that the questions and results shown in this study more than adequately show the power of the system and that it does indeed operate effectively. Despite the simplicity of the questions asked, some important information regarding the wreck has already been found through GIS analysis. The system shows that the orientation of the wreck differs from the original hypotheses on this subject. Re-orientation of the excavation based on this conclusion may be useful in the search for more artefact information and also help in the recovery of important artefact groups that have been absent to date. The GIS has also answered some important questions on the manner in which the ship was wrecked and broke up on the sea floor and given some preliminary results concerning the ownership or position of unofficial artefact assemblages such as personal trade items. These results, although tentative, go some way to exploring the lives of people on board the East India trade ships of the late 17th century and the arrangement of the people on board the vessel. The range of questions asked of the system tests the varied capabilities of the GIS. The functions used, such as overlay and neighbourhood statistics, allow this project to test its validity and application over a range of analytical processes.

The future of GIS in maritime archaeology seems to be bright. The system, as developed, can be easily adapted to deal with information from other wreck sites and to link and compare wreck sites anywhere in the world. As maritime archaeology develops and its reputation becomes more solid, it will be necessary to make use of analytical tools such as the ones described in this project. The system can also be easily adapted and used as an educational tool which allows public interaction with virtual wreck sites. The popular perception of this field as being a glorified form of treasure hunting needs to be finally and totally dispelled. In keeping with the technological advances in data analysis and by creating systems of data handling that are abreast with those in place in terrestrial archaeology, it is possible that the public and professional understanding of maritime archaeology as being concerned only with artefacts and their monetary value can be changed. Maritime history and culture and the long relationship humans have had with the sea are some of the most important aspects of history in general. The spread of people, political and social ideologies, economies and knowledge relies heavily on the sea. The world which we see around us today has been largely shaped by the earliest shipping movements and early expansion and colonisation by sea-faring nations. For this reason the field must be seen as being as important as its land based counterpart. Work such as GIS analysis will help to dispel current, incorrect perceptions of the field and introduce new understanding of the complexities of the world around us.

This project has met its aims and shown that GIS is a powerful tool in spatial analysis. It is a time saving method in that it performs analytical functions that would previously have been tedious when done by hand, in a matter of minutes. The data storage capabilities of today's computers make it possible to create files containing information concerning wreck sites that are more durable and smaller than their hard-copy counterparts and also allow for quick access and reproduction of information regarding the sites. In particular, GIS makes performing of mapping tasks easy and simple. Data features are all contained in separate overlay levels of the complete map and any artefact can be separately selected and mapped if the need arises with the greatest of ease. GIS is possibly one of the most important developments that have taken place in maritime archaeology in many years and appear to have an outstanding future in the field. Interest has already been established and is expanding at a rapid rate. It is hoped that this study will be of use in the analysis of the *Oosterland* wreck site, as well as allow others interested in the application of GIS to underwater sites to gain a better understanding of the adaptations and tools that are required to develop a truly powerful analytical system.

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