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MSC THESIS

Mapping and prediction of archaeological sites of habitation by *modern* humans using GIS and expert mapping on the south coast of South Africa

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South Africa contains many archaeological resources including shell middens from the Middle Stone Age (MSA) and Later Stone Age (LSA). These shell middens give researchers insight into the behaviour of modern humans where the first fossil evidence appears in Africa around 200 000 years ago (Klein, 2008). Research into shell middens is therefore vital to understand the origin of human kind. This study investigates whether Geographical Information Systems (GIS) is a useful tool for predicting locations of unknown shell midden sites using the characteristics of known areas of modern human habitation. This was done using suitability analysis and expert mapping techniques. Ground truthing of the results of the desktop analysis revealed that GIS is not a useful tool for predicting sites of modern habitation as the characteristics that determine human habitation are too variable.

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Chapter 1

Introduction

The western and southern Cape coasts of South Africa are rich in archaeological treasures of sites once inhabited by modern humans. Parkington (2006) describe how the "history of the South African landscape is written in the archaeological record of shell middens". Shell middens are stratified collections of debris of modern humans that include shells, bones and tool making refuse (Parkington, 2006). An extensive amount of research has been conducted on shell midden sites that are representative of modern human settlement around the world, but there is still much that remains undiscovered.

A modern human is described by Deacon (1992) as human remains that are "modern in morphology". For this reason the African fossil evidence from the Middle to Late Pleistocene period is classified as anatomically modern (Deacon, 1992). This includes the MSA and LSA periods. Sites from the Middle Stone Age (MSA) period, around 250 000 – 40 000 years ago (±250-40 ka), are important as they include the first remains of anatomically modern people (Singer & Wymer, 1982). Marean (2010) describes how human remains in these MSA sites are rare and that research is hindered by the lack of sites from this important time period (Marean, 2010). This makes the discovery of new sites from the MSA period important for research into modern humans and how they used their landscape to survive. MSA sites are the target for this study but LSA sites are also considered as Deacon and Deacon (1999) describe how LSA settlements frequently inhabited old MSA sites. In this way the location of LSA sites could be used as an indicator for the location of older MSA sites. There is also limited data on MSA settlements as a result of the rarity of these sites and were therefore not suitable for statistics. As a result, though MSA sites were the target for this investigation due to their importance, LSA were also used for the analysis.

This study utilised Geographic Information Systems (GIS) to try to locate some of these possibly important sites. A *suitability analysis* was utilised to predict areas where there is a high probability of finding sites. This was done by characterising the locations of known sites though reclassification of physical, resource based and human characteristics. The reclassified layers were then combined using the raster calculator through various equations determined through statistical analysis. Areas were then identified that contain the same characteristics of the know sites and therefore had a high probability of finding unknown sites. This form of suitability analysis has been utilised for previous studies of archaeological sites and was affective. Ground truthing was then used to verify the results of the analysis and determine whether GIS is an effective tool for locating unknown archaeological sites.

Unfortunately development of coastal areas in South Africa is threatening many known and unknown sites. In some cases, modern towns are developing right on top of undiscovered shell middens (Parkington, 2006). Legislation has been put in place to mitigate the destruction of sites and the South African Heritage Resource Agency (SAHRA) has been created to oversee the implementation of these laws(SAHRA, 2014a). Unfortunately, many developers and construction workers are unaware that the pile of shells they are removing are actually important archaeological resources. Parkington (2006) discuss the use of education as a solution to this problem, declaring education to be “the best fence [one] can put around shell middens”. This study investigates the relationship between development and archaeology and illustrates an unexpected a positive relationship between the two.

Research Question

Is GIS and expert knowledge mapping a potentially useful approach to mapping and predicting the location of archaeological sites of habitation by modern humans?

Research Aim

The aim of this research was to investigate the use of GIS and expert knowledge mapping as complimentary tools in predicting the location of archaeological sites of habitation by modern humans on the south coast of South Africa.

Objectives

The aim of this project was accomplished through the execution of six objectives:

Objective 1
To ‘characterize’ and understand the spatial dynamics of archaeological sites of modern human habitation on the southern coast of South Africa through investigation of existing knowledge and the creation of spatial layers.

Objective 2
To define and test *probability zones* in regard to yield of artefacts based on a suitability analysis of spatial layers created in Objective 1 and determine whether GIS is an appropriate tool for predicating sites of human habitation.

Objective 3
To relate results to current coastal development and identify new focus areas for research.

Chapter 2

Literature Review

This review will explore the many areas of knowledge that have bearing on this research. A background into the MSA time period will be discussed with a focus on four main research sites: Die Kelders, Klasies River, Blombos Cave and Pinnacle Point. This will set the context for this study and why it hoped to locate more of these sites. Geographic Information Systems (GIS) and associated tools were the main analysis tools for this study. Investigation into literature that has used GIS in an archaeological context is discussed as well as methodology utilised in the predictive modelling for this study. Other facets that affected the results of this study are also discussed including the concept of expert knowledge, bias, effort and development.

Klein *et al*. (2004) describe how early humans in Africa and Eurasia displayed similar behaviour during the Earlier Stone Age (ESA). At this time the single lineage of humans began to diverge into three predominant evolving human lineages: *Homo sapiens* in Africa, *Homo neanderthalensis* in Europe and *Homo erectus* in the Far East (Klein, 2008). *Homo sapiens* in Africa have been termed '*modern* humans', a term defined by Parkington (2006) as: " any skeletal remains that are effectively indistinguishable from those of our own". The origins of modern humans are strongly contested (Tribolo et al., 2006). Around 20 years ago it was believed that there were two main opposing viewpoints: some argued that modern humans appeared around 50 k.a. when *modern* behaviour began (Ambrose and Lorenz, 1990; Klein, 2000, 1995; Klein *et al*., 1994, 1989); others argued that *modern* humans appeared 70 k.a. when the Howison's Poort Industry began, indicating *modern* cognitive behaviour (Deacon, 1992; Deacon et al., 1998; Deacon et al., 1989; Wurtz, 1999). There is now consensus that *modern* humans appeared in Africa much earlier than in Europe and Asia, around 200-120 k.a. (Deacon & Geleijnse, 1988).

Research into the nature of the spread of *modern* humans or *Homo sapiens* from Africa to the rest of the world has been carried out since the 1910's and two main theories have been established (Klein, 2008). The first is the 'Out of Africa' theory (now accepted by most paleoanthropologists) which uses genetics and skeletal remains to prove that all humans share one, common African ancestor (Klein, 2008). This theory is also described by Stringer and Andrews (1988) and Deacon and Deacon (1999) as the 'African Eve' and 'Recent African Origions' theory. This theory puts forward that *Homo sapiens* originated in Africa 50 ka and spread from the continent to the northern hemisphere (Klein, 2008). The fully *modern* humans replaced both H. *neanderthalensis* in Europe and *erectus* in the Far East (Klein, 2008). However, Klein (2008) describes how some of the old and new knowledge is contradictory and ambiguous. Another theory of the emergence of modern humans is the theory of anagenesis (Deacon & Deacon, 1999). This theory puts forward that emergence of modern humans occurred through gene flow and not through migration (Deacon & Deacon, 1999). It theories that evolution occurred in one lineage and did not branch out. Interbreeding through meeting new people meant that modern humans did not have one single origin but multiple origins (Deacon & Deacon, 1999). The discovery of new sites of modern human habitation will contribute to improved knowledge and understanding of their evolution and survival.

The MSA period (±250-40 k.a.) will be the focus of this study. The term MSA was introduced in 1929 to be used as an artificial divide between the MSA and the middle Palaeolithic period (Deacon & Deacon, 1999). During this period there is a variation in lithic technology form the hand axes of the ESA and the mircolithic industries of the LSA (Klein & Cruz-Uribe, 1996). Elongated flake blades are utilised more than the retouched pieces found in LSA industries (Klein & Cruz-Uribe, 1996). Prepared cores were common and dorsal preparation was used (one or more ridges) (Deacon & Deacon, 1999). They ranged from 40 to 100mm in size and had convergent sides and a pointed shape (Deacon & Deacon, 1999).

Although the MSA period will be the focus of this study, is it described by Cochrane (2008) that both the MSA and LSA are the cultural backdrop for evolution of modern humans. Modern behaviour evolved and developed in the LSA but research shows evidence of this behaviour in the MSA (Cochrane, 2008). There are therefore many similarities between these two periods including areas of settlement as LSA humans often settled in old MSA settlements (Deacon & Deacon, 1999). The indistinct line between the cultural diversity of the MSA and LSA period needs further investigation (Cochrane, 2008). For this reason both LSA and MSA sites were included in the analysis of this study.

The MSA period shows the first development of regional culture and it is for this reason that this period is important and in need of further investigation (Deacon & Deacon, 1999). Modern behaviour can be seen in the family foraging group structures and strong kinship ties (Deacon & Deacon, 1999). This is indicated by the location of non-utilitarian objects such as 'beauty shells' (Jerardino & Marean, 2010). There is also evidence of an evolution of complexity in the material complexity in the form of bone tools, beads, worked and unworked pigments and decorated ochre (Marean, 2010). These findings all contribute to the understanding of the evolution of *modern* humans and illustrates why this time period is so important and requires more research.

The MSA period also contains the first evidence of marine coastal adaptation (Marean, 2010). *Homo sapiens* are unique in their encephalisation quotient (EQ), which is the ratio of an animal's brain weight to their body weight (Parkington, 2006). *Homo sapiens* has an enormous brain for their body weight; more than three times larger than any other animal (Parkington, 2006). Parkington (2006) describe how optimum brain function requires a large amount of docosahexaenoic acid, an acid found in a much higher concentration in seafood than in terrestrial food. This does not necessarily mean that modern humans living on the coast who collected and ate shellfish developed a larger brain but there is a strong correlation between the two (Parkington, 2006). Parkington (2006) describe diet as a framework within which brain growth was enabled; larger brains helped *modern* humans realise the accessibility of shellfish and this enabled further brain development (Parkington, 2006). The discovery of new sites will possibly shed new light on the complex relationship between sea resources and *modern* humans.

Sites from the MSA period are important as they include the first remains of anatomically *modern* humans (Singer & Wymer, 1982). The *Last Interglacial* cycle is found within the MSA period (±125-74 k.a.). The climate on the south coast of South Africa was less extreme leading to occupation by humans in this area (Deacon & Lancaster, 1988). Marean et al. (2007) discusses how the inter-glacial period (195 -130 k.a.) may have also encouraged the utilisation of marine resources as a new food source. The South coast sea level also dropped dramatically to 6-8m below the current coastline and at times even further (Phillipson, 1995). As a result of this most of these important MSA sites have been drowned, making sites rare and hindering research (Marean, 2010). Despite these limitations, the south coast of South Africa is described by Marean et al. (2004) as one of the riches areas of MSA archaeological records in the country. This is the reason why this area was selected for this study.

Within the study area there are four sites of major paleoarchaeological significance: Die Kelders, Klasies Rivier, Blombos Cave and Pinnacle Point. All four sites have been used to prove that modern humans originated from the south coast of South Africa. Die Kelders cave contains both rich MSA and LSA deposits (Schweitzer, 1979). Human teeth were found in this site that were used to show that the MSA humans residing in this area were more modern in appearance than the *Neandertha*ls that inhabited Europe at that time (Avery et al., 1997). The research from this site contributed to the understanding of the origins of modern humans and added evidence to the "Out of Africa" theory (Avery et al., 1997).

The Klasies Rivier site is another important site for this time period as it contains one of the oldest anatomically 'modern' human remains from about 100 k.a. (Singer & Wymer, 1982). The fossil record found at this site is described as being uniquely full: it contains a record of modern humans of the Last Interglacial and Early Glacial period who survived in coastal or near coastal environments (Deacon & Geleijnse, 1988). It also contains the first evidence found for systematic shellfish collection dating to between 123 and 74 k.a. (Jerardino & Marean, 2010).

Subsequently remains at the third site, Pinnacle Point, were investigated by Jerardino & Marean (2010). Their dating determined that the site contains the earliest evidence of shellfish collection (±164 k.a.). The shell middens are located in a cave that would have been relatively high above sea level during occupation and currently sits at 15m above sea level (Jerardino & Marean, 2010). Most middens from this time period are below current sea levels (±6m below sea level) and the period is therefore poorly represented in Africa (Jerardino & Marean, 2010). 'Markers' that suggest modernity found at the site include shellfish collection (anticipation, planning and cooperation) and collection of non-utilitarian shells ('beauty shells'). Ochre was also discovered in this site. These modernity markers have contributed to the theory that humans along the south coast became modern prior to the 'Out of Africa' migration that occurred between 70 and 60 k.a. (Jerardino & Marean, 2010).

At Blombos Cave unusual artefacts have been discovered including bone tools, engraved pieces of bone and ochre (C.S. Henshilwood et al., 2001). These artefacts indicate a change in behaviour towards symbology and cultural expansion (C.S. Henshilwood et al., 2001). The findings correlate with findings at other sites, which suggests that some aspects of human behaviour evolved during the Late Pleistocene period (±126-50 k.a.) (C.S. Henshilwood et al., 2001).

The aim of this study was to try and demine more important sites like the ones mentioned above using GIS techniques. GIS is a useful tool for the analysis of spatial data. The initial functions of GIS involved simply inputting maps into a digital format (Gold, 2006). These days GIS analysis has expanded to incorporate large datasets together with spatial mapping (Gold, 2006). Gold (2006) describes the "traditional analysis functions" as creating buffer zones, dissolving polygons and the overlaying of different layers. There are three stages of maturity and complexity of GIS technology (Robinson et al., 2000). The first stage is its use as an inventory and examples of this can be found in various archaeological contexts. The second stage includes more advanced analysis to determine relationships. The third stage is the most complex form of analysis; modelling. This stage moves beyond pure relationship identification into a form of predictive analysis (Robinson et al., 2000). GIS techniques have been used for predicating the locations of various entities such as the location of rare orchid habitats (Sperduto & Congalton, 1996) and breeding bird distribution (Tucker et al., 1997). GIS has also been applied in analysis in palaeontology. Nigro et al. (2003) used GIS to determine the spatial distribution of fossils at the Swartkraans fossil site. Examples of GIS being used in a predictive context can be found in Powell et al. (2005) where prediction of areas suitable for the re-introduction of rainforest shrub were made. Joy and Death (2004) used GIS and occurrence data to predict freshwater fish and decapods assemblages in the Wellington region of New Zealand. This research used GIS as a predictive tool to identify potential zones where archaeological artefacts might occur.

GIS has been used in an archaeological context for many years. It was first used to complete tasks that were already being performed in other ways, such as data management and predictive modelling (Lock, 2001) (the first stage of complexity as described by (Robinson et al., 2000)). Geophysical techniques are used to locate and delineate archaeological resources, including magnetometry, earth resistance surveys, ground-penetrating radar (GPR) and electromagnetic surveys (EM) (Gaffney, 2008). This geophysical data is very important in locating unknown archaeological resources but it cannot be used in isolation, the results need to be connected to other data sets which can be done using GIS software. GIS has become an important tool for connecting different types of data to produce more complex models that depict what occurred in the past (Gaffney, 2008).

According to Lock (2001) there are two main approaches to using GIS as a tool for archaeological research: methodical and theoretical. A methodical approach was discussed by Kohler and Parker (1986) to create a predictive model for new archaeological sites in North America: it describes how characteristics are determined that influence the location of archaeological sites. These determining characteristics are termed *decision makers* (Oheim, 2007). Three factors were described by Kohler and Parker (1986) which were considered when identifying the *decision makers*: how people make choices concerning location; identifying the variable that affects the selection of its location and finally the proposed methods of measuring these variables so that predictions can be made that are comparable to archaeological data (Kohler & Parker, 1986). The *decision makers* were determined from known sites and used to predict unknown locations of archaeological resources (Lock, 2001).

Perkins (2000) also used this type of methodical approach to identify unknown archaeological sites in the Albegna Valley, Tuscany. The *decision makers* used were altitude, slope, aspect and solid geology. The layers were then reclassified with respect to their influence on the site occurrence with the maximum score being 4. The layers were then overlaid so that the variables could be viewed in a combination and not in isolation. The weighting of these layers was described as being difficult to determine (Perkins, 2000). Perkins (2000) identified a positive relationship between different time periods and the occurrence of sites in specific areas. However, there are criticisms for this methodical approach.

The methodology used in this type of predictive modelling is criticized by Westcott and Brandon (2000) as using the same environmentally deterministic logic as was used twenty years ago which is therefore out of date. As a result, Wheatley (2000) prefers a theoretical approach, describing the methodical approach as “reductionist, anti-historical and positivist”. A theoretical approach focuses on interpreting the historical processes that cause patterns in data rather than the patterns themselves (Gaffney & van Leusen, 1995). This approach uses knowledge collected over an archaeologist’s career to make decisions and not pure statistics and modelling as used in the methodical approach. Wise (2000) describes how the methodical approach omits the ecological and phenomenological aspects of archaeology; ecology refers to the interaction of organisms with their environment and phenomenology describes the forms and varieties of human consciousness, how humans think (Wise, 2000). Contextual theory can be integrated into the methodical approach through the creation of view sheds and layers that depict ritual and symbolic systems but it is not common for this to occur (Wise, 2000). Kohler and Parker (1986) also describe how many archaeologists are against this methodical approach. They describe how some specialists think the positional modelling is “suspect and unreliable” while others feel that the use of predictive models for early project planning is encouraged (Kohler & Parker, 1986).

This study aims to bridge the gap between these two approaches by using strengths from both the environmental deterministic method and the theoretical method. Expert knowledge will play a major role in bringing these two methods together for this study as it utilises the knowledge obtained by professionals in the field of early modern humans.

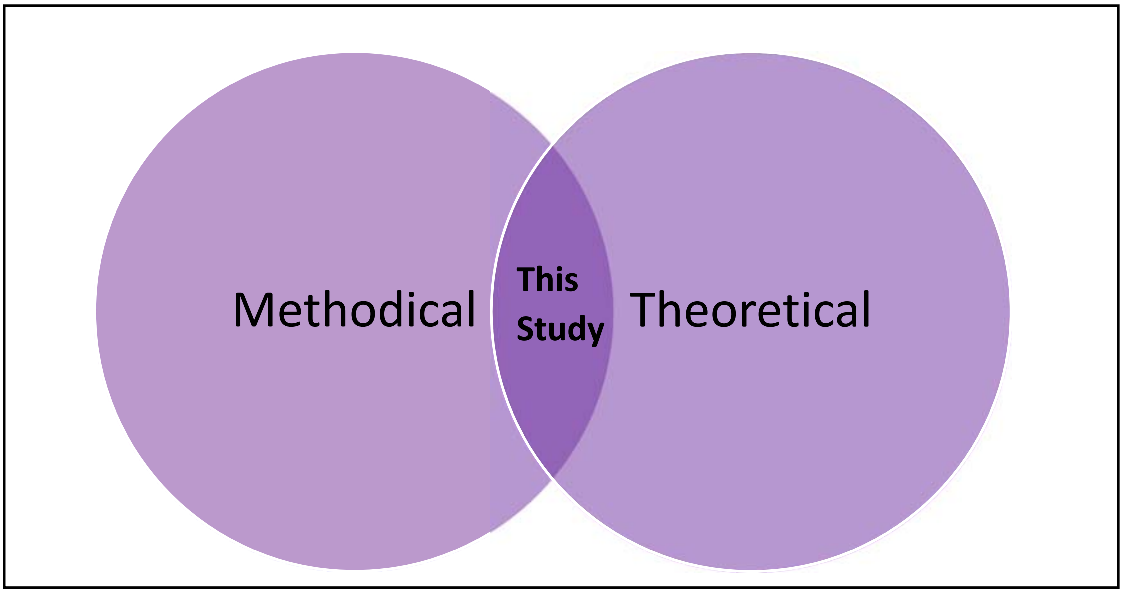

Figure 2.1: An illustration of how this study bridges the gap between the methodical and theoretical approaches.

Kohler and Parker (1986) describe how to select *decision makers* to be used in an archaeological context. Variables that must be included are: avoidance of environmental hazards, proximity to life-sustaining resources , accessibility and possibly aesthetics and other social factors (Kohler & Parker, 1986). An analysis of the sites found in published literature was performed and used as a basis for the identification of the *decision makers* (**table 2.1**.) These are the characteristics that could affect the location of sites of human habitation.

Table 2.1: Possible 'decision makers' identified through analysis of the literature.

Variable	Specific Constraint	Reference
Caves	• 18m, 16m, 0m above sea level • 8m above sea level • Caves and rock shelters	• (Deacon & Geleijnse, 1988) • (Avery et al., 1997) • (Marean, 2010)
Height above sea level	• 10m • 34.5	• (Avery et al., 1997) • (C.S. Henshilwood et al., 2001)
Distance from sea	• 5-10km • 10km max	• (Marean et al., 2007) • (Jerardino & Marean, 2010)
Physical	• Altitude, slope, aspect, solid geology, soil type • Slope, vegetation type, rock shelters, distance to resources, soil type, sea level	• (Perkins, 2000) • (Kohler & Parker, 1986)
Shore line	• Exposed to moderately rocky shores • Rocky shores and occasionally sandy beaches	• (Marean et al., 2007) • (Marean et al., 2004)
Geology	• Quartzitic sandstone	• (Marean et al., 2004)

By considering the physical, environmental and human variables that characterise the location of human habitation, this study aims to contribute to locating new potential sites of modern human habitation.

There are many methods available for combining these *decision makers* for a predictive model. This study utilised the *suitability analysis* method to predict sites of human habitation. A *suitability analysis* is an approach which uses set criteria to determine the most suitable location for specified object (Briney, 2014). Oheim (2007) describes this *suitability analysis* approach and how it was used to predict fossil locations in the Two Medicine Formation in North Central Montana. (As shell middens are often fossilised, this technique is relevant to this study.) The fossils in the area are found in mudstones and sandstones. *Suitability analysis* has six steps: the first step is to set goals or to decide on the preferred outcomes; the second step is to decide on the *decision makers* which refer to the geographical layers that will be used in the analysis (geology, vegetation cover, elevation and distance from road); the third step is to create evaluation criteria which rank the 'likelihood' within each *decision maker* (Oheim, 2007). Oheim (2007) used a rating system to show the rock types most likely to contain fossils within the geology layer, 1 being least likely and 4 being most likely. The layers were then reclassified according to the derived rating system: the cells representing low likelihood were given a value of 1 and the high likelihood cells were reclassified as a value of 4. Step five included taking note of uncontrollable variables such as the "states of nature" which include slope steepness and rivers. (These variables will ultimately affect the scope of a site.) The final step was to create a set of outcomes of the analyses. (In this study the outcomes were predictions for possible fossil deposit sites; areas that have a high probability of containing fossils.)

The reclassified layers, derived from the evaluation criteria, were used to complete the *suitability analysis*. A raster analysis of the layers was used to indicate the most likely areas to find fossils. The equation that was entered into the raster calculator to achieve this is described by Wayne (2003) as:

Suitability = (Reclassified layer 1) + (Reclassified layer 2) + ... + (Reclassified layer n)

- Where n is the number of reclassified decision making layers.

Equation 2.1: Suitability Analysis (Wayne, 2003).

However, not all categories are of equal relevance in a real world situation (Wayne, 2003). The relevance of a category can also be taken into account; Oheim (2007) gave geology the highest relevance (4) and distance from road the lowest relevance (1). Each reclassified layer must then be given a percentage of relevance that together makes 100% (Wayne, 2003). These percentages must be in decimal form. The equation including relevance is described as:

Suitability = {[(Reclassified layer 1) x 0.4] + [(Reclassified layer 2) x 0.2] + ... + [(Reclassified layer n) x 0.m]} x n

- Where n is the number of reclassified decision making layers.
- Where 0.4 + 0.2 + ... + m = 1
  (40% + 20% + ... + m = 100%)

Equation 2.2: Suitability Analysis with Relevance (Wayne, 2003).

The *suitability analysis* that includes relevance will create a raster layer that will indicate the area's most likely to yield results. This is a typical raster analysis technique.

Mensing et al. (2000) used a similar method to that of Oheim (2007) called a *weights-of-evidence* method in a study which predicted the distribution of fossil packrat, or *Neotoma*, middens in the central Nevada. The study used previous midden locations to make predictions of unknown middens which contain useful paleoecological evidence. The weights-of evidence method has three elements: training points, spatially defined study site and evidential themes. The training points are the specific points of previously known information, for example, packrat middens. The evidential themes refer to the *decision making* layers described by Oheim (2007) that are used to predict unknown training points (Mensing et al., 2000). The vector training points are converted into a raster layer with each grid cell representing density of sites.

The *weights-of-evidence* methodology dictates that a weight for each class needs to be calculated (Mensing et al., 2000). This differs from the suitability analysis as the weighting includes negative and positive values. Positive values indicate if middens are present and negative values if they are absent. The positive values are also quantified from mildly predictive (0 – 0.5) to extremely predictive (>2) (Mensing et al., 2000). Before these weightings are added a prior probability needs to be calculated by dividing the total number of training points by the total area (Mensing et al., 2000). This will be the standard from which the calculated probabilities using the evidential themes will be measured. This data was then put into the *weights-of-evidence* software which tests for conditional independence (Mensing et al., 2000). The posterior or subsequent probability, is the probability that a particular unit cell will contain a training point once the evidential themes have also been considered (Raines et al., 2000). The difference between the prior and the posterior probabilities vary in different locations dependent on the amount of positive weighted themes in the area (Raines et al., 2000).

In both of the studies discussed above, validation of the output probabilities was checked by random site verification. In Oheim (2007)sites were chosen within an 8km buffer of the road for easy access as the study site was so extensive. The field work showed that elevation and vegetation evaluation criteria were inaccurate. Modifications were then made to the predictive model and new areas of high probability were found, which were then rechecked through ground truthing.

Malakhov et al. (2009) used a different technique to achieve the same aim. Remote sensing techniques were used to recognise 'fossiliferious strata' and therefore new paleontological sites. LandSat satellite imagery, composed of three visible (red, blue and green) and four infrared bands, were used in this study. The infrared bands aid identification of exposed geology and can even pick up specific mineral compositions. This approach uses spectral parameters in contrast to the environmental parameters used by Oheim (2007) and Mensing et al. (2000). Remote sensing had to be used in this study as the study site in Kazakhstan was extremely remote and no environmental data existed for the region (Malakhov et al., 2009). There were some limitations to this method: Malakhov et al. (2009) describes how the software cannot always differentiate between closely related sets of spectra. Regardless of these limitations, the method was described as effective as there were "fragmentary fossil material in most places revealed by the Landast analysis". However Malakhov et al. (2009) describes the method as "not as precise as [analysing] local environmental variables using GIS" and cites Oheim's (2007) work as more precise.

An example of using environmental variables to predict unknown sites in archaeology can be found in Perkins (2000). Perkins (2000) also used this type of approach to identify unknown sites in the Albegna Valley, Tuscany: a variety of natural criteria were used to identify sites within a sample area. The specific decision makers were altitude, slope, aspect and solid geology (Perkins, 2000). Rainfall and soil type were not used in this study but were mentioned as other possible decision makers (Perkins, 2000). Perkins (2000) highlights the statistics used to determine whether each variable was a determining characteristic of site location. For example: limestone was described as occupying 20% of the study site. If the percentage of known sites found in the limestone layer mirrors that 20% then that specific characteristic has no effect on site location; the *observed* distributions mirrors the *expected* distribution (Perkins, 2000). It the percentage of observed sites differs from the *expected* distribution then the χ^2 test can then be used to determine if there is a significant difference between the two percentages (Perkins, 2000). This indicated whether a specific characteristic plays a significant role in site location. (The methodology of the χ^2 test is described in the methods section). Kohler and Parker (1986) also describe this method of statistical analysis using soil type as an example. This method will be used in this research as a means of statistically verifying the effect decision makers have on site locations.

Brandt et al. (1992) used a similar technique to the one described above. This is a study conducted in the Netherlands to predict unknown archaeological sites. The time period for the known sites used in the statistical analysis originate from a broad time frame of 30 000 BC to 1500AD (Brandt et al., 1992). The analysis used randomly selected points to determine the *expected* variable instead of using the entire study site coverage (Brandt et al., 1992). It is still effective for determining whether a relationship exists between the known sites and the characteristics within which they are found. This study, however, used the methodology described by Kohler and Parker (1986) and Perkins (2000).

One of the methods of data collection used in this study is that of expert knowledge. Experts in their specific fields have gathered extensive knowledge throughout their careers. Unfortunately this knowledge can be lost through career change and retirement, making it important that it is recorded for future use (Maddock & Samways, 2000). Among other things, experts can be used to define objects and identify alternatives (Bojórquez-Tapia et al., 2003). Their knowledge enables them to solve problems by assessing the alternative options (Bojórquez-Tapia et al., 2003). This is especially important in areas where little or no systematic research has been conducted (Yamada et al., 2003).

Yamada et al. (2003) utilized expert mapping to model wildlife habitats. The key aspect of including expert knowledge is that it provides a local-specific knowledge from key role-players (Randeloff et al., 1999). In this study a GIS-based graphical user interface (GUI) was created which provided the expert with a map that included spatial data such as contours, roads, etc. Yamada et al. (2003). This is a very useful format for data input as it creates a spatial platform within which the expert can input their data (Yamada et al., 2003). Expert mapping is typically used for conservation planning but its methods can be expanded to be used in this study (Bojórquez-Tapia et al., 2003). The expert knowledge was obtained through questionnaires and some interesting concepts were discussed.

The concept of *topophilia* was brought up by two of the experts interviewed for this study. Webley (2013) and Parkington (2013) both mentioned that humans like to settle in an area where they can 'attach' themselves to a physical landform, such as a hilltop, bay or river mouth. Tuan (1974) has examined the concept of *topophilia* extensively: it is described as the emotional bond that humans have between themselves and the physical landscape around them. Pile (1993) also describes this theory and how human geographers have started describing the positive emotions associated with their physical environment as *topophilia*. This theory was incorporated into this study in the form of a human characteristic layer that affects the location of sites of modern human habitation.

Bias exists in any research context but it is especially apparent in research which contains expert knowledge or personal opinion. Bias describes the difference between truth and reality of the findings of a study. Beck and Jones (1989) describe three types of bias in the archaeological context. The first is that class or attribute definitions are not properly understood; the interpretation of one experts 'straight edge' is different to another's (Beck & Jones, 1989). The second type is found in the perceptions of analysts; the same object is identified differently by different analysts. The final type of bias is found in an analysts change in perception over time. Kohler and Parker (1986) describe how there is even bias between archaeological sites: the environmental factors that that effect the location of sites in one area can be completely avoided in another. If archaeologists have worked extensively in one area then they will develop a 'bias' to the contributing factors which indicate sites locations.

Bias is a constant underlying problem in representation in the fossil record. There are two types of information that can be determined from any fossil record (Paul, 1998). The first is intrinsic character information which comes from the skeletal morphology found in these sites. The second is the extrinsic sequence of events which is displayed in the stratigraphy of the fossil record. Within each of these types bias can be found. All fossil records combined only make up 10% of living species, the fossil record is incomplete and biased towards biota that are suitable for preservation (Paul, 1998). This also translates into the stratigraphic information that only describes the small period of time within which the fossils were formed (Paul, 1998). Once this implicit bias in the fossil record is understood, corrective measures can be made to improve the objectiveness of the research.

One approach to reducing bias is to include an assessment of effort. Interest in a site generates and concentrates research effort at a site and makes it more likely that it will be visited more frequently than others. Access to a site or long term project plans could also explain an increased 'effort' in a certain area. Melly (2011) created a map to show intensity of effort when marking sightings of cetaceans in Algoa Bay. This was achieved through the use of an equation to determine the spatial sightings per unit area *SPUE* (Melly, 2011). High *SPUE's* indicated areas with low effort but high sighting while low *SPUE's* indicated areas of high effort but low sightings (Melly, 2011). This is a simple but useful concept which can be used in this research to help understand the presence/absence of archaeological sites where physical variables do, or do not, yield information.

Development is always an issue when it comes to archaeological sites. According to the National State of the Environment Report 40 % of South Africa's population live within 100km of the coast (DEAT, 1999). This is increasing as a result of coastal development. International connectivity has resulted in an increase in trade globally. Coastal areas have developed over time as hubs for shipping and the trade of goods internationally (Palmer et al., 2011). More recently, the major, inland cities have become over developed and over populated leading to more and more people migrating to the 'quieter', less developed coastal areas (Palmer et al., 2011). There are many social drivers that effect the movement of people towards coastal areas. The favourable climate and fertile land associated with coastal areas where driving forces for human habitation (Palmer et al., 2011). The proximity to coastal resources such as fish and shell fish were also major pulls towards these areas for the human during the MSA period (Parkington, 2006). This is the reason why there are so many important archaeological sites found close to the coast. These days the driving forces for coastal development are centred around 'wants' as opposed to 'needs' (Palmer et al., 2011). The favourable climate and aesthetic appeal drive people to these regions (Palmer et al., 2011). Coastal resources are no longer seen to fulfil 'needs' for survival but are more centred towards the 'wants' of a recreational habitation.

Development is increasing in coastal zones which are creating issues for the sustainability of these areas (Palmer et al., 2010). One of the major problems caused by coastal development is the change in land cover that occurs (Palmer et al., 2010). Change in land cover is the main contributing factor to the destruction of ecosystems which has a direct effect on the ability to sustain coastal livelihoods (Palmer et al., 2010). This relates to impoverished residents whose main source of income is the coastal environment within which they reside (Glavovic & Boonzaier, 2007). Increased development can also lead to degradation, coastal erosion and vulnerability to extreme weather events (Palmer et al., 2010). There are many downfalls to coastal development, including the loss of ecosystems, and this has led to the need for proper management and legislation to combat these problems.

SAHRA (2014) describes the legislation South Africa has put into place to combat unsustainable coastal development with regards to archaeology. The National Heritage Resource Act (Act no.25 of 1999, section 35(4)) was developed to ensure that no persons without a permit can destroy, damage, remove from its original position, collect or own archaeological material (SAHRA, 2014a). If one is found guilty of any of these actions they will be liable to a fine or imprisonment or both (SAHRA, 2014a). If an archaeological site is accidently disturbed then it must be reported immediately. After discussion with experts in the field it is evident that developers do not like to report archaeological material as it is costly and time consuming to deal with. As a result, many archaeological sites are never reported and therefore destroyed illegally. This study will attempt to identify areas of unknown sites so as to protect these important archaeological materials.

Study Area

The study area for this project, **figure 2.1**, is the southern Cape coast of South Africa, between Port Elizabeth in the Eastern Cape and Betty's Bay in the Western Cape. This area includes major historically important sites such as Klasies Rivier, Die Kelders, Blombos Cave and Pinnacle Point. The south coast has been chosen as the study site as much of the research into shell middens occurs on the west coast of South Africa. It is therefore possible that more undiscovered sites exist on the southern Cape coast as a result of lower research effort in the region.

The south coast of South Africa is home to the Cape Floral Region. It is unique as it is classified as its own floral kingdom and contains the highest representation of endemic plant species in the world (Goldblatt, 1996). It also contains the region within which the Indian and Atlantic Oceans meet resulting in varying oceanic environments and therefore a dense and diverse shellfish population (Menge & Branch, 2001). These environmental characteristics make the south coast a suitable area for human habitation as illustrated by the literature published about sites in this region. This study aims to identify more of these important sites.

The Garden Route is a major tourist attraction for South Africa and stretches from Mossel Bay to Storms River (GardenRoute.org, 2014). Development will be attracted to this region as a result of the tourism therefore increasing the pressure on important archaeological sites. For this reason this area has been selected for this study as it aims to identify unknown archaeological sites that can therefore be protected.

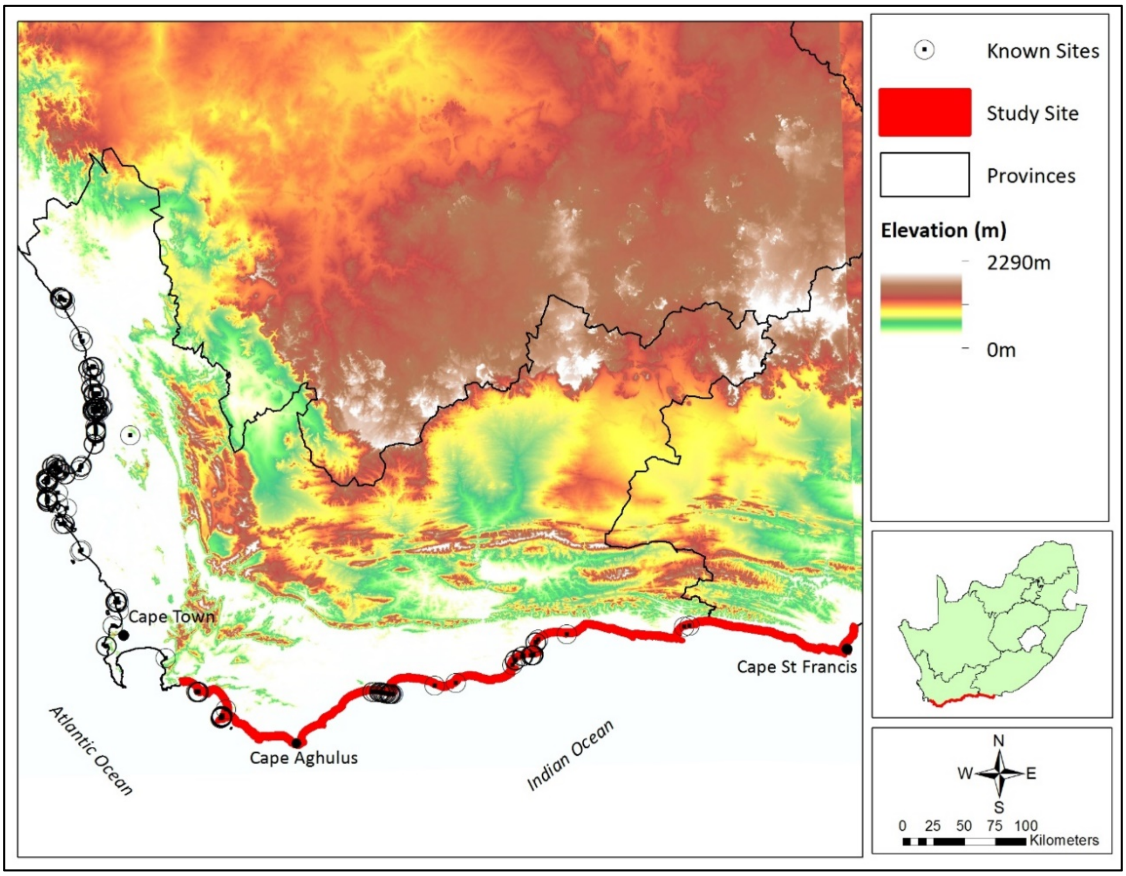

Figure 2.2: The study area and known MSA and LSA sites obtained from SARAH (SAHRA, 2014b).

Chapter 3

Methods

Objective 1

To 'characterize' and understand the spatial dynamics of archaeological sites of modern human habitation on the southern coast of South Africa through investigation of existing knowledge and the creation of spatial layers.

Method

The study area was identified by creating a 3km buffer along the south coast of South Africa. The 3km zone was chosen based on discussions with experts as well as application of logical parameters within which the modern humans would travel. Sites referred to in published research papers were identified and then recorded in a spread sheet. Academic papers were identified through the university database. All sites contained within the papers were recorded and then the literature reviews were explored to identify any further unrecorded sites. This method was repeated until all MSA sites had been recorded. It is important to note here that there are a large number of published papers on only a small number of important sites. The site coordinates, type, description, age and significance were recorded. All sites from academic records were assigned 'high' significance. Archaeological Impact Assessments (AIA) case reports from the SAHRIS data base were then examined to identify other *known sites*. The same characteristics were recorded as done with the academic sites. All case reports include a significance value for each site ranging from low to high based on the importance of each find. MSA and LSA sites were recorded from the AIA's as often no age was given for the known sites. Deacon and Deacon (1999) also describe how LSA site frequently use old MSA sites for settelments. For this reason LSA sites were also used in the analysis is try and identify possible important MSA sites. The data was combined to make one spread sheet of *known sites*. The Albany Museum in Grahamstown was contacted to determine if there were more known sites recorded (Booth, 2013). The records at the museum are all in hard copy and are currently being transferred into a digital format. The records also show the location of discovered sites which have not necessarily been examined. For these reasons the sites were not included in this analysis.

The *known sites* were separated according to their significance. Sites identified by the AIA's as low significance were then excluded from the data set as they would not be useful for determining sites of high significance. Analysis was therefore continued on sites of medium and high significance.

To begin the analysis, literature was examined to identify potential *decision makers* that would influence the occurrence of sites of modern humans. *Decision makers* are based on the extraction of physical and human parameters which are determined to influence the occurrence of these known sites. Interviews were carried out with experts who were identified from the impact assessments and academic journal articles. Four archaeological consultants and two academics were identified and asked to complete a questionnaire (**figure a.1 – a.6** of the appendix). *Decision makers* were then identified through the interviews and combined with those identified in the literature and were used to characterise the know sites. The *decision makers* were used in the suitability analysis (objective 2) to determine if GIS methods can be used to determine areas with similar characteristics to the know sites.

Various GIS data sets were used for this analysis. Existing data sets were identified and downloaded. Layers that needed to be created were done so from these existing GIS layers.

Table 3.1: GIS data sets utilised in project.

Data set name	Data type and spatial resolution	Year	Source	Use
Colour Digital Aerial Imagery at 0.5 m	Colour digital photographs (1:10000)	2009	(CD:NGI, 2009)	Used for digitising of coastline, coastline type and landform features
Topographic Data	Vector – polygon and lines (1:50000)	2008	(CD:NGI, 2008)	5 m contour lines were used to create DEMs, slope and aspect layers. River lines were used for *distance from river* calculations.
ENPAT99 – Environmental Atlas of South Africa	Vector – polygon (1:50000)	1999	(DEAT, 2001)	Vector layers were used to show rainfall, runoff, lithology, terrain and biome.
Geology	Vector- polygon (1:250000)	2001	(Council for Geosciences, 2014)	Used to show geology.
Vegetation	Vector – polygon (1:250000)	2006	(SANBI, 2006)	Used to show vegetation type.
SAHRIS	Vector - polygon	1995 - 2006	(SAHRA, 2014a)	Polygons were digitised from AIAs to show where previous research has been done.

Objective 2

To define and test probability zones in regard to yield of artefacts based on a suitability analysis of spatial layers created in Objective 1 and determine whether GIS is an appropriate tool for predicating sites of human habitation.

Method

Three methods were then used to combine this data for analysis:

a. Statistics
b. Statistics and expert opinion
c. Statistics, expert opinion and field observations.

All three methods were applied at a small scale and local scale seen in **figure 4.1**. The small, regional scale covers a study area of 2100km^2 along the south coast of South Africa from roughly Port Elizabeth (Eastern Cape) to Cape Town (Western Cape). The large, local scale covers the area between St Francis Bay and Oyster Bay (Eastern Cape), an area of 87km^2.

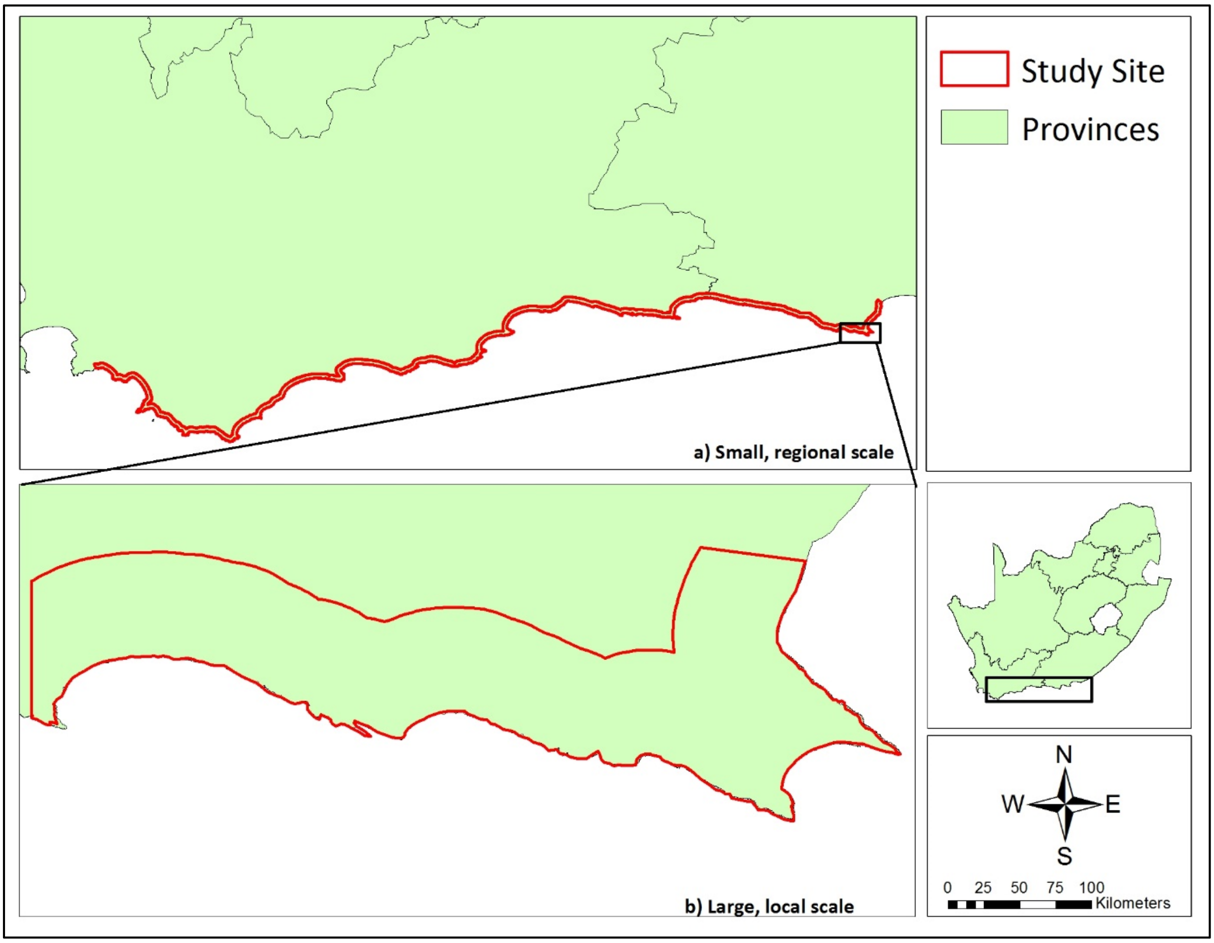

Figure 3.1: The study areas at two different scales.

a. Statistics

The *decision maker* layers were joined spatially to the *known sites* using the 'join' tool in ArcGIS. Frequency tables were created in excel using the 'histogram' data analysis tool which created frequency tables showing the number of *known sites* found in different *ranges* or *characteristics* of each *decision maker*. The percentage of sites within each *characteristic* or *range* was determined using the number of sites found versus the total number of sites which indicated the importance of each *decision makers* attribute in determining the location of known sites. (The more sites found within a *characteristic* or *range,* the more likely that it will be a determining factor for human habitation.)

The methods described by Perkins (2000) and Kohler and Parker (1986) were used to determine if the frequencies of each characteristic were significant statistically. The total relative percentage of each *characteristic* or *range* within the study area was calculated; e.g.: the percentage of *unconsolidated dune sand* within the total study site. This was then used as the *expected* variable: if the *unconsolidated dune sand* takes up 50% of the study area one expects 50% of the sites to be found in this geology. All distance calculations did not have *expected* variables as it is not possible to work out the total percentages. (The percentage of each specific distance range cannot be compared to a 'total distance' of the study area.)

The χ^2test was then used to determine whether the relationship between the percentage for each *characteristic* or *range* for the whole study area and the percentage of sites found in each *characteristic* or *range* is statistically significant. If one characteristic takes up 50% of the entire study area and 70% of the sites are found in that same characteristic, the χ^2 test will determine if the relationship is statistically significant and can therefore be used as an identifying *characteristic* for unknown sites. This test shows if the difference between the percentages of the sites (*actual* variable) are statistically different from the total percentages for the entire study area (*expected* variable).

$$\chi^2 = \frac{(Observed\ count - Expected\ count)^2}{Expected\ count}$$

Equation 3.1: The χ^2 test equation (Utts & Heckard, 2007).

A *p*-value is then computed to determine whether the χ^2 test demonstrates significantly different variables. The *p*-value is determined by computing the *degree of freedom* value for each set of data and then using the CHIDIST statistical formula in an excel spreadsheet. The distance *decision makers* were excluded as they have no *expected* variable. Once the *p*-value has been determined it is compared to the significance level of 0.05 (Utts & Heckard, 2007). A *p*-value less than 0.05 indicates that there is a significant relationship between the variables while a *p*-value greater than 0.05 indicates no significant relationship. All *decision makers* with no significant relationships cannot be used in the analysis as the *expected* and the *actual* variables are too similar; 50% of the known sites are found within one characteristic because 50% of the study site is made up of that characteristic, therefore no relationship.

The layers with significant relationships to the *known points* were all transformed into raster data sets. The frequency tables were used to reclassify each separate decision maker's *characteristics* or *ranges* into a *suitability* class. The *characteristics* or *ranges* with the highest percentage of known sites were given the value of 4 while the lower percentages were given values from 3 to 1 accordingly. This will indicate the probability of finding unknown sites within each *characteristic* or *range* of the *decision makers*; the values of 4 has the highest probability and the values of 1 have the lowest probability. The decision makers were then reclassified using the 'reclassify' tool in ArcMap.

The *terrain* physical characteristic layer was used in the analysis in the local, small scale study area as the *terrain* layer was not detailed enough. A *Topological Position Index* was used as a substitute. The TPI tool is found in the *Land Facet Corridor Analysis* tool developed by Beier and Brost (2010). This tool classifies landscape into slope position and landform feature (Beier & Brost, 2010). A *digital elevation model* (DEM) is first created and then a neighbourhood raster analysis is run. If the raster cell's elevation is less than the elevation of the neighbourhood around it, it is a valley. If the elevation is greater than that of the neighbourhood then it is a ridge top. If the elevations are around the same value then the area is flat. This tool will be useful in this study to determine terrain at a local scale.

Once all layers were classified correctly, they were added together using a raster calculator. The calculator adds all layers together using the suitability equation (**equation 3.2**).

Suitability = (Reclassified layer 1) + (Reclassified layer 2) + ... + (Reclassified layer n)

- *Where n is the number of reclassified decision making layers.*

Equation 3.2: Suitability Analysis (Wayne, 2003).

b. Statistics and expert opinion

The layers were reclassified using the methodology of method a. The expert interviews were examined to define the relevance, or *weighting*, for each layer. The expert's questionnaire responses were analysed and each decision maker was given a ranking; 4 being the most important determining factor for site locations and 1 being the least. A *weighting* for each layer was then determined by dividing the sum of the rankings for each layer by the total count of all the rankings.

The decision makers were put into the formula for suitability that includes the *weighting* or *relevance* (**equation 3.3**).

$$Suitability = \{[(Reclassified\ layer\ 1) \times 0.4] + [(Reclassified\ layer\ 2) \times 0.2] + ... + [(Reclassified\ layer\ n) \times 0.m]\} \times n$$

- *Where n is the number of reclassified decision making layers.*
- *Where* $0.4 + 0.2 + ... + m = 1$

  $(40\% + 20\% + ... + m = 100\%)$

Equation 3.3: Suitability Analysis with Relevance (Wayne, 2003).

c. Statistics, expert opinion and field observations.

The final method of data combination used the statistics determined in method b and observations made in the field. Layers were redefined or improved according to results from ground truthing in the field. The improved *decision makers* were then combined with the suitability analysis equation with relevance (**equation 3.3**).

Probability zones were determined through the *suitability analysis* of method b. The method combined the statistical data with the weighting determined through *expert knowledge*. Areas of high suitability (i.e. where there high probability of finding unknown sites) were determined through visual observation of the desktop results. GPS points were located in each area to give a starting point for ground truthing. A handheld GPS was used to locate the points in the field. Photographs were taken at each area for reference. Any tools or shell middens found were photographed and the locations were recorded using the GPS. The archaeological assistant who accompanies during field work (Gareth Angelbeck) was then consulted as too whether the area was likely to yield archaeological sites and to identify any archaeological finds. Once all sites were investigated the *field observations* were determined for method c of objective 2 (statistics plus expert opinion plus field observations).

The results from the ground truthing where then tabulated. Each site was examined and it was determined whether the *suitability analysis* results were verified by the ground truthing results or not. If the *suitability analysis* results were found to be the same as the results on the ground (*high* probability of finding human habitation and shell middens were found), then the analysis is found to be validated, a positive result, and the site is given the numerical value of 2. If the *suitability analysis* results were found to be contradicted by the results on the ground (*low* probability of finding human habitation and shell middens were found), then the analysis is found to contradict the analysis, a negative result, and the site is given the numerical value of 0. If there were other factors that influenced the results such as a parking lot on top of the point or the site is inaccessible, then the *suitability analysis* results could not be validated or contradicted. For sites where this occurs a numeric value of 1 was given. According to the expert option of John Parkington if one does not investigate a site then one cannot say that there is nothing there. One must assume that there is archaeological artefacts to be found unless proven otherwise. This is why a value of 1 is given to sites not visited and not a value of 0.

The results were then added together and a percentage accuracy was determined for each of the three analysis methods. These results were then used to determine whether GIS and expert mapping is an appropriate tool for predicting archaeological sites of habitation by modern humans.

Objective 3

To relate results to current coastal development and identify new focus areas for research.

A 'territory' or research focus areas map was created using the Archaeological Impact Assessments (AIA) obtained from the SAHRIS data base. Each case report was converted into a point data type and *Thiessen polygons* were created. This was used to discuss areas of development in coastal areas as well as areas of poor research. An investigation of literature with respect to development and archaeology was also discussed to relate the results to the conservation and research needs for these sites of modern human habitation.

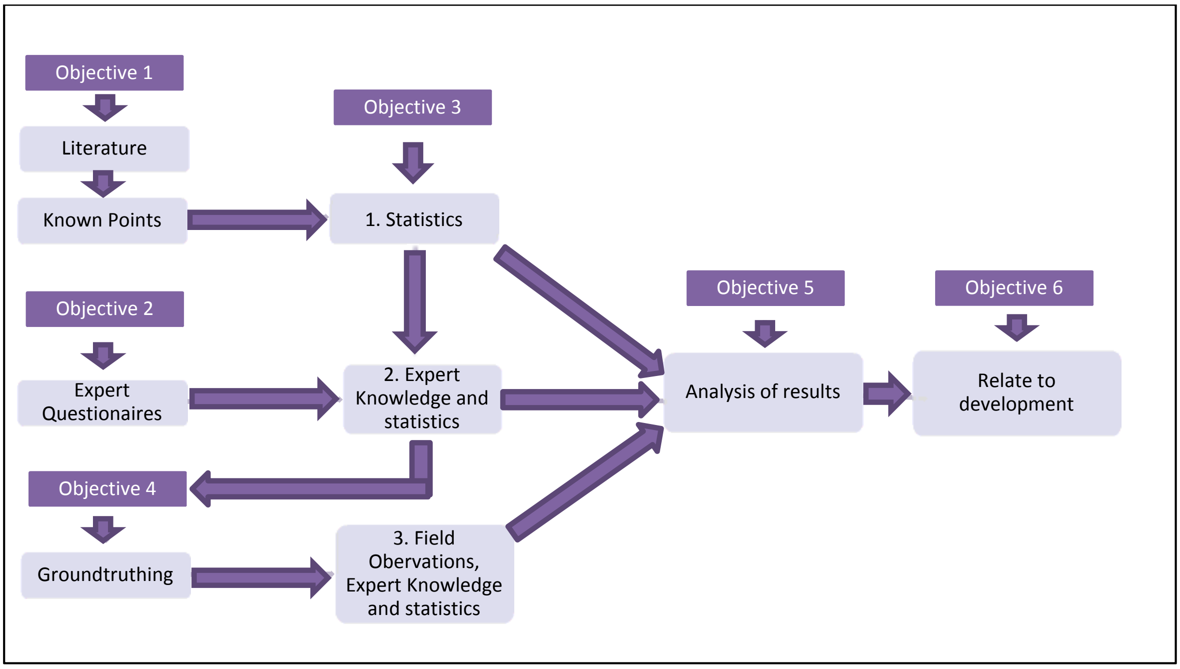

Figure 3.2: A conceptual model of the methods.

Chapter 4

Results

Objective 1 – Results

An examination of published academic journals was carried out and 8 sites were identified that were within the correct time period and fell within the study area. **Table 4.1** shows these results.

Table 4.1: The academic *known sites.*

	ID	Name	Y-axis	X-axis	Date	Significance	Author
1	DEKEL1	Die Kelders	-34,546	19,377	MSA	High	(Avery et al., 1997)
2	BLOMBOS1	Blombos	-34,414	21,223	MSA	High	(Christopher S. Henshilwood et al., 2001)
3	HEROLD1	Heralds Bay Cave	-34,054	22,391	MSA	High	(Brink & Deacon, 1982)
4	MATJIE1	Matjies River Shelter	-34,002	23,469	LSA	High	(Sealy et al., 2006)
5	KLASIE1	Klasies River	-34,108	24,390	MSA	High	(Deacon & Geleijnse, 1988)
6	PP1	Pinnacle Point	-34,208	22,090	MSA	High	(Marean et al., 2004)
7	BLAIZE1	Cape St Blaize	-34,186	22,157	MSA	High	(Keller, 1969)
8	NELS1	Nelson Bay Cave	-34,103	23,375	MSA	High	(Deacon, 1978)

The South African Heritage Resource Agency's online database (SAHRIS) houses the Archaeological Impact Assessments (AIA) completed within the study area. A total of 55 case reports were examined and 160 sites were recorded from the MSA and LSA period. Together with the academic sites, 168 *known sites* were used and became the basis for the *suitability analysis* used in this study. **Figure 4.1** shows these *known sites*. Only sites with high and medium significance will be used for this analysis so the low significance sites were excluded from the data set.

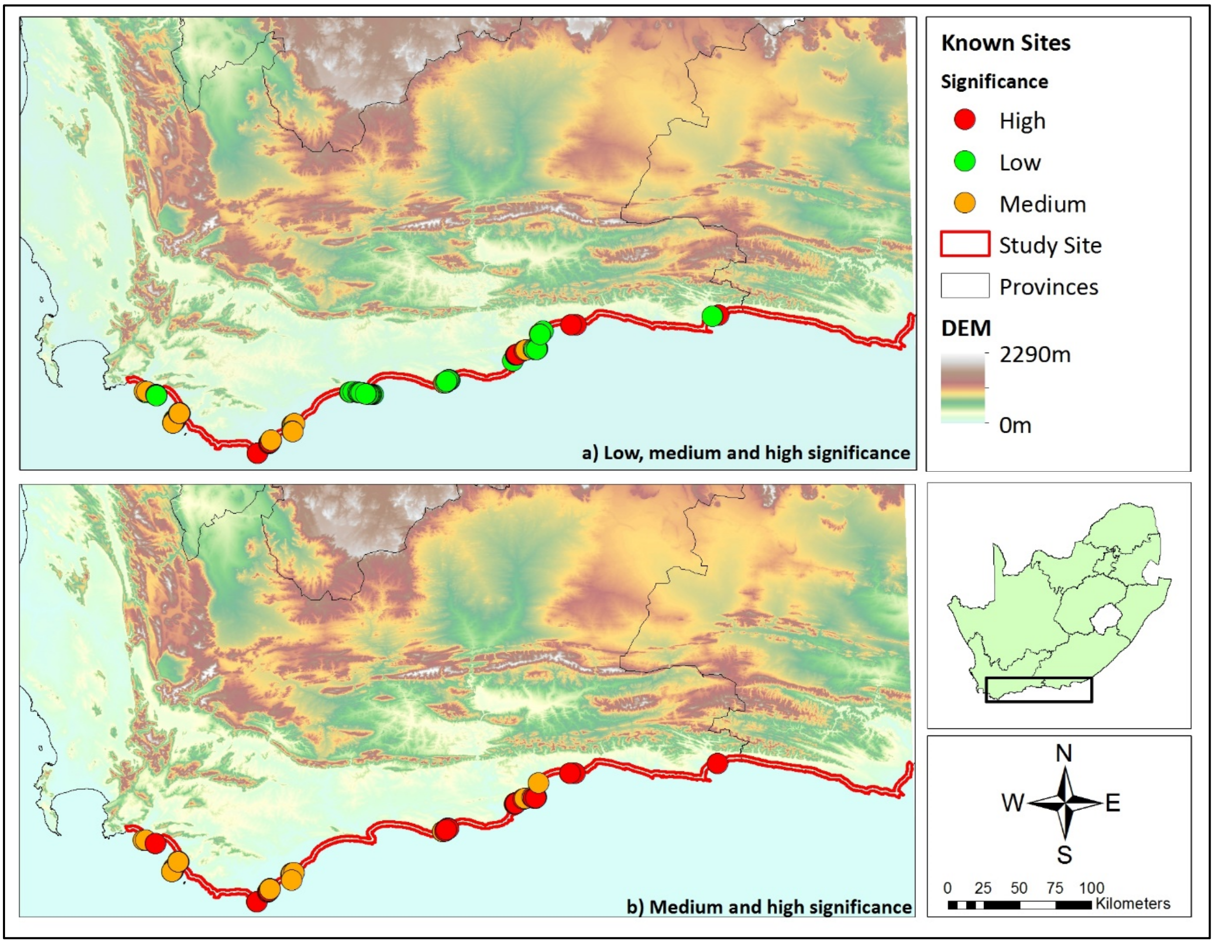

Figure 4.1: The known points determined from literature and AIAs from the SAHRIS database.

Three *decision makers* were determined from the expert questionnaires that could not be found in existing datasets. Landform features were digitised as a result of the *lithophilia* theory that was mentioned by two of the experts. An *effort* layer was created by digitising the geographical locations of the 55 case reports examined for this study. The final layer that was created was a *coast type* layer that determined whether the coast was rocky or sandy through observations of the aerial photography. These maps can be seen in **figure 4.2.**

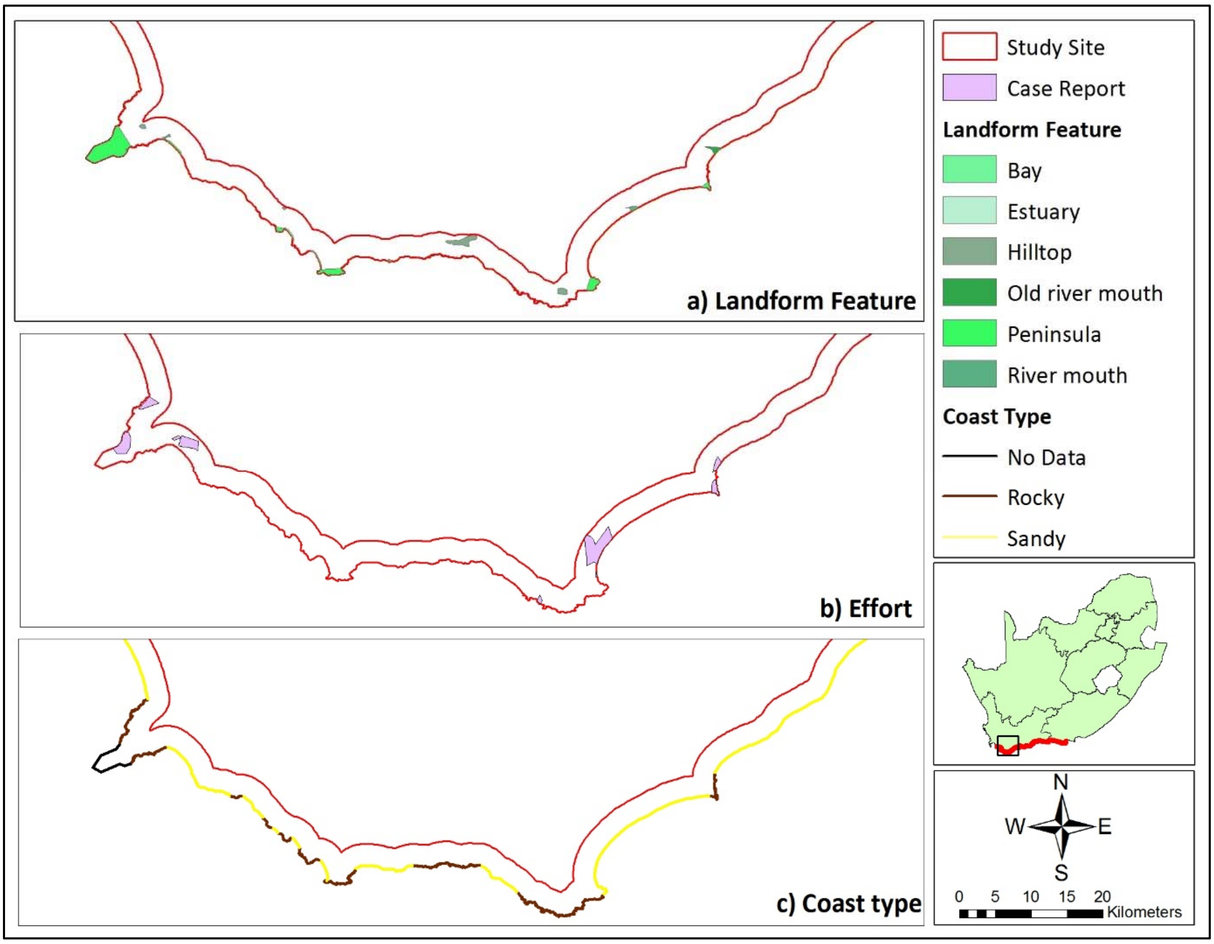

Figure 4.2: The three layers digitised from expert knowledge.

Objective 2 - Results

To define and test probability zones in regard to yield of artefacts based on a suitability analysis of spatial layers created in Objective 1 and determine whether GIS is an appropriate tool for predicating sites of human habitation.

a) Statistics

The *decision maker* layers were joined spatially to the *known sites* using the 'join' tool in ArcGIS. Frequency tables were created in excel using the 'histogram' data analysis tool which created frequency tables showing the number of *known sites* found in different *ranges* or *characteristics* of each *decision maker*. The total percentage coverage of each characteristic found in the study area was then determined for use in the χ^2 test. An example of this can be seen in **table 4.2**, the rest of the data can be found in the appendix.

Table 4.2: Known sites and geological characteristics.

Geology	***Frequency***	**Percentage of known sites (%)**	**Total of each characteristic in study site (%)**
Consolidated to semi-consolidated aeolianite (calcarenite) calcareous sand, calcrete lenses	14	19,4	8,3
Gneissic granite and granodiorite	1	1,4	3,26
Grey-weathering, massive or large-scale cross-bedded calcarenite and calcareous sandstone	4	5,6	17,93
Light-grey to red sandy soil	3	4,2	12,53
Quartzite, schist, phyllite	1	1,4	0,81
Quartzitic sandstone, minor conglomerate and shale	1	1,4	11,39
Thick-bedded, medium- to coarse-grained, cross-bedded, white-weathering, quartzitic sandstone	10	13,9	3,9
Unconsolidated dune sand	37	51,4	9,23
White, siliceous, feldspathic sandstone, subordinate mudrock in places	1	1,4	0,28
Other	0	0,0	32,37

All *decision makers* were then run through a χ^2 test to determine whether a significant relationship exists between the known sites and their characteristics. The results of this can be seen in **table 4.3**.

Table 4.3: Results from the χ^2 test.

Group	Decision Makers	*p*- value	Significant Relationship
Physical	1. Geology	4,29271E-58	Yes
	2. Lithology	0,019986087	Yes
	3. Aspect	1,83751E-42	Yes
	4. Terrain	2,4403E-18	Yes
	5. Height above sea level	3,45543E-39	Yes
	6. Annual rainfall	4,26326E-09	Yes
	7. Slope	0,112855784	No
Resource based	8. Distance from coastline	---	---
	9. Type of coastline	0,150047	No
	10. Distance from rivers	---	---
	11. Biome	0,018954116	No
	12. Vegetation type	8,41159E-68	Yes
Human	13. Effort	---	---
	14. Landscape features	---	---

Table 4.4: Final decision makers for method a) determined from the χ^2 test.

Group	Decision Makers
Physical	1. Geology
	2. Lithology
	3. Aspect
	4. Terrain
	5. Height above sea level
	6. Annual rainfall
Resource based	7. Distance from coastline
	8. Distance from rivers
	9. Vegetation type
Human	10. Effort
	11. Landscape features

The layers with significant relationships to the *known points* were all transformed into raster data sets. The frequency tables were used to reclassify each separate decision maker's *characteristics* or *ranges* into a *suitability* class (**tables 4.5, 4.6 and 4.7**).

Table 4.5: Reclassification of the geology, lithology and aspect layer.

Geology	Lithology	Aspect	*Reclassification*
Unconsolidated dune sand	Sand, limestone, conglomerate, clay, alluvium, calcrete, siltstone, silcrete, calcarenite, dune sand, aeolianite	South	4

Consolidated to semi-consolidated aeolianite (calcarenite) calcareous sand, calcrete lenses	Quartzitic sandstone, shale, tillite	Southeast	3
Thick-bedded, medium- to coarse-grained, cross-bedded, white-weathering, quartzitic sandstone	Biotite granite, Shale, sandstone, diamictite, quartzitic sandstone	East	2
Gneissic granite and granodiorite Grey-weathering, massive or large-scale cross-bedded calcarenite and calcareous sandstone Light-grey to red sandy soil Quartzite, schist, phyllite Quartzitic sandstone, minor conglomerate and shale Thick-bedded, medium- to coarse-grained, cross-bedded, white-weathering, quartzitic sandstone White, siliceous, feldspathic sandstone, subordinate mudrock	Sandstone, mudstone, shale, conglomerate, basalt, tuff, breccia	Northwest	1

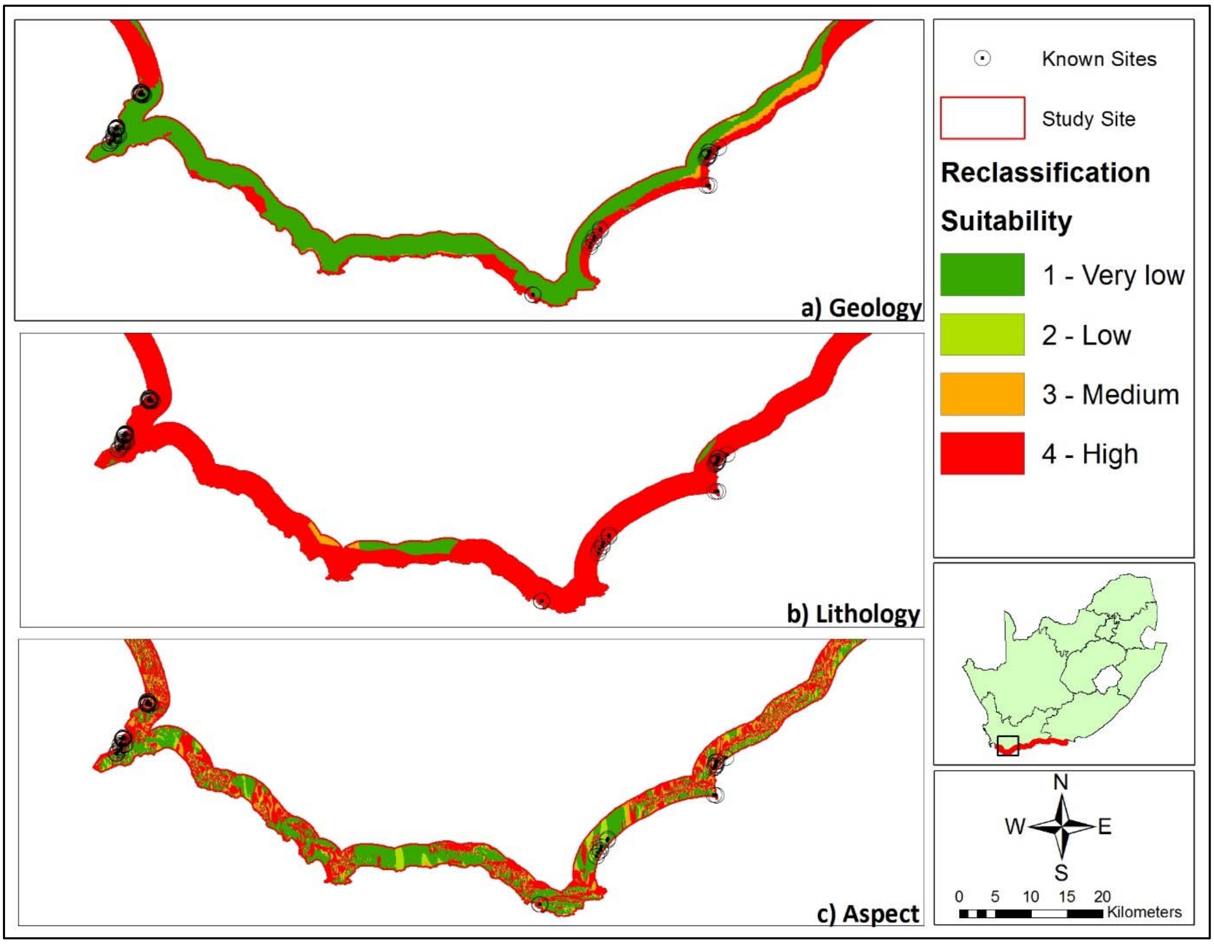

Figure 4.3: Reclassification of the geology, lithology and aspect layer.

Table 4.6: Reclassification of the distance from coast, distance from rivers and vegetation layer.

Distance from coast (m)	Distance from river (m)	Vegetation	*Reclassification*
50 - 100	0 - 500	Overberg Dune Strandveld	4
0 - 50	1000 - 1500	Blombos Strandveld	3
100 - 150 150 - 200 250 - 300	2500 - 3000	Groot Brak Dune Strandveld	2
200 - 250 350 - 1000	1500 - 2000	Canca Limestone Fynbos	1

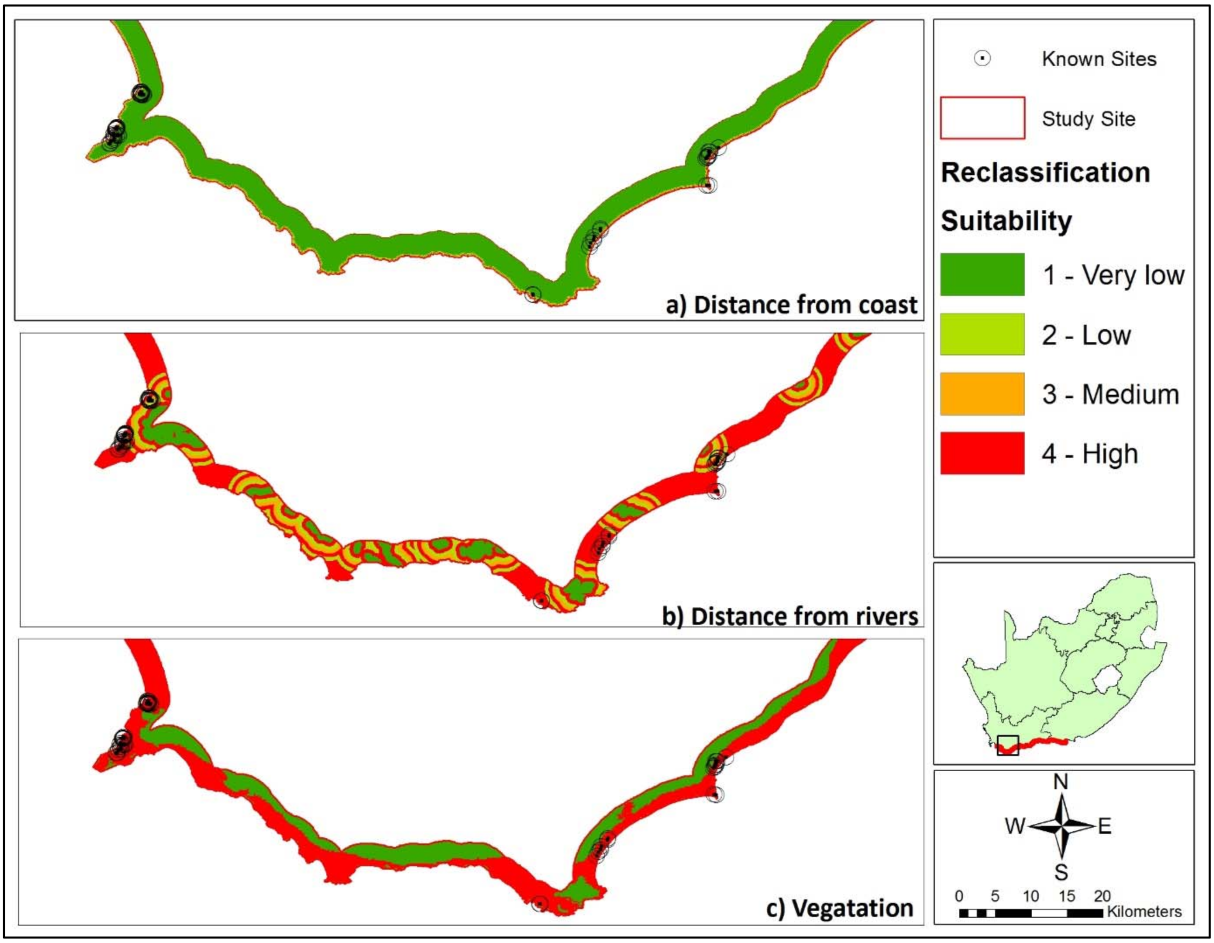

Figure 4.4: Reclassification of the distance from coast, distance from rivers and vegetation layer.

Table 4.7: Reclassification of the terrain, height above sea level and annual rainfall layer.

Terrain	Height (m)	Rainfall (mm/annum)	*Reclassification*
Dune hills (parallel crests) and highlands Plains and pans	15 - 20	300-500	4
Undulating hills	20 - 25	500-650	3
Plains	40 - 45	650-750	2
Other	0 - 15	750-900	1

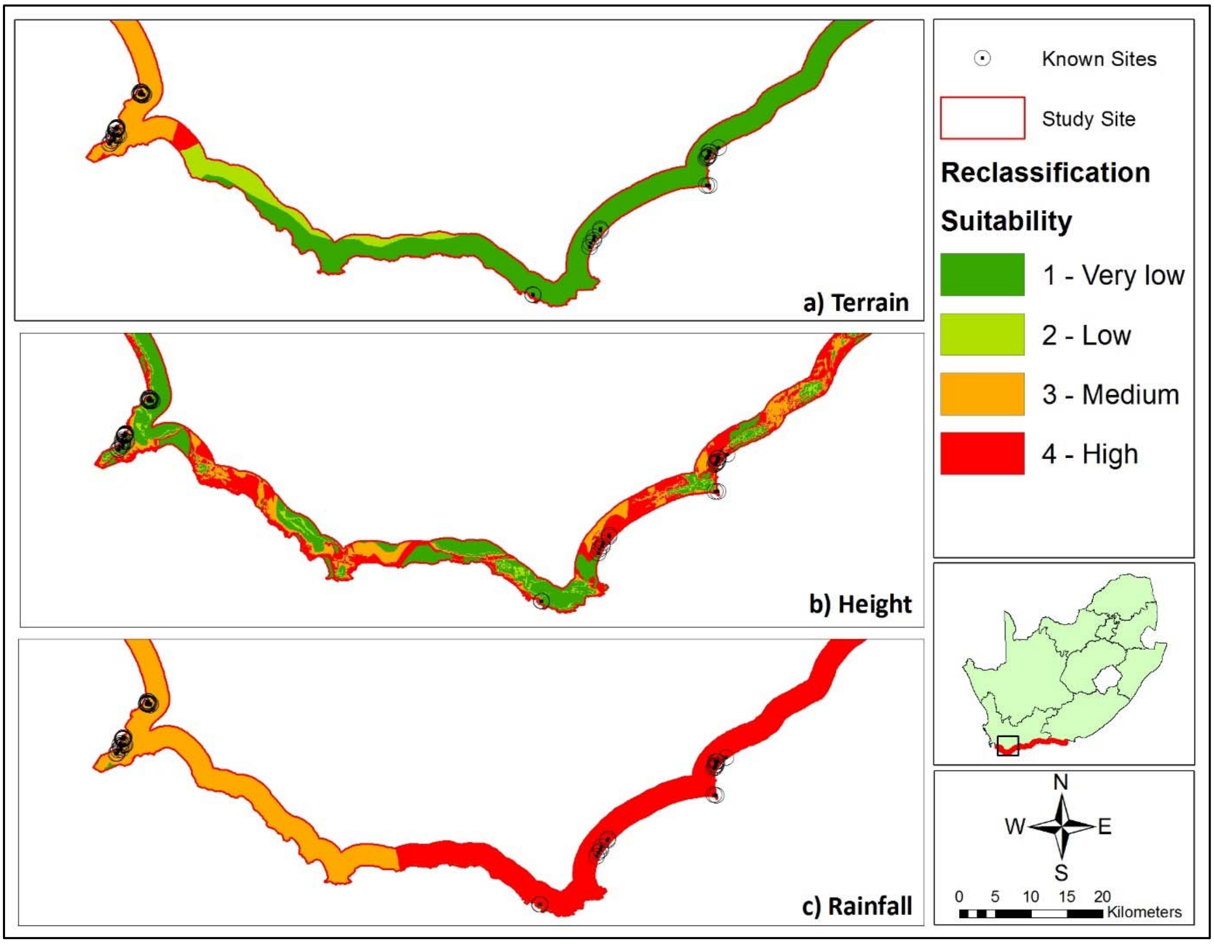

Figure 4.5: Reclassification of the terrain, height above sea level and annual rainfall layers.

Table 4.8: Reclassification of the distance from landform and effort layer.

Distance from Landform	***Effort***	***Reclassification***
0	Case report	4
0 - 200		3
200 - 400		2
400 - 2000	No case report	1

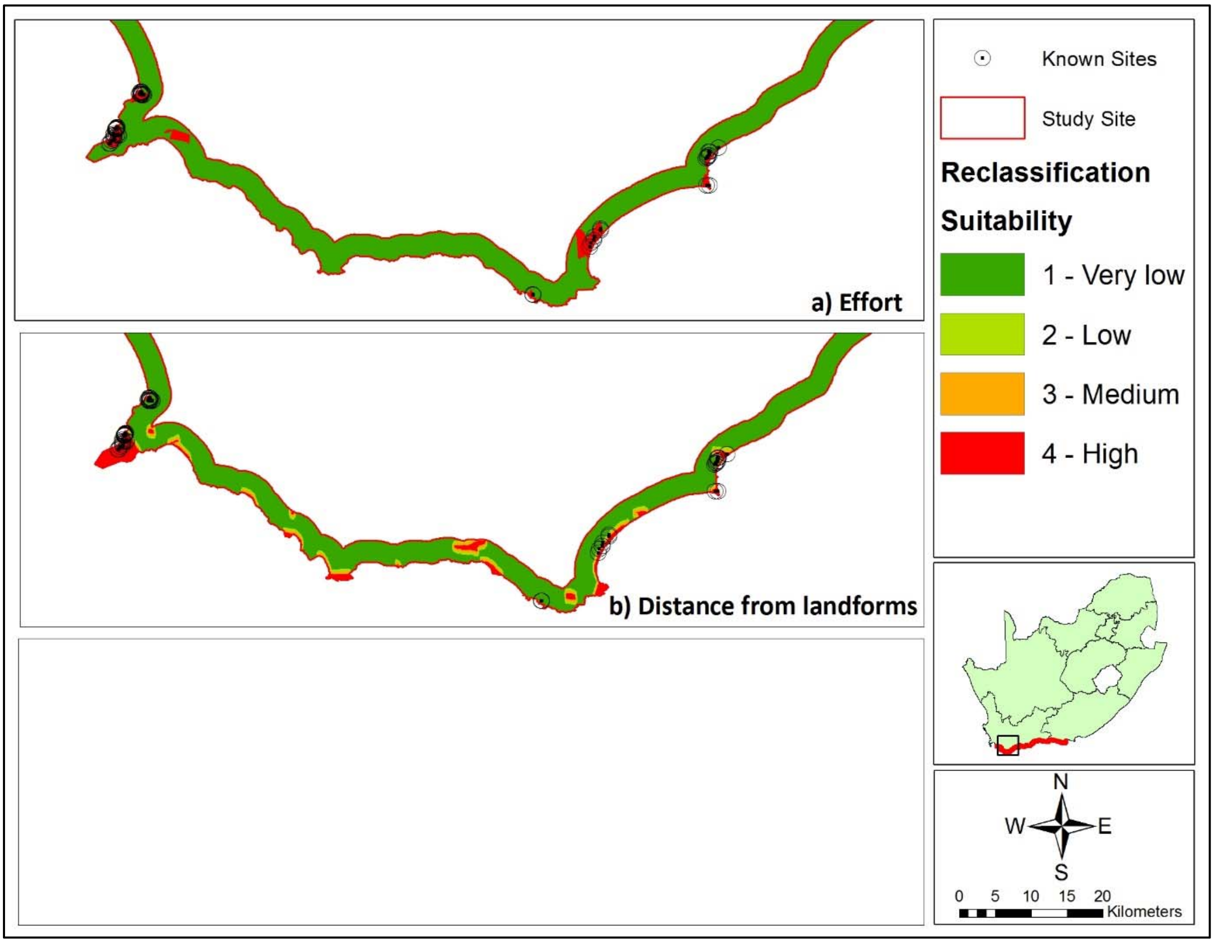

Figure 4.6: Reclassification of the effort and distance from landform layers.

The reclassified layers were then spatial added using a raster calculator in the equation bellow. This adds the reclassified value of all the cells in each layer to one another to get a total value of the suitability of the study area.

***Suitability** = (Geology) + (Distance from rivers) + (Aspect) + (Distance from coast) + (Vegetation) + (Landforms) + (Height) + (Rainfall) + (Terrain) + (Case reports) + (Lithology)*

Equation 4.1: Suitability equation for the decision makers of method a).

b) Statistics and expert opinion

Table 4.9: The relevance of decision makers identified by experts through interviews.

	4	**3**	**2**	**1**
Expert 1	Geology - ancient dunes	Type of coastline - rocky shores contain shellfish	Landform feature - topophillia	
Expert 2	Geology - limestone	Vegetation - past vegetation	Landform feature - humans like to 'tie' settlements to features	
Expert 3	Distance from coastline - important for gathering food	Aspect - related to wind	Slope - cliffs	Geology - cave formation - middens covered by sand
Expert 4	Distance from river - fresh water	Aspect - related to wind	Geology - cave formation	
Expert 5	Distance from river - all settle near water	Vegetation - access to firewood	Distance from coast and other food sources - important but more flexible	Aspect - shelter from elements

Table 4.10: Weighting/relevance of the decision makers determined through expert interviews.

Group	**Decision Makers**	**Count**	**Relevance (count/total)**
Physical	1. Geology	11	0,247
	2. Lithology	0,5	0,011
	3. Aspect	7	0,157
	4. Terrain	0,5	0,011
	5. Height above sea level	0,5	0,011
	6. Annual rainfall	0,5	0,011
Resource based	7. Distance from coastline	6	0,135
	8. Distance from rivers	8	0,180
	9. Vegetation type	6	0,135
Human	10. Effort	0,5	0,011
	11. Landscape features	4	0,090
Total		44,5	1

The reclassified layers were then spatially added through the equation below which includes a 'relevance' variable.

Suitability = [(Geology x 0,247) + (Distance from rivers x 0,180) + (Aspect x 0,157) + (Distance from coast x 0,135) + (Vegetation x 0,135) + (Landforms x 0,090) + (Height x 0,011) + (Rainfall x 0,011) + (Terrain x 0,011) + (Case reports x 0,011) + (Lithology x 0,011)] x 11

Equation 4.2: Suitability equation with relevance for the decision makers of method b).

c) Statistics, expert opinion and field observations.

During the ground truthing various *field observations* were made. These were then included in the analysis for method c).

Table 4.11: Field Observations

Group	Decision Makers	Description	Conclusion
Physical	1. Geology	No field observations.	No change.
	2. Lithology	No field observations.	No change.
	3. Aspect	No field observations.	No change.
	4. Terrain	No field observations.	No change.
	5. Height above sea level	No field observations.	No change.
	6. Annual rainfall	No field observations.	No change.
Resource based	7. Distance from coastline	Areas directly adjacent to ocean are too exposed for human settlement. Human settlements are more likely to be found in sheltered area further away from the ocean.	A new statistical analysis was then done on the *distance from coastline* layer to determine if this observation was accurate and a new reclassification was determined for this layer.
	8. Distance from rivers	The water in these rivers is saline as they are generally estuarine. A 'springs' decision maker would be more appropriate freshwater layer.	Remove layer

		'Springs' layers does not exist and would be difficult to digitise, springs are very specific water sources and their geographic locations would have changed from 250 000 y.a.	
	9. Vegetation type	No field observations.	No change.
	10. Coastline type	Though the statistical analysis indicates that sites are found equally in rocky and sandy coasts, major settlements (and therefore major archaeological sites) are more likely to be found close to rocky shores. Stratified shell middens are important as they provide a timeline for archaeologists with which to establish the significance of the finds. Middens that have been stratified are found in areas that are protected; such as caves or cliffs. This indicates that rocky shores are important for the location of stratified middens. Permanent settlements are also more likely to be located close to food sources as investigated in the literature review (Parkington, 2006). Shellfish was a major food sources and therefore rocky coastlines would have been more favourable for a human settlement than sandy shores. Stone tools are dense and therefore sink into the sand until they hit the solid soil layer beneath the shifting dune sand. As the dunes move, the substrate is revealed along with any stone tools that may have settled there. To find these artefacts the troughs of the mobile dunes need to be deep enough to reveal the substrate but this does not happen regularly. Artefacts are more likely to be found on rocky coastline.	Include layer with sandy shores being a low determining factor and rocky shores being high.

Human	11. Effort	No field observations.	No change.
	12. Landscape features	Human settlements are attracted to headlands, or peninsulas, more than they are attracted to large bays.	Remove large bays from layer.

Table 4.12: Weighting/relevance of decision makers after adjustments in method c).

Group	Decision Makers	Count	Relevance (count/total)
Physical	1. Geology	11	0,265
	2. Lithology	0,5	0,012
	3. Aspect	7	0,169
	4. Terrain	0,5	0,012
	5. Height above sea level	0,5	0,012
	6. Annual rainfall	0,5	0,012
Resource based	7. Distance from coastline	6	0,145
	8. Vegetation type	6	0,145
	9. Coastline type	5	0,120
Human	10. Effort	0,5	0,012
	11. Landscape features	4	0,096
Total		41,5	1

Suitability = [(Geology x 0,265) + (Aspect x 0,169) + (Distance from coast x 0,145) + (Vegetation x 0,145) + (Coastline type x 0,120) + (Landforms x 0,096) + (Height x 0,012) + (Rainfall x 0,012) + (Terrain x 0,012) + (Case reports x 0,012) + (Lithology x 0,012)] x 11

Equation 4.3: Suitability equation with relevance for the decision makers for method c).

The following tables and figures depict the results of objective 2 which involved ground truthing randomly selected points in various area of the study site. Five areas were visited in the small, regional scale study site: Still Bay, Witsand, Arniston, Die Mond and Struis Bay. The local, large scale study site was also investigated. In total 38 ground truth points were visited for this study and the results can be seen below.

Regional, Small Scale Study Site

1. **Still Bay**

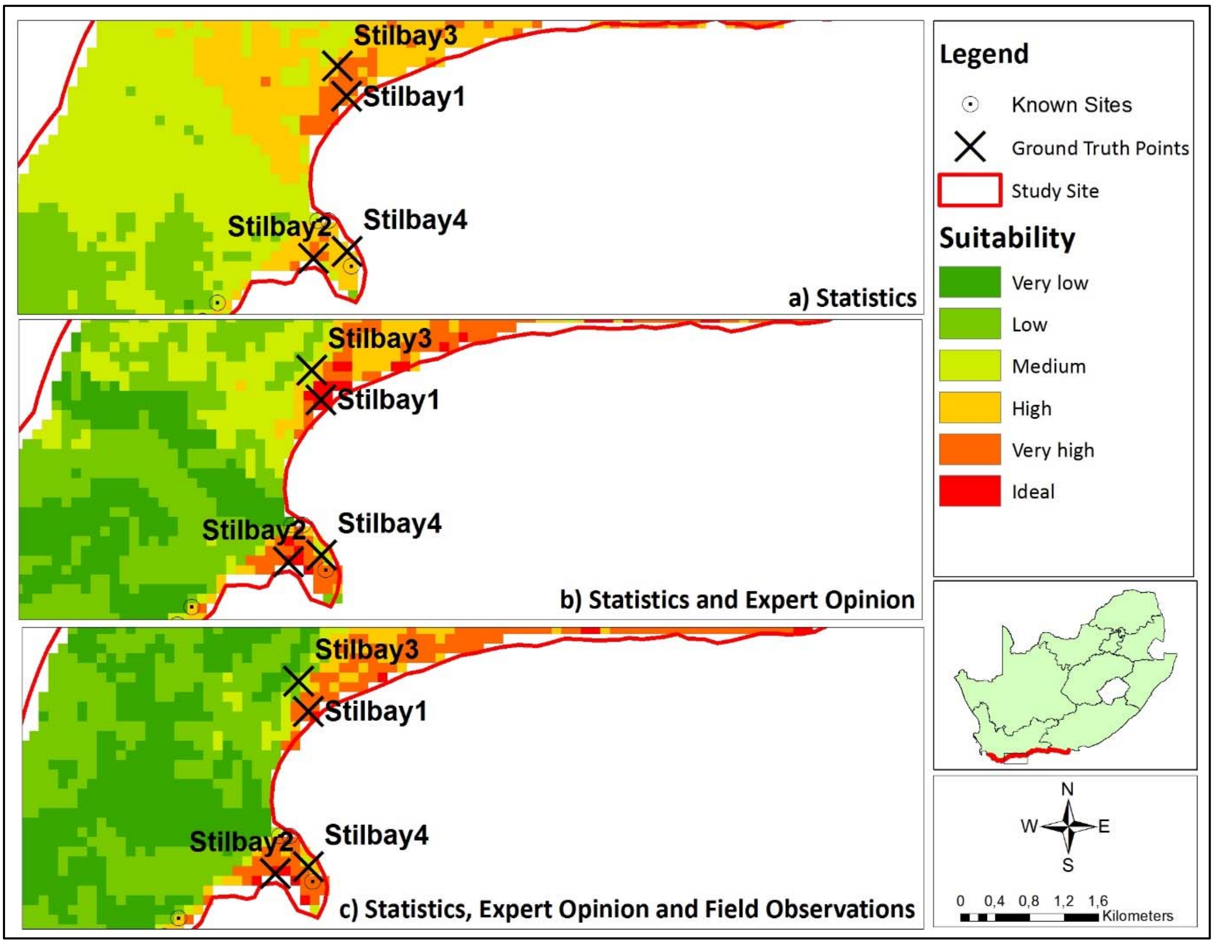

Figure 4.7: The Still Bay study area.

Table 4.13: Results of ground truthing of Still Bay site.

Site	Site Description	Method	Result
Stilbay1	 Site covered by parking lot. Could not determine probablity of finding sites of human habitation.	a. Statistics Very High probability site.	---
		b. Statistics and Expert opinion Ideal probability site.	---
		c. Statistics, Expert opinion and field obs. Very high probability site.	---
Stilbay2	 Dune troughs not deep enough to reveal substrate. Low probability of finding sites of human habitation.	a. Statistics Very High probability site.	Negative
		b. Statistics and Expert knowledge Ideal probability site.	Negative.
		c. Statistics, Expert opinion and field obs. Ideal probability site.	Negative.
Stilbay3		a. Statistics High probability site.	Positive.

	 Tools found but no age could be established. High to very high probability of finding sites.	b. Statistics and Expert knowledge Medium probability site.	Negative
		c. Statistics, Expert opinion and field obs. Low probability site.	Negative.
Stilbay4	 Small shell midden. No tools found as dunes are too stable. Medium to high probability of finding sites of human habitation.	a. Statistics High probability site.	Positive.
		b. Statistics and Expert knowledge Very High probability site.	Negative.
		c. Statistics, Expert opinion and field obs. Very high probability site.	Negative.

2. Witsand

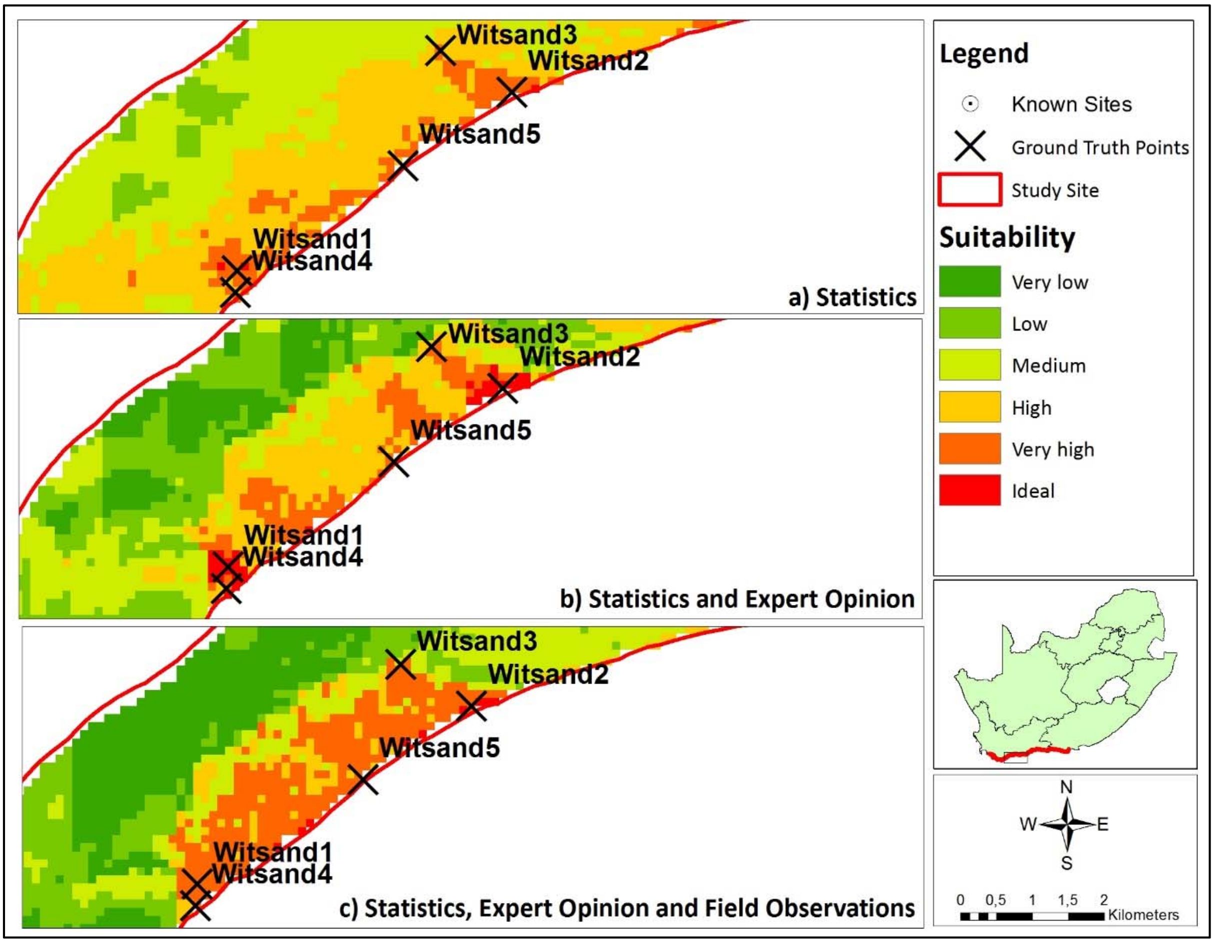

Figure 4.8: The Witsand study area.

Table 4.14: Results of ground truthing of Witsand site.

Site	Site Description	Method	Result
Witsand1	 Dune troughs not deep enough to reveal substrate.	a. Statistics Very High probability site.	Negative.
		b. Statistics and Expert knowledge Ideal probability site.	Negative.
		c. Statistics, Expert opinion and field obs.	Negative.

	Very low to Low probability of finding sites.	Very high probability site.	
Witsand2	Site not visited. Could not determine probablity of finding sites of human habitation.	a. Statistics Very High probability site.	----
		b. Statistics and Expert knowledge Ideal probability site.	----
		c. Statistics, Expert opinion and field obs. Very high probability site.	----
Witsand3	Site not visited. Could not determine probablity of finding sites of human habitation.	a. Statistics Very High probability site.	----
		b. Statistics and Expert knowledge High probability site.	----
		c. Statistics, Expert opinion and field obs. Low probability site.	----
Witsand4		a. Statistics High probability site.	Negative.

	 Site in river mouth. Very low probability of finding sites.	b. Statistics and Expert knowledge Very High probability site.	Negative.
		c. Statistics, Expert opinion and field obs. Very high probability site.	Negative.
Witsand5	 Dune too stable to find artefacts. Very low to low probability of finding sites.	a. Statistics High probability site.	Negative.
		b. Statistics and Expert knowledge Very High probability site.	Negative
		c. Statistics, Expert opinion and field obs. Very high probability site.	Negative.

3. Arniston

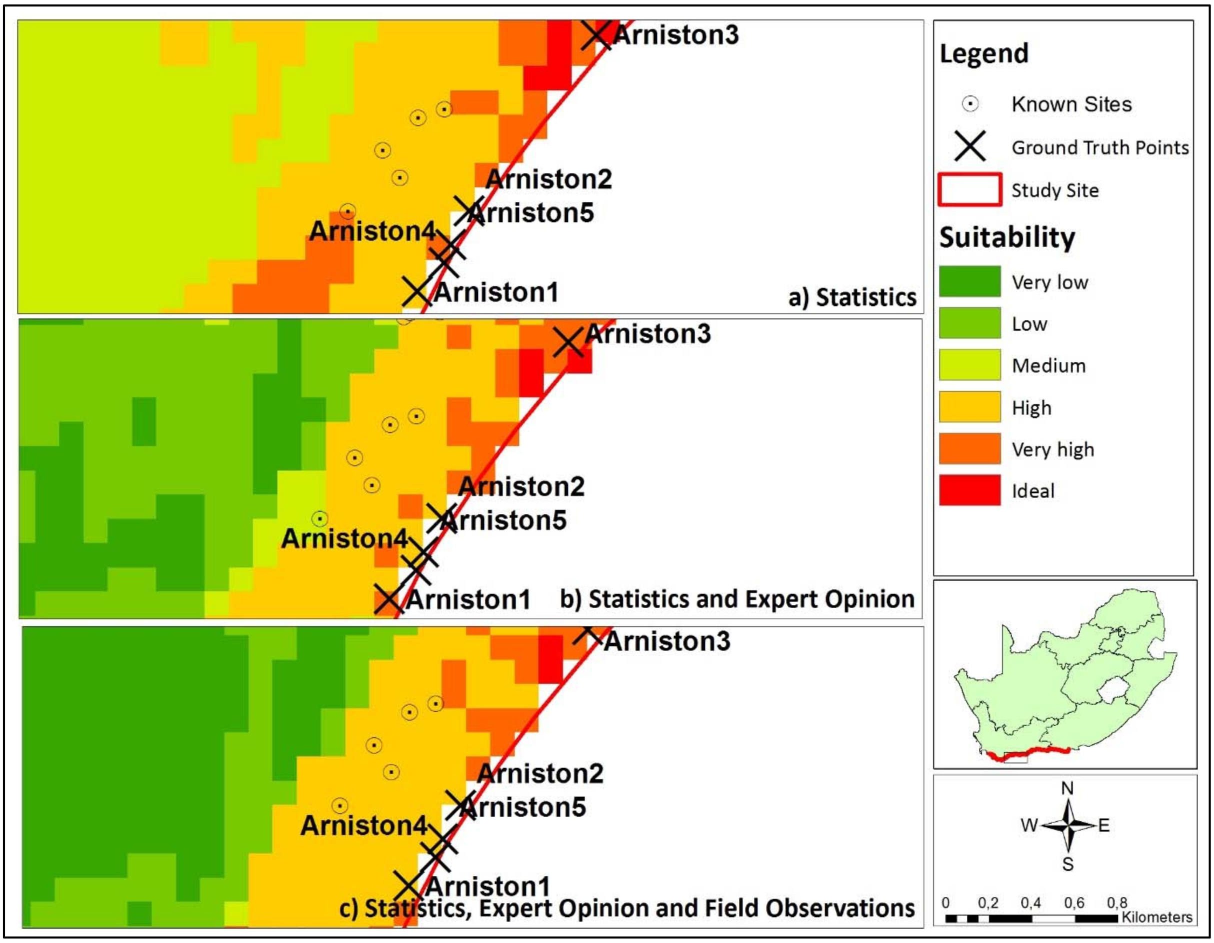

Figure 4.9: The Arniston study site.

Table 4.15: Results of ground truthing of Arniston site.

Site	**Site Description**	**Method**	**Results**
Arniston1	 Rocky outcrop. Remains of old shell midden but blown away.	a. Statistics High probability site.	Positive.
		b. Statistics and Expert knowledge Very High probability site.	Negative.
		c. Statistics, Expert opinion and field obs.	Positive.

	High to medium probability of finding sites.	High probability site.	
Arniston2	 Rocky outcrop. Remains of old shell midden but blown away. High to Medium probability of finding sites.	a. Statistics High probability site.	Positive.
		b. Statistics and Expert knowledge High probability site.	Positive.
		c. Statistics, Expert opinion and field obs. High probability site.	Positive.
Arniston3	Site not visited. Could not determine probablity of finding sites of human habitation.	a. Statistics Ideal probability site.	----
		b. Statistics and Expert knowledge Very High probability site.	----
		c. Statistics, Expert opinion and field obs. Very high probability site.	----
Arniston4		a. Statistics Very High probability site.	Positive.

	 LSA shell midden found. Very high or high probability of finding sites.	b. Statistics and Expert knowledge High probability site.	Positive.
		c. Statistics, Expert opinion and field obs. High probability site.	Positive.
Arniston5	 Tools found. High to medium probability of finding sites.	a. Statistics Very High probability site.	Positive.
		b. Statistics and Expert knowledge High probability site.	Positive.
		c. Statistics, Expert opinion and field obs. High probability site.	Positive.

4. Die Mond

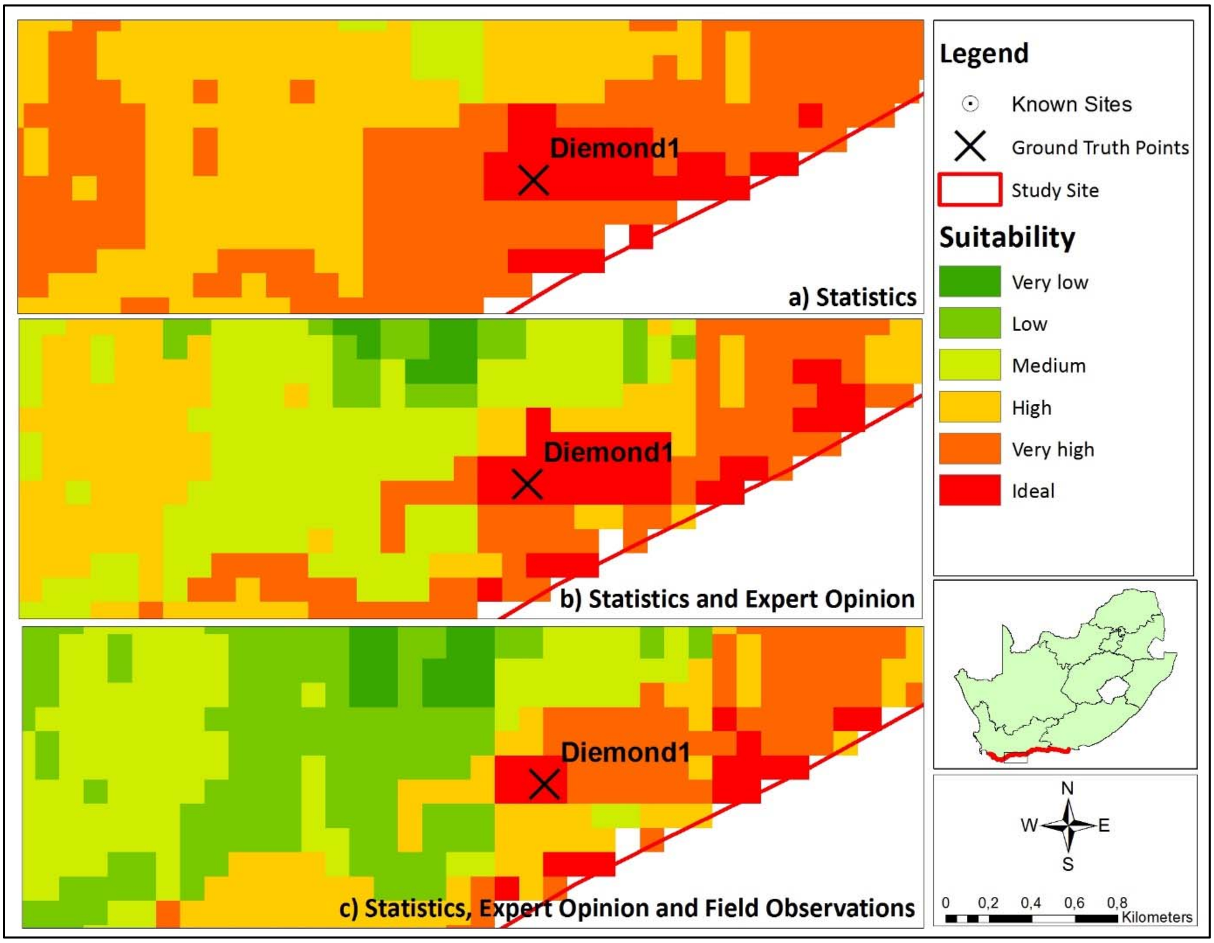

Figure 4.10: The Die Mond study site.

Table 4.16: Results of ground truthing of the Die Mond site.

Site	**Site Description**	**Method**	**Result**
DieMond1	 Dunes too stable to find artefacts. Very low or low probability of finding sites.	a. Statistics Ideal probability site.	Negative.
		b. Statistics and Expert knowledge Ideal probability site.	Negative.
		c. Statistics, Expert opinion and field obs. Ideal probability site.	Negative.

5. Struis Bay

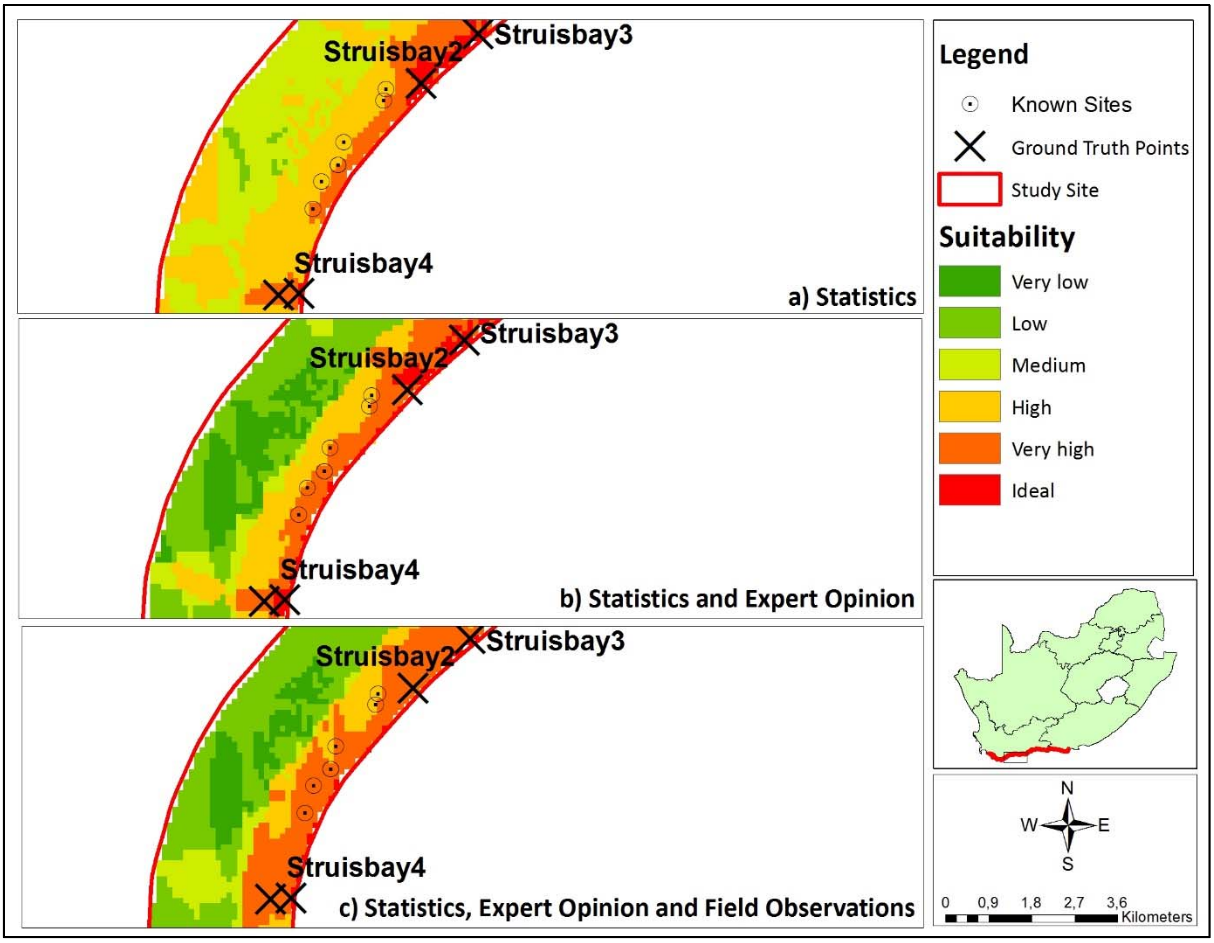

Figure 4.11: The Struis Bay study site.

Table 4.17: Results of ground truthing of the Struis Bay site.

Site	Site Description	Method	Result
Struis1	 Dunes too stable to find artefacts. Very low or low probability of finding sites.	a. Statistics Ideal probability site.	Negative.
		b. Statistics and Expert knowledge Ideal probability site.	Negative.
		c. Statistics, Expert opinion and field obs. Ideal probability	Negative.

Struis2	Site not visited. Could not determine probablity of finding sites of human habitation.	a. Statistics Ideal probability site.	----
		b. Statistics and Expert knowledge Very High probability site.	----
		c. Statistics, Expert opinion and field obs. Very high probability site.	----
Struis3	Site not visited. Could not determine probability of finding sites of human habitation.	a. Statistics Ideal probability site.	----
		b. Statistics and Expert knowledge Ideal probability site.	----
		c. Statistics, Expert opinion and field obs. Very high probability site.	----
Struis4	 Dunes with deep troughs. Informal tools were found. Very high to ideal probability area.	a. Statistics Very High probability site.	Positive.
		b. Statistics and Expert knowledge Very High probability site.	Positive.
		c. Statistics, Expert opinion and field obs. Very high probability site.	Positive.

Local, Large Scale Study Site

For this site new analysis was done at a larger scale. Methods a), b) and c) were used from objective 2 to obtain new suitability maps for this site at a larger scale.

Table 4.18: Decision makers for St Francis study site.

Group	Decision Makers	Include	Reason
Physical	1. Geology	Yes	Detailed enough for the smaller study area.
	2. Lithology	No	Too generalised. Will use geology layer as a substitute.
	3. Aspect	Yes	Detailed enough for the smaller study area.
	4. Terrain	No	Too generalised. Will use Topographic Position Index (TPI) layer as a substitute.
	5. Height above sea level	Yes	Created new height layer with more detailed contour lines (5m).
	6. Annual rainfall	No	Too generalised.
Resource based	7. Distance from coastline	Yes	Detailed enough for the smaller study area.
	8. Type of coastline	Yes	Detailed enough for the smaller study area.
	9. Distance from rivers	No	Rivers are too close to sea and are therefore saline
	10. Vegetation type	Yes	Detailed enough for the smaller study area.
Human	11. Effort	No	The new study area falls within a case report therefore there is a high effort value for the entire study site.
	12. Landscape features	Yes	Detailed enough for the smaller study area.

a) Statistics

The same statistics that were calculated for the small scale study site were used for this area. Characterises were excluded if they did not fall within the study site; there are no areas of *Overburg Dune Strandveld* so the *Algoa Dune Strandveld* was used instead.

Table 4.19: Reclassification of the geology, aspect and TPI layers.

Geology	*Aspect*	*TPI*	*Reclassification*
Semi-consolidated to consolidated calcareous sandstone and sandy limestone with large-scale cross-bedding	South	Valleys	4
Thick-bedded, medium- to coarse-grained, cross-bedded, white-weathering, quartzitic sandstone	Southeast	Lower Slopes	3
Aeolian sand Quartzitic sandstone, minor conglomerate and shale	East Northwest	Ridges	2
Shale, siltstone, subordinate sandstone Fine- to medium-grained, dark to light grey, feldspathic sandstone, shale Water Brownish-weathering, quartzitic sandstone, subordinate shale and siltstone Mudrock, siltstone Alluvium Three sandstone and three shale units	Flat North Northeast Southwest West North	Gentle Slopes Steep Slopes Upper Slopes	1

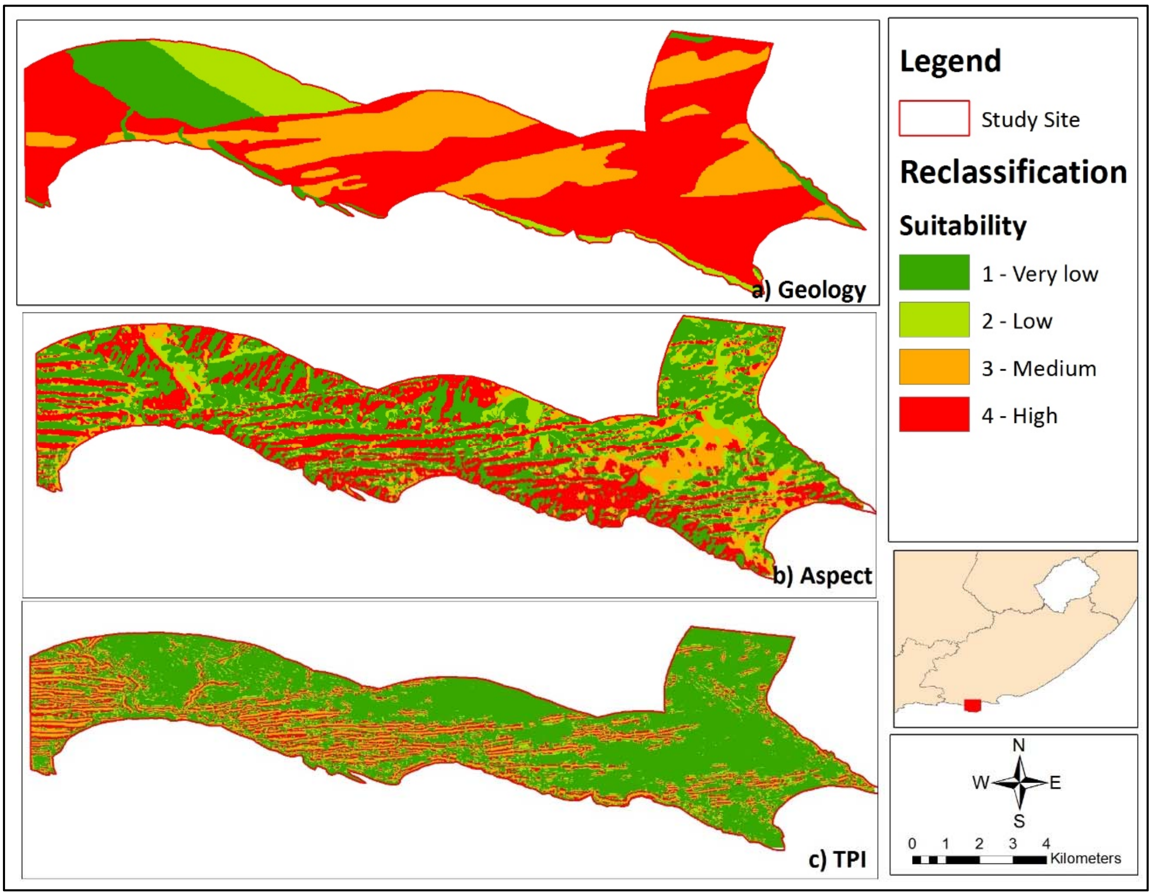

Figure 4.12: Reclassification of the geology, aspect and TPI layers.

Table 4.20: Reclassification of the height, distance from coast and type of coast layers.

Height (m)	*Distance from coast (m)*	*Type of coast*	*Reclassification*
15 - 20	50 - 100	Rocky	4
20 - 25	0 – 50		3
40 - 45	100 - 250 150 - 200 250 - 300	Sandy	2
0 - 15 **25 - 40** **45 - 100**	200 - 250 350 - 1000	Other	1

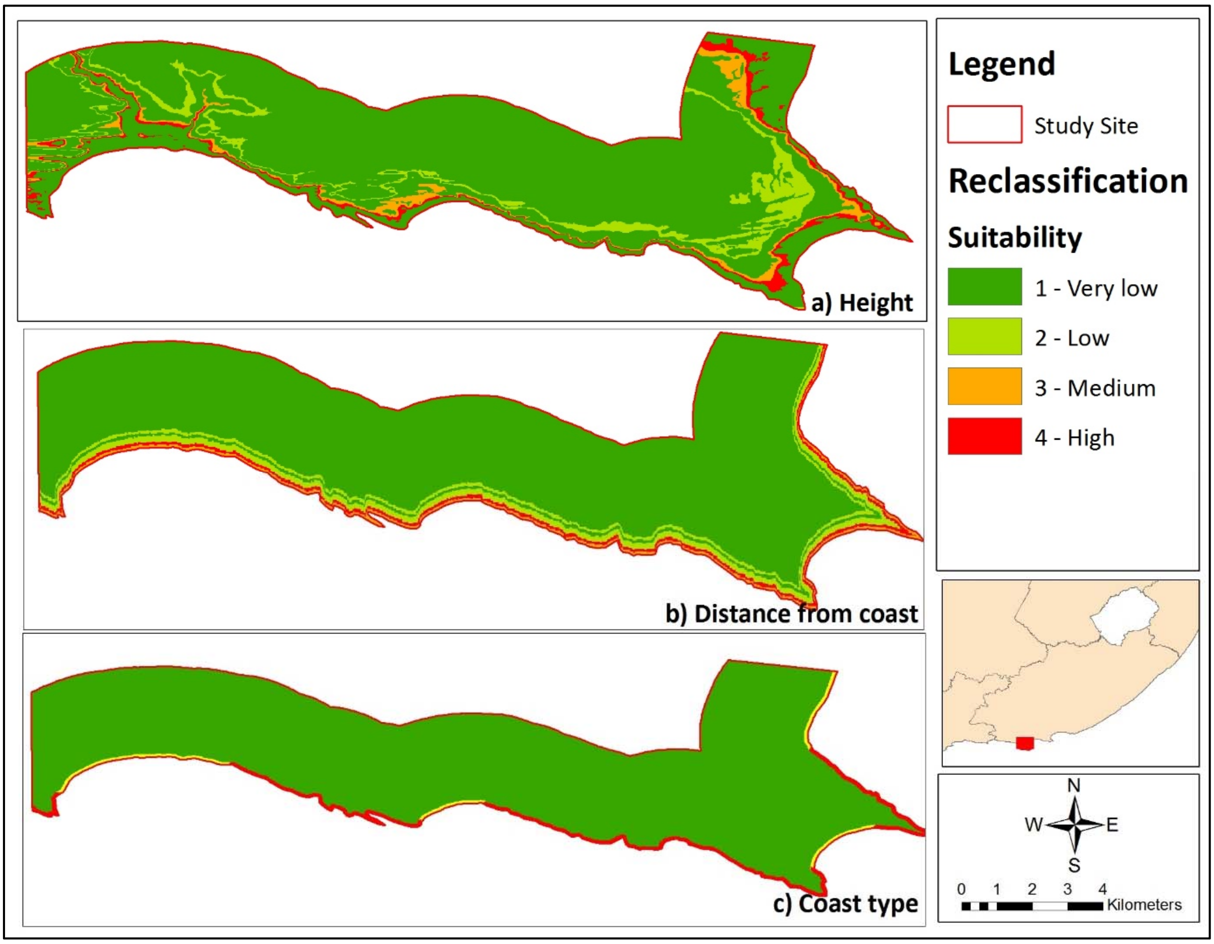

Figure 4.13: Reclassification of the height, distance from coast and coast type layers.

Table 4.21: Reclassification of the vegetation and distance from landform layers.

Vegetation	*Distance from Landform*	*Reclassification*
Algoa Dune Strandveld	0	4
Tsitsikamma Sandstone Fynbos **Southern Cape Dune Fynbos**	0 - 200	3
Cape Seashore Vegetation	200 - 400	2
Gamtoos Thicket **Eastern Coastal Shale Band Vegetation** **Cape Estuarine Salt Marshes**	400 – 1000	1

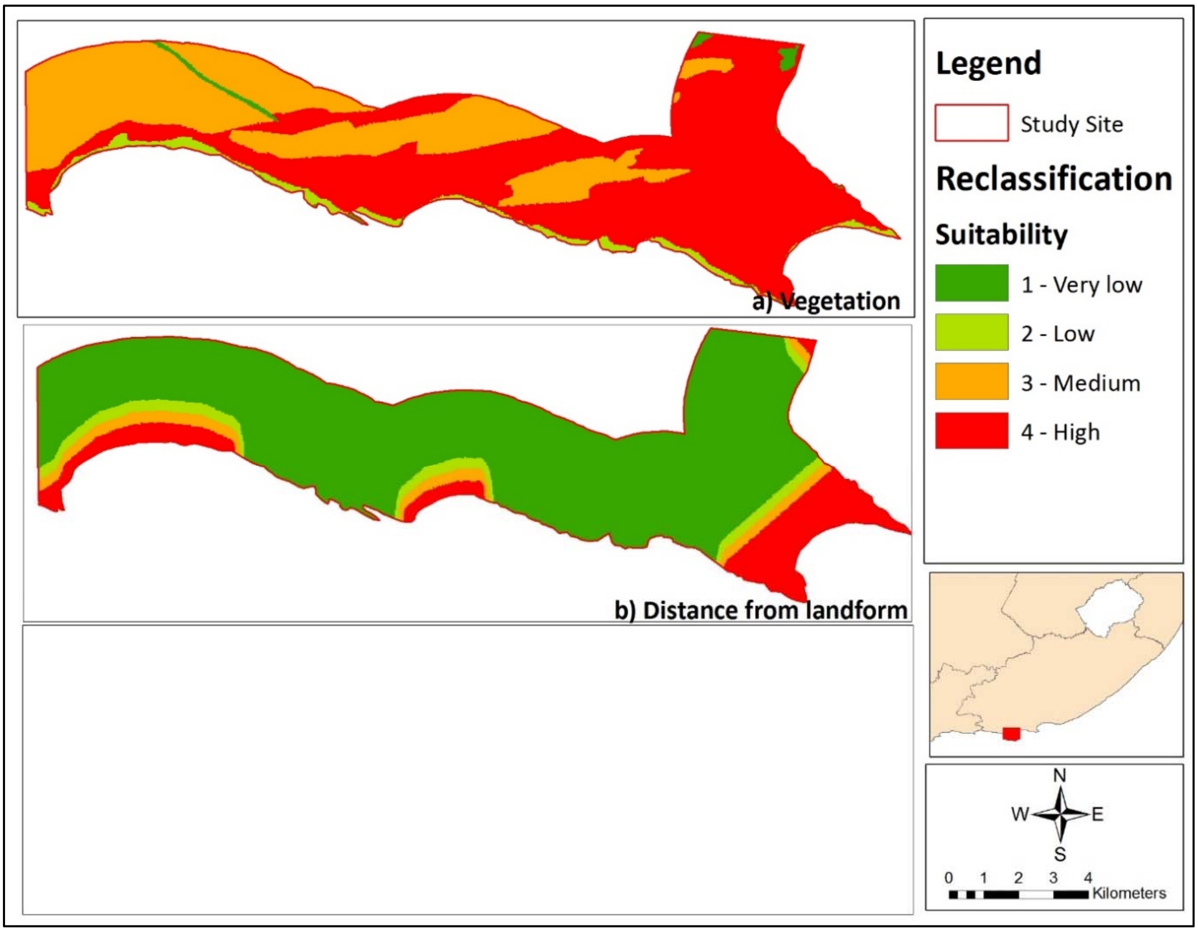

Figure 4.14: Reclassification of the vegetation and distance from landform layers.

Suitability = (Geology) + (TPI) + (Aspect) + (Distance from coast) + (Vegetation) + (Coast line type) + (Landforms) + (Height)

Equation 4.4: Suitability equation for the decision makers for method a).

b) **Statistics and expert opinion**

Table 4.22: Relevance of decision makers.

			Relevance (count/total)
Physical	6. Geology	11	0,229
	7. Aspect	7	0,146
	8. TPI	8	0,167
	9. Height above sea level	1	0,021
Resource based	10. Distance from coastline	6	0,125
	11. Vegetation type	6	0,125
	12. Coastline type	5	0,104
Human	13. Landscape features	4	0,083
Total		48	1

Suitability = [(Geology x 0,229) + (TPI x 0,167) + (Aspect x 0,146) + (Distance from coast x 0,125) + (Vegetation x 0,125) + (Coast line type x 0,104) + (Landforms x 0,083) + (Height x 0,021)] x 8

Equation 4.5 Suitability equation with relevance for the decision makers for method b).

c) **Statistics, expert opinion and field observations.**

Table 4.23: Field Observations

Group	**Decision Makers**	**Description**	**Conclusion**
Physical	1. Geology	Over the 6 study sites no correlation for where human settlement and geology have been observed. I am choosing to go against expert knowledge and remove this layer.	Remove layer.
	2. Aspect	No field observations.	No change.
	3. TPI	Some shell middens seem to be found on the top of slopes. This was also discussed with the archaeologist and it was concluded that ridges were good places for settlement as they offered good protection.	Change reclassification value of ridges to 3 and lower slopes to b.
	4. Height above sea level	No field observations.	No change.
Resource based	5. Distance from coastline	No field observations.	No change.
	6. Vegetation type	It appears that often the Algoa Dune Strandveld is too dense to find any form of human settlement. The Cape	Change reclassification value of Algoa

		Seashore Vegetation is more open and more shell middens were found in this type of vegetation.	Dune Strandveld to 3 and Cape Seashore Vegetation to 4.
	7. Coastline type	No field observations.	No change.
Human	8. Landscape features	No field observations.	No change.

Table 4.24: Relevance of decision makers after field observations.

Group	Decision Makers	Count	Relevance (count/total)
Physical	1. Aspect	7	0,189
	2. TPI	8	0,216
	3. Height above sea level	a	0,027
Resource based	4. Distance from coastline	6	0,162
	5. Vegetation type	6	0,162
	6. Coastline type	5	0,135
Human	7. Landscape features	4	0,108
Total		37	1

Suitability = [(TPI x 0,216) + (Aspect x 0,189) + (Distance from coast x 0,162) + (Vegetation x 0,162) + (Coast line type x 0,135) + (Landforms x 0,108) + (Height x 0,027)] x 7

Equation 4.6: Suitability equation with relevance for the decision makers for method c).

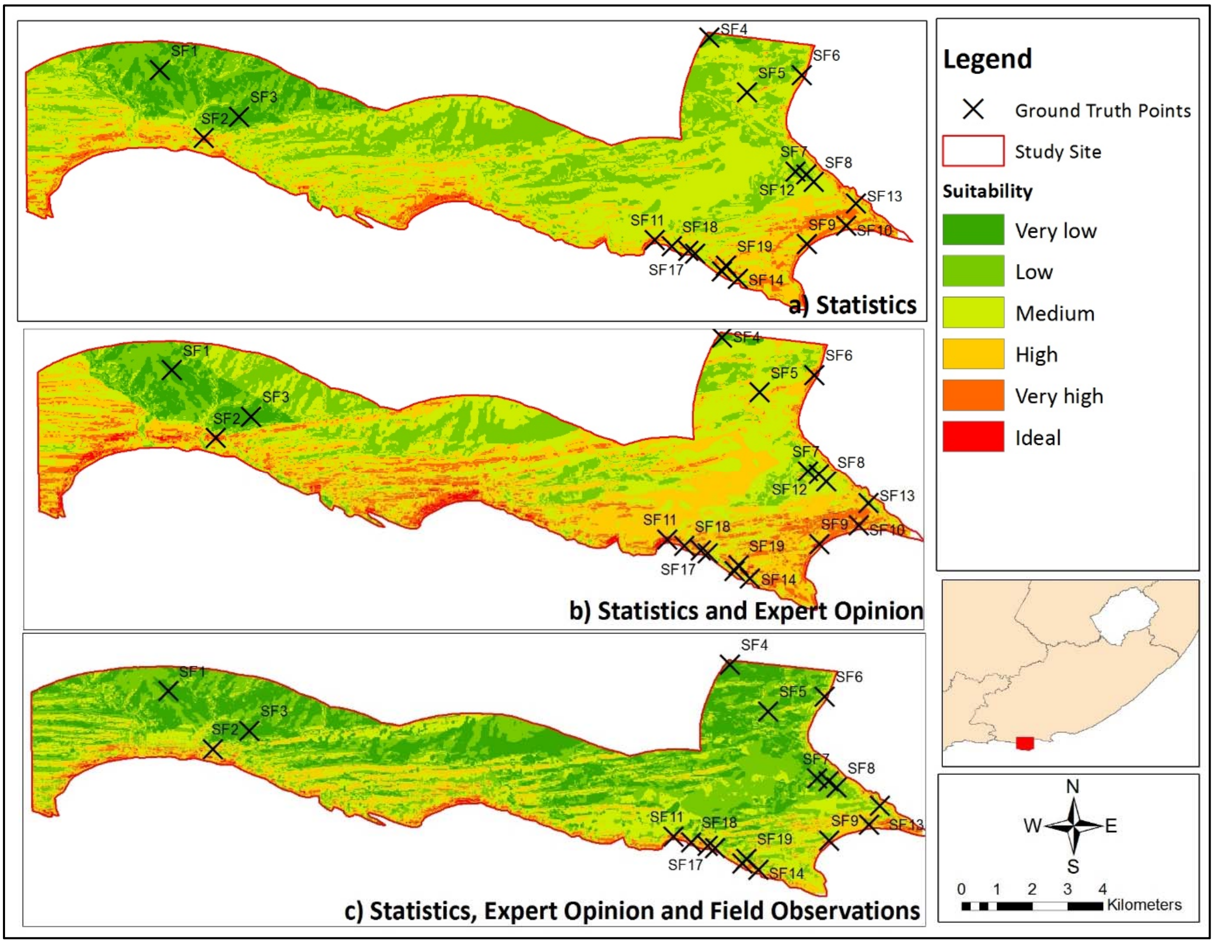

Figure 4.15: The St Francis Bay study area.

Table 4.25: Results of ground truthing of St Francis Bay site.

Site	Site Description	Method	Result
SF1	 Open farm lands, covered in vegetation.	a. Statistics Very Low probability site.	Positive.
		b. Statistics and Expert knowledge Very Low probability site.	Positive.
		c. Statistics, Expert opinion and field obs. Very Low probability site.	Positive.

	Very low to low probability of finding sites.		
SF2	 Thick vegetation in a built up areas. Could not determine probablity of finding sites of human habitation.	a. Statistics Very High probability site.	----
		b. Statistics and Expert knowledge Ideal probability site.	----
		c. Statistics, Expert opinion and field obs. High probability site.	----
SF3	 Flat grassy plains, covered with vegetation. Is fresh water source. Very low to low probability of finding sites.	a. Statistics Very Low probability site.	Positive.
		b. Statistics and Expert knowledge Very low probability site.	Positive.
		c. Statistics, Expert opinion and field obs. Very Low probability site.	Positive.
SF4		a. Statistics Very Low probability site.	----

	  Thick vegetation. Informal tools found in road cutting. Deposition of rounded, river rocks. Low to medium probability of finding sites, improved by the road cutting.	b. Statistics and Expert knowledge Very Low probability site.	----
		c. Statistics, Expert opinion and field obs. Very Low probability site.	----
SF5	 Very thick vegetation.	a. Statistics Medium probability site.	Negative.
		b. Statistics and Expert knowledge Medium probability site.	Negative.
		c. Statistics, Expert opinion and field obs.	Positive.

	Very low to low probability of finding sites.	Low probability site.	
SF6	 In parking lot behind the dunes. Could not determine probablity of finding sites of human habitation.	a. Statistics High probability site.	----
		b. Statistics and Expert knowledge Ideal probability site.	----
		c. Statistics, Expert opinion and field obs. High probability site.	----
SF7	 Thick vegetation with small patches of open sand. Low to medium probability of finding sites.	a. Statistics Low probability site.	Positive.
		b. Statistics and Expert knowledge Low probability site.	Positive.
		c. Statistics, Expert opinion and field obs. Very Low probability site.	Negative.
SF8		a. Statistics Medium probability site.	Positive.

	 Thick vegetation with small patches of open sand. Low to medium probability of finding sites.	b. Statistics and Expert knowledge Medium probability site.	Positive.
		c. Statistics, Expert opinion and field obs. Low probability site.	Positive.
SF9	 Open beach. Too exposed for sites of habitation. Very low probability of finding sites.	a. Statistics Very High probability site.	Negative.
		b. Statistics and Expert knowledge Ideal probability site.	Negative.
		c. Statistics, Expert opinion and field obs. Very High probability site.	Negative.
SF10		a. Statistics Very High probability site.	Negative.
		b. Statistics and Expert knowledge	Negative.

	 Open beach. Too exposed for sites of habitation. Very low probability of finding sites.	Ideal probability site.	
		c. Statistics, Expert opinion and field obs. Very High probability site.	Negative.
SF11	 Rocky cove, thick vegetation. Could not investigate fully. Could not determine probability of finding sites of human habitation.	a. Statistics Very High probability site.	---
		b. Statistics and Expert knowledge Ideal probability site.	---
		c. Statistics, Expert opinion and field obs. Very High probability site.	---
SF12		a. Statistics Low probability site.	Negative.
		b. Statistics and Expert knowledge	Positive.

	  Small shell midden. Stone tools and ostrich egg found. Medium to high probability of finding sites.	Medium probability site.	
		c. Statistics, Expert opinion and field obs. Low probability site.	Negative.
SF13		a. Statistics Medium probability site.	Positive.
		b. Statistics and Expert knowledge Low probability site.	Negative.
		c. Statistics, Expert opinion and field obs. Medium probability site.	Positive.

	 Small shell midden found. Many large shells. High to medium probability of finding sites.		
SF14		a. Statistics High probability site.	Positive.
		b. Statistics and Expert knowledge High probability site.	Positive.
		c. Statistics, Expert opinion and field obs. Very High probability site.	Negative.

	 Small shell midden found. Only shell found. High to medium probability of finding sites.		
SF15	 Small stratified shell midden. Shells and informal tools. Very high to high probability of finding sites.	a. Statistics Medium probability site.	Negative.
		b. Statistics and Expert knowledge Medium probability site.	Negative.
		c. Statistics, Expert opinion and field obs. Medium probability site.	Negative.

SF16	 Small scattered shell midden. Shells and informal tools. Very high to high probability of finding sites.	a. Statistics High probability site.	Positive.
		b. Statistics and Expert knowledge High probability site.	Positive.
		c. Statistics, Expert opinion and field obs. Medium probability site.	Negative.
SF17	 Small stratified shell midden. Shells and informal tools. Very high to high probability of finding sites.	a. Statistics High probability site.	Positive.
		b. Statistics and Expert knowledge Very High probability site.	Positive.
		c. Statistics, Expert opinion and field obs. Ideal probability site.	Negative.

SF18	 Small stratified shell midden. Very high to high probability of finding sites.	a. Statistics Medium probability site.	Negative.
		b. Statistics and Expert knowledge High probability site.	Positive.
		c. Statistics, Expert opinion and field obs. Medium probability site.	Negative.
SF19	 Very thick vegetation. Very low to low probability of finding sites.	a. Statistics Medium probability site.	Negative.
		b. Statistics and Expert knowledge Medium probability site.	Negative.
		c. Statistics, Expert opinion and field obs. Low probability site.	Positive.

Each site was examined and it was determined whether the *suitability analysis* results were verified by the ground truthing. If the *suitability analysis* results were found to be the same as the results on the ground (i.e.: *high* probability of finding human habitation and shell middens were found), then the analysis was found to be validated (a positive result) and the site is given the numerical value of 2. If the *suitability analysis* results were found to be contradicted by the results on the ground (i.e.: *low* probability of finding human habitation and shell middens were found), then the analysis was found to contradict the analysis (a negative result) and the site is given the numerical value of 0. If there were other factors that influenced the results such as a parking lot on top of the point or inaccessibility, then the *suitability analysis* results could not be validated or contradicted and were given the value of 1 was given. (According to expert opinion if you do not visit a site you cannot assume there is nothing there, hence the value of 1).

Table 4.26: Results for all the sites.

Site Type	Site	Site ID	Method a	Method b	Method c
Small Scale	Stil Bay	Stilbay1	1	1	1
		Stilbay2	0	0	0
		Stilbay3	2	0	0
		Stilbay4	2	0	0
	Witsand	Witsand1	0	0	0
		Witsand2	1	1	1
		Witsand3	1	1	1
		Witsand4	0	0	0
		Witsand5	0	0	0
	Arniston	Arniston1	2	0	2
		Arniston2	2	2	2
		Arniston3	1	1	1
		Arniston4	2	2	2
		Arniston5	2	2	2
	Die Mond	DieMond1	0	0	0
	Struis Bay	Struis1	0	0	0
		Struis2	1	1	1
		Struis3	1	1	1
		Struis4	2	2	2
Local Scale	St Francis	SF1	2	2	2
		SF2	1	1	1
		SF3	2	2	2
		SF4	1	1	1
		SF5	0	0	2
		SF6	1	1	1
		SF7	2	2	0
		SF8	2	2	2
		SF9	0	0	0
		SF10	0	0	0

		SF11	1	1	1
		SF12	0	2	0
		SF13	2	0	2
		SF14	2	2	0
		SF15	0	0	0
		SF16	2	2	0
		SF17	2	2	0
		SF18	0	2	0
		SF19	0	0	2
Total			40	36	32
Percentage			52,6%	47,3%	42,1%

The results of **table 4.27** show that the *suitability analysis* is only validated between 42-52% of the time. This indicates that the areas of high probability only have about a 50% chance of containing sites of modern humans; the probability zones are wrong as many times as it is right.

Objective 3 - Results

During the course of this study, it became evident that most new archaeological surveys in the last decade were promoted by development. New developments are required by SAHRA and the National Heritage Act to conduct an AIA. It therefore became necessary to investigate the relationship between archaeological finds and development over the last 10 years.

An investigation into the case reports found on the South African Heritage Resource Agency's online data base (SAHRIS) was conducted to examine the relationship between development and archaeological site discovery (results table in appendix). A summary of the results can be seen in **figure 4.16** and **4.17.**

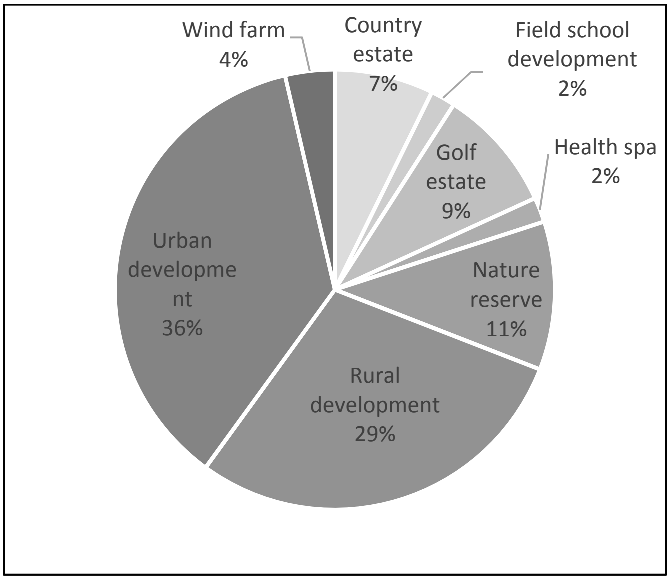

Figure 4.16: Percentage of different development types from the case studies.

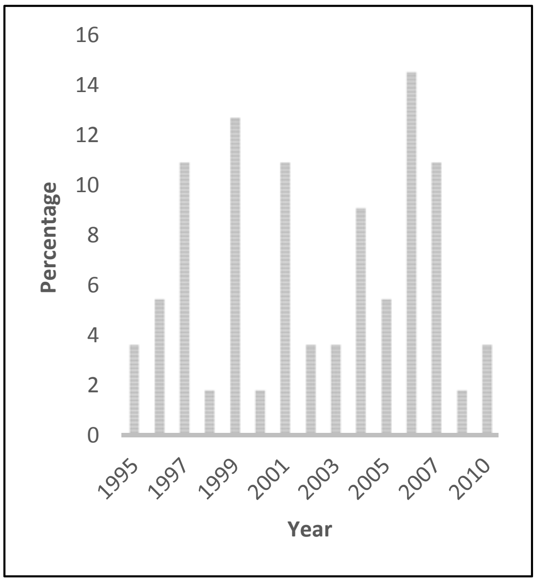

Figure 4.17: Percentage of case reports submitted for each year.

Figure 4.16 indicates that most sites are discovered through rural or urban development (65%). Development and conservation in nature reserves also lead to the discovery of archaeological sites. **Figure 4.18** indicates archaeological 'territories' or research focus areas based on the case reports, or AIAs, found in the SAHRIS database. One can see that Kaplan has done work on the entire south coast and does not seem to have a focused research area. Halket and Hart work mainly in the western area while Webley and Van Ryneveld work mainly in the eastern area. Deacon and Nilssen's work focuses in the middle of the study area. These focus areas indicate the region within which each expert in familiar though the characteristics of these areas may vary. This is important to note as the expert opinion from each expert may vary according to the area with which they are most familiar.

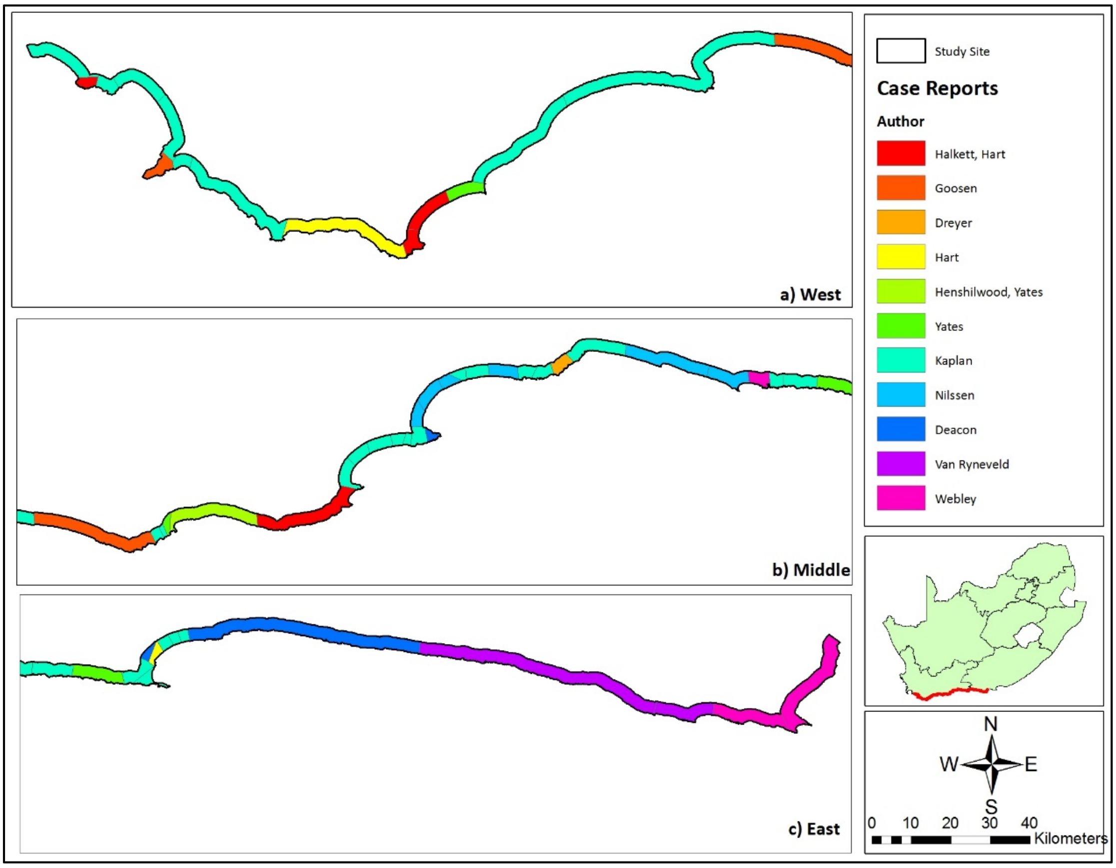

Figure 4.18: The research focus areas of the case reports.

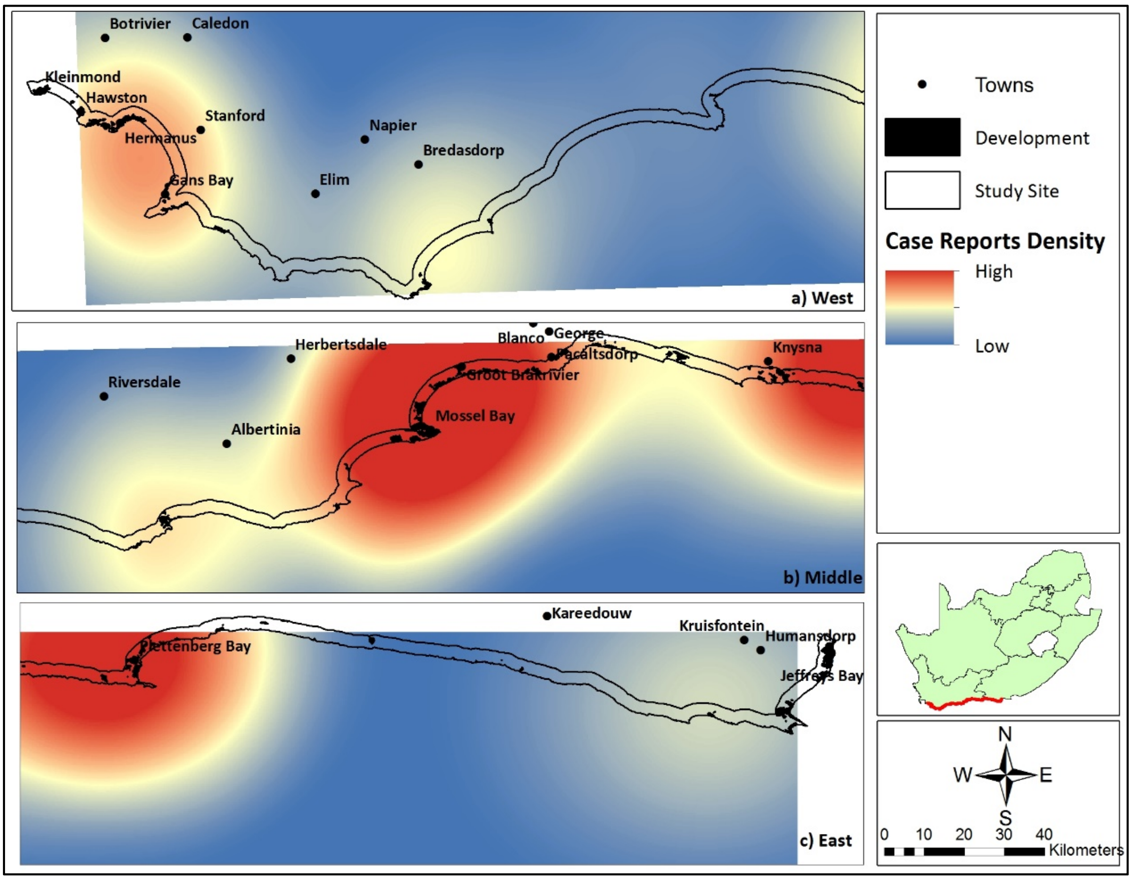

Figure 4.19: Density of case reports and development.

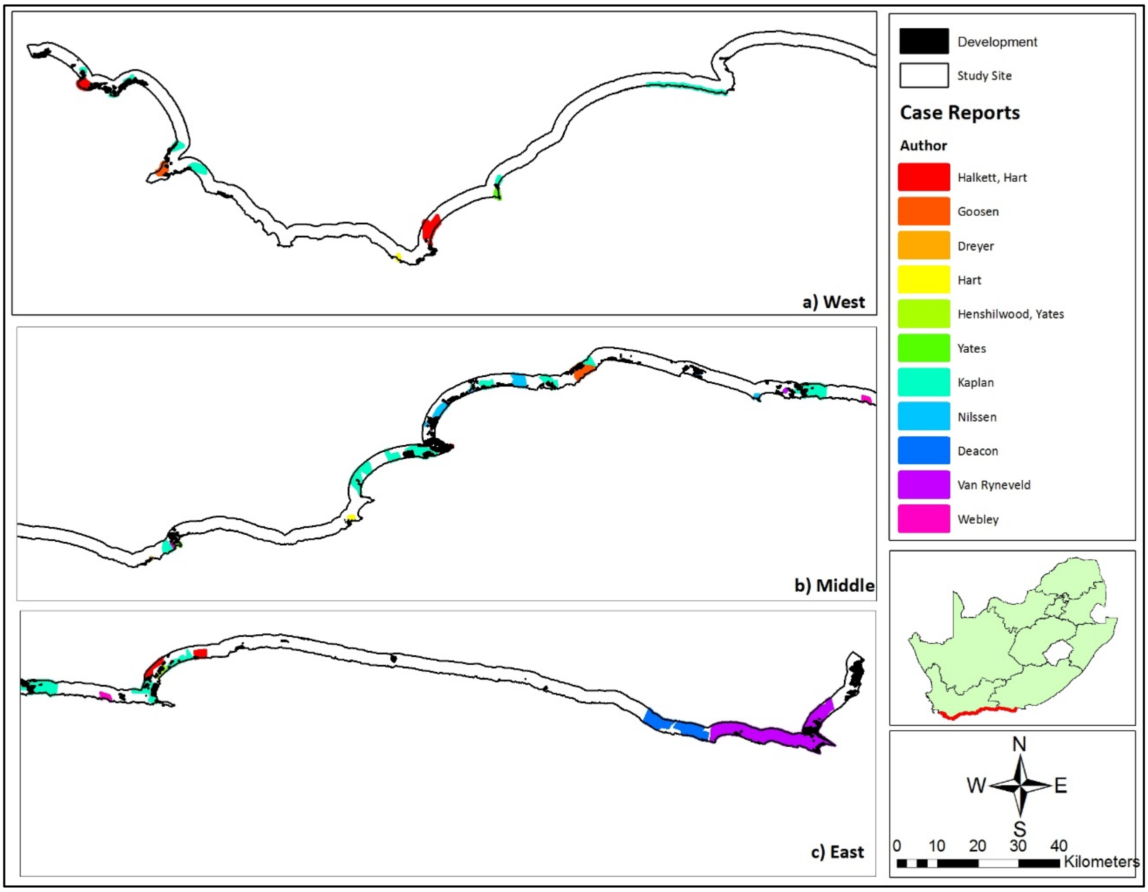

Figure 4.20: The location of the case reports and associated development.

Figure 4.19 illustrates that the archaeological surveys are most dense around areas of development. The densest area of archaeological surveys can be found around the Mossel Bay area. **Figure 4.20** illustrates the areas where archaeological surveys have been completed as well as the areas of development. From the figure above it is evident that there are large areas where no research has been undertaken and where development may still take place.

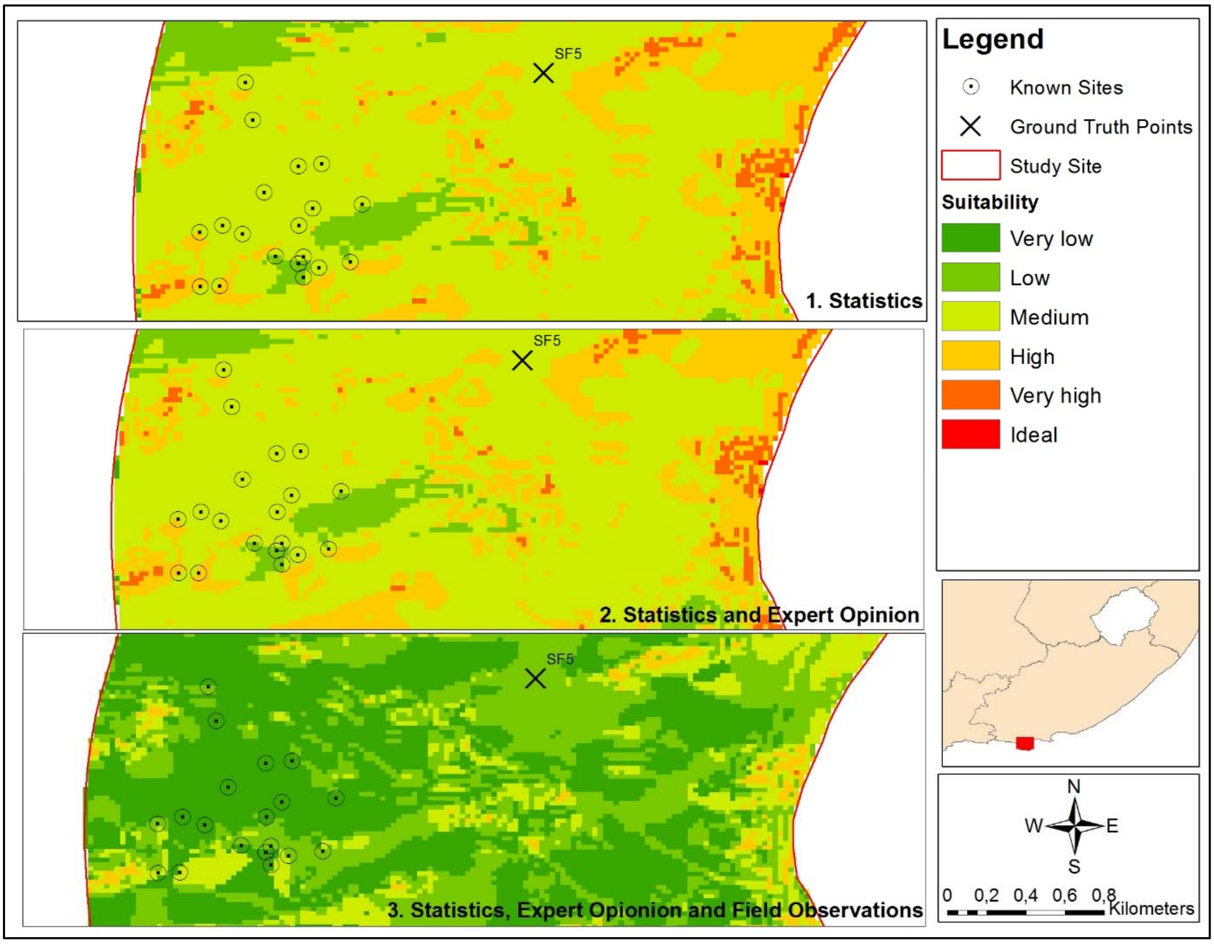

Figure 4.21: Known sites in St Francis Bay.

Figure 4.21 indicates the many archaeological sites discovered in St Francis Bay during the development of the St Francis Links Golf Estate. The known sites are found in **very low** to **medium** *suitability* areas. The discovery of these sites is as a direct result of the development of the golf estate and the associated concentration of survey effort.

Chapter 5

Discussion

This study attempted to discover unknown sites of *modern* human habitation during the MSA. These *modern* humans first evolved in the MSA period (±250-40 k.a) where the first remains of humans that were anatomically similar to ourselves were found (Singer & Wymer, 1982). MSA sites are rare as the sea level has risen since this period, drowning most of these potentially important sites (Jerardino & Marean, 2010). This discussion will investigate whether the objectives of this study were met as well as present limitations and possible future research.

The aim of the first objective was to 'characterize' and understand the spatial dynamics of archaeological sites of modern human habitation on the southern coast of South Africa. This was completed using a combination of literature and the Archaeological Impact Assessments (AIAs) found in the SAHRIS database. Only 8 sites were located from academic journals that were strictly MSA sites. This was not a big enough sample to run statistics for this study so less specific sites were used from the AIA's; including both MSA and LSA sites. Though the sites were not specifically from the MSA period that was being investigated they were still useful for this study. These sites were recorded and their geographical locations were illustrated through the use of GIS tools. An attribute table was then created for each site containing the site's characteristics needed for the analysis.

This study used *expert mapping* and other physical layers as a tool to better understand these sites of human habitation. Lock (2001) describes how GIS has been used as a tool for archaeological research through two main approaches: methodical and theoretical. The methodical approach uses physical layers to determine the locations of unknown sites while the theoretical approach uses past historical process to determine patterns and therefore possible locations of unknown sites (Lock, 2001; Wheatley, 2000). This study aimed to bridge the gap between these two approaches through the creation of expert maps. Most archaeologists unknowingly use the theoretical approach when trying to identify unknown sites. This is a result of accumulated knowledge and experience that allows them to make connections to characteristics that determine where humans like to settle. The questionnaires completed by the experts were an attempt to capture some of that inherent theoretical knowledge and map it as a 'physical' layer. This method was quite effective as three new expert layers were determined through the questionnaires: *type of coast line*, *distance from landforms* and *effort* layers. The inclusion of these layers elevated this study from a purely methodical analysis to a study that combines both methodical and theoretical. The remaining methodical *decision makers* were determined though literature as well as expert knowledge. The results of combining both physical and theoretical *decision makers* (**figure 2.1**) indicates that objective 1 of this study was met.

The aim of objective 2 was to create *probability* zones using the *suitability analysis* methodology and the results of objective 1. Fourteen physical and theoretical d*ecision maker* layers were determined using the knowledge gained from objective 1. For this study the χ^2 test was used to determine whether the *decision makers* had a significant relationship to the location of sites of human habitation. This methodology was utilized in past studies under the same conditions (Brandt et al., 1992; Kohler & Parker, 1986; Perkins, 2000). It was effective in these past studies in determining the relationship between known sites and the characteristics at each site and was therefore also considered effective for this study.

The *decision makers* with significant relationships to the known sites were then combined through the *suitability analysis* described by Oheim (2007). This form of analysis was chosen as it best suited to the context of the study. It utilised the reclassification of the *decision makers* into new values between 1 and 4; 4 being most suitable and 1 being the least. This method was appropriate for this study and will be easy to duplicate. The *suitability* equations described by Wayne (2003) were accurate as they included relevance for each layer. This included the *expert knowledge* obtained from objective 1 with respect to how important they were in determining site location.

The three methodologies of combining the *decision makers* that were statistically significant with the known sites are all taken from published papers describing these methods. The statistical method of simply adding all the decision makers together was described by Oheim (2007), Wayne (2003) and Perkins (2000). Including a weighting or relevance for each *decision maker* is more popular and is described by Oheim (2007), Wayne (2003), Mensing et al. (2000) and Brandt et al. (1992)**.** Oheim (2007) then describes how ground truthing was performed and field observations were made to make modifications to the model if necessary. The amount of literature on each methodology indicates that the methods are sound and can output positive results. In this study the three methodologies produced three different probability zone maps.

The results of each probability zone created was then verified through field work. In total 38 sites of varying probabilities were visited in order to verify the desktop results which indicated the likelihood of finding sites of human habitation. An archaeological assistant was present for half of the sites to ensure that any findings were correctly identified. This allowed for a more accurate assessment of unknown sites that were located. The methodology was developed in conjunction with the archaeological assistant and was therefore suitable for both GIS and archaeological research.

Part of objective 2 of this study was to investigate how appropriate GIS is in predicting sites of human habitation. Each methodology created different probability zones and therefore had different accuracy rates. **Table 4.27** shows the results for each method and indicates that:

- Method **a)** (statistics) is most accurate (52.6%),
- Method **b)** (statistics and expert opinion) is the next most accurate (47.3%) and
- Method **c)** (statistics, expert opinion and field observations) is the least accurate (42.1%).

This is counterintuitive as it is expected that the method that included weighting of the *decision makers* as well as modifications from field observations should be the most accurate. This indicates that the statistics of the known points were accurate but the weighting and field observations may have skewed the results. Overall the accuracy of predicting unknown sites for this study was 42- 53% which shows that the probability zones were correct as many times as they were incorrect. Though there are many examples of this type of analysis working in published studies, GIS is not an appropriate tool for predicting archaeological sites in this context. The reasons for objective 2 not being met are discussed in the limitations of the study.

Objective 3 aimed to relate the results of the study to current coastal development and identify new focus areas for research. The AIA's used as a basis for the statistical analysis of this study are directly related to development. **Figure 4.19** shows how the AIA's are clustered around developed areas. This correlation is understandable to be expected as AIA's are produced in response to a new development as required by the National Heritage Resource Act (SAHRA, 2014a). As a result of South Africa's divided past, the country has struggled to support local research and academics (NRF, 2014). This is where development has a positive effect on archaeological finds. It is a legal requirement for all developers to complete a full Environmental Impact Assessment (EIA) before going through with a planned development; an AIA makes up part of this EIA. This means that developers are obliged to fund archaeological surveys in areas and supply the machinery to exhume any finds that are deemed important. This is highlighted in **figure 4.21** where an impact assessment was done in St Francis Bay at the Links Golf Estate. 19 archaeological sites were determined in this small area even though the analysis of this study showed that the probability of finding sites were **very low** to **medium**. Silberbauer (2014) attributed this to the large amount of earth work that was carried out for this development. These sites were only discovered as a result of the developers digging in the area. In this way development is actually aiding archaeological research in this country.

There is one major issue with development funding archaeological research: any research will have to be conducted in areas being developed. This has created a bias of finding archaeological sites only within developed areas. **Figure 4.20** shows that there are large areas of the south coast of South Africa that are not developed and hence no detailed archaeological surveys have been completed within these areas. This study aimed to identify areas with a high probability of yielding sites so that research outside of AIA could be targeted in these undeveloped areas. Unfortunately the study was not able to identify these high probability areas and therefore the use of GIS as a tool for determining possible sites of human habitation is limited. In this way the aims of objective 3 were only partly met. The study met the objective of relating the results to development as they have a direct relationship. However it could not identify specific areas for future research as GIS was not an effective tool in determining area of high probability of finding sites of human habitation.

Limitations

Table 5.1: Limitations of this study.

Limitations		
Researchers skills	Archaeology	As a geographer I had very little prior knowledge of archaeology. Studying published literature and utilising expert knowledge from objective 1 aided better understanding of sites of human habitation. Though this was effective, my lack of previous knowledge could have skewed the results of this study as incorrect conclusion and decisions could have been made as a result of poor understanding. An example of this is the radius of the study area from the coast. The researcher determined 3 km to be an accurate foraging radius but was directed to Marlowe (2005) which states that the radius is 10km.
	Publications	One of the other limitations of this study is the number of sites identified in published research. Only 8 sites were identified and a number of experts expressed concern that this number is very low. The constraints of the time period and area of research resulted in many sites from published research being excluded from the analysis. But, this is one of the reasons that this study area was selected as it was identified as a region where research is limited. There are numerous MSA sites within the study site that exist but no research has been carried out on them making it difficult to identify their locations. The Albany Museum, like many South African museums, have hard copy records of known sites that have been recorded but have not been researched. These locations and characteristics are currently being transferred into an electronic database (Booth, 2013). Once this is complete more locations of known MSA sites within the study area could be available. Unfortunately for this study the only accessible data was that of published literature and AIA reports on the SAHARIS database.
Ground truthing	Physical Landscape	Many of the sites that were deemed acceptable for human habitation are heavily developed. This had a negative effect on the ground truthing process as many high probability sites have already been developed and artefacts in the area could possibly have been destroyed.
	Vegetation	Vegetation was one of the major limiting factors when it came to ground truthing. If the vegetation

		was too dense it covered up any artefacts that could have been at or below the soil surface.
	Size	Scale is a limitation in this type of study. The shell midden sites can be between $2m^2$ and $10m^2$. In a study area that is $2100km^2$ it is very difficult to identify such small areas.
	Assistance	During field work I had an archaeological assistant for the first 19 ground truthing sites but he was unable to accompany me on my 19 localised, large scale points. This may have led to some sites being less accurately investigated and may have skewed the results. Ideally an archaeological assistant should have accompanied me to all 38 of my ground truth points.
Data	SAHRIS	The selectivity of sites found in the AIA's could have led to bias within the known sites. Though the record of impact assessments seems to be comprehensive, there could be many that are not included. Silberbauer (2014) mentioned that the Eastern Cape Province is not reliable with publishing these types of assessments. This may have led to a selective amount of known sites that could have skewed the data for this study.
	Accuracy	The accuracy of the data used as *known* sites was poor. Some of the assessments were almost 20 years old and are therefore quite dated. The locations of the sites could have been inaccurate as the technology was not as advanced. The bulk of the data used in this analysis was taken from AIA's. This is a very specific source and may have led to a poor sample for statistics. As this known data is the basis for the statistical analysis part of this study, the poor accuracy could have led to error propagation. As described by Store and Kangas (2001) the accuracy of the results of any study depends on the quality of the source data (illustrated in **figure 5.1**.). The results from the χ^2 test, **table 4.3**, showed that there was no relationship between site location and type of coast line within which they were found, despite being mentioned by all experts as a major contributing factor. This indicates that the known sites used in the analysis are not strictly a collection of sites of human settlement as described by the experts. Some of the known sites are more temporary, nomadic settlement sites that are not only found on rocky coastlines close to food sources. This also indicates poor data accuracy as the sites

		were not an accurate representation of permanent human settlement.
	Resolution	The data layers used for this study had resolutions of between 1:10 000 and 1: 250 000. The environmental layers from which most of the *decision makers* were determined had a scale of 1:250 000. The results of the analysis are limited by the scale, or resolution, of the input layers. Given that the archaeological sites that were investigated were between 2m^2 and 10m^2 in area, the resolution needed to properly investigate these small areas was not matched by the scale at which the output layers were determined. This will have caused error propagation.
	Current vs. Paleo	This study aimed to investigate if more of the 'rare' MSA sites could be discovered but the landscape change seems to be too great to obtain positive results. The coastline during the MSA period was 6-8m below what it is currently which indicated that the landscape has changed dramatically from 125 k.a. (Phillipson, 1995). As this study uses physical features to determine unknown site locations it is understandable that a negative result was concluded. One of the reasons for using physical layers was to determine if possible sites where humans would have settled 125 k.a. could be identified from current landscape conditions. It appears that the time period was too great for there to be a correlation between past landscapes and current favourable habitation conditions.
Nature of topic	Number of experts	Archaeology is a broad subject as there are many time periods in which one can specialise. For this reason there are a limited number of experts in South Africa that focus on the time period used in this study. 5 experts where consulted which is a small sample size. A larger sample size might have increased the accuracy of the expert knowledge obtained for this study.
	GIS	GIS as a technology has some inherent limitations. One of the major issues is the use of Boolean Logic. Store and Kangas (2001) describe how this form of analysis either accepts or rejects a certain area in a study with respect to given 'threshold' values. If the 'threshold' values are too generalised or, on the opposite side of the scale, too limiting then information can be lost (Store and Kangas, 2001). This study made use of this Boolean style of analysis

		and this may have led to the occurrence of error propagation.
	Expert bias	Expert mapping was effectively utilised in this study as a tool to determine *decision makers* and the relevance of each layer with respect to their importance in predicting unknown site locations. One of the major issues is that there is limited availability of the archaeological community who have research focused within the studies time period as well as the specific focus area. There is a limitation within the *expert knowledge* as there is bias towards the expert's specific area of study. *Decision makers* that would be important in one area could not be effective predicating factors in another. Kohler and Parker (1986) describe how the environmental factors that that effect the location of sites in one area can be completely avoided in another. This concept could possibly have led to bias in determining *decision makers* and their relevance/weighting in determining locations of human habitation. **Figure 4.18** shows the research focus areas of the archaeologists who completed the AIA's that are uploaded into the SAHRIS database. The type of bias described by Kohler and Parker (1986) could also exist within these focus areas which may have skewed the choice of *decision makers* in this study.
	Bias in fossil record	Bias also exists within the fossil record itself as described by Paul (1998).The MSA fossil record is especially affected by this bias as most sites are under water. This means that research is limited in this period to selective sites that are exposed. This can lead to bias in the records of the *modern* humans who inhabited these area; more sites available for research could possibly have led to different conclusions about this time period.

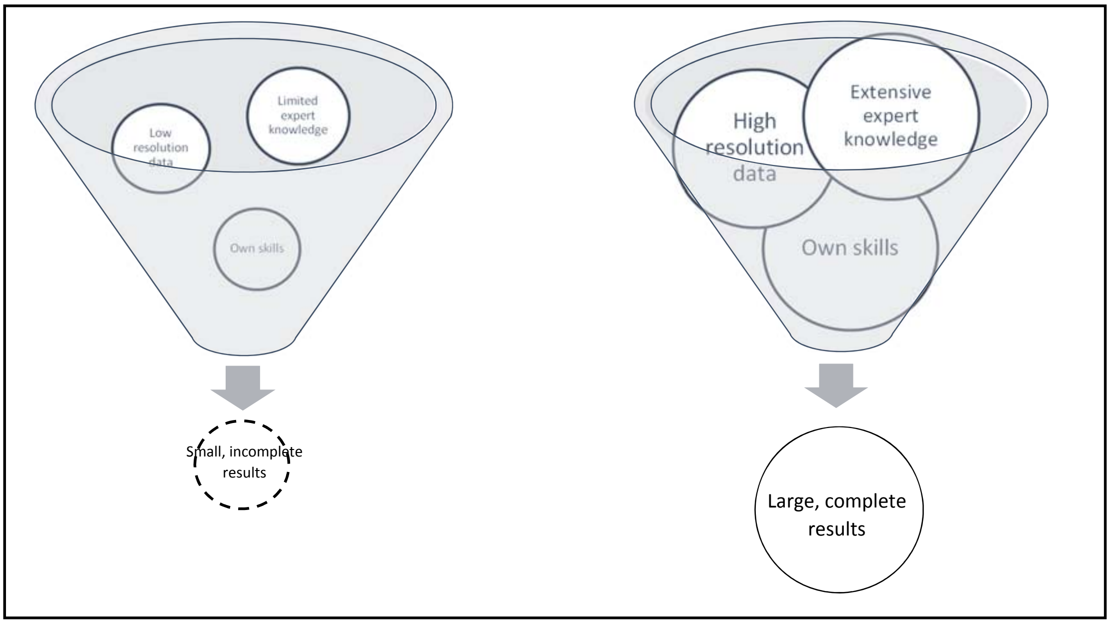

Figure 5.1: An illustration of the importance of good input data to obtain good results.

Chapter 6

Conclusion

This study aimed to determine whether GIS was an appropriate tool for using the characteristics of know sites to predict unknown sites of *modern* human habitation. Out of the 3 objectives in this study 2 were met which indicates that the research was partly successful. The first two stages of complexity of GIS, described by Robinson et al. (2000), are demonstrated in this application: GIS is shown to be an effective tool for the inventory and statistical analysis of sites of human habitation. The SAHRIS database is an effective inventory tool which has been translated into a geographical representation of sites of human habitation. It represents the data in an easily accessible manner. Apart from anything else it gives a framework within which to store the characteristics of the sites in an orderly and comparable way. This data can then be collated and used for various spatial analysis.

The aim of objective 2 was to show that GIS is an appropriate tool for predicting or modelling sites of human habitation. This objective was not met as no specific areas were identified which might be worth archaeological exploration. This third and highest level of complexity, where GIS is used as a predictive tool (Robinson et al., 2000), was therefore not achieved in this study. This made it difficult to fully meet objective 3, which relied on the results of objective 2 to enable recommendation of specific areas of future research. However it was shown that there is a positive relationship between development and archaeological research: development has promoted the discovery of archaeological finds through funding and obligatory AIA. Although development has promoted discovery it has not necessarily promoted conservation or protection of discoveries.

There are many examples of GIS being used an effective predictive tool (representing the third level of complexity as described by Robinson et al. (2000)) for various areas of research, for example: freshwater fish distribution (Joy & Death, 2004), fossil locations (Nigro et al., 2003), rare orchid habitat identification (Sperduto & Congalton, 1996) and breeding bird distribution (Tucker et al., 1997). GIS is often seen as a magical tool for solving spatially related problems but this study shows that there are still some limitations with this technology as this research gives some insight into where GIS fails as a predictive tool.

The results of this research were affected by various limitations, some of which were beyond the researchers control or inherent in the research topic, while others could have been addressed. The lack of prior archaeological knowledge and limited access to locational information of archaeological sites may have resulted in poor decision making for the analysis of this research. Limitations during ground truthing exercise included: existing development, impenetrable vegetation, small size of the sites and the lack of an experienced archaeological assistant. This may in turn have affected the accuracy of the results. The poor resolution and accuracy of the data used in this study were a major limiting factor as it determined the accuracy and resolution of the final output layers. The SAHRIS database, though seemingly comprehensive, contained only a specific set of publications (AIA's) which includes a variety of types of sites (permanent and temporary) as well as sites of varying significances (low to high). This too may have affected the results of this study as the data was used as the basis for the statistical analysis to determine the *probability zones*. The nature of the topic also had inherent limitations such as the bias in the paleoarchaeological record and the possible bias of experts towards their focused research areas. The number of experts available for consultation only provided a small set of expert knowledge. The inherent assumptions of the GIS approach (using Boolean Logic to represent spatial data) is in itself a widely recognised limitation when dealing with information that cannot necessarily be reduced to mere numbers.

The *suitability analysis* methodology used in this study was utilised in many published papers with positive results but seemed unsuccessful under these specific conditions. There are some different methodologies that could be used in future research to try to obtain a positive result. Mensing et al. (2000) describe a similar methodology where the values for reclassification include negative numbers. This would have been an interesting concept to include as the negative values would be used to indicate areas of 'absence': areas where sites of human habitation would not occur. This would have affected the *probability zones* as areas where sites would not occur would have had much lower values.

Another methodology that could be utilised for future studies is the use of remote sensing. Malakhov *et al*. (2009) used remote sensing to determine paleontological sites but this methodology could be interpolated to be used in an archaeological context. The infrared bands were able to pick up exposed geology and this could be useful in an archaeological context. It is difficult to locate unknown archaeological sites if the vegetation is too thick. This method would indicate patches of bare earth where sites could be exposed. In this study some shell middens were found in **low** to **very low** probability areas (site **SF12** in **Table 4.26)** as a result of soil being exposed. Remote sensing could be utilised in future studies to pick up these exposed sites.

This study illustrates that GIS is an effective tool for inventory and basic analysis of sites of human habitation but it has limited application as a predictive tool for locating unknown sites of *modern* human habitation. One of the outcomes of this study was the exposure of the relationship between development and archaeology. The implementation of the National Heritage Resource Act has resulted in AIA's being completed at all new development sites which has 'funded' and focussed archaeological research in these areas of development and led to major finds including the Pinnacle Point sites. However, there is still a need for research in areas that are not currently being developed. A possibility for future study would involves trying to create a more accurate probability map (dependent on the availability of higher resolution data) for finding sites so that the high probability zones in these undeveloped areas could be identified.

Based on this research it may be concluded that archaeological research may be aided by GIS and that there is potential for more advanced use of GIS within this context.

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Appendix

Table a.1: Known sites and distances from rivers.

Distance from river (m)	*Frequency*
500	21
1000	5
1500	9
2000	8
2500	4
3000	9
3500	1
4000	1
4500	4
5000	2
5500	0
6000	3
6500	3
7000	2
More	0

Table a.2: Known sites and coastline characteristics.

Coastline type	*Frequency*	Percentage of known sites (%)	Total of each characteristic in study site (%)
Rocky	42	58,3	58,34
Sandy	27	37,5	37,87
More	0	0,0	3,79

Table a.3: Known sites and distances from the coast.

Distance from coast (m)	*Frequency*
100	26
150	7
200	6
250	2
300	6
350	4
400	5
450	4
500	3

550	4
600	1
650	1
700	1
750	0
800	0
850	1
900	0
More	1

Table a.4: Known sites and aspect characteristics.

Aspect	***Frequency***	**Percentage of known sites (%)**	**Total of each characteristic in study site (%)**
Flat	1	1,4	0,0
North	0	0,0	8,4
Northeast	4	5,6	5,4
East	9	12,5	4,4
Southeast	18	25,0	9,5
South	25	34,7	43,3
Southwest	0	0,0	9,4
West	3	4,2	4,8
Northwest	12	16,7	6,1
North	0	0,0	8,8
More	0	0,0	0,0

Table a.5: Known sites and height characteristics.

Height (m)	***Frequency***	**Percentage of known sites (%)**	**Total of each characteristic in study site (%)**
5	0	0,0	2,7
10	2	2,8	2,0
15	5	6,9	3,5
20	25	34,7	12,1
25	14	19,4	8,6
30	2	2,8	2,1
35	2	2,8	1,7
40	5	6,9	3,5
45	7	9,7	3,1
50	1	1,4	1,5
55	3	4,2	1,4
60	4	5,6	0,3
65	1	1,4	2,1

70	0	0,0	2,4
75	0	0,0	1,3
80	1	1,4	1,3
More	0	0	50,3

Table a.6: Known sites and slope characteristics.

Slope (°)	***Frequency***	**Percentage of known sites (%)**	**Total of each characteristic in study site (%)**
5	39	54,2	64,4
10	12	16,7	13,8
15	10	13,9	7,3
20	4	5,6	5,0
25	4	5,6	3,3
30	3	4,2	2,1
35	0	0,0	1,6
40	0	0,0	1,1
45	0	0,0	0,7
50	0	0,0	0,4
More	0	0,0	0,1

Table a.7: Known sites and rainfall characteristics.

Rainfall (mm/annum)	***Frequency***	**Percentage of known sites (%)**	**Total of each characteristic in study site (%)**
300-500	39	54,2	35,3
500-650	26	36,1	22,2
650-750	4	5,6	11,8
750-900	2	2,8	18,3
900-1050	1	1,4	12,3
More	0	0,0	35,3

Table a.8: Known sites and lithiological characteristics.

Lithology	***Frequency***	**Percentage of known sites (%)**	**Total of each characteristic in study site (%)**
Biotite granite	2	2,8	5,8
Quartzitic sandstone, shale, tillite	19	26,4	25,8

Sand, limestone, conglomerate, clay, alluvium, calcrete, siltstone, silcrete, calcarenite, dune sand, aeolianite	47	65,3	52,4
Sandstone, mudstone, shale, conglomerate, basalt, tuff, breccia	1	1,4	5,0
Shale, sandstone	1	1,4	6,0
Shale, sandstone, diamictite, quartzitic sandstone	2	2,8	1,7
More	0	0	3,4

Table a.9: Known sites and terrain characteristics.

Terrain	***Frequency***	**Percentage of known sites (%)**	**Total of each characteristic in study site (%)**
Dune hills (parallel crests) and highlands	19	26,4	8,7
Plains	16	22,2	9,3
Plains and pans	19	26,4	16,1
Undulating hills	18	25,0	52,7
More	0	0,0	13,2

Table a.10: Known sites and biome characteristics.

Biome	***Frequency***	**Percentage of known sites (%)**	**Total of each characteristic in study site (%)**
Azonal Vegetation	7	9,7	5,5
Forest	1	1,4	6,2
Fynbos Biome	64	88,9	85,4
More	0	0	2,9

Table a.11: Known sites and vegetation characteristics.

Vegetation	***Frequency***	**Percentage of known sites (%)**	**Total of each characteristic in study site (%)**
Blombos Strandveld	14	19,4	2,9
Canca Limestone Fynbos	2	2,8	8,7
Cape Seashore Vegetation	7	9,7	1,0
Garden Route Granite Fynbos	1	1,4	3,1
Groot Brak Dune Strandveld	12	16,7	4,1
Hangklip Sand Fynbos	2	2,8	1,3

Overberg Dune Strandveld	33	45,8	15,6
Southern Afrotemperate Forest	1	1,4	5,9
More	0	0,0	57,4

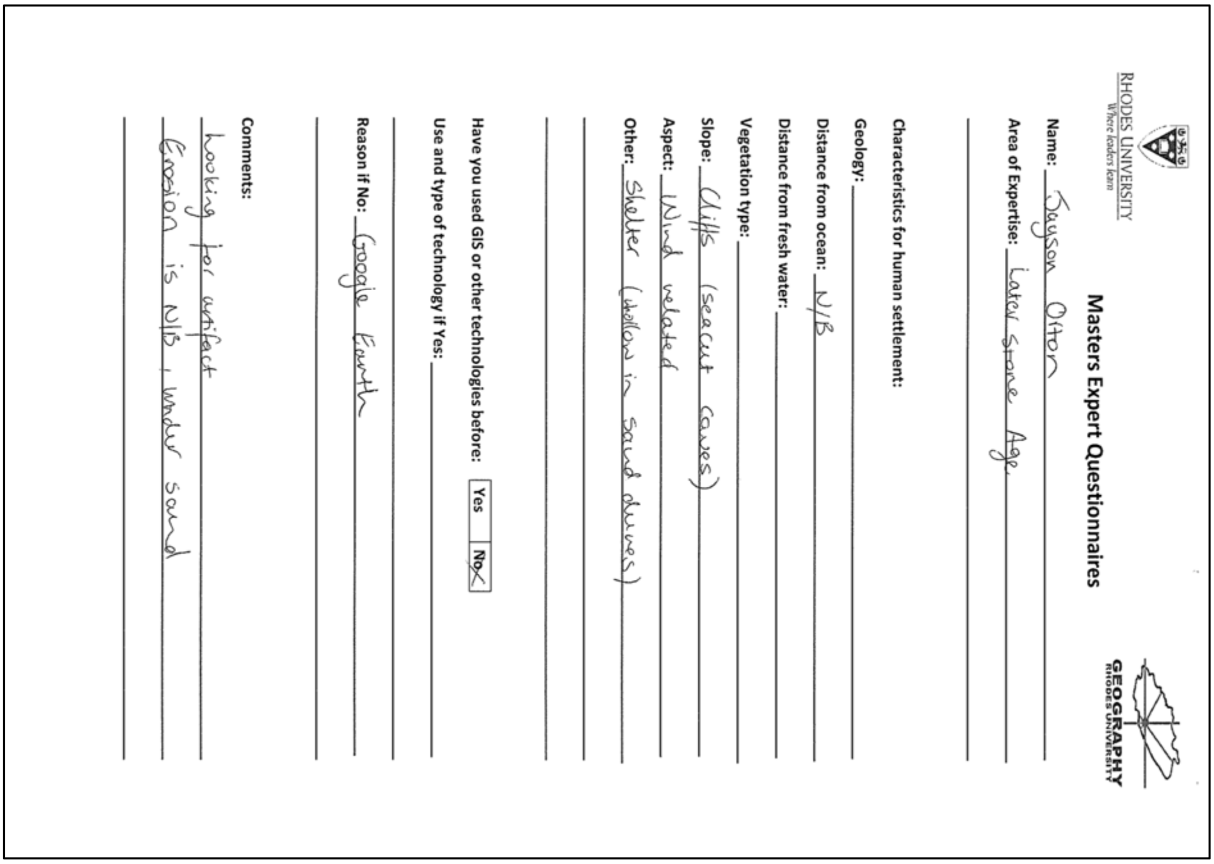
Table a.12: Known sites and landform characteristics.

Distance from Landform	***Frequency***
0	23
200	10
400	7
600	2
800	2
1000	3
1200	2
1400	0
1600	1
1800	2
2000	2
More	18

Table a.13: The case studies investigated from the SAHRIS database.

ID	**MAPID**	**Author**	**Year**	**Type**
1	2652	Kaplan	1998	Rural development
2	1866	Halkett, Hart	1996	Urban development
3	109	Kaplan	1997	Urban development
4	1862	Goosen	1996	Urban development
5	1889	Nilssen	2006	Urban development
6	2739	Kaplan	2006	Urban development
7	2848	Dreyer	2006	Field school development
8	114	Kaplan	2001	Golf estate
9	2738	Kaplan	2007	Country estate
10	124	Halkett, Hart	1997	Rural development
11	2860	Kaplan	2006	Rural development
12	1897	Nilssen	2008	Health spa
13	1818	Kaplan	1996	Rural development
14	192	Henshilwood, Yates	2001	Nature reserve
15	2383	Webley	2006	Rural development
16	749	Webley	2006	Rural development
17	188	Van Ryneveld	2010	Wind farm
18	188	Van Ryneveld	2010	Wind farm
19	1337	Deacon	2001	Urban development
20	102	Kaplan	1999	Urban development
21	117	Kaplan	1997	Rural development

22	1947	Goosen	1999	Rural development
23	102	Kaplan	1999	Rural development
24	102	Kaplan	1999	Rural development
25	104	Hart	2001	Golf estate
26	1407	Deacon	2007	Urban development
27	1977	Kaplan	2002	Golf estate
28	2756	Kaplan	2000	Country estate
29	301	Yates	1997	Rural development
30	2761	Kaplan	2001	Country estate
31	1976	Kaplan	2002	Country estate
32	1903	Webley	1999	Rural development
33	1906	Nilssen	2007	Nature reserve
34	116	Kaplan	2004	Urban development
35	116	Kaplan	2004	Urban development
36	2630	Kaplan	2007	Nature reserve
37	2799	Hart	2004	Rural development
38	2784	Kaplan	2003	Rural development
39	2951	Kaplan	2007	Rural development
40	1952	Yates	2006	Urban development
41	2955	Kaplan	1997	Rural development
42	1338	Deacon	1999	Urban development
43	115	Kaplan	1997	Golf estate
44	1946	Kaplan	2004	Urban development
45	122	Kaplan	2001	Golf estate
46	49	Kaplan	2006	Urban development
47	120	Kaplan	2004	Nature reserve
48	38	Kaplan	2005	Nature reserve
49	1912	Nilssen	2007	Urban development
50	2792	Kaplan	2003	Urban development
51	1941	Nilssen	2005	Urban development
52	1917	Nilssen	2005	Urban development
53	1836	Yates	1999	Nature reserve
54	107	Halkett, Hart	1995	Urban development
55	119	Halkett, Hart	1995	Urban development



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Masters Expert Questionnaires

Name: Jayson Orton

Area of Expertise: Later Stone Age.

Characteristics for human settlement:

Geology:

Distance from ocean: N/B

Distance from fresh water:

Vegetation type:

Slope: Cliffs (seacut caves)

Aspect: Wind related

Other: Shelter (hollow in sand dunes)

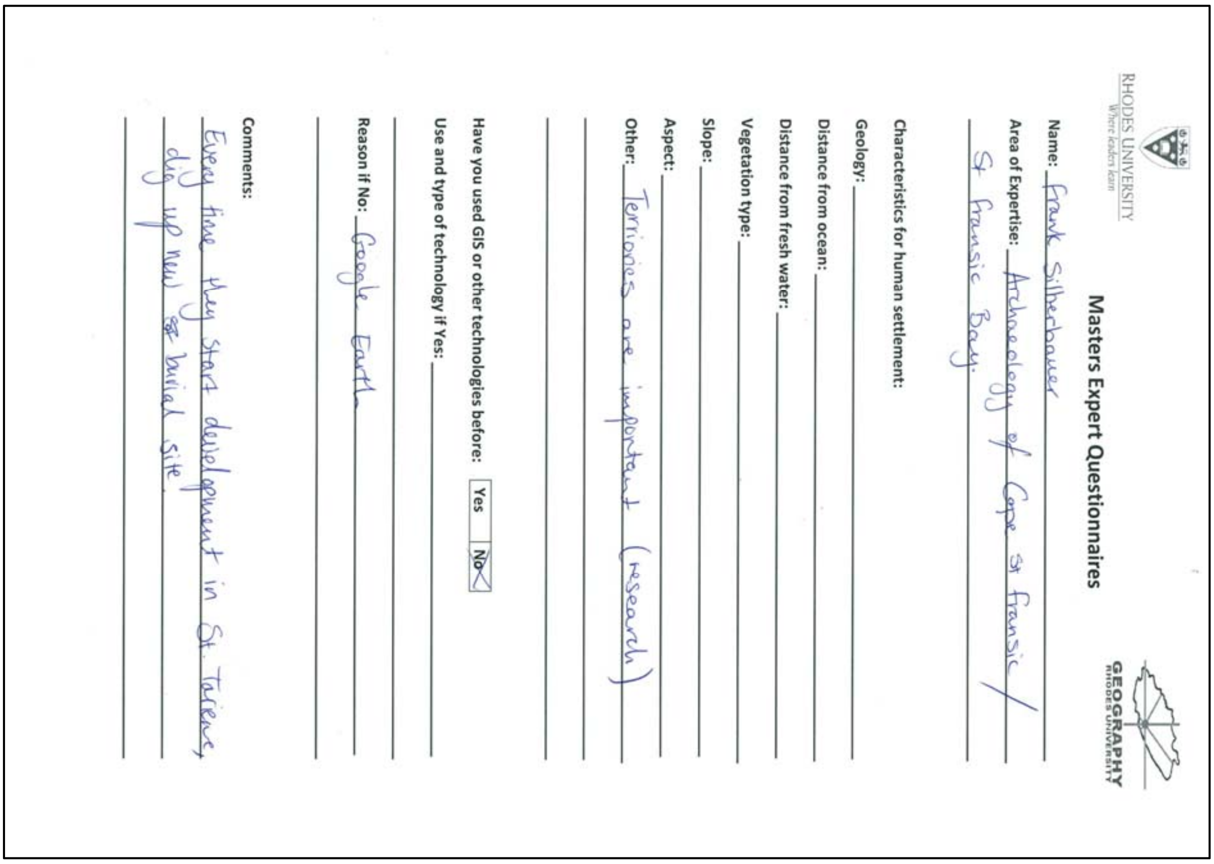
Have you used GIS or other technologies before: Yes / No (No marked)

Use and type of technology if Yes:

Reason if No: Google Earth

Comments:
looking for artifact
Erosion is N/B, under sand

Figure a.1: Expert interview with Jayson Orton (15/10/2013).



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Masters Expert Questionnaires

Name: Frank Silberbauer

Area of Expertise: Archaeology of Cape St Fransic / St Fransic Bay.

Characteristics for human settlement:

Geology:

Distance from ocean:

Distance from fresh water:

Vegetation type:

Slope:

Aspect:

Other: Terrioies are important (research)

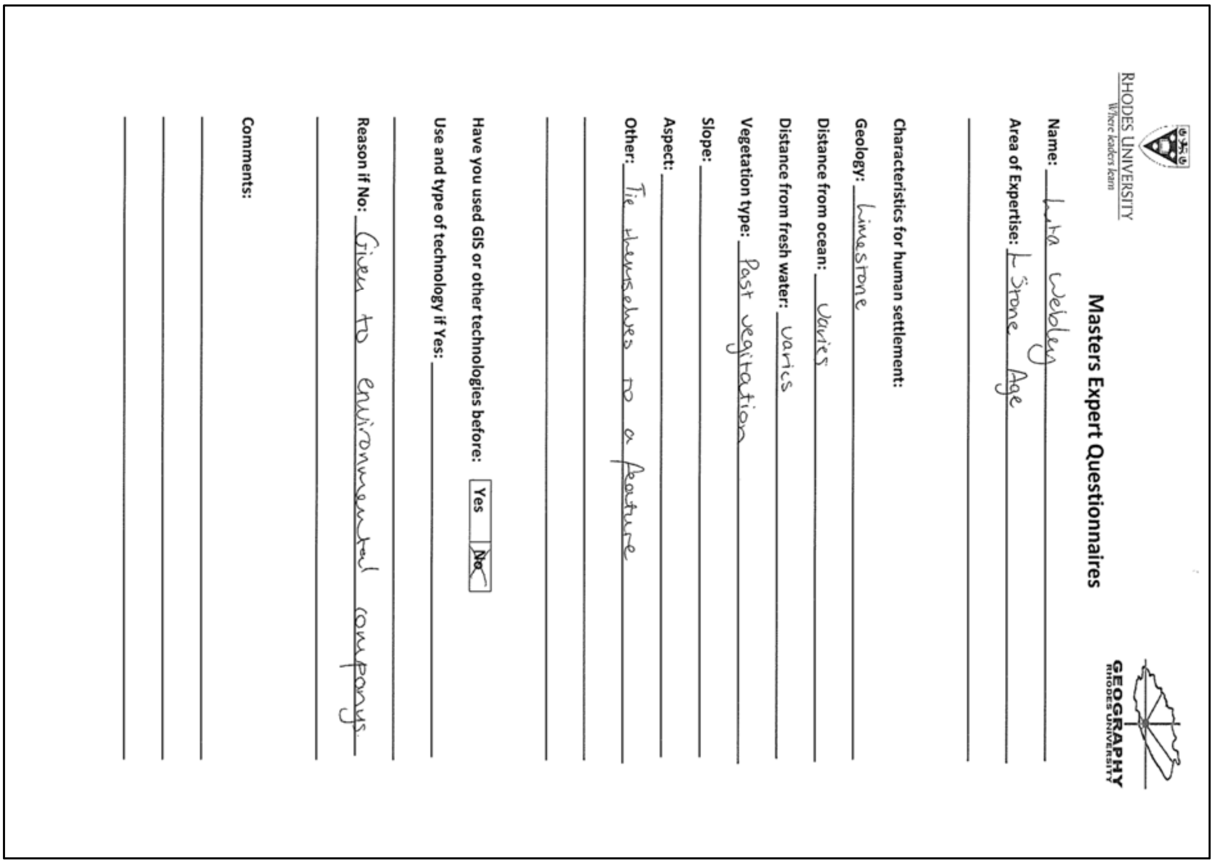
Have you used GIS or other technologies before: Yes / No (No marked)

Use and type of technology if Yes:

Reason if No: Google Earth

Comments:
Every time they start development in St. Tarine,
dig up new burial site.

Figure a.2: Expert interview with Frank Silberbauer (11/09/2014).



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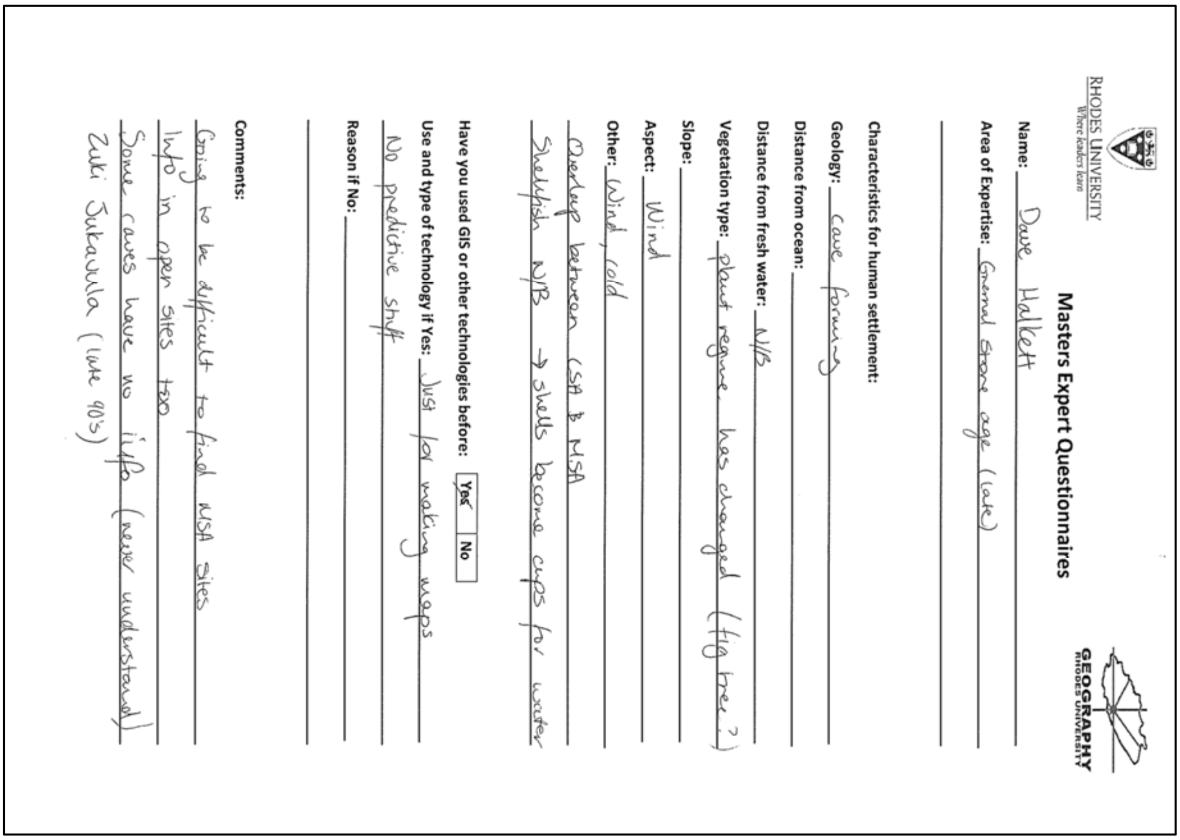
Name: Lita Webley
Area of Expertise: L Stone Age

Characteristics for human settlement:
Geology: Limestone
Distance from ocean: Varies
Distance from fresh water: Varies
Vegetation type: Past vegetation
Slope:
Aspect:
Other: Tie themselves to a feature

Have you used GIS or other technologies before: Yes ~~No~~
Use and type of technology if Yes:
Reason if No: Given to environmental company

Comments:

Figure a.3: Expert interview with Lita Webley (15/10/2013).



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GEOGRAPHY
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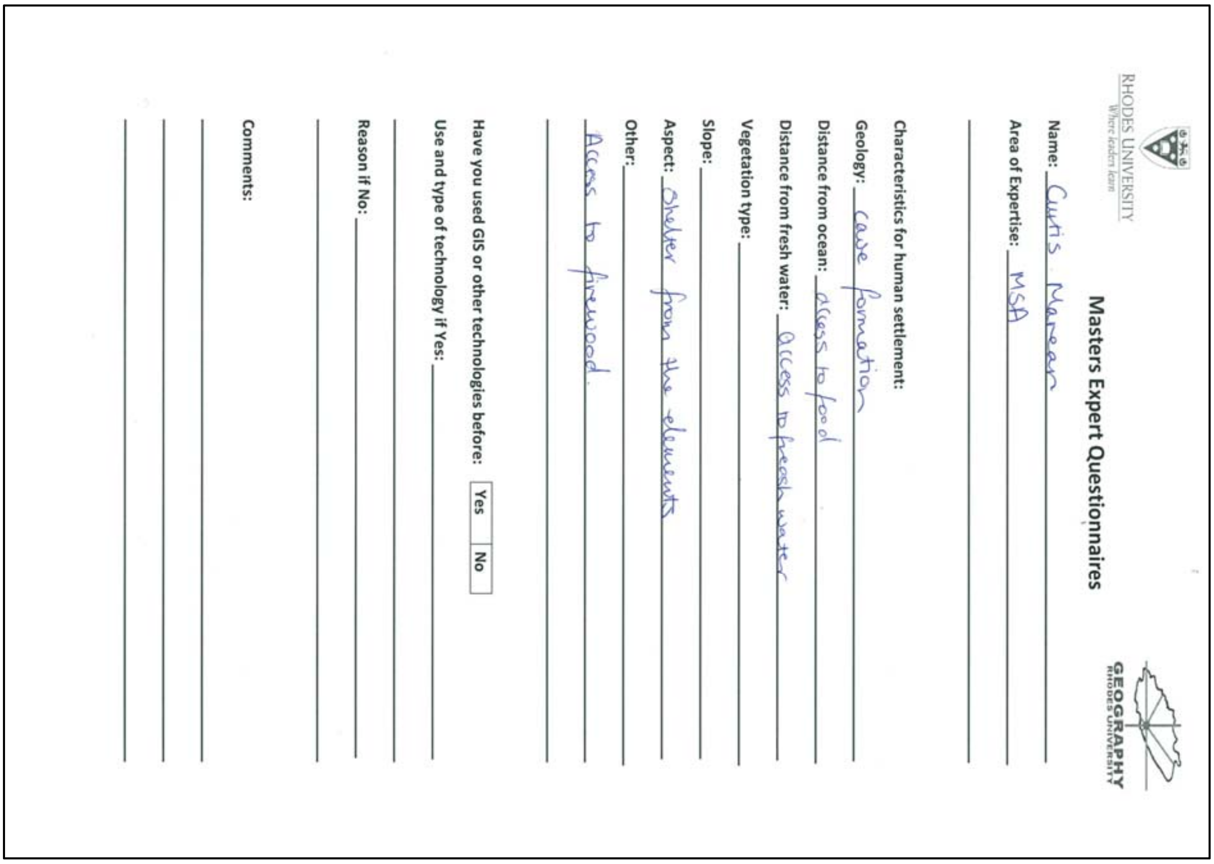
Name: Dave Halkett
Area of Expertise: General Stone age (late)

Characteristics for human settlement:
Geology: cave forming
Distance from ocean:
Distance from fresh water: N/B
Vegetation type: plant regime has changed (fig tree?)
Slope:
Aspect: Wind
Other: Wind, cold
Overlap between LSA & MSA
Shellfish N/B → shells become cups for water

Have you used GIS or other technologies before: ~~Yes~~ No
Use and type of technology if Yes: Just for making maps
No predictive stuff
Reason if No:

Comments:
Going to be difficult to find MSA sites
Info in open sites too
Some caves have no info (never understand)
Ziki Sikawula (late 90's)

Figure a.4: Expert interview with Dave Halkett (15/10/2013).



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GEOGRAPHY
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Name: Curtis Marean

Area of Expertise: MSA

Characteristics for human settlement:

Geology: cave formation

Distance from ocean: access to food

Distance from fresh water: access to fresh water

Vegetation type:

Slope:

Aspect: shelter from the elements

Other: Access to firewood.

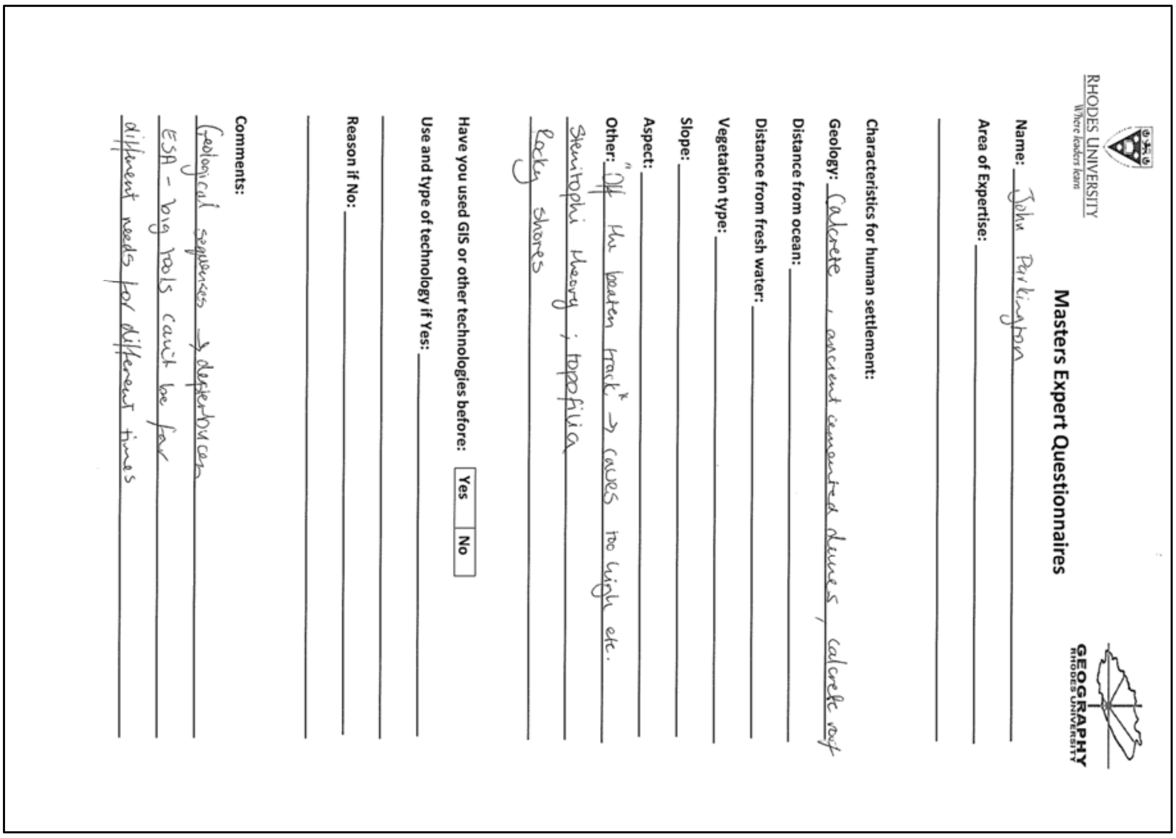
Have you used GIS or other technologies before: Yes | No

Use and type of technology if Yes:

Reason if No:

Comments:

Figure a.5: Expert interview with Curtis Marean (27/03/2014).



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Name: John Parkington

Area of Expertise:

Characteristics for human settlement:

Geology: Calcrete, ancient cemented dunes, calcrete rock

Distance from ocean:

Distance from fresh water:

Vegetation type:

Slope:

Aspect:

Other: "Off the beaten track"* → caves too high etc.
Steinitophi theory; topofilia
Rocky shores

Have you used GIS or other technologies before: Yes | No

Use and type of technology if Yes:

Reason if No:

Comments:
Geological sequences → deeperburner
ESA - big tools can't be far
different needs for different times

Figure a.6: Expert interview with John Parkington (15/10/2013).