BETTER MANAGEMENT THROUGH MEASUREMENT:
Assessing the conditions of coastal archaeological sites using spatial technologies—applied to Blueskin Bay, New Zealand

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ABSTRACT

The world's coastlines are becoming increasingly volatile for archaeological sites. This instability can be primarily attributed to climate change and its associated influence on oceanic processes, which are aggravating already unfavourable conditions for the endurance of coastal sites. Alongside these adverse developments have been rapid improvements in the abilities of scientists to observe, measure, and model the effects of those impacts. For archaeologists, advances in computers and spatial technologies offer the capability of quickly and accurately recording real-world positions of archaeological features across large coastal landscapes. This digitised site information can be incorporated into monitoring projects and spatial analysis, ultimately providing opportunities for improved site management strategies. Although these capabilities have been available for some time, many coastal nations, including New Zealand, have failed to fully implement them widely into site surveys or site management. As such, this thesis presents a three-step approach for assessing the conditions of coastal archaeological sites through a synthesis of documentary research, an in-person site survey, and computer-based spatial analysis. This methodological approach is then applied to Blueskin Bay, a New Zealand-based case study area. Together, the three phases divulged a significant amount of information about the estuary including its past and present site conditions, as well as the trajectories of shoreline change (erosion and progradation), and the possible future impact of rising sea levels across site areas. In addition to the presentation and application of the assessment approach are discussions regarding site management in New Zealand, coastal archaeological site impacts, spatial technologies, and the efficacy and limitations of the presented approach.

KEYWORDS: Blueskin Bay, GIS, GPS, DSAS, LiDAR, Coastal Archaeology, Climate Change, Sea Level Rise, Erosion, ArchSite, Site Management Strategies, Spatial Technologies, Archaeological Site Conditions
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1. The Problem

Coastlines lie in an intermediary zone between society and the untamed environment. The qualities that draw humanity to shorelines, the food resources, ease of travel, and opportunities for enterprise, occur alongside the illimitable presence of the ocean and its associated processes. In this role, the condition of coastlines are often used as a proxy to understand the progress and possible outcomes of the world’s changing climate. Whether through the monitoring of melting icecaps, understanding oceanic carbon capture, or predicting the extent of rising sea levels, the exacerbation and adjustment of oceanic processes to a warming planet has very real implications for humanity and increasingly so (IPCC, 2013). These ongoing concerns have resulted in an outpouring of research by academics relating to the susceptibility of their particular industry or area of academic interest to the effects of those processes (Lovejoy & Hannah, 2005; Pendleton & Thieler, 2005; Goodhue et al., 2012; Thomas-Hope, 2017). Archaeologists are no exception, and arguably for practical reasons (Bickler et al., 2013). Archaeological sites by their very nature typically represent locations that have been relatively stable from their inception until the present. As rising seas continue to erode and inundate coastlines, areas that have long served as repositories of cultural information are at a heightened risk of being degraded or destroyed.

These alarming environmental developments draw attention to the current abilities of archaeologists in New Zealand and elsewhere to manage these and other natural and anthropogenic impacts to sites (Hamel, 1978:2; Walton, 2007:186). While some of the damaging effects of human-based disturbances such as urban development, forestry, and farming can be diminished through continued enforcement of legislative protections (such as the Heritage New Zealand Pouhere Taonga Act, 2014), managing the impact of environmental processes is not always as straightforward. Moreover, there is a growing body of evidence put forth by climate scientists that suggests climate change is exacerbating environmental hazards (IPCC, 2013). For coastal regions this means higher sea levels, increasing regularity of storm fronts, and more damaging storm surges (ibid).

Acknowledgement of these adverse effects on coastlines and their archaeological sites has resulted in the development of management approaches both in New Zealand and overseas (Sharples, 2006; Brooks & Jacomb, 2012; Westley & McNeary, 2014). Some, such as Tony Walton (2007), have deliberated on hazards through a policy-based framework, while others have incorporated computer-based models that pinpoint areas of susceptibility (Goodhue et
In addition to these have been approaches of a more pragmatic nature, incorporating site visitations and community involved coastal monitoring projects (Walton, 2006; Brooks et al., 2008; Dawson, 2015; Jacomb et al., 2015). Throughout all of this literature is the common underlying axiom that effective site management requires a clear, comprehensive, and up-to-date understanding of conditions present at sites.

Currently, information relating to the condition of sites in New Zealand is almost exclusively gathered on a site by site basis, and typically when threat of development mandates assessments or fieldwork (Carter, 2011:219). There are examples of regional studies that have incorporated site condition into their methodology (Hamel, 1978; 2004; Walton, 2006; Carter, 2011:218; Bickler et al., 2013; Jacomb et al., 2015), but the coverage of these represent only a small proportion of New Zealand’s coastline. The New Zealand Archaeological Association's (NZAA) 2006 site upgrade project did provide some updated information concerning the conditions of sites it relocated, but this was not comprehensive enough for significant inferences to be made. Without up-to-date information it is hard to accurately determine rates of degradation, making it difficult to effectively prioritise resources for coastal sites. In examples when salvage excavation has taken place, this has typically occurred under calamitous circumstances when the archaeological community has felt compelled to act (Allingham, 1976; 1986; Hamel, 1980:1; Weisler, 1996; Barber & Walter, 2001). Such decisions are much harder to make for sites impacted gradually over longer timespans. In these situations sites can become incrementally degraded or even completely disappear without management strategies ever having been considered. It is therefore crucial for information relating to site conditions to be gathered and assessed across entire landscapes.

Recent developments in spatial technologies such as Geographic Information Systems (GIS), Global Positioning Systems (GPS), and Light Detection and Ranging (LiDAR) are enabling archaeologists to more accurately measure, model, and manage the effects of oceanic processes on archaeological sites (McCoy & Ladefoged, 2009; Reeder et al., 2012; McCoy, 2017; 2018). These improvements are rapidly improving the ability of archaeologists to consider impacts across larger regions at increasingly fine scales. For site management, such capabilities could facilitate a transition away from reactive and remedial measures towards proactive preparatory steps. While it remains impossible to mitigate harm across all of New Zealand’s archaeological sites, through the utilisation of those technologies, archaeologists are becoming better equipped to manage the future destructive extent of natural and anthropogenic impacts.
Over the next few decades there will almost certainly be an increased integration of spatial technologies into coastal archaeological site management. This thesis will explore some of the practicalities of this pairing through the presentation and application of a coastal assessment approach to a New Zealand based case study area. The specific area chosen for this research is Blueskin Bay, an estuary 20 kilometres north-east of Dunedin in New Zealand’s South Island (Figure 1). While New Zealand has many sections of coastline capable of demonstrating the applicability of this methodological approach, Blueskin Bay was particularly well-suited for the following reasons: 1) Blueskin Bay is represented by a diverse range of different coastal landform types, including dune systems, mudflats, floodplains, and cliff faces; 2) the estuary contains a large number of archaeological sites that are known to be affected by numerous site impacts (determined through information in Site Record Forms (SRF)); and 3) due to its relatively close proximity to a population centre, Dunedin, the area is well-covered by both historical aerial imagery and LiDAR. These qualities allowed the presented approach to be trialled and tested across a varying mix of different site areas, teasing out the benefits, limitations, and implications of an integration of spatial technologies into more traditional means of site management.

Figure 1. The location of the Blueskin Bay case study area.
1.1 AIMS AND OBJECTIVES:

It is exceedingly difficult to effectively manage archaeological sites without a clear understanding of existing site threats or a baseline upon which to measure future deterioration or improvement. If such a proposition is true, the acquisition of such data plays a vital role in the future endurance of coastal archaeological sites. Presently, information relating to the condition of coastal sites in New Zealand is typically retrieved through unsystematic one-off site assessments or relies on outdated regional site surveys. This thesis will begin to rectify this paucity of up-to-date regional site information through the presentation of an approach that synthesises documentary research, an in-person site survey and assessment, and data collected and analysed through the use of spatial technologies. Combining these three methods of investigation will allow the condition of the case study area, Blueskin Bay, to be considered from the past to the present, with the trajectories of rising sea levels cast prospectively into the future. Although this methodological approach will be applied to a single New Zealand case study area, the methods employed are not specific to any given shoreline and could be applied throughout New Zealand or overseas.

Pursuing the core aim of establishing a means of more accurately understanding coastal site conditions, this thesis will:

1. Describe some of the natural and anthropogenic impacts that affect coastal archaeological sites in New Zealand
2. Visit and assess recorded archaeological sites present along Blueskin Bay's coastline
3. Create a GIS database of visible cultural features present at each visited site
4. Use GIS along with spatial technologies such as georeferenced aerials, differential GPS, and LiDAR to measure rates of shoreline change and model the predicted impact of SLR
5. Provide some site management recommendations for the Blueskin Bay case study area
6. Evaluate the strengths and limitations of the methodological approach presented during this thesis
1.2 SUMMARY OF CHAPTERS:

Chapter Two will provide a background that covers New Zealand's legislation and archaeological site management, the natural and anthropogenic impacts that affect coastal archaeological sites, the use of spatial technologies to track and predict the impact of erosion and SLR, and a physical description of the Blueskin Bay case study area. Each of these topics will be discussed in turn to provide a context for this thesis and its applied methodological approach.

Chapter Three will outline the specific methods employed in this thesis including documentary research, a site survey and assessment, and the use of spatial technologies to measure and model site impacts.

Chapter Four will present the results of the Blueskin Bay assessment. This will be split into three sections, each focusing on one of the three employed methodological strategies.

Chapter Five will summarise and discuss the results of the Blueskin Bay assessment while presenting some management suggestions for its archaeological sites. Additionally, the strengths and weaknesses of the presented methodological approach will be discussed, followed by some thoughts regarding the current and future direction of site management in New Zealand and finally, some concluding remarks.
2. The Context

In the previous chapter several interconnected themes relating to site impacts, conditions, and management were briefly introduced. Ultimately those topics coalesced into a single overarching problem: In light of a coastal environment that is rapidly changing, how can archaeologists effectively manage archaeological sites without knowing their current conditions or spatial extent? While the methodological approach presented later in this thesis will address aspects of that problem, the use of those techniques and modes of analysis are not without precedence. This research draws upon a large body of work carried out by archaeologists, academics, and scientists from a broad range of different disciplines. As such, this chapter will outline some of that previous research, while providing a context for the methods applied to the case study area presented later in this thesis. The location of Blueskin Bay and the author prompts the need for a review of New Zealand specific legislation and archaeological site management. Although there will be an inevitably strong New Zealand focus throughout this research, the application of the methodological approach presented here is not geographically restricted to any specific coastal area. With that said, this chapter will take place through sections that focus on: Archaeological site management in New Zealand, natural and anthropogenic impacts to coastal sites, measuring and modelling coastlines and archaeological sites using spatial technologies, and the physical setting of Blueskin Bay; followed by a brief summary.

2.1 ARCHAEOLOGICAL SITE MANAGEMENT IN NEW ZEALAND:

Before this thesis progresses any further it is first pertinent to define some of the general terms and concepts used relating to archaeological sites and their management in New Zealand. While the exact definition of an archaeological site may vary between countries, current legislation in New Zealand (Heritage New Zealand Pouhere Taonga Act 2014) defines an archaeological site as:

Any place in New Zealand, including any building or structure (or part of a building or structure), that was associated with human activity that occurred before 1900 or is the site of the wreck of any vessel where the wreck occurred before 1900; and provides or may provide, through investigation by archaeological methods, evidence relating to the history of New Zealand (HNZPTA, 2014: Section 6).

This act also provides blanket protection to any such sites from being modified or destroyed unless an authority from Heritage New Zealand is requested and granted (unless it is an existing pre-1900 building, which can be modified, but not wholly demolished). In cases
where authorities are granted any work on sites must be overseen or undertaken by an archaeologist who meets the criteria defined in Section 45 of the legislation, which includes having a minimum of 26 weeks of field experience, a Masters degree in archaeology, and a minimum of three reports relating to the authority process (HNZPTA, 2014: Section 45). The legal protections offered through the legislation apply to any archaeological site in New Zealand, regardless of whether or not it has previously been encountered or recorded (ibid: Section 42). Offences are enforced through fines of up to $150,000 for individuals or $300,000 for public private entities (ibid: Section 87). The 2014 legislation represents a continuation from previously enacted acts including the Historic Places Act 1954, Historic Places Amendment Act 1975, Historic Places Act 1980, and Historic Places Act 1993. Of those, the Historic Places Amendment Act 1975 is particularly noteworthy as it was the first to provide a definition for an archaeological site in New Zealand and blanket statutory protections.

Alongside the enactment of those legislative acts were the founding and development of two major New Zealand based archaeological organisations: New Zealand Historic Places Trust (NZHPT) and the NZAA. Founded in the mid-1950s, both organisations had a strong focus on the recording and preservation of New Zealand’s archaeological sites, with the former tasked with the maintenance of a site register and management of sites, and the latter as an association of archaeologists (Walton & O’Keeffe, 2004:267). In 1957, NZAA initiated the Site Recording Scheme (SRS), which was a paper-based recording system for information relating to archaeological sites (Walton, 1999:ix). Those records included drawings, photographs, field notes, and a standardised form that collected information such as the site’s location, description, and condition. Today these documents are referred to as Site Record Forms (SRF). In 1975, the Historic Places Amendment Act 1975 legally recognised those listed sites and established a governmentally protected register known as the Central Index of New Zealand Archaeological Sites (CINZAS) (HPAA 1975: Section 9g).

In addition to mandating protection for archaeological sites, the passage of HPAA 1975 also initiated a period of intensified site recording in New Zealand (Walton & O’Keeffe, 2004:269). This work was funded by groups such as the NZHPT, the New Zealand Forest Service, and the Department of Lands and Survey and lasted from 1975 to 1987 (Walton, 1999:2). During this time numerous regional site surveys took place with examples including the surveying and recording of sites along the majority of the Otago coastline (Croad & Huffadine, 1976; Hamel, 1977; Teal, 1977; Anderson et al., 1978; Harsant, 1980), as well as many other such instances across New Zealand (Ritchie, 1977; Vincent, 1980; Jones, 1985; Furey, 1987). Following 1987 there were still moderate levels of site recording and excavations, but funding for both
became less prevalent due to governmental restructuring (Walton, 1999:117; Walton & O’Keeffe, 2004:271). By 1999, the SRS had an index of over 50,000 recorded archaeological sites (Walton, 1999:3). It was around this time that the NZAA council began a decade long project of transitioning to a digitalised version of the SRS called ArchSite (www.archsite.org.nz), which went online June 2009 (Figure 2) (Law, 2007:59; NZAA, 2009).

Figure 2. The ArchSite web map, focused on the Otago Harbour, adjacent to Dunedin, New Zealand. In this example red stars are sites that are still pending addition to the SRS (map accessed 7th March 2018 www.archsite.org.nz).

During the digitalisation of CINZAS and SRS site records, all grid coordinates (easting and northing) were converted into the New Zealand Transverse Mercator (NZTM) projection using the NZGD2000 datum (Law, 2007:61). This resulted in a publicly accessible web map that displays (at a scale purposely limited for nonregistered members) all of the SRS’s recorded sites, which at time of writing (February 2018) totalled 69,853. Furthermore, once registered for ArchSite, an up-to-date version of the index is available for download and can be imported into GIS mapping programs such as ArcMap where it can be used for spatial analysis or resource management (Walton & O’Keeffe, 2004:276; Carter, 2011; Hil, 2016; McCoy, 2018).
It was around the time of the SRS digitisation in 1999 that concerns were raised within NZAA’s council about the quality of information for recorded sites, particularly regarding the accuracy of site coordinates (Law, 2007:59). The eastings and northings collected for archaeological sites between the 1950s and 1970s were typically within approximately 100 metres or more of where a site may have actually been located and in many cases those inaccuracies were further compounded by their conversion into metric equivalents (Walton, 1999:23; Law, 2007:61). As such, between 1999 and 2007 the NZAA Archaeological site upgrade project was initiated, whereby all recorded archaeological sites within New Zealand were revisited and ideally given an updated location using a hand-held GPS. Overall, while the project improved the accuracy of the ArchSite database, it was not comprehensive and in cases where archaeological sites were not relocated in the field (or presumed destroyed) they were not given updated site coordinates (Bickler et al., 2013:14). Moreover, of the archaeological sites that were relocated, the amount of information recorded in regards to a site’s condition, description, or location ranged greatly in terms of quantity and quality. For those reasons, while the NZAA database is an invaluable tool to archaeologists in New Zealand, its use comes with necessary caveats relating to the accuracy of site information and location.

The combination of a centralised site register and protective legislation have greatly improved the ability of archaeologists to manage human-based impacts to sites such as development, forestry, and fossicking. However, in cases where impacts to sites are not anthropogenic, the responsibility to conserve and manage archaeological sites becomes less clear. All archaeologists who become NZAA members agree to follow a code of ethics that were endorsed by the association in January 1999 (NZAA Code of Ethics, 1999). These ethical guidelines were largely adopted from the Society for American Archaeology’s Principles of Archaeological Ethics and the Society for Professional Archaeologist's 1976 Code of Ethics. In terms of protecting and conserving archaeological sites from natural impacts the most relevant of the nine upheld principles is number one, which is titled 'Stewardship':

The archaeological record, that is, in situ archaeological material and sites, archaeological collections, records and reports, is irreplaceable. It is the responsibility of all archaeologists to work for the long-term conservation and protection of the archaeological record by practising and promoting stewardship of the archaeological record. Stewards are both caretakers of and advocates for the archaeological record. In the interests of stewardship, archaeologists should use and advocate use of the archaeological record for the benefit of all people; as they investigate and interpret the record, they should use the specialised knowledge they gain to promote public understanding and support for its long-term preservation. (NZAA Code of Ethics: P1)
Although all NZAA members agree to uphold these ethical principles, they are not legally binding or largely enforceable. It is therefore up to individual archaeologists or other stakeholders (such as local iwi, landowners, or members of the community) to report incidences where damage or destruction to archaeological sites is imminent so the correct management procedures can take place. In any situation where a site must be modified in order to mitigate harm a request to HNZPT in the form of an Emergency Authority must take place \textit{(HNZPT, 2014: Section 61)}. As is the case with all authorities, any modifications to the fabric of the archaeological site (or in the case of a rescue excavation, destruction) must be overseen by an archaeologist who meets the requirements of \textit{HNZPT 2014’s Section 45}. This process occurs most readily in situations where a site is being impacted severely and visibly over a short duration. In cases where damage to an archaeological site occurs incrementally over decadal timespans site management options become less well-defined.

Due in part to concerns over the lack of available regional information about archaeological sites, over the past ten years there has been a renewed interest in large scale site surveys that consider site conditions. One of the best New Zealand examples of this comes from Southern Pacific Archaeological Research’s (SPAR) Southland Coastal Heritage Inventory Project (SCHIP) \textit{(Brooks et al., 2008)}. From 2004 to 2008 their team surveyed approximately 400 km of the Southland coastline, revisiting previously recorded archaeological sites and recording any new sites they encountered. If erosion was found to be affecting an archaeological site area the team coupled aluminium datum pegs with GPS to track the shoreline retreat over time. In addition to discovering and recording 109 new archaeological sites, this project also determined that, out of the 228 Southland sites they assessed, 157 or 69\% were being impacted by some form of erosion. Other recent New Zealand-based surveys include the monitoring of coastal middens at Queen Elizabeth Park along the Kapiti coastline \textit{(Walton, 2006)}, an MA undertaken by Matt Carter \textit{(2011)}, which surveyed and recorded new sites within the Otago Harbour, a GIS-based risk assessment of archaeological sites located in the Whangarei District \textit{(Bickler et al., 2013)}, and another coastal survey project by SPAR carried out at Mason Bay on Stewart Island \textit{(Jacomb et al., 2015)}. Overall, these projects are beginning to identify the scale at which impacts such as erosion are affecting New Zealand’s archaeological sites. The next section will now outline how such impacts affect coastal sites and some of the ways those effects can be mitigated.
2.2 NATURAL AND ANTHROPOGENIC COASTAL SITE IMPACTS:

Broadly speaking, all impacts that affect coastal archaeological sites are either natural or anthropogenic. However, from those two categories individual impacts can be further classified into additional sub-groups, such as those that cause incremental degradation and those that are caused by one-off events. Examples of incremental threats to sites include tidally-induced erosion, vehicular damage to sites through tracks, and gradually rising sea levels. Impacts that occur through one-off events include tsunamis, earthquakes, or site destruction through unauthorised land development. While each of those two sub-categories are destructive to sites, the former can usually be measured, managed, and mitigated while the latter are less defensible. As such, this background section will focus primarily on impacts classed as incremental, thus manageable. Of those threats, erosion and SLR will be given the greatest focus due to the scale at which they operate and their overall prevalence (Walton, 2007:187; Daly, 2011:6).

2.2.1 Erosion:

Erosion is among the most commonly reported impacts to coastal archaeological sites in New Zealand (Hamel, 1978:3; Walton, 2007:187; Bickler et al, 2013:37). However, as a process, erosion has a tendency to be over-simplified or applied as a blanket catch-all impact that affects coastal sites. Clear distinctions can and should be made between erosion caused by tidal, fluvial, aeolian, and gravitational processes. Such differentiations are important as each form necessitates differing methods of mitigation or management. Furthermore, in-section midden sites, which are a very common site type in New Zealand, are typically, by their very nature, experiencing erosion (Hamel, 1978:2). It is therefore useful for further delineations to be made in order to properly understand their condition both collectively (relative to all other midden sites) and singularly (on a site by site basis).

Tidal Erosion:

The first form of erosion previously listed, tidal, represents the disintegration and removal of coastal substrate through wave action (MfE, 2008:32-40). For affected archaeological sites this process is most pronounced during a combination of a spring tide and storm surge, but its effects can also take place year round through the gradual accumulative effects of lapping waves (Lumsden, 2003:20; Davidson-Arnott, 2010:40). This process can eventually remove both a site and the ground it once occupied (Figure 3). Fundamentally, tidally-induced erosion is a physical manifestation of energy transference from the ocean to a coastline.

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1 This statement is particularly in reference to SRFs updated during the NZAA site upgrade project, which for many coastal sites in Otago simply state under ‘Condition Description’: “Site not located, perhaps due to erosion.” For examples see sites: I45/18, H45/14, I45/37, I45/68, and numerous others in vicinity.
The origin of this tidal energy can be traced to numerous sources such as winds and tectonics, but primarily it is derived from astronomical forces (Lumsden, 2003:20). As the Moon orbits the Earth and both orbit the Sun, those gravitational forces pull and push the Earth's surface, which eventually reach the coast in the form of waves (Pethick, 1984:47-56). The impact those waves have on a given section of coast is determined by the angle and depth of the sea floor, as well as the shape and geomorphic composition of the coastline (Davidson-Arnott, 2010:40). The end result for areas experiencing erosion is the removal and gradual breaking down of consolidated coastal material into finer parts.

Figure 3. North facing photo of the Firman Joinery Factory in Oamaru. This was taken June 2007, soon before a large proportion of the building disappeared into the Pacific Ocean (courtesy Otago Daily Times; published 27, June 2007).

When a coastal area is eroded the resulting sediment is transported, either in close vicinity or further down current where it can build up through a process of accretion. The processes of erosion and accretion are often dynamic and can even occur cyclically whereby a given region may retreat for a decade or more before undergoing a period of progradation (Hamel, 1978:3; Toynes et al., 2015). This system and the various mechanisms that contribute to it are complex, and its intricacies are well beyond the scope of this background section. However, in terms of its implications for coastal archaeological sites, the main point of focus is that tidal erosion is a dynamic process. When elements of a coastal system are adjusted, such as rising sea levels, changes in sediment budgets, or the reshaping of a coastline through either natural or anthropogenic means, tidal erosion will often take place at an increased rate.
until a new point of equilibrium is reached or, in the case of soft-shore regions, harder substrate (Lumsden, 2003:20). It is thus important to be acutely aware of how a given coastal area of interest has progressed over time, what elements are contributing to its levels of erosion or accretion, and how it might respond to future changes.

In terms of management, tidal erosion is notoriously difficult and expensive to meaningfully mitigate (Williams et al., 2017). Those tasked with its management have the following options (Rupp-Armstrong & Nicholls, 2007:1421):

1) Do nothing: Monitor the erosion's progress;
2) Hold the line: Use hard-defences such as sea walls and armouring or soft-defences such as dune stabilisation or beach replenishment in an attempt to halt the ocean's progress;
3) Advance the existing defence line: Actively produce a buffer zone between the ocean and the coast through methods such as reclamation or offshore structures;
4) Managed realignment (or managed retreat): Work with erosion through the use of engineering or ecological solutions to limit its destructive extent.

Each strategic approach has its positives, challenges, drawbacks, and associated costs. Due to the complexity and importance of effectively managing tidal erosion it is an area of research that has been covered extensively elsewhere (National Research Council, 1990; Scottish Natural Heritage, 2000; French, 2001; Williams et al., 2017). Possible options for managing its effects include hard coast defences such as sea walls, groins, breakwaters, and armouring (French, 2001:47; Rouse & Goff, 2003:298; Dickson et al., 2007:3), soft defences such as beach nourishment (Komar, 1998:500; Dean, 2002), eco-friendly approaches including the encouragement of saltmarsh species in intertidal zones (Luisetti et al., 2011:213; Esteves, 2013), or the use of native and non-native plant species to stabilise dune systems (Hilton, 2006:116; Jones, 2007:30). This is an area of archaeology where it is particularly advantageous to take a holistic approach that incorporates the expertise and research of coastal geomorphologists and geographers. In New Zealand, regional councils are a useful source of information relating to erosion management, and are also responsible for issuing permits to anyone seeking to significantly modify coastal areas as per the Resource Management Act 1991 (Jones, 2007:32).

River Erosion (Fluvial):

Rivers are often situated at the junctures of resource zones and have long provided humanity with access to drinkable water, fresh and saltwater species of flora and fauna, and ease of inland travel (Anderson & Smith, 1996:360; Hamel, 2001:72). Due to the large proportion of
archaeological sites typically located within their vicinity, the expansion of river banks and the meandering of rivers across the landscape is of significant management concern. Fluvial erosion is most active during and after storm events, in response to upstream modifications to water flow (such as changes in river infrastructure), or when there have been localised changes in bank vegetation (Bull, 1997:1110; Bridge, 2002). While coursing waters do cause river banks to disintegrate, this process is greatly expedited by transported sediments and debris. At high velocity, materials such as gravels and plant matter can cause immediate abrasion to riverbanks. However, more concerning and perhaps less intuitively, finer grained silts and clays can cause even greater erosion to banks through their gradual accumulation at river bends (Rinaldi & Darby, 2008). Over time, this collected sediment can redirect a stream or river’s currents eventually changing its course into an entirely new direction (Figure 4) (Jones, 2007:30). As with most forms of erosion, establishing a river’s trajectory and the trends of any localised meandering is an important prerequisite to any subsequent modes of mitigation or management. Once such trends are established bank protection or river training are two possible options for mitigation, but all modifications to river systems should take place through relevant regional councils (Jones, 2007:31).

Figure 4. Diagram showing some of the dynamics of fluvial erosion and river meandering (image taken and modified from: Earth Science World Image Bank, http://www.earthscienceworld.org/images).
Wind Erosion (Aeolian):

While wind erosion can affect any archaeological feature or deposit exposed to air, its impact is most pronounced when sediments making up the fabric of the site are fine and dry (Livingstone, 1996:2). The impact is particularly concerning from a taphonomic perspective as its effects can confuse site contexts and deflate multi-layered dune sites into a single consolidated cultural layer (MacInnes et al., 2014:5). If enough time passes between periods of wind deflation its effects can be difficult to identify and are thus dangerous to site interpretation (Rick, 2002:829). Wind erosion can also become self-perpetuating when mobile sands bury and kill previously stabilising vegetation, leaving dune systems unprotected and vulnerable to further degradation (Jones, 2007:30). Methods of intervention include the use of wind break fabrics to control sand movement and the use of vegetative planting regimes (ibid:30).

Landslides (Gravitational Erosion):

Landslides, also known as slope failure or mass wasting, can completely destroy coastal archaeological sites in an instant. This process is commonly triggered by earthquakes or heavy storms along areas that have previously been compromised through track or road cuttings (Einstein, 1997:25-50). While discrete landslide events can occur, the impact typically affects a given slope incrementally and repeatedly (Violante, 2009:5). It is thus useful to document the frequency, degree, and cause of landslides in an area in order to manage its effects on any archaeological sites located there. In terms of mitigation Kevin Jones (2007:32) suggests constructing retaining walls along road cuts and back filling them where possible, improving water drainage, and stabilising susceptible slopes with adequate vegetation. In cases where slopes are large and the danger of slips is significant, engineering advice should be sought.

2.2.2 Sea Level Rise:

From 1901 to 2010 sea levels across the globe rose approximately 190 mm, which is an average rate of 1.7 mm per year (Figure 5) (Church et al., 2013:1139). However, from 1993 to 2013 that average rate was 3.4 mm per year (ibid). In terms of causes, anthropogenic-based climate change is a primary driver of such elevated rates, but rising sea levels are also part of naturally occurring cyclical geomorphic processes (Marcos & Amores, 2014). As greenhouse gas emissions continue to warm average global temperatures, land-based ice sheets will melt at increasingly high rates causing the amount of water circulating in the planet’s oceans to grow (Bird, 1996:87-89). This added heat is also being absorbed by the ocean, which causes the water to expand and inflate sea levels further still (Raper et al.,
1996:19). Naturally there has been increasing concern around the world about the implications for such trends and how cities, infrastructure, and areas of cultural significance might be affected in the near future (Goodhue et al., 2012; Bickler et al., 2013; IPCC, 2013; Bell et al., 2017).

![Figure 5. Global Mean Sea Levels (GMSL) from 1880 to 2014 (image courtesy: CSIRO, www.cmar.csiro.au).](image)

Predicted rates of SLR vary across the globe due to differences in gravitational forces and localised climatic zones (Raper et al., 1996:12). For New Zealand, current predictions show that by 2100 tides may rise by as much as one metre from 1986 to 2005 global averages (MfE, 2016). As these SLR predictions are based on models that factor different rates of greenhouse gas emissions and the efficacy of proposed decarbonisation efforts, scientific bodies such as the Intergovernmental Panel on Climate Change (IPCC) have best and worst case scenarios regarding these potential rates of change. For example, if rapid global decarbonisation does occur alongside reduced emissions then SLR may be limited to 0.3 metres by 2100 rather than the aforementioned one metre (MfE, 2016). Higher tides will inevitably mean increased occurrences of inundation, larger storm surges, increased rates of coastal erosion, and a reduced effectiveness of coastal defences (Bickler et al., 2013:11).

Like climate change, SLR represents an exacerbation of impacts that are already present along coastlines such as tidal-erosion and inundation (Walton, 2007:187). For erosion, higher water levels cause waves to break closer to shorelines, which accelerates incidences of retreat (Leatherman, 2001:189). These effects are most pronounced during storm surges,
where sea levels temporarily swell above already elevated heights. While erosion causes land substrate to become displaced and transported, inundation represents the repeated and eventually permanent submergence of low-lying land by water (Bickler et al., 2013:20). Inundation does not necessarily displace shoreline sediments, but as sea levels reach further inland increased rates of erosion occur in conjunction along affected areas (Leatherman, 2001:192). Once water permanently submerges an archaeological site, it becomes more difficult to investigate it or meaningfully mitigate any further harm. Additionally, repeated submersion by saltwater can cause dramatic transformations along site areas, converting vegetation such as pastoral grasses into saltmarsh plant species (Esteves, 2013:933). Alongside these effects, changes to soil salinity can also degrade subsurface cultural deposits (Walton, 2007:189). Finally, as sea levels encroach on new inland areas intertidal animals such as crabs and shellfish can follow suit, damaging archaeological sites through burrows or other alterations to substrate (ibid).

In terms of mitigation, there are currently numerous intergovernmental and scientific bodies examining and measuring local and global trends of SLR (IPCC, 2013). Even in best case scenarios, sea levels will rise and will increasingly affect coastal areas and their archaeological sites. Currently, meaningful mitigation of harm to coastal sites is best achieved through a combination of policy change (in regards to greenhouse emissions) and the same modes of management introduced in the previous section on tidal-erosion. Understanding where, when, and how rising sea levels are likely to impact specific coastal sites will enable archaeologists to make better and more informed decisions regarding possible management strategies.

2.2.3 Other Natural Coastal Site Impacts:

In addition to erosion and SLR are a few other natural impacts that can be defined as incremental, which include:

- Weathering caused by wind, rain, sun (Campbell, 2005)
- Gradual rot, rust, and general decay (particularly for built heritage) (Wilkes & Page, 2004)
- Vegetation by unfavourable plant species (such as through root damage or upturned trees) (Jones, 2007:33-44)
- Animal activity including burrowing, tramping, gnawing or other related disturbances (Jones, 2007:68)

These impacts are typically localised and affect areas on a site by site basis. As with all threats classed as incremental, effective management and mitigation requires monitoring the
progress of the specific impact and then following best practice procedures. Examples of this could include removing saplings of unfavourable plant species growing close to historic buildings, treating areas with woodworm or rot, and limiting access to site areas from disruptive animal species (Wilkes & Page, 2004; Jones, 2007).

2.2.4 Anthropogenic Coastal Site Impacts:

Besides the impact that humanity is having on archaeological sites through climate change and its related processes, there are numerous other human-related impacts that affect coastal archaeological sites. Currently in New Zealand, of those impacts, urban development, forestry, and farming take place on the largest scales, while site threats such as vandalism, fossicking, pedestrian traffic, and stock trampling tend to be more localised (Jones, 2007; Bickler et al., 2013:2; NZTA, 2015). Although systemic fossicking caused significant damage to archaeological sites from the middle of the nineteenth century until the second half of the twentieth century, this impact has become greatly reduced since the 1970s (Hamel, 2001:52; Samson, 2003). The lessening of this impact can be attributed primarily to the passage of legislative protections starting with HPAA 1975, but also through changes in public attitudes (Hamel, 1978:5). Those same legislative protections have also worked to better manage the effects of development, farming, and forestry on sites. While coastal archaeological sites are still being greatly affected by those impacts, the role of the legislation is to strike a balance between contemporary land use needs and the preservation of national heritage (Walton & O’Keeffe, 2004:274). As long as landowners, farmers, and developers abide by the relevant statutory requirements (HNZPTA 2014), the degradation of New Zealand’s coastal sites will continue to be unfortunate, yet managed.

Other incremental human-related impacts to sites such as pedestrian traffic along walking tracks or the movement of stock across site areas are usually quite easy to mitigate, but have to be observed before any changes in specific land uses can take place. Kevin Jones (2007) offers detailed guidance regarding managing such impacts throughout Caring for archaeological sites: Practical guidelines for protecting and managing archaeological sites in New Zealand.
2.3 ASSESSING COASTLINES USING SPATIAL TECHNOLOGIES:

There is a growing need for archaeologists and those from other disciplines to better understand the scale and extent of impacts affecting coastal areas. While the threat posed by impacts such as erosion and SLR are by no means novel, as climate change continues to exacerbate their effects, avenues for proactive management are in danger of being replaced by remedial measures. Bridging the divide between uncertainty and action are two approaches used for deducing the potential effects of impacts: measuring and modelling. These can either be used individually or in unison to determine how environmental or anthropogenic processes have previously affected coastal areas or how they might affect those areas in the future. In terms of understanding site conditions, measuring and modelling are essentially synonymous with the terms ‘tracking’ and ‘predicting.’ In recent years the development of spatial technologies such as differentially corrected GPS, LiDAR, and GIS have significantly improved the speed and accuracy at which archaeological sites can be recorded and the impacts affecting them mapped. Moreover, the integration of spatial technologies into site management are also allowing archaeologists to assess recorded sites on larger scales, faster, and through desk-based means. This section will provide information about those technologies including some of their developmental history and their applications, both for assessing impacts to coastal areas and their archaeological sites. While the potential scope of this background section is considerable, it will instead be focused primarily on using spatial technologies to measure the effects of coastal erosion and model predictions of SLR on coastal areas. Doing so provides a context for the methodological approach presented in the following chapter.

2.3.1 Measuring Shoreline Change:

It is quite likely that some field-based methods of measuring shoreline change through erosion predate western civilisation. However, it is only within the past 100 or so years that maps and aerial imagery have been of a high enough resolution or accurate enough to where such measurements could be carried out reliably using desk-based means (Moore, 2000:113). Before the first vertical black and white aerial photos were taken in the 1920s the most authentic representations of shorelines were recorded through hand-drawn cadastral plans and topographic maps (Anders & Byrnes, 1991). Due largely to the needs of military reconnaissance, during the Second World War there were dramatic improvements in aerial imagery capture. These advances overcame many of the technological and methodological hurdles involved in collecting vertical high resolution images capable of being used for mapping and measurement purposes (Anders & Byrnes, 1991:21). Some examples of these
impediments included lens distortion and film deformation, as well as inconsistencies in airplane tilt and altitude during image capture (Thieler and Dansforth, 1994:551).

By the 1960s aerial photographs began being used by coastal geomorphologists to interpret shoreline change through paper-based measurements (Moffitt, 1969; Stafford, 1971; Anders & Byrnes, 1991:20). From then on techniques for measuring erosion through imagery have continued to improve and have been increasingly applied to coastlines around the world. Two early examples were undertaken along New Zealand's coastline by Jeremy Gibb (1978) and David Nicholson (1979). Gibb’s assessment incorporated nineteenth century cadastral plans and aerial images dating from 1934 to compare the difference in high-water marks across 471 New Zealand coastal locations. He achieved this by measuring and comparing the distances of shorelines from a baseline established between two common control points found in each printed image (Gibb, 1979:431). The second New Zealand example, by Nicholson (1979), used tracing paper on top of cadastral plans and aerial images to track the movement of vegetated shorelines between 1863 and 1979 at Purakaunui and Long Beach (just north of Dunedin, New Zealand). In this case, Nicholson used rock formations and unchanged cliff edges to align the respective shorelines at the required scales (Single, 2015:12). While each study employed differing methods of aerial alignment and measurement, their outcomes proved the value of the general approach for New Zealand coastlines.

The development of digitisation instruments such as the Map-O-Graph and Zoom Transfer Scope introduced some of the first digital spatial technologies to the shoreline change tracking process (Anders & Byrnes, 1991:23). These tools and the techniques associated with them allowed printed maps or aerial images to be traced and imported into computer programs (ibid). Once digitised, traced shorelines could be converted into a required scale, then be measured and compared using perpendicular measurement transects (Dolan et al., 1978). By the 1980s, this process had developed to the point where aerial images could be imported directly into a computer where they could be assigned spatial coordinates, traced, and measured on screen with a mouse (Figure 6) (Leatherman, 1983; Moore, 2000:117). Thieler and Danforth (1994) provide a detailed discussion of the individual steps that were required to track shoreline movements using computers in the early 1990s, including an application of GIS to do so.
GIS has radically improved the ability of archaeologists to measure shoreline change, model environmental trends, and manage archaeological sites (Reeder et al., 2012; Bickler et al., 2013; Al-Ruzouq & Abu Dabous, 2017). GIS (or a GIS) is a mapping software package that allows geographic data to be collected, managed, manipulated, visualised, and analysed (for an overview of GIS see Bernhardsen, 1992 and Huang et al., 2018). Some examples of programs that can be considered a GIS include ArcMap, QGIS, GRASS, and Google Earth. While each of these applications are powerful mapping and spatial analyst tools singularly, they also act as gateways for the integration of other spatial technologies such as GPS. GPS is a navigation system that uses a constellation of satellites to triangulate the position of a GPS receiver anywhere on Earth with an unobstructed line of sight to four or more satellites (Hegarty, 2017). For archaeologists, this capability allows archaeological sites to be given
spatial coordinates in the field, which can later be used for assessment and management purposes.

In the early 2000s GPS systems had a standard error of 10-15 metres (Walton, 2002). Since then, improvements in technology such as differential correction have brought this error radius down to 300 mm (Yang et al., 2017). Differential correction uses a nearby base station located at a fixed point to fine-tune the location of a mobile GPS receiver (Wanninger, 1998:86). The base station does this by continuously recording its exact fixed location on Earth, which it then uses to calculate and correct the error range of the unfixed mobile receiver (ibid). The combination of differentially corrected GPS and GIS allows archaeologists to easily and accurately compare a present day shoreline to shorelines derived from historical aerial imagery.

GIS has been used extensively to measure shoreline change along coastlines (Hiland et al., 1993; Esteves et al., 2009; Smith et al., 2012) and their archaeological sites (Chapman et al., 2001; Güimil-Fariña et al., 2016), including two recent applications in New Zealand (Ramsay, 2014; Hil, 2016). Additionally, there is also a software extension for GIS called the Digital Shoreline Analysis System (DSAS), which was developed by the United States Geological Survey and a software company named Innovate! Inc. (Thieler et al., 2017). First released in 1992, DSAS allows users to digitally calculate rate-of-change statistics for shorelines through automatically generated transects (Esteves et al., 2009; Ato Armah, 2011; Oyedotun, 2014; Kallepalli et al., 2017). DSAS was recently used in New Zealand to track shoreline change at an archaeological site complex at Papanui Inlet, near Dunedin (Figure 7) (Hil, 2016:54-58).

Figure 7. An example of the DSAS extension used at Papanui Inlet near Dunedin (figure taken from Hil, 2016:55).
2.3.2 Using Spatial Technologies to Model Sea Level Rise:

Due to the enormity of the threat posed to the world's coastlines by SLR, over the past few decades there has been a considerable amount of research devoted to understanding the scale and possible extent of its impact. Traditionally, this information has been drawn up through three lines of evidence (Sharples, 2006:18): 1) direct observations and monitoring of coastlines where land subsidence has recently resulted in significant rates of SLR (Bird, 1993); 2) determining how SLR has previously affected coastlines through study of the geological and geomorphic record; 3) using experimental simulations and computer-based models to act out possible SLR scenarios. While recent developments in spatial technologies have greatly improved the capabilities of scientists to carry out all three of the approaches, these new faculties have been particularly useful in terms of modelling and simulating the potential impact of SLR on coastlines. Before personal computers and digitalised environmental datasets existed this research was pursued in laboratories using wave tanks (Schwartz, 1965) or through paper-based theoretical mathematical equations (Bagnold, 1946; Fairbridge, 1961). Today, SLR models can be split into two camps, those that model the susceptibility of shorelines to rising seas and those that model the outcome of that process.

Modelling the susceptibility of a coastline to natural impacts such as erosion or SLR is achieved by translating complex environmental variables into numerical values that can be ranked and incorporated into algorithmic equations. For example, if determining the susceptibility of a shoreline to the effects of erosion, numerical risk values from one to five are given for variables such as an area's geomorphology, elevation, slope, and previous wave activity, which are then weighted and averaged using algorithms to produce a single susceptibility value (Gornitz & Kanciruk, 1989). This risk ranking can then be compared to those retrieved from other coastlines in order to focus management efforts to areas under greatest threat. While there are examples where this process has been carried out using field methods and paper based calculations (for erosion: Gibb, 1992; for SLR: Gornitz, 1991), this approach is well-suited to computer-based applications such as GIS. As GIS allows scientists to combine and display large environmental datasets spatially, it is ideal for modelling environmental susceptibility to erosion, SLR, or any other natural or anthropogenic impact. There are many examples of GIS being used to carry out coastal vulnerability models both in New Zealand (Goodhue et al., 2012) and overseas (Thumerer et al., 2000; Pendleton & Thieler, 2005; Sharples, 2006; Westley et al., 2011), including recent examples that consider archaeological sites overseas (Reeder et al., 2012) and in New Zealand (Bickler et al., 2013; Ramsay, 2014; Hil, 2016).
GIS has also proven itself useful for modelling and visualising predictions of SLR along coastal areas. This is most commonly achieved by modelling the height of sea levels against Digital Elevation Models (DEM) to determine which areas will become inundated and to what extent. DEMs are a continuous gridded representation of a topographic surface’s elevation values. In simpler terms, DEMs turn the Earth’s surface into a grid of square cells, with each cell representing an elevation (height) relative to a datum point, typically Mean High Sea Level (MHSL). Depending on the precision or resolution of the DEM, the size of those cells can range anywhere from less than a metre to upwards of 250 metres. Typically, a smaller cell size is indicative of a more accurate representation of a given area’s surface, both vertically and horizontally (Figure 8). The resolution of a DEM can be directly linked to the scale at which that DEM can be used to model the effects of SLR along a given coastline. For example, a recent New Zealand case study combined a 25 metre DEM and NZAA’s ArchSite dataset within GIS to rank recorded archaeological sites for susceptibility to SLR based on their location’s elevation relative to sea level (McCoy, 2018). This analysis found 9,430 or 14% of New Zealand’s archaeological sites to be within 5 metres of sea level (McCoy, 2018:13). While this study worked well on regional scale, its use of a 25 metre DEM prevented it from determining how sea levels might impact specific beaches or individual archaeological site areas.

![Figure 8](image.png)

Figure 8. A side-by-side comparison of an 8 metre DEM (left) versus a DEM derived from LiDAR (right). The area shown is Warrington Spit, located within the Blueskin Bay case study area (8 metre DEM retrieved from www.linz.govt.nz & 2004 LiDAR courtesy the Otago Regional Council).
To model the effects of SLR on localised areas, scientists have begun using LiDAR to produce DEMs with a metre or less resolution (Cooper et al., 2013). LiDAR, which stands for Light Detection and Ranging, is a remote sensing technology that uses pulsed lasers (typically sent to the ground through airborne means) combined with precise GPS measurements to collect a given surface’s elevation values across a very fine scale (Chase et al., 2012:12920). This technology has been heralded as the biggest improvement to archaeological practice since radiocarbon dating, and for apt reasons (ibid:12917). As LiDAR produces millions of lasers to gather elevation readings it is able to penetrate dense vegetation such as jungle canopy to map the ground and any archaeological features hidden beneath (Chase et al., 2012; Evans et al., 2013). For those concerned with environmental processes such as SLR or erosion, LiDAR is able to track small and incremental changes to landforms caused by meandering rivers or eroding shorelines (Jones & Bickler, 2017:41). When applied to SLR modelling, a DEM produced from a LiDAR’s point cloud can be used to visualise the extent of inundation on a coastal area at scales appropriate for site-level interpretations (Poulter & Halpin, 2008; Cooper et al., 2013). Through the combination of differential GPS data, DEMs derived from LiDAR, and GIS, site managers are now able to track and model environmental processes in increasingly accurate and useful ways.
This section will provide a brief overview of the physical setting of the Blueskin Bay case study area. Blueskin Bay is located 20 kilometres north-east of Dunedin and is called home by the residents of Waitati, Warrington, Michies Crossing, Evansdale, and Doctors Point (Figure 9). At four-kilometres-long by two-kilometres-wide the estuary is of a moderate size and enjoys a relatively sheltered position, owing to its surrounding hillslopes and the two-kilometre-long sand spit that extends along its eastern side. At the spit’s southern extent is a 250-metre-wide entrance to the Pacific Ocean, which is accompanied at its interior by the one-kilometre-long Rabbit Island. The estuary’s soft-shore areas such as its spit, island, and muddy interior took their approximate forms after 6500 BP when seas stabilised to their current levels (Healy & Kirk, 1992:162; Single, 2015:4). The sands making up those areas are mostly quartz-based and originate from South Otago where they were carried north and deposited by Otago’s powerful offshore currents (Elliott, 1958:66; Berryman & Hull, 2003:35). The muddy deposits are mostly alluvial in nature and were supplied primarily by the Waitati River or through run-off from the estuary’s neighbouring hills. Blueskin Bay’s hard-shore areas and its adjacent ranges were formed by Dunedin’s eroded shield volcano (Rakiriri), which emerged and erupted during the Middle to Late Miocene (13 to 10 million years ago) (Glassey et al., 2003:23). The various compositions of basalt found within the estuary and elsewhere in the vicinity of Dunedin are by-products of those same ancient processes (Bishop and Turnbull, 1996).

There are dramatic shifts between low and high tides at Blueskin Bay and, with the exception of a few deep channels, its flat muddy bottom is nearly entirely exposed for a few hours of each day. This muddy interior transitions to low-lying grass covered floodplains at Waitati and Evansdale along its southern and north-western sides, respectively. From Warrington to Doctors Point are dune systems that are vegetated by a mixture of marram grass, pine trees, and scrub. From Doctors Point past Michies Crossing to the northern side of the Waitati River’s mouth are undulating coastal cliffs, fronted by varying compositions of basalt, capped by topsoil and a mixture of native and non-native species of vegetation. Blueskin Bay’s western and northern sides are made up of alluvial deposits that cap basalt bedrock, however these sections of shoreline are superseded on their seaward side by the infrastructure of the railroad, State Highway One, and Coast Road. As will be discussed in chapter four, these widely ranging landforms and the enumerable natural resources they contain and support play a key role in the narrative of Blueskin Bay and the formation and subsequent condition of its archaeological sites.
Figure 9. Aerial view of the Blueskin Bay case study area and its recorded archaeological sites (aerial imagery taken March 2013: courtesy DCC).
2.5 SUMMARY:

To summarise, the capability of archaeologists in New Zealand to effectively manage and mitigate harm to archaeological sites has improved significantly over the past century. These improvements can be attributed in part to the adoption of legislation that is favourable for the general protection of archaeological sites from human-based disturbances. Alongside the implementation of these statutory requirements have been large scale site recording surveys, which have collected information relating to the location, extent, and condition of New Zealand’s archaeological sites. While the combination of HNZPTA 2014 and the SRS have lessened the impact of anthropogenic threats to sites they do little to moderate the ongoing effects of natural processes such as erosion and SLR. As was addressed throughout this chapter, a prerequisite for effectively managing these incremental site impacts is developing a clear understanding of their extent and trajectory. Due to the global prevalence of erosion and SLR (including their ongoing exacerbation), archaeologists and scientists from other disciplines have invested a significant amount of resources towards tracking and understanding them, and are thus becoming better equipped to measure, model, and manage their impacts. In recent years these developments have been increasingly driven through the advancement and adoption of spatial technologies, particularly GIS, GPS, and LiDAR. Although the applicability and benefit of these approaches have already been proven elsewhere, as of yet these have not been widely implemented in New Zealand for archaeological site management purposes. Building upon this context the next chapter will present a site assessment framework that combines some of those technologies and techniques with more traditional site assessment methods, which will then be applied to the Blueskin Bay study area.
3. The Approach

You can’t manage what you don’t measure  
-Peter Drucker

The above axiom, which is generally attributed to a twentieth century management theorist Peter Drucker, forms the basis of the methodological approach presented and employed during this thesis. Too often, archaeologists, heritage managers, and other stakeholders pursue coastal heritage management strategies that are both reactive and constrained in their scope (Brooks et al., 2008:3; Wickham-Jones, 2010:214; Bickler et al., 2013:37). Without a current and systematic understanding of the impacts that are affecting coastlines and their archaeological sites it is difficult to work proactively towards conserving sites, mitigating threats, or ultimately salvaging a coastline’s degrading heritage. The act of managing the coast and its archaeological sites is based on numerous ‘best practice’ strategies that are outlined through a wide-range of site conservation literature (eg. Jones, 2007; ICOMOS, 2010). However, the prerequisite of measuring sites and their impacts requires further deliberation. In order to measure, one must first observe either an object or a phenomenon and then describe it either quantitatively through the use of some form of metric, or qualitatively through a standardisable description. In terms of this thesis, the objects or phenomena in question are the individual impacts that are affecting, or will affect, coastal archaeological sites. The severity of each impact is relative to the extent and expression of the cultural features present at each site. For example, a site that is represented by a single nineteenth century fence post may be impacted severely by even the smallest amount of woodworm or rot. However, a large historical estate may endure years of rot, storms, and vandalism and still remain principally intact. Therefore, truly understanding site impacts mandates the measurement of both the impacts present at any given site and the extent or expression of the archaeological site itself.

This methods chapter has two purposes: first and foremost, it will present the methods used to assess the condition of the 26 recorded archaeological sites found within the Blueskin Bay case study area. Its second intention however, is to present methods of assessing coastlines and their archaeological sites that are not specific to any one coastal area. While these methods are presented using environmental datasets and site recording data that is New Zealand specific, such steps could be adapted comfortably to other coastal areas as long as adequate aerial imagery coverage and elevation data (such as LiDAR or a DEM) of the area are accessible. As such, this chapter is formatted in a way where each described step is both
relevant to the assessment of the Blueskin Bay case study area and to any other coastal areas with recorded archaeological sites. Using this approach the specific steps taken for each of the three presented methodological phases will be given alongside details of their application to the Blueskin Bay study area. Those three phases are: 1) documentary research, 2) an in-person site survey and assessment, and 3) computer-based spatial analysis.

The first phase, documentary research, consists of background research relating to the extent, composition, and condition of sites located along any given coastal area of interest. This research also includes investigations of how impacts (such as development, flooding, and erosion) have previously affected that coastal area. The second phase of the assessment takes inventory of a coastal area’s sites through an in-person site survey and assessment. During this step information relating to the visible spatial extent and condition of sites is collected using differential GPS and through in-person observations. The third and final phase combines that data using spatial technologies such as GIS and LiDAR to evaluate how threats (namely SLR and erosion) have already impacted sites, while predicting how those same threats may impact sites in the future. Overall, this three-part-approach works towards establishing a better understanding of on-the-ground conditions at coastal archaeological sites across local, regional, and temporal scales.

The rest of this chapter will now elaborate on each of those three methodological phases, describing how and why each step was employed, while relating that information to the Blueskin Bay case study area.

3.1 DOCUMENTARY RESEARCH:

Documentary research forms an important first step of the assessment’s approach as it guides the in-person survey and assessment, while providing the background information and context necessary for the placement of all generated data and interpretation. The literature used for this step can be split into two primary categories: documentation relating directly to individual coastal archaeological sites and supplementary information pertaining to a case study area or a coastline as a whole. The former is comprised of excavation reports, regional site surveys, SRFs, and any relevant academic papers. For the purposes of assessing Blueskin Bay these documents were retrieved through traditional methods of academic research and through the NZAA’s ArchSite online database (www.archsite.org.nz). In cases where Blueskin Bay's archaeological sites were no longer visible from the surface (or destroyed) these documents were sometimes the only sources of site information available. As coastlines are dynamic environments, plan drawings and other recorded locational aids can prove invaluable in situations where dramatic landform change has occurred. These
works also provide a means of understanding how the impacts present at each coastal archaeological site have progressed since they were first observed. Photographs taken at the time an archaeological site was first recorded are particularly useful. Overall, having the ability to compare earlier investigations to the present is integral to making inferences concerning the trajectories of current site threats into the future.

Sources of other supplementary information include local histories, ethnographic accounts, coastal vulnerability studies carried out by local and governmental councils, and scientific literature pertaining to natural impacts. These resources each contribute to developing a regional understanding of a coastal area including its history, geomorphology, and how large scale hazards such as flooding and erosion are anticipated to impact that coastal area in the future.

Together, this documentation combines to produce a profile for a chosen coastal area and provides a foundation for the subsequent site survey and assessment.

3.2 SITE SURVEY AND ASSESSMENT:

As of yet, there is no real substitute to on-the-ground assessment of coastal sites when identifying the existence and extent of site threats. While background research, desk-based methods of analysis, and computer modelling can provide predictions and preliminary information for possible management strategies, it is only through ground-truthing that unequivocal conclusions can be made about the conditions of sites. As such, the assessment process presented and undertaken during this thesis has a particularly strong focus on in-person site survey and assessment. The methods used for this will be detailed in the following two sub-sections, which cover the methods relating to the survey itself, and the subsequent post-processing for any of the data collected.

3.2.1: Site Survey and Assessment:

The site survey and assessment undertaken for Blueskin Bay took place over six days between June 27th and August 27th, 2017. This fieldwork enlisted the help of four volunteers\(^2\) who accompanied the author to the estuary and provided, among other things, a valuable extra pair of eyes during site surveys and assurance during any cases of accident or injury. Tide times and weather were each considered during the planning process in order to make the most of each trip. Additionally, to determine the impact of storm surge on Blueskin Bay's sites one trip was specifically taken immediately after a large storm had struck the area.

\(^2\)Richard Walter (June 27th); Alana Kelly (June 29th); Phil Latham (July, 9th); Kate Roscoe (July 27th; August 10th & 27th).
The following equipment and documentation were on-hand during each coastal site assessment:

**Equipment:**

- A Garmin hand-held GPS (GPSMAP 64s) (accurate to 3 metres)
- A Trimble differential GPS (GeoXT 6000) (once corrected this was typically accurate to 300-500 mm)
- A 12 mega-pixel digital camera
- Two ranging poles
- An 8 metre measuring tape
- A 30 metre measuring tape
- An all-weather notepad and pens
- First aid kit

**Documentation:**

- A printed satellite image with identified approximate site locations
- Relevant Site Record Forms (SRFs)

Each survey day began with a drive to a convenient access point near the required study area. Upon arriving, the Garmin hand-held GPS was combined with a printed satellite image to locate each coastal site. Once the GPS coordinates of a given site location were reached, SRFs were used to determine the previous extent and expression of the archaeological site. If exposed cultural features were located, these were photographed (using the ranging poles as scales) and briefly described in the all-weather notepad. Wherever possible, contextual photographs showing site location were taken in addition to close-up shots of sites. For the vast majority of the visited coastal sites (92%) ‘exposed cultural features’ consisted of eroding sections of midden or ovens. In such cases the measuring tapes were used to provide information such as the length or thickness of exposed sections. After noting these down, the Trimble differential GPS was used to create a digital record of those extents. For non-midden sites, each site was similarly assessed, measured, photographed, and had differentially corrected GPS data taken of its location. The ultimate purpose of this step was to record spatial data that can be incorporated into future monitoring or management strategies, as well as any subsequent analysis of shoreline change or SLR.

In addition to site specific data, the Trimble unit was also used to collect information such as the extent of coastal edges, the location of spatially significant photographs, and the locations of individual site impacts (such as rabbit burrows or tracks cutting through areas of midden).
3.2.2: Post-Processing of Survey Data:

The site survey and assessment generated a large amount of data relating to each site area. As such, effective data management was an important preparatory step for all post-processing. Doing so ensured the data collected for each site was organised and easily accessible for later consideration. All sites were given their own digital folder, which contained GIS shapefiles, associated photographs, and SRFs (this data can be found in the DVD at the back of this thesis). Within ArcMap (version 10.3.1) a GIS file geodatabase was made for the Blueskin Bay case study area and a feature dataset was made for each archaeological site (Figure 10).

![Image of GIS database organisation](image)

Figure 10. An example of the GIS database organisation used during the post-processing of the site survey.

The Trimble differential GPS data collected during each survey was uploaded to GPS Pathfinder Office where it was differentially corrected by the Land Information Base Station in Dunedin. This typically brought the accuracy of the data from one to six metres to +/- 300 - 500 mm. Once this spatial data was imported into ArcMap it was colour-coded or symbolised based on the type of data it represented. The specifics of those classifications are provided in the legends of each of the maps presented in the results chapter.
3.3 COMPUTER-BASED SPATIAL ANALYSIS:

The combination of GIS, LiDAR, and geo-referenced historical aerial photographs allows the effects of erosion, progradation, and rising sea levels on archaeological site areas to be both measured and visualised. This analysis offers a unique vantage point upon which to consider the past and future of archaeological sites, particularly when combined with the information collected through the two previous phases of the coastal assessment.

3.3.1 Tracking Rates of Erosion and Progradation:

In order to track the rates of shoreline change along Blueskin Bay's shoreline and archaeological sites, aerial images were first gathered from a few different digital sources. These ranged from the use of the Historic Image Resource (http://retrolens.nz), an ArcMap basemap, and the Otago School of Surveying's GIS-based database. A list of all imagery used during this analysis is found in Table 1, which includes the image's location, date, source, and quality (cell size). Typically, the smaller the cell size the higher the quality and resolution of the image.

Table 1. Showing a list of all aerial imagery utilised during the Blueskin Bay case study assessment.

<table>
<thead>
<tr>
<th>Blueskin Region</th>
<th>Date</th>
<th>Cell Size</th>
<th>Rectification:</th>
<th>Source:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctors Point</td>
<td>1982</td>
<td>0.960</td>
<td>Georeferenced</td>
<td><a href="http://retrolens.nz">http://retrolens.nz</a></td>
</tr>
<tr>
<td>Michies Crossing</td>
<td>1979</td>
<td>0.220</td>
<td>Georeferenced</td>
<td><a href="http://retrolens.nz">http://retrolens.nz</a></td>
</tr>
<tr>
<td>Waitati</td>
<td>1979</td>
<td>0.689</td>
<td>Georeferenced</td>
<td><a href="http://retrolens.nz">http://retrolens.nz</a></td>
</tr>
<tr>
<td>Evansdale</td>
<td>1978</td>
<td>0.170</td>
<td>Georeferenced</td>
<td><a href="http://retrolens.nz">http://retrolens.nz</a></td>
</tr>
<tr>
<td>Warrington</td>
<td>1982</td>
<td>0.709</td>
<td>Georeferenced</td>
<td><a href="http://retrolens.nz">http://retrolens.nz</a></td>
</tr>
<tr>
<td>Rabbit Island</td>
<td>1982</td>
<td>0.727</td>
<td>Georeferenced</td>
<td><a href="http://retrolens.nz">http://retrolens.nz</a></td>
</tr>
<tr>
<td>Entire Estuary</td>
<td>2000</td>
<td>0.125</td>
<td>Orthorectified</td>
<td>School of Surveying &amp; Dunedin City Council</td>
</tr>
<tr>
<td>Entire Estuary</td>
<td>2007</td>
<td>0.125</td>
<td>Orthorectified</td>
<td>School of Surveying &amp; Dunedin City Council</td>
</tr>
<tr>
<td>Entire Estuary</td>
<td>2013</td>
<td>0.400</td>
<td>Orthorectified</td>
<td><a href="http://www.linz.govt.nz">www.linz.govt.nz</a> &amp; Dunedin City Council</td>
</tr>
</tbody>
</table>

Once collected, each aerial image was assigned spatial coordinates. Doing so allowed digital measurements taken within ArcMap to authentically reflect real-world metrics. In some instances, such as the aerials provided by the Otago School of Surveying, orthorectification had already taken place. The orthorectification process pairs up images with DEMS and satellite metadata to assign true-to-scale spatial locations to images. These orthorectified images were used as a reference to accurately link up the rest of unassigned aerial images, which was achieved using the georeferencing tool within ArcMap. Georeferencing uses common control points found between a referenced and non-referenced image to give spatially undefined images real-world coordinates. Good control points typically include bridges, fence posts, railroad lines, and rock formations that are not likely to have changed position since the earliest image was collected. It is important to note that the accuracy of georeferencing is dependent on a number of factors, particularly the resolution of the aerial
image and the steepness of an area's terrain. As georeferencing does not correct for terrain displacement its application should be restricted wherever possible to relatively flat areas. These distortive effects can be mitigated by cropping large images to specific areas of interest and choosing control points that are all of a similar elevation. For Blueskin Bay this was accomplished by using fence posts that cross the estuary's mudflats, which had remained unchanged in position from the oldest to most recent aerial images.

After each image had been georeferenced ArcMap was used to digitally trace shorelines. For the purposes of this approach vegetative shorelines were chosen over other definitions of coastal edge (such as MHSL) as vegetative edges were most recognisable in georeferenced imagery and in most cases represented the edge along which eroding middens were exposed. A polyline shapefile named 'Shoreline' was created for each assessment area, which contained a “DATE” attribute field. Each shoreline was then traced at whatever scale provided the highest resolution of the pertinent vegetative edge. In all cases this occurred between 1:100 and 1:400, with the differences dependent on the quality of the georeferenced image.

3.3.2 Measuring Shoreline Change with the DSAS Extension:

Although measuring the amount of change between shorelines can be accomplished using ArcMap’s measurement tool this process can only be used to produce one measurement transect at a time. The use of the DSAS extension allows shoreline change to be calculated systematically across many hundreds of evenly spaced transects at once. To use the program, the user must first manually trace the vegetated shoreline of each aerial image within ArcMap. The DSAS extension then allows the user to define the desired length of and spacing between each of the assessment transects. Those transects are then automatically propagated along the entire length of shoreline from a manually positioned baseline that runs approximately parallel to its length. As shown in Figure 11, all measurements occur between each derived shoreline, thus the baseline influences the placement and initial angle of the transect, but not the final calculation of shoreline change. Due to the perpendicular angle of the assessment transects, the DSAS system works best for straight or gradually curving coastlines. However, as will be shown in the next chapter, the ArcMap extension can be used to systematically calculate shoreline change across a broad range of coastal landform types. In situations where an assessed area is not a straight or gradually curving shoreline, the user can customise the position, angle, and length of each transect before the program performs the shoreline change calculations.
The end result of the DSAS processing are Net Shoreline Movement (NSM) calculations that quantify the distance a shoreline has eroded or prograded between the dates of derived shorelines. By dividing the amount of change by the number of years this data can be used to determine rates of erosion and progradation (average metres per year) across that section of coastline. Once NSM values are produced for a given area, these are then joined to the measurement transects and then colour-coded relative to the amount of shoreline progression or retreat they represent. Any transect that related to progradation was made green, whereas transects of areas that eroded were made yellow, orange, or red depending on their amount relative to the greatest incidence of retreat. For example, if an area eroded a maximum of nine metres then transects -0.01 to -3.0 are made yellow, -3.01 to -6.00 are made orange, and -6.01 to -9.00 are made red. This information is provided in the legends of each DSAS results figure. Under the right circumstances DSAS provides a systematic and straightforward way of determining shoreline change over a coastal area and has shown its merit across a number of other studies (Thieler and Danforth, 1994; Aiello et al., 2013; Bheeroo et al., 2016) including a recent successful application in New Zealand (Hil, 2016).

3.3.3 Modelling sea level rise:

Modelling SLR was achieved using GIS (ArcMap version 10.3.1) in conjunction with DEMs derived from LiDAR taken of the case study area. The particular LiDAR dataset used for this analysis was collected for the entire Otago coastline by the Otago Regional Council (ORC) in 2004. This spatial analysis approach drew inspiration from a number of previously
conducted coastal hazard management studies (Poulter & Halpin, 2008; Cooper et al., 2013; Thorner et al., 2014). Typically these have used DEMs and various forms of spatial analysis to model the movement of rising water and flooding across coastal landscapes. While such studies sometimes use sophisticated algorithmic modelling to understand the dynamics of rising seas, those studies have also indicated that inundation is primarily dependent on coastal elevation. As this assessment was solely concerned with the maximum spatial extent of rising sea levels along archaeological site areas a simplified approach that focused exclusively on elevation values was employed.

For the purposes of this analysis, a multipoint shapefile of the ORC’s LiDAR of coastal Otago was spatially clipped to the Blueskin Bay study area and turned into a terrain model. A terrain model is a digital representation of elevation data points, which are triangulated and interpolated to form a 3D surface. When a terrain model is created within GIS an ‘average point spacing’ value is required. This value allows GIS to determine the amount of interpolation needed to produce the surface, while ensuring it is as accurate as possible. These point spacing values were identified using ArcMap’s ‘LAS dataset properties’ statistics tool. At Blueskin Bay for example, LiDAR points had an average point spacing of 3.296 metres. Using this value during the creation of each terrain model allowed their resolution to be as high as the data could reasonably allow. Figure 12 shows how this point spacing appeared visually and Figure 13 provides an example of a terrain model surface created for a selected area of Blueskin Bay. Besides the inputted point spacing value, the creation of each terrain was completely automated by ArcMap.

![Figure 12. An example of the 2004 ORC LiDAR point spacing (aerial imagery taken March 2013: courtesy DCC).](image)
After each terrain model had been constructed, DEMs were created using ArcMap’s ‘Terrain to Raster’ tool. This final preparatory step produced a raster file made up of cells containing elevation data for each of the case study areas. As DEMs are essentially a visual representation of a gridded system of elevation values (Figure 14), these can be numerically evaluated within GIS using conditional ‘if’ and ‘then’ statements. The DEMs used during the final stage of the SLR analysis were given a relatively small cell size of 0.250 metres for aesthetic purposes (this DEM can be found in the attached DVD). The fact the cell size was smaller than each terrain’s average point spacing did not influence the SLR analysis as the rasters were simply a gridded representation of the already interpolated surface models.
Once created, DEM rasters can be used to visualise the extent of rising seas by giving all elevation values under a predicted sea level height a distinctive value or colour. Before this could be carried out for the case study area, the establishment of a base sea level upon which to model future sea level predictions was required. For this, a predicted average of Mean High Water Spring (MHWS) values for the Otago region from January 2000 to December 2018 was used (retrieved from www.linz.govt.nz using methods developed by Baker and Watkins, 1991). MHWS represents an average of the levels of two successive high waters during the greatest yearly period of tidal range (in spring). Once this average high tide value was added to the vertical datum of the 2004 ORC LiDAR, a sea level MHWS baseline of +1.189 metres was determined. MHWS was used over other possible tidal averages as it represented the maximum height tides could be expected to reach (excluding tsunamis or extreme storm events) in any given year. Even if infrequent, such high tidal levels are still likely to cause significant degradation both to sites and their surrounding landscape.

This calculated MHWS value was then used in conjunction with ArcMap’s conditional spatial analyst tool, a DEM, and orthorectified aerial imagery to visualise MHWS along the case study area. The ‘Con’ tool was used with the SQL expression: “VALUE <= 1.189”. Figure 15 shows ArcMap’s Con tool and the parameters used to carry out this step. Once the baseline MHWS value was established this process was repeated for best and worst case SLR predictions of +0.3 metres and +1.0 metre. In simple terms, the Con tool gives a single value (in this case 0) to all areas of the DEM where the elevation is less than or equal to 1.189 metres. Areas with that given value (0) can be given a distinct colour representing predicted tidal levels.

![Figure 15. Example of the parameters used within the ArcMap con tool to produce SLR predictions.](image)
Once all elevations within the predicted tidal range were colour-coded an image editor was used to remove any instances where affected areas were inland and isolated from the ocean’s reach (Figure 16).

This was done by inserting an unaltered aerial image layer under the model’s results and simply erasing any of the unconnected colour-coded regions. While areas of lower elevation are still at an increased risk of being inundated or flooded, their presence added undue uncertainty to the model’s results.

When combined with the spatial data gathered for each site during the site survey and assessment, this analysis was able to provide clear estimations of the extent at which archaeological site areas could be affected by rising sea levels.

3.4 SUMMARY:

Each of the three methodological strategies presented in this chapter worked towards establishing a better understanding of site conditions both along Blueskin Bay, or potentially any other coastal area. While each of these methods were singularly valuable, when combined they produced a perspective that was more useful than the sum of their parts. By combining elements such as the differentially corrected GPS of site features with historic accounts and aerial photographs, a much clearer picture of on-the-ground site conditions was achievable. The following chapter presents a real-world example of this methodological approach through its application to the Blueskin Bay case study area.
4. The Case Study

This chapter presents the results of the Blueskin Bay coastal site assessment. As a case study area, Blueskin Bay acted as an important and ultimately productive proving ground for the three previously outlined assessment strategies. Each of those three avenues of inquiry will be presented, in order, through three corresponding sections: documentary research, site survey and assessment, and computer-based spatial analysis.

4.1 DOCUMENTARY RESEARCH:

The documentary research undertaken for Blueskin Bay drew information from a broad range of different sources, including local histories (Pullar, 1957; Church et al., 2007), historical newspapers, a coastal hazard assessment conducted by the ORC (Goldsmith & Sims, 2014:68-78), excavation reports, site assessments, and SRFs. Once assimilated this literature provided insights relating to the location and composition of the estuary's archaeological sites, previous natural and anthropogenic impacts, and the effects of nineteenth and twentieth century industry and development on the coastal landscape. This section contains two subsections, the first of which deals with research relating directly to Blueskin Bay's archaeological sites, while the second considers impacts relating to the estuary as a whole from the middle of the nineteenth century to the present.

4.1.1 Blueskin Bay's Recorded Archaeological Sites:

Along Blueskin Bay's shoreline are 26 recorded archaeological sites that range in size from single exposures of midden to large multi-layered Māori settlements. Most of what is known about the pre-European sites comes from excavations at Warrington (Allingham, n.d.a; n.d.b; n.d.c; Hamel, n.d; 2000; Walter & Jacomb, 2008) and Doctors Point (Allingham, 1991; Church et al., 2007:9) or through information recorded in SRFs by Brian Allingham in the 1980s. In fact, of the 24 sites that are likely pre-European, 22 were initially recorded between 1982 and 1989 by Allingham. The SRFs for these, and the bay's other recorded sites, indicate that 20 (77%) were being impacted by erosion at the time of their recording. Overall, the density and composition of the sites suggest Blueskin Bay has acted as a hub for a broad range of human activities for at least 500 years.

The two largest sites, Warrington (I44/177) and Doctors Point (I44/74), have multiple layers of occupation, with their lowest levels potentially relating to Otago's earliest known period of human settlement (Walter and Jacomb, 2008:2). At Warrington, a layer yielding numerous deposits of moa bone and eggshell as well as artefact types typically described as 'Archaic,'
produced a radiocarbon date (taken from a cockle shell *Chione stutchburyi*) of (+/- 55) 1380 AD (Allingham, 1988). Material yielded from subsequent layers of the site are consistent with a later phase of Māori settlement and have been dated to 1460 AD (+/- 55), 1495 AD (+/- 55), and 1602 AD (+/- 55) (*ibid*). While no dates have been taken at Doctors Point the material uncovered there is again indicative of a long, but intermittent period of human settlement (Allingham, 1991; Church et al., 2007:8), which may have at times been contemporaneous with the Warrington site (Allingham, pers. comm., July 7th, 2017). In addition to Warrington and Doctors Point, Waitati is the only other site area of Blueskin Bay that has been described previously as containing any quantities of moa bone (*Otago Witness*, July 14th, 1892; Anderson, 1989).

The other pre-European archaeological sites located around the estuary include midden exposures, a stone source, and isolated earth ovens. The recorded midden suggest a broad spectrum of food sources were exploited by Māori populations including shellfish, fish, sea mammals, and sea birds; all of which would have been readily available in the surrounding landscape. As formal archaeological excavations have only thus far taken place at Warrington and Doctors Point, the nature and timing of the other archaeological sites located along the estuary remains tentative (Church et al., 2007:9).

Supplementary to modern archaeological inquiry are accounts by fossickers and ‘curio-hunters’ of the nineteenth century. The first series of these was written in the *Otago Witness* by Alfred Reynolds under the pen name “Aparata Renata” in July 1892 (*Otago Witness*, July 7th, 1892; July 14th, 1892; July 28th, 1892). These works summarise activities carried out by Reynolds and his associates at Blueskin Bay and other coastal areas in Otago in the late nineteenth century. In the first article, titled “Unearthing Māori Idols,” Warrington is referred to as the location where “three or four” green-stone implements were discovered following a gale. The discovery of these items subsequently led to a full day of digging by Reynolds at the site with a spade. However, after failing to locate any further curios, the fossicker lamented that “little could be done by searching where others had been doing so for years” (*Otago Witness*, July 7th, 1892). More winds were documented at Warrington in 1901, which exposed human remains, moa eggshells, shellfish, and stone pavements (Church et al., 2007:10).

In the second and third articles both Waitati and Doctors Point are also described as places where greenstone implements had been uncovered, with the former referred to as a place with moa bone and the latter as a settlement (*Otago Witness*, July 14th, 1892; July 28th, 1892). A final piece by Reynolds was written in 1894 and refers to a Warrington site (likely I44/177) as an “ancient Māori residence” where digging had revealed “stone floors of native construction,” a great quantity of moa bones and moa egg shells, and “two Māori skeletons
under one of which there were two stone chisels and one of greenstone” (*Otago Witness*, January 11th, 1894). While such accounts of previous site disturbance can be frustrating to read they offer valuable clues relating to the extent of fossicking activity in the area and information about the material they uncovered. In this case it is apparent that large areas of the Warrington site have previously been exposed and wind deflation has been impacting the area as early as the 1890s. Additionally, the numerous mentions of greenstone are worth noting as there are two midden sites (I44/190 and I44/191) that are located in an area just south of Evansdale with the Māori place name “Hohopounamu”, translating to “rubbing the greenstone” (Chapman, 1891). While occurrences of fossicking have diminished greatly in Otago and New Zealand (mostly due to protections to sites offered by *Heritage New Zealand Pouhere Taonga Act 2014* and earlier renditions of the legislation), commercial and residential development remains a destructive force at Warrington (Hamel n.d.; 2000; Walter and Jacomb, 2008).

Blueskin Bay has two recorded historical archaeological sites that are both found in Waitati. The first, I44/477, is a post and rail fence that was built between 1875 and 1876 during the construction of the railway line through Waitati (Figure 17) (Church et al., 2007:76). The second site, I44/455, relates to the homestead and associated buildings of Alexander Grant who emigrated from England and settled in Waitati in 1870. Although he returned to England in 1878, during his time at Blueskin Bay he was a sheep farmer and owned a flaxmill and a
ropeworks (Pullar, 1957:65-69). Both sites were visited and recorded in 2009 by Emma Brooks and Chris Jacomb (2010) as part of a site assessment for the realignment of State Highway One by the New Zealand Transport Agency. During their site visit no surface features associated with Grant’s estate were located, but a row of intact posts was discovered adjacent to the still operating railroad line.

4.1.2 Historical Account of Blueskin Bay Impacts:

Although Blueskin Bay has just two recorded historical archaeological sites, local histories written about the estuary suggest it has been a locus of European activity for well over 150 years. Its first Pākehā settler, Archibald Anderson, secured grazing rights in the Waitati area in 1848. By this time there were reportedly no permanent Māori settlements present along the bay and its adjacent hillslopes were covered in thick forests of rimu, broadleaves, kowhais, maples, and fuchsias (Pullar, 1957:14; Church et al., 2007:12). In 1859, Alexander Garvie surveyed the township of Blueskin (now known as Waitati) and drafted up street plans, including reserves for a cemetery, school, and library (Pullar, 1957:20). A metalled horse track was formed leading up to the township from 1859 to 1860 and by 1866 the settlement had a post office and a hotel (Church et al., 2007:12, 26). At first the land was used by European runholders for stock grazing, but this was soon supplemented by the large scale felling of local forests for the sale of firewood (Pullar, 1957:14). While this opened up acres of new land for farming it had the disastrous added consequence of increasing the susceptibility of the area to flooding. Without leaves or a vegetated forest floor to absorb water during downpours the Waitati River was suddenly and frequently well over capacity. Between 1868 and 1886 were four devastating floods, during the course of which the Waitati River shifted into an entirely new direction (Church et al., 2007:84). In cadastral surveys of the township it is possible to see the old course and mouth of the river (Figure 18).

The ORCS’s Coastal Hazards of the Dunedin City District (Goldsmith & Sims, 2014:69), indicates there have been numerous other flooding events since the nineteenth century including those in the 1920s, 1957, 1968, 1991, and 2006. In 2017 a large storm caused the river to swell enough to overflow its banks along State Highway One where it exposed a cable that supplies internet to all of Southland and Otago south of Waitati. The regional council suggests that as the catchment of the Waitati River is short and steep, heavy rainfall coupled with an abnormally high tide can cause water levels to rise rapidly to dangerous levels (Goldsmith & Sims, 2014:68).

In addition to clearing forests, Blueskin Bay’s residents also made their living through harvesting oysters and cockles from the estuary’s muddy bottom. The oysters were the first local source on the Dunedin market and boasted as being some of the best quality in New
Zealand (Church et al., 2007:48). In 1868 a tsunami struck the east coast of Otago with enough force to breach the Warrington Spit, burying and destroying most of the oyster bed. This forced harvesting to cease for seven years until 1875 when the beds were reopened. In 1924, local histories report a storm surge occurred that was so large that it again broke through the spit, this time purportedly burying the estuary's previously exploited eel holes permanently (Pullar, 1957:11). Such accounts are in agreement with the regional council's risk assessment of Evansdale, which suggests storm surge, tsunamis, and inundation are the area's greatest threats (Goldsmith & Sims, 2014:74).

Figure 18. Town of Blueskin and townships of Waitati and Merchiston (now collectively Waitati), S.A. Park, May 1926. Note the old course of the Waitati River shown in the centre of the plan (sourced from LINZ. Crown Copyright reserved).

In the nineteenth century economic undertakings by the bay's residents also included an unsuccessful attempt at goldmining by some 150 men in the 1860s, timber milling operations in the 1870s, and a relatively prosperous flax milling industry that reached its peak production in 1873. Coal and oil shale were discovered near Evansdale, but these were not considered to be high enough quality to match the investment required to extract them.
(Church et al., 2007:52-57). These activities, while reasonably productive, did not drastically reshape or alter the estuary's landscape. However, in March 1876, a contract for a railroad line from Waitati to Brinds Point was signed, which included the construction of bridges, culverts, drainage ditches, a tunnel, 63 cuttings, and 61 embankments (Church et al., 2007:12). The previously mentioned post and rail fence (site I44/477) was one section of over 11,000 posts and 44,000 rails that were built over the course of this contract (Pullar, 1957:72). While such a project was an outstanding achievement, the path the railroad takes follows closely along the estuary's western shoreline and cuts through a large floodplain delta at Waitati, which currently contains six recorded archaeological sites. As such, there is no telling the amount of wanton site destruction that must have taken place during this period. That being said, due to its antiquity the railroad and its associated structures are themselves now archaeological sites and warranting of management.

In summary, the documentary research that was carried out for Blueskin Bay divulged a significant amount of information about previous human activity at the estuary, its archaeological sites, and past and present site impacts. The literature produced from excavations at Warrington and Doctors Point allude to the longevity of human settlement in the region. Such findings are also supported by the coarse spadework that occurred in the late nineteenth century by fossickers through their written accounts. Blueskin Bay's numerous midden sites contain a broad range of marine and terrestrial species, which suggest its earliest inhabitants made full use of the estuary's abundant food resources. In terms of site impacts, observations of site conditions in SRFs indicate erosion has been a primary threat to sites since the 1980s when a majority of the sites were recorded. Other described natural and anthropogenic impacts that are present at Blueskin Bay include the flooding of the Waitati River, tsunamis, storm surge, inundation, and land development. Overall, these sources coalesced to produce a profile for the estuary and its archaeological sites while providing a context for the next two phases of the area's site assessment.
4.2 SITE SURVEY AND ASSESSMENT:

The site survey and assessment carried out for Blueskin Bay took place between June 27th and August 27th, 2017. At completion, 21 of the estuary's 26 recorded archaeological sites were relocated, with 16 of those 21 possessing visible cultural features. In the five cases where archaeological sites were not relocated, this was either due to the masking of the site area by preventatively thick vegetation, or the alteration of the shoreline through erosion. For such sites it was not possible to non-invasively determine where sub-surface remains were likely to be situated. Additionally, a previously unrecorded nineteenth century seawall associated with the railroad was also encountered. This survey was the first to systematically revisit the estuary's sites since the NZAA's site upgrade project in 2007. During the course of the upgrade project 17 of the estuary's 24 archaeological sites were relocated and all 17 were found to have visible cultural features. Table 2 compares the final results of the two surveys and splits the estuary's archaeological sites into five separate zones (starting with Doctors Point and continuing clockwise to Warrington). These zones are each representative of an approximate geographical area of Blueskin Bay and were chosen solely for the presentation of these results throughout the rest of the chapter (Figure 19).

Table 2. Summarised outcomes of the 2007 NZAA upgrade project and the 2017 site survey and assessment.

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Total Sites: 26  Total Checks: 17  17  21  16
Of the sites that were not relocated in 2007, two had incorrect grid references (I44/188 and I44/192 were previously placed on Mt Cargill), three had eroded to the point where their original site locations were unknown, and two simply had no updated information from the revisit on ArchSite (I44/125 and I44/177). Additionally, as Blueskin Bay’s two historical sites were not yet recorded at the time of the upgrade these were not visited in 2007 either.

Due to the inconsistent nature of information provided on SRFs during the site upgrade project it was not possible to make any other broad comparisons between the two surveys. It is worth noting that such results should not be viewed in terms of success or failure, but should rather be used as yet another coarse-grained tool to determine the visibility and conditions of sites and how that has changed since 2007. Table 3 reveals all natural and anthropogenic impacts that were encountered during the 2017 site survey and assessment, while indicating their presence or absence at each of Blueskin Bay’s archaeological sites.

### Table 3. Summarised outcomes of the site survey and assessment: showing presence or absence of site impacts.

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<th>Animal burrows</th>
<th>Visitor damage</th>
<th>Erosion (river)</th>
<th>Pines</th>
<th>Erosion (slips)</th>
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Sites: 26  Totals: 16 9 8 6 6 5 2 2 2 1

As shown, 16 or 64% of Blueskin Bay’s sites are being affected by tidally-induced erosion. This was by far the most common impact present at the estuary. Moreover, if the two other forms of erosion (river and slips) are also included it brings the total amount of sites being affected by some form of erosion to 21 or 84% of sites. Inundation was encountered at a third
of Blueskin Bay’s sites. While such a result was not unexpected, it is significant as both erosion and inundation are among the hardest impacts to mitigate (Williams et al., 2017).

Figure 19. Aerial view of the five colour-coded assessment zones and their recorded archaeological sites (aerial imagery taken March 2013: courtesy DCC).
4.2.1 Doctors Point (Zone #1) Site Survey and Assessment:

Doctors Point is a 300-metre-long peninsula found along the south side of the estuary's entrance to the Pacific Ocean. While this part of Blueskin Bay has just two recorded sites, the whole vegetated dune system contains material associated with a multi-layered Māori settlement. The first site in the area to be assessed was I44/74. The GPS coordinates recorded on ArchSite relate to a 30-metre-long discontinuous exposure of middens and ovens along the beachfront (Figure 20). Although there are two primary midden layers, there are also ovens and smaller lenses of midden occurring sporadically across the exposure. Cutting through the middle of these cultural layers are three large animal burrows, which extend all the way through to the other side of the dunes (Figure 22). The biggest examples of these are large enough for a dog to run through and animal tracks found along the top of the dune system suggest this is in fact an ongoing occurrence.

The sediments that make up the dune system are fine and offer little resistance to disturbance. In Figure 20 the seaweed visible beneath the ranging pole suggests waves had recently reached these exposed sections of midden. Additionally, behind the beach is a walking track that cuts into additional areas of midden located in the interior of the dune system (Figure 21).

Figure 20. The ArchSite location of I44/74, showing collapsed sections of midden and the presence of seaweed beneath the ranging pole (photo taken facing northeast, July 2017).
Figure 21. Aerial view of Doctors Point showing sites I44/74 & I44/182 with GPS data of visible features and impacts (aerial imagery taken March 2013; courtesy DCC).
Along the tracks is evidence of animal disturbance (likely from dogs), which has brought cockle and pipis to the surface. Approximately 50 metres inland from the beach front are mature pines, whose roots are also disturbing cultural layers.

**Figure 22.** Example of a large animal burrow affecting site I44/74 (photo taken facing south, July 2017).

After a severe storm struck the region of Otago between July 21\textsuperscript{st} and July 23\textsuperscript{rd}, 2017, following the initial assessment of Doctor's Point, the site area was revisited to determine if any further damage had taken place. During this second trip a previously unexposed oven feature was discovered on the south side of the peninsula. This six-metre-long exposure is at beach level and is comprised of cockle shells in a 200 mm thick darkened soil layer containing fire cracked rocks and charcoal (Figure 23). As the material appeared to be in situ it may represent the first time this area of Doctors Point has been exposed to tides or the surface since before it was deposited.

Doctors Point's other site, I44/182, is comprised of a 20 metre section of midden in the same bay as the newly exposed material in Figure 23. Besides the ongoing effects of erosion, the other site impacts present in this area include three mature pines whose roots are disturbing the ground, a walking track that cuts through a section of midden, and vehicular damage (presumably from boat launching). The seaweed spread across the area also indicates parts of the site are being inundated during storm surges. As shown in Figure 24 the tide undercuts the lower levels of the shoreline, causing the rest to collapse forwards in large sections.
Figure 23. Newly exposed oven section along the south side of Doctors Point (photo taken facing north, July 2017).

Figure 24. Collapsed section of midden at I44/182. Note the high quantity of storm debris found coating the coastal edge (photo taken facing east, July 2017).
4.2.2 Michies Crossing (Zone #2) Site Survey and Assessment:

Michies Crossing is an elevated region of Blueskin Bay that contains three midden sites and an archaeological phonolite source. The sites in this area have been recently impacted by a native bush planting regime, which included the establishment of a walking track that cuts through numerous sections of midden. As the landscaping project occurred around the time of NZAA’s site upgrade project in 2007 a photograph was taken that can be used to illustrate the alterations to the area. Figures 25 and 26 show ‘before and after’ views for I44/183, which is a midden site found on either side of a small creek. On the eastern side of the creek is a low-lying grassed terrace fronted by a sea barrier of loosely placed rocks. Where this terrace meets the estuary are salt marsh plant species and seaweed, which suggests that parts of the area are being inundated during high tide. The site area’s western extent is represented by a 500 mm long section of midden that is being cut into by the walking track.

Michies Crossing’s two other midden sites, I44/196 and I44/197, are approximately 350 and 600 metres further west of I44/183, respectively, and each contain sections of midden that are also being affected by the track. Additionally, I44/196 is being impacted by tidal erosion at the water’s edge and I44/197 has several mature pine trees that are degrading areas of the midden located between their roots. In some instances these pines have slipped six metres from the edge of the cliff to the foreshore, taking large sections of midden with them. Although the recent planting regime has degraded some of the midden found close to the surface, the shallow roots of the native species may now be helping to mitigate the ongoing impacts of erosion (Figure 27).

The last site within the Michies Crossing assessment area is I44/198, a source of phonolite. This occurs in the form of a large boulder of fine grained phonolite that is well-marked by flaking scars (Figure 28). As noted in the SRF by Allingham in 1984, there appears to be noticeable distinctions between earlier and later flake scars based on their subsequent weathering. There is a seawall found 170 metres south of the boulder that had pieces of what appeared to be this same form of phonolite included during its construction (Figures 29 & 30). This may suggest that the nineteenth century railway workers who built the wall either took large pieces from the neighbouring foreshore, or perhaps produced some of the more recent flaking scars on the archaeological stone source (potentially using a cold chisel to do so). The biggest threat to the source is likely to be lithic enthusiasts whose sampling could remove evidence of its prior archaeological use.
Figure 25. Two photos taken ten years apart of the eastern side of I44/183. Using the power pole as a reference note the difference in the amount of vegetation and the eroding section of midden along the centre of the top photo (photos taken facing southwest: top: May 2007; bottom: July 2017) (top photo credit: Phil Latham).
Figure 26. Two aerial views of Michies Crossing taken during and after the landscaping project (including sites 144/183, 144/196 and 144/197 (aerial imagery taken March 2007 & March 2013: courtesy DCC).
Figure 27. Eroding midden at site I44/197, including archaeologist Phil Latham (photo taken facing west, July 2017).

Figure 28. Site I44/198, a phonolite source site with visible flaking scars (photo taken facing south, July 2017).
Figure 29. Seawall, likely associated with the construction of the Waitati railway line in the nineteenth century (photo taken facing southeast, July 2017).

Figure 30. Aerial views of site I44/198 and seawall (aerial imagery taken March 2013: courtesy DCC).
4.2.3 *Waitati (Zone #3) Site Survey and Assessment:*

The Waitati zone has eight recorded archaeological sites: six ‘midden/oven’ sites found within its 700-metre-wide floodplain delta and two historical sites located along its north western extent. During the site survey and assessment all but one of these sites were relocated and all that were discovered were represented by at least one visible cultural feature. Overall it appears that significant amount of change has taken place to the area since Allingham first recorded the six pre-European sites in the 1980s. Sites such as 144/185, 144/186, and 144/188, which were all originally recorded as having multiple areas of midden or ovens, are now comprised of singular sparse deposits. Using Allingham’s notes as a comparative guide it was quite evident that the whole area had become degraded through both erosion and inundation over the past three and a half decades. 144/189, a site initially recorded as a section of midden in a drainage ditch south of the railroad, appears to have eroded significantly as it was not relocated ten years ago during the upgrade project and remained unseen during this assessment.

Sites 144/187 and 144/188 are located on either side of the previous mouth of the Waitati River (Figure 31). Although the Waitati River no longer flows through the outlet, it appears that a substantial amount of water still moves through there during and after heavy storms. This activity is causing erosion on the eastern side of 144/187, which is also being affected by tidal erosion, inundation, and small animal burrows produced by crabs.

The crab burrows honeycomb a majority of the delta’s tidal margin and in some cases are directly affecting layers of cultural deposits. On the northern side of the 144/187 site area is another intact section of midden (Area A in Allingham’s SRF notes) (Figure 32), as well as another area of midden at (Area B), but no material was seen to the west (Area C). Additionally, two other small areas of midden and charcoal were observed on the eastern and southern sides of the tidal island, respectively. The part of the floodplain making up the site area of 144/188 was originally recorded as two oven features and a section of 500 mm thick midden, but is now a slightly elevated patch of mud with a single 200 mm long lens of charcoal (Figure 33).
Figure 31. Aerial view of Waitati sites I44/186, I44/187, I44/188, and I44/189, including collected GPS data (aerial imagery taken March 2013: courtesy DCC).
Figure 32. Site I44/197 (Area A). An eroding section of charcoal and cockle shells. Note how the salt marsh vegetation transitions to pasture (photo taken facing south, July 2017).

Figure 33. Site I44/188, now represented by a small, ephemeral patch of charcoal. As shown, the tidal island here is quickly transitioning to mudflat (photo taken facing east, July 2017).
Approximately 100 metres west of I44/186 is a larger portion of the floodplain delta, which contains sites I44/184 and I44/185 (Figure 35). These sites have also degraded significantly since they were first recorded by Allingham in 1983. I44/184 was originally represented by three areas: several metres of fire cracked rocks and charcoal (Area A), an oven in a small tidal island (Area B), and around 20 metres of an ‘occupation layer’ (Area C) (as described in the SRF). The small tidal island that was described as making up Area B has subsequently eroded into a circular patch of what are likely to be oven stones. Area A has also experienced some erosion and degradation through inundation. Figure 34 compares two photos taken of Area A in 2007 and 2017. As shown, erosion has affected the small oven located along the section (located two thirds along from the left side of the 2007 image). Additionally, the entire area has been impacted by the effects of inundation. The pasture that used to top the area’s surface has now been mostly replaced by salt marsh plant species. Two depressions located less than a metre from the eroding edge, which may themselves be further ovens, have now become filled with salt water. This form of degradation appears to be quite recent and will likely exacerbate the erosion that has already affected the area. Further damage is also taking place through the movement of stock (cows) across the site.

Similar conditions were also observed at I44/185 and it seems likely that another ten years of inundation and erosion will transition the site areas towards a similar condition as I44/188 (Figure 32). As no archaeological investigations have taken place at any of Waitati’s pre-European sites their ongoing degradation is of particular management concern.
Figure 34. Two photos of I44/184 (Area A) taken ten years apart. Note how repetitive inundation has transitioned the pasture to salt marsh species, while flooding possible oven depressions (photos taken facing south, top: May 2007; bottom: July 2017) (top photo credit: Phil Latham).
Figure 35. Aerial view of Waitati sites I44/184 and I44/185, including collected GPS data (aerial imagery taken March 2013: courtesy DCC).
Waitati’s first recorded historical archaeological site (I44/455), the subsurface remains associated with Alexander Grant’s 1870s estate, is likely to be located on the western side of State Highway One and as such, is currently unaffected by impacts such as erosion or inundation. As long as the area does not undergo any further development for the time being the subsurface features associated with the site are not under any immediate threat. Site I44/477 is a line of fence posts that were constructed in the 1870s. As shown in Figure 36, the posts are in fairly poor condition, but considering they are now over 140 years old that is to be expected. Their top halves are covered in lichen, and their lower halves are waterlogged, but they do not appear to be overly rotten. Other than relocating them to a controlled environment there does not appear to be much that can be done to prevent further weathering from taking place.

Figure 36. Site I44/477, a row of nineteenth century fence posts associated with the railway line (photo taken facing north, July 2017).

4.2.4 Evansdale (Zone #4) Site Survey and Assessment:

The township of Evansdale is situated on the north-eastern corner of Blueskin Bay, but for the purposes of the presentation of these results its zone was extended south to also cover site I44/199. This site, which was originally recorded as a two-metre-long midden exposure containing 100 mm of cockle, pipi, and mudsnail, was not relocated during the site survey and assessment. It appears a significant amount of erosion has taken place at the site,
removing any trace of the recorded cultural features. In 2007, when it was last observed, it was described as being a "small sparse eroding mudsnail midden". Although the whole coastal edge was systematically searched, no such exposures were encountered.

A distance of 1.5 km north of I44/199 are two sites, I44/190 and I44/191, that are associated with the Māori place name Hohopounamu ("rubbing the greenstone"). A 15-metre-long 150 mm thick section of charcoal associated with I44/190 was found along the eastern side of Carey’s Creek. The creek is the primary threat to the site as it appears to swell significantly during and after heavy rainfall, causing erosion to take place.

![Figure 37. Photo of site I44/191 taken during the 2007 site upgrade project. This section of midden was not relocated during the 2017 site survey and assessment (photo taken facing south, May 2007) (photo credit: Phil Latham).](image)

Carey’s Creek has also severely impacted I44/191, which is no longer visible anywhere along the described location. Figure 37 shows a photo taken of the site in 2007 in which midden was clearly visible. It appears the creek has subsequently eroded this material away, although sub-surface features may still exist within the bank.

Another 350 metres north of this area is I44/192, a site described by Allingham in 1983 as having three areas: a 60 mm thick band of charcoal (Area A), charcoal and fire cracked rocks in a 150 mm lens in a small bank (Area B), and an oven 400 mm in length (Area C). However, during the site survey and assessment only one very small section of charcoal was observed on the ground in front of Area B, with no other visible features discovered anywhere else (Figure 38). Site I44/193, described as being along the bank of a creek 180 metres north of I44/192, was not rediscovered during the assessment or previously in 2007.
The final site visited in the Evansdale area is I44/201, which was described by Allingham in 1989 as a one metre section of midden (cockle, pipis, and fish bone) found high up on a bank above Coast Road just below a modern dwelling. As Allingham suggested in the SRF, the midden did not appear to show same age as the other middens recorded along the estuary, perhaps indicating they were modern refuse. Some sparse examples of mussel, cockle, and pipi were discovered at the location eroding down the slope, however, these were mixed in with modern broken glass, ceramics, and plastic, again bringing the site's antiquity into question.

4.2.5 Warrington (Zone #5) Site Survey and Assessment:

Warrington was a region of Blueskin Bay that was discussed at some length during this chapter's documentary research section (Figure 39). This was due primarily to its large multi-layered Māori settlement site (I44/177) and the longevity of the various inquiries that have taken place there. For those reasons it was anticipated to be an area with an abundance of locatable archaeological features. However, the main site area of Warrington is located approximately 100 metres inland from the coast and did not appear to possess any visible surface features. There has been continual development in the area for decades now, which will continue to threaten the site as the township located there undergoes further expansion.
The other sites found throughout the Warrington zone are situated closer to the shoreline and sites I44/179, I44/180, and I44/178 have been affected by erosion since the time they were recorded by Allingham in 1983. The midden site I44/179 was not relocated in 2007 or during this assessment (likely due to erosion). The 2017 survey of the spit took place in July soon after the previously mentioned storm that battered this part of the New Zealand coast.
Figure 40 shows the site location of I44/180, but as shown the entire area was buried under storm debris. As such, the sections of midden in Allingham’s description of the site were not visible. Erosion clearly remains an ongoing threat along this part of the spit, particularly during storm events.

Site I44/178 was described in its SRF as a significant quantity of shells found within the roots of pine trees, as well as being associated with artefact finds. As was recognised by Allingham when the site was recorded in 1983, the absence of charcoal and general stratigraphy might indicate the site was produced by a flood event, rather than as a cultural deposition. As shown in Figure 41 the pine trees appear to be impacting any deposits found in the area.

The last two sites within the Warrington zone (I44/200 and I44/125) are each located in areas that have subsequently become covered in thick vegetation. Without being able to see the stratigraphy associated with I44/200 it was not possible to determine where the midden described in the SRF was located. Site I44/125 has a detailed sketch map and as such its approximate location was found, however, the vegetation there was too thick to rediscover any of the described cultural features. Those features include a 750 mm lens of darkened soil and oven stones, which were recorded by Ian Smith in 1978 and a 60 metre terrace with eroding shell that were recorded by Allingham in 1982. This area has prograded since the
1980s and the deposits are now well out of reach of waves and under a thick layer of vegetation (Figure 42). As this area continues to prograde the road that leads to the beach front might extend, which may eventually encroach on the deposits located there.

**Figure 41.** Site 144/178, a large exposure of shells that are being impacted severely by the area's mature pine trees (photo taken facing south, August 2017).

**Figure 42.** Aerial view of site 144/125 including approximate area of Allingham's terraced midden described in the SRF (aerial imagery taken March 2013: courtesy DCC).
4.3 COMPUTER-BASED SPATIAL ANALYSIS SHORELINE CHANGE:

Erosion is an impact that has been noted as affecting Blueskin Bay since at least the 1980s when a majority of its sites were first recorded. While it was undoubtedly an ongoing process, exactly how this threat manifested itself across the estuary’s shoreline was not apparent. To rectify this, high resolution aerial imagery was combined with GIS to systematically calculate the distance between derived vegetative shorelines at a total of 3,587 individual assessment transects. Each of these were placed two metres apart and quantified the amount of erosion or progradation that had occurred at key positions within each of the five assessment zones. Wherever possible this analysis incorporated aerial photographs that dated closely to the time each archaeological site was recorded. Doing so allowed shoreline change to be calculated for an assessed area from the time a site was first registered with the NZAA until its recent past. Overall this temporal coverage was not universal, but by making full use of the imagery that was available the DSAS was able to determine both the amount and rate of shoreline change across twelve different areas. A summary of those results is presented in Table 4, which again splits Blueskin Bay into the five assessment zones and indicates the areas and sites incorporated into the DSAS calculations. As shown, the amount of erosion and progradation varied significantly between each of the five zones, which broadly demonstrates the dynamic nature of the estuary’s shoreline. In particular, areas such as Warrington and Doctors Point have each experienced high rates of both erosion and progradation over the past two decades. For GIS shapefiles of all traced shorelines used in this analysis please refer to the DVD at the back of this thesis.

Notably, all significant occurrences of shoreline advancement took place along the estuary’s exterior regions, while its interior has typically experienced trends of retreat. As was anticipated, the highest rates of erosion were found in sections of the estuary that were either exposed directly to tidal channels, or adjacent to freshwater outlets such as the Waitati River. The following subsections will now present the full results of the shoreline analysis for each zone through description and annotated figures.
Table 4. Summarised outcomes of the DSAS extension undertaken for each of the assessment zones, including the associated Figure #s.

Blueskin Bay Shoreline Change
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<th>Avg. Erosion Rate (metres per year)</th>
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<th>Max. Progradation Rate (metres per year)</th>
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4.3.1 *Doctors Point (Zone #1) (Shoreline Change):*

Doctors Point is a region of Blueskin Bay that was noted as being particularly susceptible to the effects of erosion during the site survey and assessment. The area’s large mobile vegetated dune system and its numerous exposures of archaeological material made it an ideal candidate for the utilisation of the DSAS. This process made it possible to visualise the area’s shoreline change over 17 years from October 2000 to June 2017. For the purposes of this analysis measurement transects were generated every two metres along 766 metres of shoreline, resulting in 383 NSM measurements. These were then colour-coded in order to reflect the amount of progradation or erosion that had occurred at each transect. As shown in Figure 43 the dune system making up Doctors Point has transitioned significantly since 2000, with some regions prograding by as much as 37.3 metres (an average rate of +2.24 m/yr) and others eroding by up to 8.38 metres (an average rate of -0.5 m/yr).

The high incidence of progradation along the northern regions of Doctors Point is particularly noteworthy as that region of Doctors Point appears to have remained stable since at least 1982 (Figure 44). As shown, far less change took place across this specific region of Doctors Point in the 18 years between 1982 and 2000 as took place in the subsequent 17. It was tempting to make further use of the 1982 imagery to systematically quantify shoreline change across the entirety of Doctors Point, but the quality of the aerial was simply not high enough to provide accurate shoreline measurements (this was particularly true for areas along the southern areas of the image). However, as is visible in Figure 44, there appears to have been trends from 1982 to 2000 of coastal retreat across midden sections at I44/74 and I44/182 and progradation along the western facing dunes.
Figure 43. The DSAS results for Doctors Point, including sites/features associated with I44/74 and I44/182 (aerial image taken October 2000: courtesy DCC and Otago School of Surveying).
Figure 44. Aerial view of Doctors Point from 1982, including vegetative shorelines derived from 2000 and 2017, and GPS data of archaeological features (aerial imagery taken March 1982: Crown Aerial: SN 8040 E/1) (sourced from Retrolens.nz, licensed by LINZ CC).
As shown in Figure 43, the point at which progradation transitions to erosion occurs at the eastern extent of Doctors Point's north-facing midden exposure (I44/74). This section of midden experienced an average of 3.5 metres of retreat between 2000 and 2017 (average of -0.21 m/yr) across its nine measurement transects with the highest transect showing 4.2 metres retreat (average of -0.25 m/yr). Erosion was also found to have affected the south-facing side of Doctors Point, but not to the same degree as the north. At the newly exposed section of southward facing midden an average of 0.93 metres of retreat took place (average of -0.06 m/yr) across its three measurement transects with the highest showing a loss of 1.16 metres (average of -0.07 m/yr). Along the area of exposed midden at I44/182 an average retreat of 1.54 metres took place (average of -0.09 m/yr) with the highest transect showing 2.03 metres of loss (average of -0.12 m/yr). As indicated in Figure 43, no data was retrieved for some parts of the site due to the large pine tree that over-hangs the shoreline.

![Figure 45](image_url)

**Figure 45.** Aerial view of the northeast side of Doctors Point, including 2000, 2007, and 2017 shorelines and GPS data of midden (aerial imagery taken March 2007 and October 2000) (Courtesy: DCC and Otago School of Surveying).

To determine if the rates of shoreline change at Doctors Point occurred linearly, imagery from March 2007 was traced and compared to the 2000 shoreline (Figure 45). As shown, the marram grass (*Ammophila arenaria*) present along this section of coast has experienced a period of rapid seaward propagation. Between 2000 and 2007 the shoreline prograded by as much as 23.4 metres (average of +3.65 m/yr). As indicated by the differential GPS collected in June 2017, this process is continuing to prograde the shoreline along this region of the estuary.
Figure 46 shows imagery from the same timespan along the I44/74 site location. Between October 2000 and March 2007 three metres of erosion took place along I44/74’s northward facing section of midden (average of -0.47 m/yr), with a further three metres taking place in the ten years between March 2007 and June 2017 (average of -0.29 m/yr). It is very likely that further erosion along this section of coast will continue to expose, degrade, and remove more of the site if left unchecked.

4.3.2 Michies Crossing (Zone #2) (Shoreline Change):

As was previously addressed, in 2007, Michies Crossing was the site of a planting regime. This landscaping appeared to have significantly impacted the recorded archaeological sites present there. The shoreline change analysis provided evidence for this assertion as up to 4.61 metres of erosion took place at parts of I44/183 from 2000 to 2007 (average of -0.72 m/yr). A georeferenced aerial photograph of this part of Michies Crossing taken in 1979 suggests that the area had prograded between 1979 and 2005. Figures 47 and 48 reveal how the shoreline transitioned before and after the landscaping project (Figure 48 also presents the results of the DSAS). It is likely that during the landscaping the area experienced greater susceptibility to erosion. Very little change took place between 2007 and 2013 indicating the area may have since stabilised. The terrace on the eastern side of the creek does not appear to have eroded or prograded significantly from 1979 to 2013.
Figure 47. Aerial views of I44/183 from 1979 and 2000, including vegetative shorelines derived from 2000 and 2007, and GPS data of archaeological features (left aerial imagery taken March 1979; Crown Aerial: SN 5248 L/3; Sourced from Retrolens.nz, licensed by LINZ CC) (right aerial imagery taken: October 2000; courtesy DCC and Otago School of Surveying).
Figure 48. Aerial views of I44/183 from 2007 and 2013, including DSAS results (left), vegetative shorelines derived from 2000 and 2007, and GPS data of archaeological features (left aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying) (right aerial imagery taken March 2013 imagery: courtesy DCC).
The other two midden sites located at Michies Crossing are at a higher elevation than I44/183 and as such they do not appear to have experienced the same levels of erosion during the landscaping. The shoreline analysis for these elevated regions was hindered by the cliff’s gradient and the vegetation present along it. This made it difficult to determine where the cliff edges terminated using aerial imagery. Overall, while the 2007 landscaping project at Michies Crossing may have caused some degradation to its sites, the shallow roots of the native plant species might be mitigating future harm by slowing erosion rates.

4.3.3 Waitati (Zone #3) (Shoreline Change):

The low-lying floodplain delta at Waitati contains ovens and sections of midden that are represented by six recorded archaeological sites. So far archaeological investigations of the area have not progressed further than basic field survey methods and as such our understanding of the timing, significance, and distribution of the sites is limited. For this reason it was particularly important to establish which areas were eroding and to what extent. To calculate this an aerial image from March 1979 of the main part of the alluvial fan was georeferenced and traced within ArcMap. The date of this aerial photograph was useful as it was collected less than four years before two of the area’s archaeological sites were recorded by Allingham. The whole delta’s vegetated shoreline was also derived from imagery dating to 2005, 2007, and 2013. Figure 49 shows a broad overview of the traced shoreline and the extent of the coverage provided by the 1979 aerial imagery. Once completed, the DSAS was used to quantify rates of shoreline change across each of the site areas.

The first Waitati sites assessed for shoreline change were I44/186, I44/187, I44/188, and I44/189, which are situated along and adjacent to the antecedent mouth of the Waitati River. Although the tidal islands that make up the site areas were not within the coverage of any of the high resolution aerial images found of Blueskin Bay from the twentieth century it was still possible to see a clear transformation along the pertinent tidal islands between March 2000 and March 2013. Figure 51 presents the DSAS results for all four of the sites and, as shown, the area showed a general trend of retreat. This was particularly true along either side of the channel, which has entirely removed two small tidal islands while incrementally degrading site areas associated with I44/187 and I44/188. The average amount of change across the 694 transects was -0.88 metres (an average of -0.067 m/yr).
Figure 49. Aerial view for part of the Waitati floodplain delta from 1979, including derived vegetative shorelines and ArchSite locations (1979 imagery: SN 5388 M/4; sourced from Retrolens.nz, licensed by LINZ CC).
Figure 50. The DSAS results for I44/186, I44/187, I44/188, and I44/189, including 2000 and 2013 derived vegetative shorelines, ArchSite locations and GPS data of archaeological features (aerial imagery taken March 2013: courtesy DCC).
Due to the low elevation of the tidal islands their marginal zones can erode horizontally (towards their interior) and vertically (top down) simultaneously. Under such conditions vegetated shorelines can become progressively degraded from both directions until eventually becoming indistinguishable from the surrounding mudflat. This process is most apparent along the site area associated with I44/188 where 6.2 metres of loss occurred during the 13 year duration (average of -0.48 m/yr). The final site in the area, I44/189, has its ArchSite location in a region of 1.8 metres of loss, but it remains undeterminable if the exposure of midden associated with the site eroded away from that location or elsewhere prior to 2000.

Site I44/185 was included within the coverage of an aerial photo from 1979 so it was possible to use the DSAS to measure shoreline retreat from four years prior to the date it was recorded till 2013 (Figure 51). This site was described by Allingham in 1983 as four areas (A through D), which included oven exposures at A and C, circular and rectangular depressions at B, and a metre-long section of charcoal at D.

![Figure 51](image.png)

*Figure 51.* The DSAS results for I44/185, including 1979 and 2013 derived vegetative shorelines, ArchSite location and GPS data of oven feature (aerial imagery taken March 2013: courtesy DCC).

As shown in Figure 51, since 1979 the small channel that runs through the middle of the site area has expanded and removed large sections of the delta just south of Areas A and B. Additionally, a channel now cuts through Area B, which has likely degraded or removed any features that were present there. Quantifying those alterations to the site area was beyond
the capabilities of the DSAS measurement transects, but their impact to the site area is still visually apparent. The only observed exposure across the vegetated shoreline of the four site areas was an oven exposure at Area A, which is situated in a section showing 1.2 metres of loss (average of -0.034 m/yr). The average measurement of the 295 transects used to assess the entire site area was -1.32 metres (average of -0.037 m/yr), however, such a figure does not reflect the shoreline loss relating to the emergence of the channels.

Figure 52. The DSAS results for I44/184, including 1979 and 2013 derived vegetative shorelines, ArchSite location and GPS data of oven features (aerial imagery taken March 2013: courtesy DCC).
Figure 52 exhibits the shoreline change at site I44/184 between 1979 and 2013. As shown, the perimeter of the tidal island that makes up Area C has become diminished since 1979 with 2.49 metres of loss (average of -0.07 m/yr) adjacent to an exposed oven. The 79 transects that measured the island had an average value of -1.52 metres (average of -0.045 m/yr), while the whole area’s combined 276 transects had an average value of -1.4 metres (average of -0.041 m/yr).

Area B, which was described as a tidal island containing an oven, was hard to distinguish from the surrounding mudflat even prior to the date the site was recorded. The exposed oven at Area A experienced a relatively small amount of erosion (-0.76 metres) between 1979 and 2013, but interestingly the shoreline to its immediate east eroded a significant 6.99 metres (an average of -0.206 m/yr). In the 2013 aerial imagery it is possible to see hoof prints emanating from this area, suggesting stock may be using it as an access point to the rest of the delta. This evidence coupled with the cow present near the bottom middle of the figure suggests stock grazing may be contributing to rates of shoreline retreat across this and perhaps other sections of the Waitati area.

4.3.4 Evansdale (Zone #4) (Shoreline Change):

The first site analysed from the Evansdale assessment zone was I44/199. This was a site that was not relocated during the site survey and assessment, with the likeliest cause for this attributed to coastal erosion. Unfortunately the shoreline change analysis for this section of Blueskin Bay coast was largely inconclusive. This evaluation was primarily hindered by the thick overhanging vegetation that extends along the entire associated site location. However, the shoreline was also masked in thick shadows in aerial imagery from 2007 and was not included in the aerial coverage of the estuary from 2000. Figure 53 compares imagery from 1978 and 2013 and Figure 54 provides an example of the overhanging vegetation present along the site area. Under such conditions any measurements taken by the DSAS transects are indistinguishable between shoreline change and the growth of vegetation.

As shown in Figure 53, along areas unaffected by the thick vegetation up to five and a half metres (average of -0.16 m/yr) and six and a half metres (average of -0.19 m/yr) of shoreline retreat took place between 1978 and 2013, respectively, with a section near the middle prograding by 13 metres (average of +0.37 m/yr). This area of progradation could likely be attributed to human agency as a series of tyre tracks are visible leading up to the area in the 1978 imagery (perhaps relating to the adjacent railway line). Without having GPS data or a better locational aid for the site it is not possible to make any other inferences about the possible impacts of these changes.
Figure 53. Aerial view of I44/199 from 1978 and 2013, including their respective vegetative shorelines and measurements of observable changes (left aerial imagery taken February 1978: Crown Aerial: SN 5248 J/4) (Sourced from Retrolens.nz, licensed by LINZ CC) (right aerial imagery taken March 2013: courtesy DCC).
Approximately 1.5 km north of I44/199 are sites I44/190 and I44/191, which are positioned along the eastern side of Careys Creek. During the site survey and assessment a 15-metre-long dark charcoal layer was found in the site area associated with I44/190 and no archaeological features were observed at I44/191. To determine the area's NSM an aerial photograph of the creek from February 1978 was georeferenced, traced, and compared to a shoreline derived from March 2013 (Figure 55). The 391 DSAS assessment transects (spaced two metres apart) revealed up to 11.37 metres of shoreline retreat (average of -0.33 m/yr) took place in the area over the 35 years from 1978 to 2013. The area containing a section of charcoal eroded an average of 2.24 metres (average of -0.06 m/yr) across its nine assessment transects. Although the ArchSite location for I44/191 placed it 20 metres away from the exposure associated with I44/190, Allingham's 1983 sketch map suggests its location is actually a further 80 metres north (Figure 56). This proposed site location falls within an area of significant retreat and had an average loss of 7.4 metres (average of -0.21 m/yr) across its 26 (orange and red) transects. The two sections of shoreline labelled 'No data' were obstructed by tree growth. Overall, the analysis revealed a general trend of retreat along the centre of the assessed area with the greatest incidences of retreat occurring along the eastern side of each creek bend.
Figure 55. The DSAS results for I44/190 and I44/191, including 1978 and 2013 derived vegetative shorelines, proposed and current ArchSite locations, and GPS data of charcoal feature (aerial imagery taken March 2013: courtesy DCC).
Site I44/192 was recorded by Allingham in 1983 and given three site areas: A through C. During the site survey and assessment, a small sparse deposit of charcoal was relocated on the tidal island making up Area B, but no archaeological material was observed at A or C. Figure 57 presents the DSAS results, which used 512 transects to measure the whole area’s NSM. As shown, this process revealed why perhaps so little archaeological evidence was discovered in this region during the site survey. Area C in particular eroded significantly in the area that Allingham had labelled as archaeological in his sketch map. Overall, the floodplain has experienced a trend of retreat with transects showing erosion averaging -1.3 metres over the 35 years (average of -0.037 m/yr) and the greatest showing -8.81 metres (average of -0.252 m/yr). The erosion of the site can be attributed to the estuary’s tides and to the channel that winds through the area. As was found at the floodplains in Waitati the margins of the tidal islands here are eroding vertically as well as horizontally, suggesting the impact to the area by erosion could be greater than is depicted by the DSAS results.

Figure 56. Sketch map by Allingham in 1983 taken from the I44/190 SRF.
Figure 57. The DSAS results for I44/192, including 1978 and 2013 derived vegetative shorelines, ArchSite location and GPS data of charcoal deposit (aerial imagery taken March 2013: courtesy DCC).
The last site area to be analysed from the Evansdale assessment zone was site I44/193. The location of this site was again included in Allingham’s sketch map of the Evansdale area (Figure 56), but no sections of midden were observed in 2007 during the site upgrade or during the 2017 site survey and assessment. Figure 58 presents the results of the DSAS and proposes a new site location (40 metres northwest) based on Allingham's plan. As shown, the channel that runs through the location has gradually eroded its banks since 1978, with the greatest amount of retreat taking place along its northern side and the area adjacent to I44/193. On average the 174 transects had a value of -0.81 metres (average of -0.023 m/yr). The greatest area of loss (-7.44 metres), retreated at an average rate of -0.21 metres per year.

Figure 58. The DSAS results for I44/193, including 1978 and 2013 derived vegetative shorelines and a proposed and current ArchSite location (aerial imagery taken March 2013: courtesy DCC).

4.3.5 Warrington (Zone #5) (Shoreline Change):

The Warrington assessment zone is comprised of a two-kilometre-long sand spit that is vegetated almost entirely along its seaward tidal margin by marram grass. As was found at Doctors Point, the propagation of this plant species has resulted in a highly mobile dune system. Figure 59 compares the spit's shoreline from 1982 to 2013. The date of the aerial image is once again significant as it was taken less than a year before a majority of Warrington's archaeological sites were recorded. It was also the only twentieth century aerial image found of the area that was of high enough quality to be georeferenced and interpreted for shoreline change. Unfortunately, even this imagery had a cell size of 0.709
metres, which meant its resolution was 4.2 times lower than the 1978 aerial used during the Evansdale analysis (which had a 0.17 metre cell size). This relatively low resolution, coupled with the area’s dynamic environment made it very difficult to precisely georeference the aerial image. As a result even with 12 control points the margin of error for the 1982 georeferenced image was +/- four metres, which was too high to accurately quantify small scale shoreline change along the spit. However, as shown in Figure 59 some regions of the spit eroded by up to 167 metres (average of -5.39 m/yr) and prograded by as much as 147 metres (average of +4.74 m/yr) during the 31 year duration. Given the high instances of shoreline change the potential four metre margin of accuracy of the georeferencing was negligible. This did however prevent it from being used to determine rates of change at Warrington’s archaeological sites using DSAS. In a ‘worst case’ example, a site area that had experienced two metres of erosion could have potentially been calculated by the DSAS as having prograded by up to two metres.

To determine if the spit’s significant rates of progradation occurred linearly its shoreline was also derived from orthorectified imagery dating to 2007. As shown in Figure 60, between 2007 and 2013 the vegetated shoreline of the spit prograded in some places by as much as 101 metres (an average of +16.83 m/yr). This amount of marram grass propagation continued its trajectory from the +46 metres of growth that occurred previously from 1982 to 2007 (an average of +1.84 m/yr). While that particular transect of the spit had, by far, the greatest incidence of progradation, other areas to the north prograded by 50 metres during the same six year timespan (average of +8.33 m/yr). It should be noted that the marram grass that developed into the 2013 vegetated shoreline was already in an incipient state in 2007, but was sparse enough not yet to be considered as being fully vegetated (as visible in the bottom half of Figure 60). Under such conditions the vegetated shoreline can prograde rapidly in large sections that advance towards the sea in ephemeral patches that become established and once again advance in a seemingly continuous cycle.
Figure 59. Aerial views of Warrington Spit from 1982 and 2013, including derived vegetative shorelines and measurement transects at areas of interest (left aerial imagery taken: March 1982: Crown Aerial: SN 8040 E/I; sourced from Retrolens.nz, licensed by LINZ CC) (right aerial imagery taken: March 2013: courtesy DCC).
Figure 60. Aerial view of the middle section of Warrington Spit, including 1982, 2007, and 2013 derived vegetative shorelines and ArchSite locations (aerial imagery taken March 2007 and March 2013) (courtesy: DCC and Otago School of Surveying).

To determine the effect shoreline change has had on Warrington’s archaeological sites the DSAS was employed at I44/180 and I44/177 using a shoreline derived from orthorectified imagery from October 2000 and differential GPS collected during the site survey and assessment in August 2017 (Figure 61). As shown, up to 3.87 metres of erosion (an average of −0.229 m/yr) took place along the two sites’ coastal section. The average value of the 88 transects was -1.81 metres (an average of -0.107 m/yr). The greatest incidences of retreat
took place along the south-eastern extent of the beach, which is 105 metres away from I44/177’s ArchSite location. Although this ArchSite location places I44/177 a significant distance from the coastal edge, it is representative of Warrington’s multi-layered settlement site complex, which is potentially Blueskin Bay’s largest archaeological site. As the site’s full extent is not yet known concretely it remains unclear when exactly the shoreline retreat taking place at the beach will start impacting its subsurface remains.

![Warrington Spit Sites I44/180 & I44/177: 2013](image)

**Figure 61.** The DSAS results for I44/177 and I44/180, including 2000 and 2017 derived vegetative shorelines and ArchSite locations (aerial imagery taken March 2013: courtesy DCC).

The shoreline adjacent to site I44/178, which consists of exposed deposits of shells under pine tree roots was obscured by the same mature pines that top the site. This prevented the shoreline analysis from being carried out for the area. The site area of Warrington’s southernmost site, I44/200, was visible and provided an opportunity to measure the effects of shoreline change on lower half of the sand spit. Figure 62 shows the DSAS results for 600 metres of the spit and uses shorelines derived from 2007 and 2013. As shown, there is a gradual increase in erosion from north to south along the western side of the spit, which reaches a maximum erosion value of -7.12 metres (an average of -1.19 m/yr). The eastern length of the spit revealed some of the same high levels of progradation that were visible in Figure 60.
Figure 62. The DSAS results for shoreline change at the middle of Warrington Spit between 2007 and 2013, including ArchSite location of I44/200 (aerial imagery taken March 2013: courtesy DCC).

The 202 DSAS transects north of and including the highest value of 101 metres had an average of value of +41.4 metres (average of +6.9 m/yr). This analysis, coupled with Figures 59 and 60, indicate the spit is moving on a north eastern seaward trajectory, with rates of change highest along its southern extent. Figure 63 provides a closer view of the DSAS results for site I44/200. As shown, from 2007 to 2013 the area experienced significant retreat. The transect with the greatest incidence of erosion had a value of -3.69 metres (average of 0.62 m/yr) with another 20 metres of the site showing -3.21 metres (average of -0.54 m/yr),
which are some of the highest rates of retreat occurring within Blueskin Bay’s site areas. The value of a transect placed directly in front of the site’s given location was -1.44 metres (an average of -0.24 m/yr). As the site was not relocated during the site survey it is not possible to ascertain exactly how much of the site has likely eroded in recent years. However, given the general trajectory of the spit from 1982 to 2013, the site has likely retreated significantly since it was first recorded.

Figure 63. A close-up view of the DSAS results for I44/200, including 2007 and 2013 derived vegetative shorelines and ArchSite location (aerial imagery taken March 2013; courtesy DCC).
The last Warrington site to be assessed for shoreline change was I44/125, which is located on the north-eastern side of the spit. Although the site was not relocated in 2007 or 2017 the sketch map included in Allingham’s SRF provided a good indication of its likely position. Figure 64 shows the DSAS results for the area, which quantified the amount of shoreline change that took place along the section of coast from 2000 to 2013. In order to provide an indication regarding the trajectory of the progradation shorelines were also included in the figure from 1982 and 2007. Due to apprehensions about the +/- 4 metre accuracy of the 1982 imagery it was not included in the DSAS measurements of areas shoreline change, but nevertheless it provides an indication of the coasts movement over the past three decades. The average of all 197 transects shown in the figure was +27.76 metres (an average of +2.23 m/yr), with a maximum value of +100.28 metres (an average of +8.08 m/yr). As is apparent by the amount of progradation that occurred between 2007 and 2013, this process does not appear to be slowing.

Figure 64. DSAS results for I44/125 measuring shoreline change between 2000 and 2013, including 1982 and 2007 derived vegetative shorelines, described midden area, current ArchSite location and proposed site location (aerial imagery taken March 2013; courtesy DCC),
4.4 COMPUTER-BASED SPATIAL ANALYSIS SEA LEVEL RISE:

Up until this point, this assessment of the Blueskin Bay case study area and its archaeological sites has been carried out using information drawn from the past and the near present. While understanding current and prior impacts is crucial to effectively managing archaeological sites, such strategies should also be anticipatory. Although intergovernmental panels have given predictions of how high sea levels may become by the end of this century, without having a way to visualise those effects it is hard to use these for management purposes. To remedy this, the following sections will provide examples of how SLR predictions can be applied visually to a coastal area, while demonstrating how those predictive scenarios may impact Blueskin Bay's archaeological site areas. In the maps of each assessed area 2004 colourised LiDAR elevation data is layered on top of orthorectified 2007 aerial imagery, which was the closest in date to the collected data that could be located. Each map also includes the ArchSite location for each site found within the assessed area, as well as the most recent shoreline incorporated during the shoreline analysis (either 2013 or 2017). Overall this analysis revealed that while rising sea levels may not impact all of Blueskin Bay's site areas uniformly, very few are likely to escape some degree of increased degradation through inundation by 2100. In most cases there was also a marked difference in the level of impact between the best and worst case SLR scenarios. A map showing the terrain model used for the SLR model is found in Appendix I, as well as visual representations of MHWS, best, and worst case scenarios for the entire estuary in Appendix II.

4.4.1 Doctors Point (Zone #1) (Sea Level Rise):

Doctors Point was the first area modelled for the SLR predictions and provided a useful example of how the two possible tidal increases might look on a given coastal area. Figure 65 first gives an approximation of MHWS levels at Doctors Point in 2004. As shown, water levels come into full contact with a majority of the peninsula, particularly in areas now known to have experienced relatively high rates of retreat. The region that has seen the most marram grass propagation since 2000 was still well out of reach of tidal currents at MHSW levels. The best case scenario for SLR predictions is shown in Figure 66. Here, the increased sea levels appear to have an exacerbating effect, with areas that were already under threat now increasingly so. The effect of inundation on the I44/182 site area becomes more pronounced and areas already affected during storms may become increasingly flooded for longer durations. Figure 67 provides a predicted view of Doctors Point in 2100 if yearly maximum sea levels do increase by a full metre. In such a scenario both site areas would likely be unreachable by vehicle. While even one episode of such levels would likely cause severe degradation, their repeated effect could greatly alter the form of the affected areas.
Figure 65. MHWS levels for Doctors Point in 2004, including a vegetative shoreline from 2017, ArchSite locations, and areas of midden (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).

Figure 66. Best case scenario of 0.3 metres SLR for Doctors Point by 2100, including a vegetative shoreline from 2017, ArchSite locations, and middens (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
Since the LiDAR was collected in 2004 there has been a high rate of progradation along the proximal end of the peninsula, which may now act as a buffer to archaeological deposits found inland. This may help mitigate some of the impact of SLR to the northern extent of the site. However, as the model does not take existing erosion rates into account it is likely that even this worst case scenario might be understating the impact of SLR on the area by 2100.

4.4.2 Michies Crossing (Zone #2) (Sea Level Rise):

Due to its relatively high elevation, most of Michies Crossing was generally unaffected by either of the two 2100 SLR scenarios, with the exception of site 144/183. Figure 68 shows the site area with 2004 MHWS levels and suggests the area’s low-lying grassed terrace is already being inundated during maximum high tides. Figure 69 shows the site after a storm in July 2017, with a line of debris that likely marks the extent of the storm surge. There is a visible difference in vegetation between the lower and higher elevations of the terrace, which may indicate such levels have been reached before. Figure 70 combines the predictive SLR scenarios into a single figure. In the worst case scenario a majority of the terrace will likely be submerged. The site area’s western regions may be protected by some of the damaging effects of the increased tides and inundation by the thick vegetation that now tops it.
Figure 68. MHWS levels for site I44/183 in 2004, including a vegetative shoreline from 2013, ArchSite location, and areas of midden (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).

Figure 69. The site area of I44/183, showing grassy terrace with debris from storm surge (photo taken facing east, July 2017).
4.4.3 Waitati (Zone #3) (Sea Level Rise):

The Waitati floodplain delta is an area of Blueskin Bay that has already been noticeably affected by the effects of inundation, both through the development of new water channels and the transitioning of its grasses to salt marsh species. As shown in Figure 71, the 2004 MHWS levels for the area already places a large proportion of the delta under seawater. Site I44/188, which already appeared to be severely degraded by the effects of inundation during its site visit, is covered entirely by water at 2004 MHWS levels. The tidal islands found in its vicinity also appear to be experiencing significant levels of inundation during maximum high tides. Figures 72 and 73 provide the area’s best and worst case predictive scenarios by 2100. In either scenario the site areas are all completely submerged. The difference between the two scenarios are essentially indicative of the speed at which SLR will degrade the floodplain and its archaeological sites. As tides increasingly affect areas further inland, areas on the peripheries will be submerged for longer periods of time and experience greater rates of degradation. Of particular concern is the potential impact of SLR on parts of the Waitati Township, which is within the reach of tides during the worst case scenario (Appendix III). Even in the worst case scenario the site location associated with the subsurface remains of Grant’s historic estate will likely be unaffected by SLR. As seawater already affects the fence posts associated with I44/477 SLR should not introduce a new threat to the site, but may hasten their deterioration.
Figure 71. MHWS levels for the Waitati floodplain delta in 2004, including a vegetative shoreline from 2013, and ArchSite locations (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).

Figure 72. Best case SLR scenario for the Waitati floodplain delta, including a vegetative shoreline from 2013, and ArchSite locations (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
Figure 73. Worst case SLR scenario for the Waitati floodplain delta, including a vegetative shoreline from 2013, and ArchSite locations (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
4.4.4 Evansdale (Zone #4) (Sea Level Rise):

Like Waitati, the low-lying floodplains at Evansdale are also likely to experience a dramatic transformation over the next 80 years. As shown in Figure 74, the site area making up I44/192 is already within the reach of 2004 MHWS levels. Such a finding was not unexpected given the low elevation of the tidal islands and their proximity to the tidal zone. The site area for I44/193 is likely being inundated by the swelling of its adjacent creek. Figures 75 and 76 show the best and worst case scenarios for the area. As was found at Waitati, in either scenario all site areas are within the predicted submersion zone.

Figure 74. MHWS levels for the Evansdale floodplain in 2004, including a vegetative shoreline from 2013, and ArchSite locations (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
Figure 75. Best case SLR scenario for the Evansdale floodplains by 2100, including a vegetative shoreline from 2013, and ArchSite locations (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).

Figure 76. Worst case SLR scenario for the Evansdale floodplains by 2100, including a vegetative shoreline from 2013, and ArchSite locations (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
4.4.5 Warrington (Zone #5) (Sea Level Rise):

Over the past 13 years Warrington’s sand spit has both eroded and prograded significantly. As such, using LiDAR from 2004 to model the extent of rising sea levels by 2100 produced results that even in 2017 are unlikely and outdated. This is primarily the case for the seaward side of the spit, which progradated an uncommonly high average of 3.97 metres a year from 2007 to 2013. Figure 77 provides a broad overview of how the two SLR predictions are might impact Warrington Spit by 2100. As shown, in the worst case scenario sea levels come close to reaching the vegetated shoreline visible in the 2007 aerial imagery. It is quite likely that if the model was repeated using 2013 LiDAR the predicted levels would not reach nearly as far inland.

Figure 77. Best and worst case SLR scenario for Warrington Spit by 2100, including a vegetative shoreline from 2013, and ArchSite locations (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
The results for the western side of the spit were more conclusive. While erosion will continue to affect the spits interior, doing so should not drastically alter the elevation of inland areas. Figures 78 and 79 provide a closer view of the model's results for sites I44/180 and I44/177.

**Figure 78.** MHWS levels for sites I44/180 & I44/177 in 2004, including a vegetative shoreline from 2013, and ArchSite locations (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).

**Figure 79.** Best and worst case SLR scenario for sites I44/180 & I44/177 by 2100, including a vegetative shoreline from 2013, and ArchSite locations (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
As shown in Figure 78, in 2004 MHWS levels already abutted the 2007 shoreline. This, coupled with the area's shoreline change analysis results, suggests that rising sea levels will likely correlate to incidences of retreat. If one metre of SLR takes place by 2100 the ArchSite location for the settlement that makes up site I44/177 may be just 50 metres from the shoreline.

Approximately 650 metres south along the spit’s interior side is the site area associated with I44/200. The midden exposure described in its SRF was not relocated during the 2017 site survey and the shoreline analysis revealed the area eroded a yearly average of 0.3 metres from 2007 to 2013. The SLR model’s results for the area showed a similarly dire outcome for the site (Figures 80 and 81). As shown, while 2004 MHWS levels lap the shorelines edge, by 2100 tides could reach between 30 and 80 metres further inland.

The final site area considered for SLR was I44/125 (Figure 82). This site provides a good example of how the rapid progradation of a vegetated dune system can affect the accuracy of the SLR visualisations. From 2007 to 2013 the area prograded by an average of 27.6 metres, which meant the LiDAR collected in 2004 was significantly off the mark in terms of where sea levels are likely to reach by 2100. In addition to its seaward advancement, the dune system also grew vertically, which might limit the prospective reach of inundation in coming decades. This specific application of the SLR model highlights the importance of understanding the past and current trajectories of site impacts when considering future hazard scenarios.

The GIS-based raster files used in each of this section’s figures can be found in the DVD at the back of this thesis.
Figure 80. MHWS levels for site I44/200 in 2004, including a vegetative shoreline from 2013, and ArchSite location (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).

Figure 81. Best and worst case SLR scenario for site I44/200 by 2100, including a vegetative shoreline from 2013, and ArchSite locations (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
Figure 82. Best and worst case SLR scenario for site I44/125 by 2100, including a vegetative shoreline from 2013, and ArchSite locations (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
5. The Findings

This thesis began with the presentation of a problem. In short, the prospective endurance of New Zealand's coastal archaeological sites is becoming increasingly less assured. This uncertainty can be attributed both to the ongoing trajectories of oceanic processes linked to climate change and the general paucity of information relating to the current extent and condition of coastal sites. While archaeologists are reasonably well equipped to manage and respond to anthropogenic impacts such as forestry and urban development, in cases where sites are being incrementally degraded by environmental processes, management strategies are frequently limited to reactive, remedial measures. In order to make proactive, anticipatory management decisions, the location, current condition, and susceptibility of individual archaeological sites should be sufficiently understood and gathered on a regional level. Considering sites on a fine scale, regionally, allows archaeologists and those with a vested interest to better utilise limited resources and to be more responsive in situations where site conditions are rapidly deteriorating. To address aspects of that process, a three-pronged methodological approach was introduced in the third chapter. While the individual methods included in that approach are far from novel, the pairing of spatial technologies with more traditional means of site assessment is advantageous as it allows site specific information to be gathered both quickly and accurately. Once collected, that digitised site information can be used as a baseline for future monitoring and assessment purposes while providing opportunities for computer-based spatial analysis. To test some of those presumptions, in the previous chapter the assessment approach was applied to Blueskin Bay. This chapter will now summarise and discuss the findings of that assessment while considering the efficacy of the approach and its implications for site management at the estuary. This will be followed by some thoughts on future directions for site management in New Zealand; succeeded by some final concluding remarks.
5.1 BLUESKIN BAY ASSESSMENT DISCUSSION:

Prior to the work undertaken during this thesis, in the last thirty years Blueskin Bay’s recorded archaeological sites had been systematically visited and assessed twice; once when a majority of the sites were recorded in the 1980s, and again in 2007 during the NZAA site upgrade project. Other than the excavations carried out at Warrington Spit (I44/177) and Doctors Point (I44/74), very little work has taken place at the estuary’s other 24 archaeological sites, leaving interpretations of their provenance, spatial relationship, and regional significance largely up to initial observations made at the time they were recorded.

In the 1980s and in 2007, almost all of the estuary’s sites were found to be experiencing erosion, among other damaging site impacts. While 20 of the 26 archaeological sites had some form of erosion listed under ‘Condition’ in their SRFs, without knowing the rate of shoreline change or the spatial extent of the site it was virtually impossible to determine from SRFs how much of each site was left or how much each had eroded since being recorded. The relatively high density of such sites, coupled with the area’s varied landform types made the four-kilometre-long estuary an ideal candidate for the employment of the assessment approach.

The first phase of the assessment, documentary research, was greatly benefited by information provided in two local history books (Pullar, 1957; Church et al., 2007), reports relating to excavations at Warrington Spit (Allingham, n.d.a; n.d.b; n.d.c; Hamel, n.d.; 2000; Walter, 2008), and the detailed sketch maps and notes taken by Allingham for a majority of the sites when they were recorded in the 1980s. These, in addition to a coastal hazard assessment undertaken by the ORC in 2014 (Goldsmith & Sims, 2014), provided a wealth of background information concerning the composition of sites, as well as the effects of past and present impacts. Of particular note was information relating to the previous fossicking in the area, the construction of the Waitati railroad line, and the redirection of the Waitati River’s mouth in the mid-nineteenth century. While not all of the collected information was directly applicable to the subsequent site survey and assessment or computer-based spatial analysis, the documentary research produced a useful narrative for the area and aided in the general interpretation of results in the two later phases.

Armed with that contextual information, the site survey and assessment was used to systematically revisit each of Blueskin Bay’s 26 recorded archaeological sites. For the 21 that were relocated, information was gathered relating to the visible extent of the cultural features and any of the impacts found to be affecting them. This process revealed that 84% of the estuary’s sites had the appearance of being impacted by some form of erosion and 35% by inundation. Of the impacts that did not fall under erosion or inundation, the next most
frequent threats to sites were animal burrows and visitor impacts (namely damage from walking tracks). Due to previously incorrect grid references or a lack of information included during the upgrade project, three sites were relocated and assessed for the first time since the 1980s (I44/125, I44/188, and I44/192). Additionally, two site areas that were relocated in 2007 were no longer discoverable ten years later (I44/200, I44/199). The survey also discovered a previously unrecorded nineteenth century seawall, which was found to contain a piece of phonolite from a neighbouring pre-European Māori source site (I44/198). Finally, the comparison of photographs taken during the site survey with those from the 2007 upgrade project also produced some valuable insights relating to changes in the estuary’s landscape, particularly in terms of vegetation. For example, at Waitati, photographs revealed that grass pastures have been recently transitioning to salt marsh plant species, hinting at the advancing reach of inundation.

Through the use of the DSAS extension the assessment was able to provide some metrics regarding the extent of shoreline change across the estuary’s archaeological sites. Previously, while it was well known that erosion was present along a majority of site areas, it was not possible to discuss the impact in relative terms between sites. Utilising a total of 3,587 transects spread across the five assessment zones, the analysis revealed that:

1) Since at least the 1980s there has been a steady trend of erosion along the interior of the estuary and significant progradation along its exterior;

2) Of the assessment zones, Warrington Spit has experienced the highest rates of erosion on its interior and progradation on its exterior, with the most dramatic shifts found along its distal end;

3) At Doctors Point there has been a significant episode of progradation along its northern proximal side, which transitions to erosion towards both sides of its distal point;

4) The native bush planting regime that took place at Michies Crossing in 2007 appears to have triggered up to 4.6 metres of retreat along one of its site areas, but the area seems to have since stabilised;

5) The floodplain deltas found in Waitati and Evansdale have both been eroding incrementally over the past 35 years with the greatest incidences of retreat found along each of the area’s water channels. At parts of Waitati, stock grazing also appears to be contributing to some of those erosion rates.
In all, the combination of differential GPS and the DSAS allowed rates of erosion to be considered across individual sections of midden and ovens, providing a useful means of tracking the impact of erosion along both the estuary and its associated archaeological sites.

The final phase of the assessment, the SLR modelling, allowed IPCC predictions of rising sea levels in New Zealand to be visualised across each of Blueskin Bay’s site areas in a quick and relatively straightforward manner. This analysis revealed that sites found on the floodplain deltas at Waitati and Evansdale have likely experienced incidences of inundation even at 2004 levels. That finding is in agreement with observations made during the site survey and upgrade, including the presence of seaweed found across site areas, the honeycombing of eroding sections of cultural deposits by crabs, and the previously discussed evidence of grasses that are transitioning to salt marsh species. As anticipated, there was a considerable difference between how the best and worst case SLR scenarios might affect the five assessment zones. At some areas of Waitati and Evansdale the worst case scenario could result in the inundation of between 130 and 150 metres of land that is currently unaffected by sea levels. By 2100, inundation may also cause significant degradation to the multi-layered site complexes found at both Warrington Spit and Doctors Point. As the model does not factor in the rates of erosion that would inevitably occur in conjunction with inundation, the dune systems along those two assessment zones could likely be impacted even more severely than was depicted across their numerous analysis figures. Lastly, the model’s results for Michies Crossing demonstrated that although site I44/183 may be increasingly affected by sea levels in the coming decades, the rest of the zone’s sites are at a high enough elevation to remain largely unaffected by SLR. As was also the case with the shoreline change analysis, the SLR model provided a means of considering the susceptibility of Blueskin Bay’s archaeological sites both individually and as a whole.

5.2 RECOMMENDATIONS FOR BLUESKIN BAY SITE MANAGEMENT:

This thesis was tasked with developing a means of establishing a better understanding of site conditions. Although the recommendation of site specific management strategies falls beyond that primary focus, it would be irresponsible not to offer some general management suggestions after visiting, assessing, and analysing the estuary’s archaeological sites. Therefore, while this section will provide some management suggestions, these will ultimately be tentative in nature and are intended to rouse future dialogue rather than asserting the necessity of any particular measures. Further to that, first and foremost, more monitoring of Blueskin Bay’s sites and their impacts is required before any concrete and irreversible management decisions should take place. In terms of site management, the collection of baseline data during the assessment should be seen as a means to an end rather
than an end in itself. In 2018, the Dunedin City Council has suggested that it will be collecting new aerial imagery of the district, which will eventually be orthorectified and accessible through ArcMap and LINZ.govt.nz (Jack Tang (DCC) pers. comm., January 4th, 2018). For many of the estuary's archaeological sites the incorporation of that updated imagery into future shoreline change analysis should allow sites to be considered across an additional five years. Doing so could determine whether the trajectories of retreat across the site areas are slowing, accelerating, or steady.

Once shoreline change trends have become more robustly established it could be beneficial to initiate conversations with coastal geomorphologists as to whether any meaningful methods of mitigation may exist for any of the affected sites. For regions such as Doctors Point where archaeological material is actively eroding mere metres away from areas of progradation, there may be opportunities for dune stabilisation through vegetative means. Additionally, as walking tracks in the area appear to be actively degrading sub-surface material it may also be worthwhile to consider measures such as geotextiles. Across the Waitati and Evansdale assessment zones there are also numerous sections of midden and ovens that are becoming rapidly deteriorated through both erosion and inundation. As available options for mitigating those effects might be limited, it may be beneficial to establish a repository of samples from sites in those areas while dateable material is still retrievable. The intricacies of collection and storage, as well as securing permission and any funding required for both are again beyond the scope of this thesis, but such an undertaking could offer some assurance against the ongoing loss of sites and their cultural information. Beyond the effects of erosion and inundation, sites lying in those areas are also being impacted by crab burrowing and stock grazing. While efforts to prevent crabs from burrowing along the tidal edge would likely be futile, the removal of cows from those areas could ameliorate some of the ongoing erosion and overall degradation taking place to its sites.

Along the northern side of the estuary it could also be useful to establish the western extent of the Warrington Spit site complex through auguring or test pitting. Doing so could allow archaeologists to acquiesce when and how severely the site might be impacted by the combined impacts of erosion and inundation in the near future. Beyond those general recommendations, monitoring the progress of each of the recorded impacts across Blueskin Bay's sites could aid in the effectiveness of any future management decisions made for the estuary.
5.3 THE APPROACH: STRENGTHS AND LIMITATIONS:

This section will consider some of the strengths and limitations of the assessment approach, both in its application to Blueskin Bay and for other future uses of the approach. In terms of strengths, the core benefit of this assessment strategy is that coastlines and their archaeological sites are researched, visited, and considered for past, present, and future impacts. Regardless of its overarching efficacy, for site management purposes any level of site monitoring or risk assessment is arguably better than none. At a fundamental level, the approach utilises many of the same techniques and strategies that archaeologists have been employing along coastal site areas for decades. The key addition to that standard model of site assessment has been the use of spatial technologies to consider coastal processes systematically across site areas. Coastal sites face a different set of management challenges than are found inland and, as such, having the ability to quantify, compare, and consider impacts such as erosion and inundation alongside more traditional assessment considerations is of significant benefit. In New Zealand, and certainly elsewhere, the use of the conservation philosophy model (ICOMOS, 2010), whereby archaeologists attempt to disturb archaeological sites as little as possible during research or development, falls short of mitigating damage to eroding, incrementally degraded, coastal sites (Jones, 2007:24). Leaving sites alone that are actively eroding or facing impending inundation essentially ensures their eventual destruction. Therefore, the main benefit of the approach is that it allows archaeologists to observe coastal site impacts over greater time depths, possibly improving their ability to make decisions before sites are too far gone to be salvaged. Ultimately this process may pave the way for future anticipatory management strategies.

With those strengths in mind, the assessment is not without its practical and theoretical limitations. Some of those limitations pertain to the availability of documentary resources, aerial imagery, or LiDAR data. Without having access to a high resolution DEM or historic aerial imagery it may not be possible to measure long term shoreline change or accurately model SLR for a given coastal area. Additionally, as the approach is non-invasive, in scenarios where a recorded archaeological site has no visual surface features, the approach can offer few site specific insights beyond those relating to broader environmental changes. Other limitations can be attributed to isolated or accumulative margins of error. For the shoreline change analysis in particular, if aerial imagery is of a low resolution, contains significant terrain displacement, or was poorly georeferenced, those inaccuracies may limit the overall accuracy of the analysis. Unfortunately, determining whether a given source of error is isolated or cumulative is not always a wholly straightforward task. The potential margins of error associated with tracking shoreline change using historic aerial imagery is an issue that
has also been discussed at length elsewhere (Anders & Byrnes, 1991; Thieler & Dansforth, 1994; Smith & Cromley, 2012).

As was noted during the presentation of the DSAS results, in scenarios where a site area’s shoreline is not a straight or gradually curving beachfront the DSAS extension’s perpendicular transects can become less effective. If for example, a large tidal island erodes into two smaller islands, which then each erode further, it would be difficult to retrieve an average number of metres of retreat per year using transects extending from a baseline running parallel to the initial extent of the large tidal island. One suggestion for dealing with such a limitation would be to quantify shoreline change through polygonal area rather than assessment transects (this has been trialled elsewhere: Smith & Cromley, 2012). The DSAS extension is also limited to quantifying horizontal incidences of shoreline change, making it unsuitable for tracking erosion that takes place in a top-down, vertical fashion. At what point does a tidal island cease to be an island and becomes a slightly elevated region of a mudflat? Those particular limitations were particularly apparent when applying the shoreline change analysis to the floodplains at both Waitati and Evansdale. Finally, for shorelines that do not stand out against the surrounding landscape or are obscured by overhanging vegetation, the DSAS is again constrained in its function.

There were also some limitations associated with the use of the SLR model. As is true with any environmental model, its results produce a perspective that is inherently simplistic. In the case of its application at Blueskin Bay, the SLR model did not factor in the absorptive qualities of the estuary’s varying landform types, vegetation, or any other factors that might influence the reach of rising tides. Additionally, as was discovered on the seaward side of Warrington Spit, the use of LiDAR from a fixed point in time to accurately depict nearly one hundred years of SLR along a rapidly prograding dune system was impractical. As the model has no way of including shoreline change into its analysis, it is highly likely that some of the areas deemed as susceptible to inundation will have long since eroded by the year 2100. With those limitations in mind, the model’s true value lies in its ability to rapidly visualise IPCC predictive scenarios across both regions of coastline and individual site areas. Being able to demonstrate susceptibility of any given area visually may be useful for securing funding for long term monitoring projects or for guiding anticipatory management strategies.
5.4 FUTURE DIRECTIONS FOR NEW ZEALAND SITE MANAGEMENT:

As is true for essentially any area of research, anticipating the future requires interrogating the present. Endorsing that rationale, perceiving the future direction of site management in New Zealand necessitates a discussion of its current state, shortcomings, and areas of ongoing development. Over the past 50 years archaeological practice and management in New Zealand has been shaped considerably by the passage of legislation such as the HPAA 1975, nationwide efforts to record archaeological sites, and the succeeding digitisation of that SRS data. Occurring alongside those developments have also been rapid advances in both computers and spatial technologies such as GPS, GIS, and LiDAR.

The amalgamation of policy, fieldwork, and spatial technologies have rapidly improved the capabilities of New Zealand archaeologists to record, consider, and manage the archaeological record. Although the capacity for archaeologists to manage archaeological sites has never been so high, as a whole the nation is still fundamentally deficient in its implementation of those techniques and technologies. While the NZAA site upgrade project revisited and provided updated information for a large proportion of New Zealand's archaeological sites, ten years has since passed and for many archaeological sites it remains difficult to determine the location of a site within approximately 100 metres using digital means. For a vast majority of coastal archaeological sites there is simply not enough baseline data recorded to identify whether a site's condition is deteriorating or stable. Given the widespread use of mapping programs such as ArcMap, QGIS, and Google Earth, the ability to upload GIS-based GPS shapefiles of an archaeological feature or adjacent shoreline to ArchSite could be of significant benefit to site managers and stakeholders. The implementation of such a strategy would no doubt require a rigid standardisation of both data collection and recorded metadata, but could pave the way for an improved means of monitoring the effects of impacts like shoreline change on coastal sites.

In terms of collecting site data, recent survey and monitoring projects such as SCHIP in Southland (Brooks et al., 2008), work by Tony Walton along the Kapiti coastline (Walton, 2006), and work by SPAR at Stewart Island (Jacomb et al., 2015) have demonstrated the feasibility and value of gathering site data across regional scales. The involvement of local community groups to carry out continued monitoring of coastal areas (as exemplified in SCHIP work) is also of added benefit as it works to forge and strengthen local connections, while fostering an increased appreciation for coastal heritage sites. Overseas, the Scottish Coastal Archaeology and the Problem of Erosion (SCAPE) project provides an example of a successfully executed nationwide volunteer-based approach to coastal site monitoring (Dawson, 2015). The implementation of such projects across more of New Zealand's coastal
regions could provide opportunities to conserve and salvage rapidly deteriorating sites, while inevitably producing new insights about the past.

Beyond the collection of site specific spatial data, developments such as improving GIS capabilities and the widespread collection of LiDAR are also reshaping the way that archaeologists in New Zealand can manage and consider archaeological sites. In the past five years there have been at least four New Zealand-based assessments that have combined environmental datasets with ArchSite spatial data within GIS to identify the vulnerability of coastal sites (Bickler et al., 2013; Ramsay, 2014; Hīl, 2016; McCoy, 2018). Studies of this nature are allowing site managers to identify areas of heightened susceptibility, making them better equipped to consider possible mitigation strategies. LiDAR is also being used, particularly in North Island, for a host of novel and informative management projects, such as the automatic identification of archaeological features across landscapes through machine learning, tracking changes in elevation resulting from erosion and accretion, and rapidly recording earthwork features at pa sites (Jones & Bickler, 2017; McCoy, 2017:88). In terms of future directions, site management in New Zealand would be benefited by the further collection of LiDAR across more areas and the continued application of GIS-based assessment studies across both local and regional scales.

In recent years there has been an increase in the availability of spatial information in the form of geospatial data and aerial imagery. Digital repositories such as the Land Information New Zealand’s (LINZ) web-based data service (https://linz.govt.nz) and Koordinates (https://koordinates.com) are providing archaeologists access to ever-expanding inventories of useful geospatial datasets. These include DEMS, LiDAR, digital imagery, and GIS-based shapefiles, all of which can be incorporated into increasingly sophisticated assessments and environmental models. Additionally, LINZ is currently engaged in a multi-year project to digitally scan and index the Crown historic aerial photo archive, which contains over 600,000 aerial images of New Zealand from nearly 7,000 aerial surveys flown between 1936 and 2008 (available at the Historic Image Resource http://retrolens.nz). Access to those images was vital during the shoreline change analysis portion of the Blueskin Bay site assessment and the continued expansion of the database should continue to bolster the ability of archaeologists to consider changes to the landscape, including the past and future trajectories of site impacts such as erosion.
5.5 CONCLUSION:

The aim of this thesis was to establish a means of better understanding coastal site conditions. This aim was pursued through the development of a three-step approach that assesses sites through the combination of previously conducted research, a site survey, and computer-based spatial analysis. It was posited that the three methods would produce a clearer understanding of conditions at sites by examining the past, present, and the possible future extent of site impacts. Once described, the approach was then applied to the Blueskin Bay case study area in order to test its efficacy while identifying its shortcomings. Overall, the approach served its purpose by producing insights into the estuary’s site conditions, while collecting baseline data that may aid in future research. Although the approach will need to be applied to more areas before its versatility and robustness can be fully validated, thus far the benefit of its methods appear to outweigh its limitations. Alongside the design and employment of the approach, this thesis also provided some overarching discussion on site management in New Zealand, the presence and influence of incremental impacts on archaeological sites, and the use of spatial technologies to better measure and ultimately manage coastal archaeological sites. In summation, while challenges to long term archaeological site security are mounting in the form of climate change, such developments are occurring alongside rapid improvements in the abilities of archaeologists to record, assess, and ideally manage those impacts. Although there will no doubt continue to be a high degree of uncertainty regarding the prospective endurance of New Zealand’s coastal sites, what is certain is that the work undertaken in the coming decades will be pivotal in influencing the nature of those eventual outcomes.
REFERENCES


Jones, B. & Bickler, S. 2017. High Resolution LiDAR Data for Landscape Archaeology in New Zealand. Archaeology in New Zealand, 60 (3), 35-44.


Appendix I

The terrain model derived from LiDAR and used for the Blueskin Bay SLR modelling.
Figure 83. The terrain model of Blueskin Bay used for the SLR model, including a MHSL polyline (polyline retrieved from linz.govt.nz & 2004 LiDAR courtesy the Otago Regional Council).
Appendix II

Two figures showing the SLR model’s results for the entirety of Blueskin Bay.
Figure 84. Calculated 2004 MHWS levels for Blueskin Bay (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
Figure 85. Best and worst case SLR scenario for Blueskin Bay by 2100, (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
Appendix III

Two figures showing the SLR model’s results for Waitati including 2004 MHWS and the predicted best and worst case scenarios for 2100.
Figure 86. Calculated 2004 MHWS levels for the Waitati Township (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).
Figure 87. Best and worst case predicted SLR scenarios for the Waitati Township (aerial imagery taken March 2007: courtesy DCC and Otago School of Surveying).