1. INTRODUCTION

1.1 INTRODUCTION

The Clarence River estuary and surrounding coastline, northern New South Wales, Australia (Figures 1.1 and 1.2), is host to a number of Aboriginal shell midden deposits. These deposits are found in a variety of geomorphic environments including estuarine sites (riverbank/creekbank) and coastal sites (beach foredune, headland). The availability of study sites in a variety of geomorphic environments, coupled with the enthusiasm of the Yaegl Local Aboriginal Land Council (LALC) to participate in the study meant the study area was an ideal location to undertake research into geomorphic processes affecting the accumulation, degradation and preservation of Aboriginal shell midden sites.

The ancestral Yaegl community inhabited the land surrounding the mouth of the Clarence River and spoke the language Yaygirr (Muurbay Aboriginal Language and Culture Cooperative). At the time of European contact the Yaegl people had a well developed material culture, including sophisticated wooden canoes and permanent settlements comprising large bark huts (McSwan, 1978). By as early as 1929, however, only a couple of Yaygirr speakers remained, and the language was no longer spoken right through (Muurbay Aboriginal Language and Culture Cooperative). Given the rich ancestral history of the area and its Indigenous inhabitants, the current Yaegl Local Aboriginal Land Council are highly active in, and determined to, preserve all possible aspects of their cultural history. This research project makes a significant contribution to this aim.

Providing the Yaegl LALC with effective site-specific conservation management recommendations, as well as more general, environment-specific management guidelines for broader application, requires a comprehensive understanding of the processes causing accumulation, degradation and preservation of midden sites, referred to as site formation processes. Adopting a multidisciplinary approach involving the synthesis of analysis techniques used in the disciplines of Environmental Science and Archaeology was essential in the development of the 3 erosion hazard assessment techniques presented in this thesis.

Study sites were proposed and approved by the Yaegl Local Aboriginal Land Council based on local knowledge and information contained in the state of New South Wales' Aboriginal Sites Register. Appropriate Government permits were obtained on the basis that there would be minimal disturbance of the sites through sampling. One of the strengths of the erosion hazard assessment methods developed in this study is that they are able to be performed with minimal sampling, and thus minimal disturbance, to Aboriginal shell midden sites.

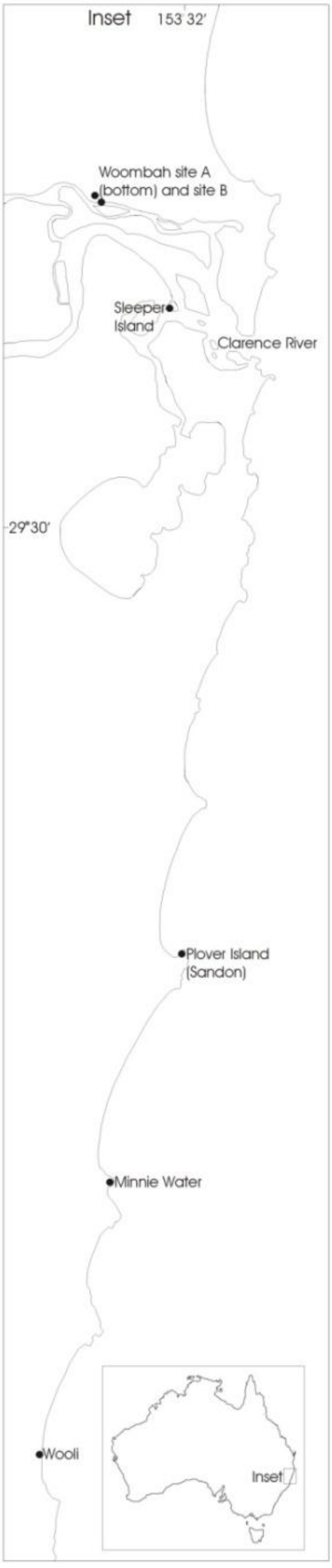


Figure 1.1: Location of the study sites.

Figure 1.2: Aerial photographs showing the location of the study sites.

1.2 AIMS

The key aims of this project were:

- **To prepare accurate site descriptions for inclusion in the AHIMS (Aboriginal Heritage Information Management System) database.**
- **To document and interpret the taphonomy of shell and artifactual material present in the Aboriginal shell midden deposits.** Understanding environmental processes to which shells and artifacts may have been subjected can assist determination of the origin of a deposit and how it has formed.
- **To document and interpret the species composition of the deposits.** The study of species composition provides information regarding the environments in which the species lived, and also whether anthropogenic selection or size-sorting as a result of environmental processes has occurred.
- **To compare site formation processes between the study sites.** Identification of similar environmental impacts in similar geomorphic contexts is used to formulate environment-specific midden management and conservation guidelines. Identification of different environmental impacts in similar geomorphic contexts is used to formulate site-specific midden management and conservation guidelines.
- **To develop 3 erosion hazard assessment techniques which can be used by different stakeholder groups** – Environmental Scientists, Archaeologists and Aboriginal community groups/Local Aboriginal Land Councils. Development of a standardised, comprehensive management strategy facilitates greater ownership of cultural resources by local Aboriginal communities as well as more effective communication between stakeholder groups.

- **To develop site-specific and broader environment-specific management and conservation recommendations for Aboriginal shell midden sites.** The development of site-specific recommendations specifically satisfies the requirements of the Yaegl LALC. Environment-specific recommendations can be used by the Yaegl LALC as well as other Australian Indigenous Land Councils and also international indigenous communities.

1.3 OUTLINE

Chapter 2 reviews the geology and stratigraphy of the Clarence-Moreton Basin within a Quaternary geomorphic context and includes a preliminary discussion of coastal and estuary dynamics in the study area. The concept of the discipline of Geoarchaeology is also introduced, along with an explanation of how geoarchaeological techniques have been used by other researchers to study site formation processes. Previous archaeological studies undertaken in the study area are reviewed and the process of identification of research sites for the current study is outlined.

Chapter 3 introduces the study sites and provides information on their location, geomorphic context and a brief description of the archaeological material present. Research methodologies are presented in Chapter 4 prior to the presentation and discussion of results. This chapter includes a discussion of analysis and data collection techniques and presents information on techniques used to assess site formation processes and major geomorphic impacts at the study sites.

Chapters 5, 6 and 7 present a comprehensive analysis of site formation processes and major impacts causing site degradation through interpretation of sites' stratigraphy (Chapter 5), biological and taphonomic analyses of archaeological material (Chapter 6) and analysis of erosiove processes (Chapter 7). In Chapter 5 stratigraphic information is linked between sites in similar geomorphic environments and with previous local studies. This facilitates a sound understanding of the environmental context of the Aboriginal shell midden deposits. The results of biological and taphonomic analyses are presented and discussed in Chapter 6. Analyses include species composition, size range of shells and post-mortem modification of the condition of shells and artifacts. This information is used to determine the likely origin of the deposits and the likely agents of reworking if it has taken place. Analysis of erosive processes is presented in Chapter 7. This encompasses analyses of the past, present and potential impact of anthropogenic channel modifications to the Clarence River estuary, sea level change, flooding, tidal inundation and erosion. This information is then used to formulate 3 erosion hazard assessment techniques. The methodology of each technique is presented in Chapter 4. Outcomes and validity of the techniques are presented and discussed in Chapter 7.

Site-specific and environment-specific management and conservation guidelines, based on the outcomes of the erosion hazard assessment techniques, are presented in Chapter 8. Conclusions, broader applications of the methodologies developed in this study and areas for further research are presented in Chapter 9.

2. BACKGROUND AND CONCEPTUAL FRAMEWORK

An essential prerequisite of the study of archaeological site formation processes involves a review of local and regional geology and stratigraphy within a Quaternary geomorphic context. A review of the geology of the Clarence-Moreton Basin provides the necessary framework for a preliminary discussion of coastal and estuary dynamics in the study area, presented in section 2.1.5. The concept of the discipline of Geoarchaeology is introduced in section 2.2, along with an explanation of how geoarchaeological techniques have been used by other researchers to study site formation processes. A process-based approach to the study of Aboriginal shell midden accumulation, degradation and preservation is the key principle of this research project. Section 2.2.8 reviews previous archaeological studies undertaken in the study area and outlines the process of identification of research sites for the current study.

2.1 GEOLOGY AND STRATIGRAPHY

2.1.1 **Introduction**

The Clarence River estuary overlies the Clarence-Moreton Basin (Figure 2.1), a narrow extension of the Great Artesian Basin (Haworth and Ollier, 1992), with an area of ~40000 square kilometres (Day *et al.,* 1974). The Clarence-Moreton Basin is only open to the coast between Broom's Head and Schnapper Point and the bedrock here is present at shallow depths (Haworth and Ollier, 1992; Roberts and Boyd, 2004). The Clarence-Moreton Basin began to develop in the Late Triassic (Day *et al.,* 1974) and the basin sequence is entirely Mesozoic (McElroy, 1969). The basin forms part of the Tasman Geosyncline and unconformably overlies Palaeozoic rocks of the New England Fold Belt and Yarraman, D'Aguilar and Beenleigh Blocks, as well as rocks of the older Triassic Esk Trough and Ipswich and Tarong Basin sediments (Day *et al.,* 1974). The intermontane Clarence-Moreton Basin is part of a craton which stabilised in Late Triassic – Early Jurassic time, with the initiation of extensive quartzose sandstone sedimentation (Day *et al.,* 1974).

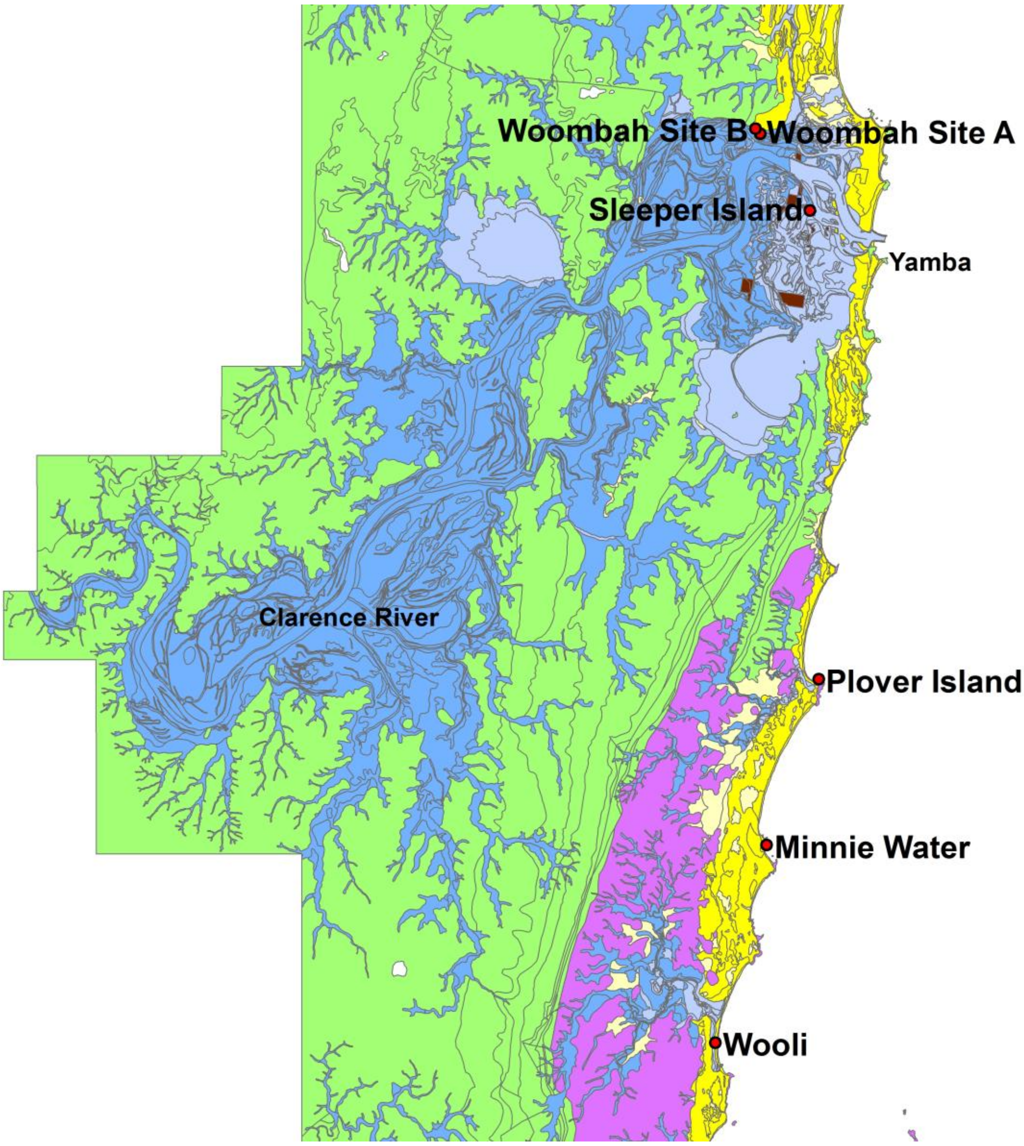


Figure 2.1: Regional geology of the study area.

KEY:

2.1.2 **Sedimentation and Major Stratigraphic Units**

The present erosional margin of sediments of the Bundamba Group (McElroy, 1962) defines the margins of the Clarence-Moreton Basin (Day *et al.,* 1974). Day *et al.* (1974) and Cranfield and Schwarzbock (1972) refer to this unit as the Woogaroo sub-Group. Rocks of the Bundamba Group form a near continuous outcrop containing arenaceous sediments with characteristic cross-bedded units (McElroy, 1962). Friable sandstone with considerable iron-staining is present in the northeast quarter of the outcrop (McElroy, 1962). The deposition of extensive quartzose sandstones (McElroy, 1969) forming this outcrop occurred in the Triassic – Jurassic (Day *et al.,* 1974).

The Marburg Formation is a less quartzose unit which conformably overlies the Bundamba Group (McElroy, 1969). Formation of this unit occurred no later than the Upper Triassic, as indicated by the presence of a labyrinthodont jaw (*Austropelor wadleyi*) (Whitehouse, 1952). The Marburg Formation is more labile (Day *et al.,* 1974) and contains a higher proportion of shale and silty sandstones than the underlying Bundamba Group (McElroy, 1962). It is predominantly composed of cross-bedded medium to coarse quartz sandstones with a variable proportion of clay matrix and rock fragments interbedded with grey shales and claystones (McElroy, 1962). Igneous intrusions are absent (McElroy, 1969).

McElroy (1962) divided the southern part of the Marburg Formation into two distinct formations; a basal conglomerate he referred to as the Layton's Range Conglomerate and an overlying siltstone-sandstone formation named the Mill Creek Sandstone. These units do not appear on Day *et al.*'s (1974) Upper Triassic – Lower Cretaceous stratigraphic sections.

Conformably overlying the Marburg Formation are the Walloon Coal Measures. McElroy (1962) describes this unit as predominantly consisting of grey claystones which are commonly carbonaceous, or contain thin coal seams and fine to medium grained soft grey lithic sandstones.

The sandstones are usually calcareous and concretionary ironstones are common. McElroy (1962) also notes the characteristics of the Walloon Coal Measures differ in the Nymboida-Kangaroo Creek area. Here quartz-lithic sandstone containing very little shale or claystone predominates in the sequence.

Planar cross-bedding is well developed in the quartzose Kangaroo Creek Sandstone which is largely made up of medium to coarse white and cream sandstone; iron stained matrix is common and this affords the sandstone some friability (McElroy, 1962; 1969). The Kangaroo Creek Sandstone has also been secondarily cemented by iron oxides, and there is evidence of the burrowing activity of the Banded Bee (*Anthrophora* sp.) (McElroy, 1962). In parts this unit lies unconformably on the Walloon Coal Measures, however it grades conformably upwards into the Grafton Formation (McElroy, 1962).

Lithic sandstones with an even, well-sorted texture dominate the Grafton Formation which contains a sequence of poorly outcropping soft sandstones, siltstones and claystones, at times interbedded with carbonaceous or coaly bands (McElroy, 1969). The Grafton Formation extends along the Clarence-Moreton Basin south of Grafton to north of Casino (McElroy, 1962). It is not overlain by other consolidated sediments and the outcrop is masked by extensive areas of Quaternary alluvium associated with the Clarence and Richmond Rivers (McElroy, 1962). Tertiary volcanic rock is present in the north of the basin and runs northwest through Lismore and Toowoomba (Haworth and Ollier, 1992).

2.1.3 **Uplift of Australia's Eastern Highlands**

Uplift of the Eastern Highlands, which border the Clarence-Moreton Basin to the west, has likely played a significant role in the development of the current drainage pattern of the Clarence River (Haworth and Ollier, 1992). In order to interpret the modern drainage pattern of the Clarence

River it is necessary to understand the origins of the river systems in this area and the effect tectonic uplift has had on these systems.

It is generally agreed that formation of the Eastern Highlands was initiated around 90 Ma ago (Ollier, 1978; Jones and Veevers, 1983; Wellman, 1987). The removal of the lower lithosphere underneath the highlands caused tectonic uplift due to crustal underplating and crustal heating (Wellman, 1987). This process took place at the time of rifting which formed the Tasman and Coral seas (Jones and Veevers, 1983). Early Cretaceous sediments are present on the summit and slopes of the highlands in Queensland and northern New South Wales, showing most uplift occurred in the region after this time (Wellman, 1987).

2.1.4 **Drainage Pattern of the Clarence River**

Dendritic drainage patterns are characteristic of terrain which has a uniform lithology and where faulting and jointing are insignificant (Whittow, 1984). Some characteristics of simple river systems are as follows:

- tributaries have a steeper gradient than the main stream but their junctions are at the same elevation (Playfair's Law).
- tributaries join the main stream at an acute angle pointing downstream.
- simple valleys increase in width and become flatter in the downstream direction.

The Clarence River has an anomalous drainage pattern (Haworth and Ollier, 1992). Its catchment is asymmetrical in shape and its trunk stream runs along a valley ~200 km long. The major feeders to the Clarence River originate on the New England Block and flow east across the Great Escarpment (Haworth and Ollier, 1992). The Continental Divide separates the Condamine River to the west, with a simple dendritic drainage pattern, from the Clarence River to the east, with a highly complex drainage pattern (Ollier, 1978). Ollier (1978) suggests the complex drainage pattern east of the Continental Divide was a result of folding and faulting during the Late Tertiary, as the eastern Australian coastline shifted west.

2.1.5 **Quaternary Sediments and Geomorphology**

McElroy (1962) briefly describes Quaternary sediments of the Clarence-Moreton Basin in his published work on basin stratigraphy. This description includes the presence of extensive Quaternary alluvium, consisting predominantly of silt and sand, associated with the lower course of the Clarence River. Thicknesses of Quaternary sediments were measured at Grafton no. 1 bore (104 ft) and Bungawalbyn Creek near the Richmond River junction (88 ft). He also observed the presence of carbonaceous sandrock in sea cliffs in the Redcliffe – Wooli areas, associated with leached and redeposited humic material.

Since this work, further geomorphic studies involving shoreline morphodynamics (Roy *et al.,* 1994; Carter and Woodroffe, 1994), offshore sediments and stratigraphy and Late Holocene shoreline alignment (Roberts and Boyd, 2004; Goodwin *et al.,* 2006) have been published. Various studies of estuarine dynamics (including Carter and Woodroffe, 1994; Eyre, 1998 and Roy *et al.,* 2001), local floodplain environments (Brierley *et al.,* 1995 and references therein) and general local geomorphology and soil landscapes (Morand, 2001) have increased our understanding of Quaternary sediments and geomorphology of the Clarence River, estuary and coast.

2.1.5.1 *Coastal sediments and geomorphology*

Southeast Australia is a wave- and oceanic current-dominated coast (Roy *et al.,* 1994; Roberts and Boyd, 2004). Sand is moved and deposited largely by waves and wave-induced currents, although ebb tide deltas do form at the mouths of larger rivers such as the Clarence (Roy *et al.,* 1994). In contrast to Swift and Thorne's (1991) accommodation-dominated settings, where basins supplied with sediment are large compared with sediment input, Roberts and Boyd (2004) class the NSW coast as low-accommodation. Geological inheritance plays an important role in the geomorphology of modern coasts (Roy *et al.,* 1994). It is therefore necessary to focus some attention on nearshore deposits in order to understand the origin of beach sediments and the history of the Clarence coast.

Underlying the inner- and mid-shelf sediments in the Yamba-Tweed Heads region are laterally continuous terraces of the offshore Yamba trough, an extension of the Clarence-Moreton Basin (Shaw *et al.,* 2001). The shelf physiography in this region is narrow and steep (Roberts and Boyd, 2004). Bedrock-compartmentalised beaches extend to submerged reefs at depths of <25-30 m and a lobate (10 × 20 km) subaqueous delta front extends seaward of the Clarence River (Roberts and Boyd, 2004). An extensive lobe of shoreface sand occurs north from Iluka Bluff and another northeast from the Shelly Beach Head – One Man Bluff area (Goodwin *et al.,* 2006).

Roberts and Boyd (2004) have identified the timing of the Pleistocene-Holocene post-glacial marine transgression in the offshore Clarence region at 12 780 +/- 150 BP. Estuarine deposits were formed during this time, but the relative thinness of offshore estuarine channel fill led Roberts and Boyd (2004) to suggest that valleys were not deeply incised seaward of the modern shoreline, and that much of the earlier estuarine deposits outside the channels has been removed by wave/current action.

Well sorted, fine- to medium-grained, angular to subangular quartz-rich shoreface sands with low carbonate and mud content fine seaward (Goodwin *et al.,* 2006). Inner shelf muddy sands and sandy muds are poorly sorted, fine- to medium-grained quartz-rich sediments with up to 30% mud content (Walsh and Roy, 1983). The source of these sediments is the Clarence River (Roberts and Boyd, 2004). Roberts and Boyd (2004) state these fine sediments are able to accumulate on the seafloor due to the weakened influence of the East Australia Current between Ballina and Yamba.

Goodwin *et al.* (2006), however, note some southward transport of outer-shelf sediments by the East Australia Current.

Shoreline alignment on the NSW north coast during the Late Holocene sea level stillstand has been dynamic. Episodes of shoreline recession and realignment have punctuated barrier progradation during this time (Goodwin *et al.,* 2006). The Iluka-Woody Bay sand barrier forms part of one of the most extensive Holocene strandplains on the NSW far north coast (Roy, 1982). Its morphology has been influenced by longshore gradients in sand transport and fluctuations in mean wave direction on centennial to millennial time scales (Goodwin *et al.,* 2006). The history of Late Holocene shoreline alignment can be seen in Figures 2.2 and 2.3. Migrating sediment not only changed the shape of the beaches between Woody Head and the main Clarence River entrance, it also changed the dynamics of the Clarence River, with the North Arm no longer reaching the ocean after ~1500 years BP.

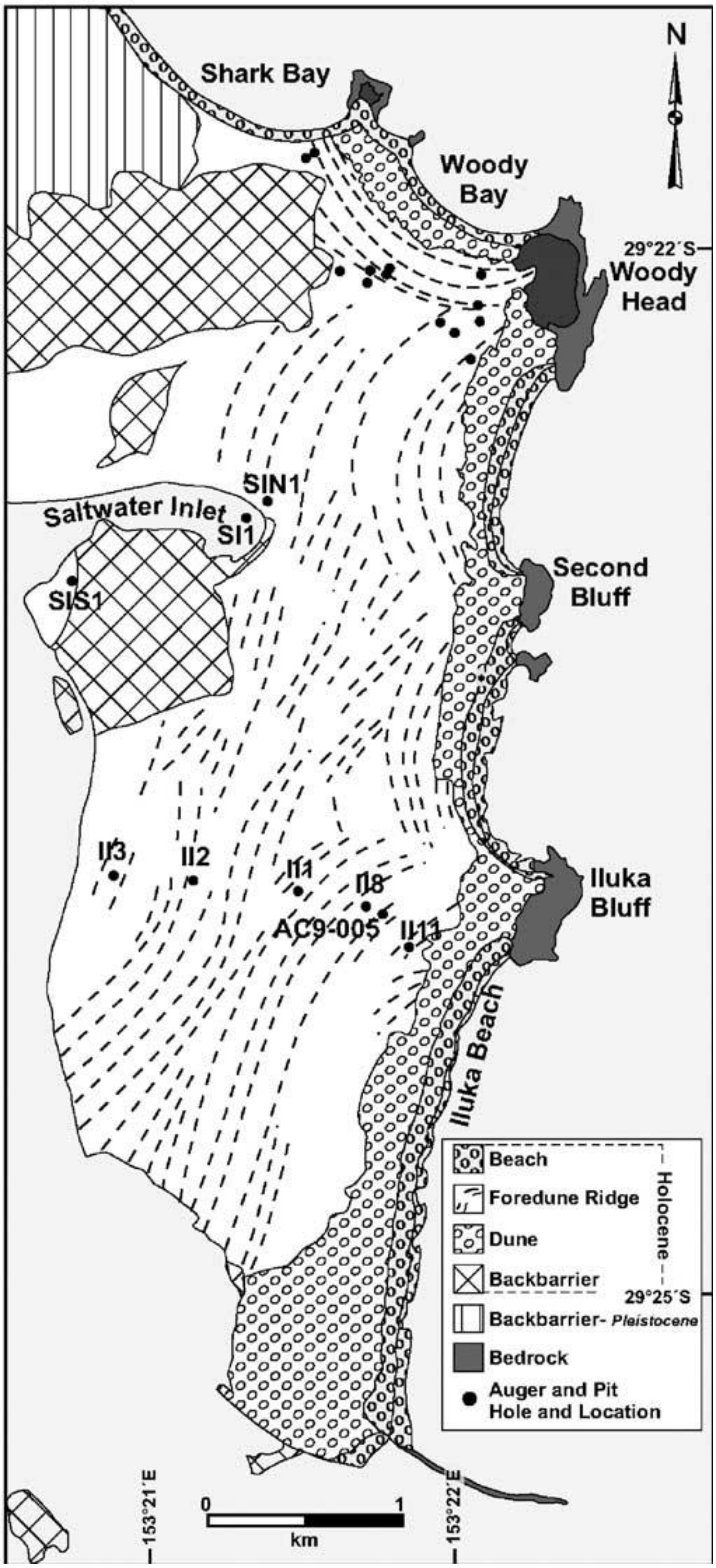


Figure 2.2: Pleistocene and Holocene geomorphology of the Iluka to Woody Bay sand barrier. Dashed lines indicate relic foredune ridges comprising the Holocene strandplain. Source: Goodwin *et al.,* 2006, p. 130.

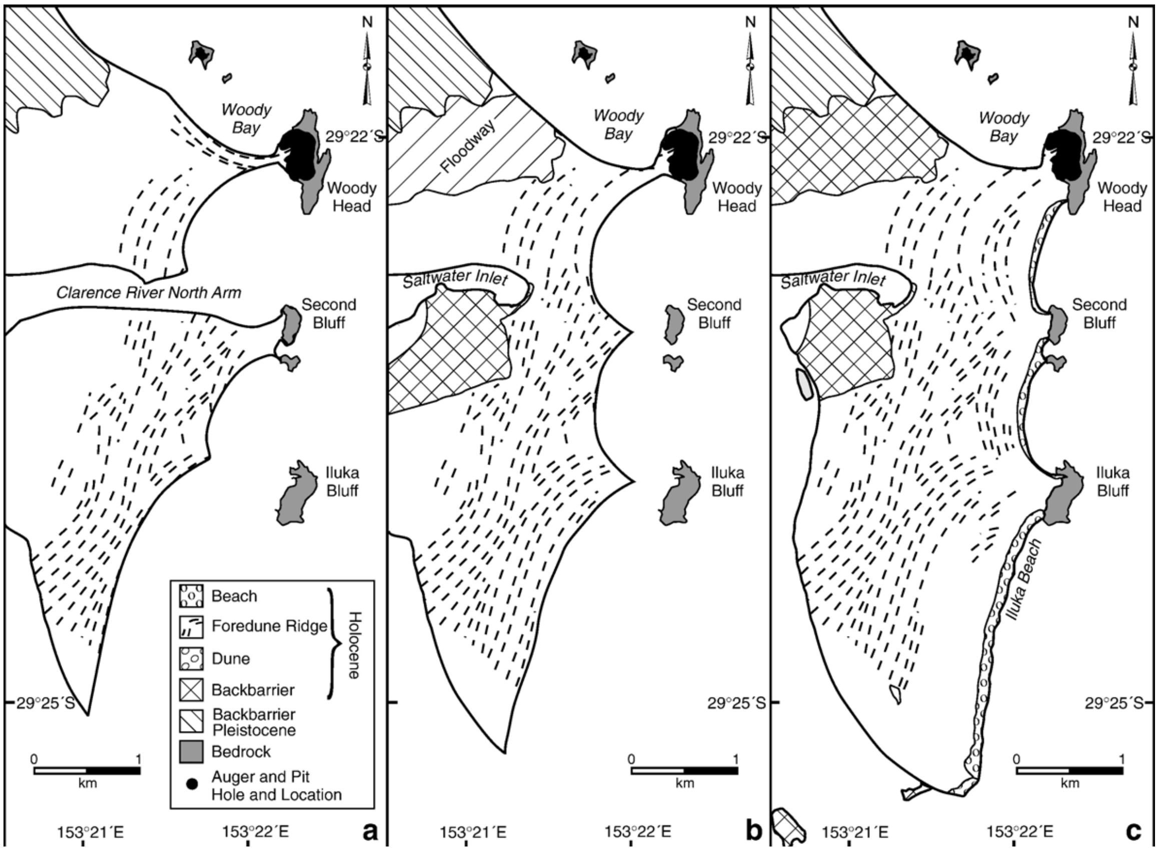


Figure 2.3: Configuration of the coastline and Clarence River entrances at (a) 1600 yr BP, (b) 1500 yr BP, and (c) 1000 BP. Dashed lines indicate relic foredune ridge crests, showing the successive position and shape of the shoreline. Source: Goodwin *et al.,* 2006, p. 136.

Large deposits of Quaternary sand occur along the coast in what Morand (2001) has termed the Bundjalung and Angourie Dunefields. Pleistocene dune systems are situated inland of Holocene beaches, foredunes and hind dunes; Quaternary deposits are composed of marine and aeolian quartz sands (Morand, 2001). The Bundjalung Dunefield occurs parallel to the coast. Dunes, sandsheets and beach ridges are common and swamps are present in poorly drained areas such as swales and deflation depressions. The rocky headlands of Snapper Point, Woody Head and Iluka Head are outliers of the Clarence-Moreton Basin (Morand, 2001). Deep Podozols (humus podzols) are common on Pleistocene dunes. Holocene beach sands contain rapidly drained Shelly or Arenic Rudozols (calcareous and siliceous sands) and associated dunes contain rapidly drained Arenic

Rudosols. Sandsheets within swamps commonly contain Organosols and Hydrosols, and Anthroposols occur within old sand mining areas (Morand, 2001).

Following is a description of the Clarence Coast beach/barrier landscape given by Morand (2001). The type location for this environment is Ten Mile Beach at Shark Bay. Beaches (swash zone) have a relief of <5 m with slopes at 1-3%. Barrier beaches, including Ten Mile, Evans Head and Iluka, are usually >5 km long and >50 m wide. Mainland beaches, including Red Hill, Yamba and Convent, are <1 km long, their configuration and extent determined by the surrounding headlands. Dunes form moderately to steeply inclined sand ridges with a relief of 5-15 m and slopes at 20-50%. An incipient foredune, at times with a small wave-cut scarp at its seaward edge, generally lies at the foot of these dunes. These incipient foredunes are generally 30-50 m wide, showing a hummocky, wind-induced microrelief. Dunes are aligned parallel to the coast and blowouts are common.

2.1.5.2 *Estuarine sediments and geomorphology*

Estuary morphodynamics are a function of inherited topography, including geological factors which control the size and shape of the estuary basin and nature of the sediment, and sea level changes (Carter and Woodroffe, 1994; Roy and Boyd, 1996; Roy *et al.,* 2001; Figure 2.3). During glacial periods estuaries became displaced onto the continental shelf and coastal sediments were eroded as rivers cut through previously submerged terrain (Roy and Boyd, 1996). During interglacial periods coastal valleys became drowned, subsequently forming estuaries which started to fill with marine, fluvial and terrestrial sediment (Roy *et al.,* 2001). Repeat glacial-interglacial cycles have left a complex sedimentary record in NSW estuaries (Roy and Boyd, 1996). The most recent phase of estuary sedimentation on the NSW coast began ~7-8 ka ago, during the Pleistocene-Holocene Post-glacial Marine Transgression (Roy *et al.,* 2001). The size and shape of existing valleys are the result of prior erosion and emplacement of coastal sand barriers, and this inherited pre-Holocene topography determines the accommodation space available for Holocene sedimentation (Roy *et al.,* 2001).

Along the northern NSW coast storm and swell waves and oceanic and meteorological currents affect the hydrodynamic regime of estuaries (Roy *et al.,* 2001). Waves are the dominant force controlling sediment movement so sand barriers at the mouths of bedrock valleys are common. Locally, variability in the size and orientation of embayments and headlands plays an important role in estuary mouth hydrodynamics (Roy *et al.,* 2001).

River dominance and evolution are linked by the concept of estuary maturity (Roy and Boyd, 1996). The level of maturity of an estuary affects sedimentation, water quality and biological productivity. Allowed sufficient time, an estuary will infill with sediment and become mature. Fluvial sedimentation and the expansion of alluvial plains over former estuary lagoon/lake basins causes sediment infilling leading to increased river dominance where fresh water is discharged directly to the sea through a mature alluvial plain (Roy and Boyd, 1996). As estuaries approach maturity salinity gradients become more pronounced, particularly in semi-mature barrier estuaries where their side arms (eg. cut-off embayments) exhibit more marine conditions than the main channel; saline bottom waters can become trapped and deoxygenated (Roy *et al.,* 2001). Discharges of acid groundwater from acid sulphate soils predominantly affect riverine channels. Biological productivity is at its peak during intermediate and semi-mature stages of estuary evolution, as the expansion of fluvial deltas allows for an increase in the diversity of biological habitats (Roy *et al.,* 2001).

The Clarence River estuary is a mesotidal mature barrier estuary which enters the high energy wave regime of the south west Pacific Ocean (Carter and Woodroffe, 1994; Roy *et al.,* 2001). It is composed of 2 fluvioestuarine basins separated by a bedrock barrier; the inner basin is protected by this barrier and lacks high energy Holocene coastal features, being divided into extensive low energy backwater swamps, the outer basin has a similar morphology to other south eastern Australian barrier-basins (Carter and Woodroffe, 1994). A coastal barrier of marine sands impounds the outer basin. These sands were driven shoreward during the Pleistocene-Holocene Post-glacial Marine Transgression (Carter and Woodroffe, 1994). Progradation of the Clarence River delta front has formed the cut-off embayments of Lake Wooloweyah, the Broadwater and Everlasting Swamp, which are at progressive stages of infilling (Roy *et al.,* 2001). The islands of the outer basin originated as estuarine sand shoals (Roy, 1984).

Barrier estuaries such as the Clarence, are wave-dominated (Carter and Woodroffe, 1994; Roy and Boyd, 1996; Roy *et al.,* 2001). Highly variable river flows (Eyre, 1998) coupled with their situation on a wave-dominated coastline (Roy and Boyd, 1996) means many south east Australian estuaries fall into this category. Wave-dominated estuaries occur behind sand barriers on exposed sections of the coast and thus their tidal inlets are constricted by wave-deposited beach sand (Roy *et al.,* 2001). Estuary mouth sands are typically composed of fine-grained shelly and coarse low-shell sand facies and only rarely exceed thicknesses of 15-20 m (Roy and Boyd, 1996). Dominant sediment transport mechanisms include local wind waves and wind-induced water movements however river discharge also has a strong influence leading to well developed flood tide deltas (Roy *et al.,* 2001). Ebb tide deltas can also form at the mouths of larger rivers such as the Clarence (Roy *et al.,* 1994). Delta growth during sea level stillstand conditions occurs at the inner edge of active entrance channels but this is a relatively minor contribution, as deposits are mostly, and more rapidly, emplaced towards the end of transgressive sea level conditions (Roy and Boyd, 1996).

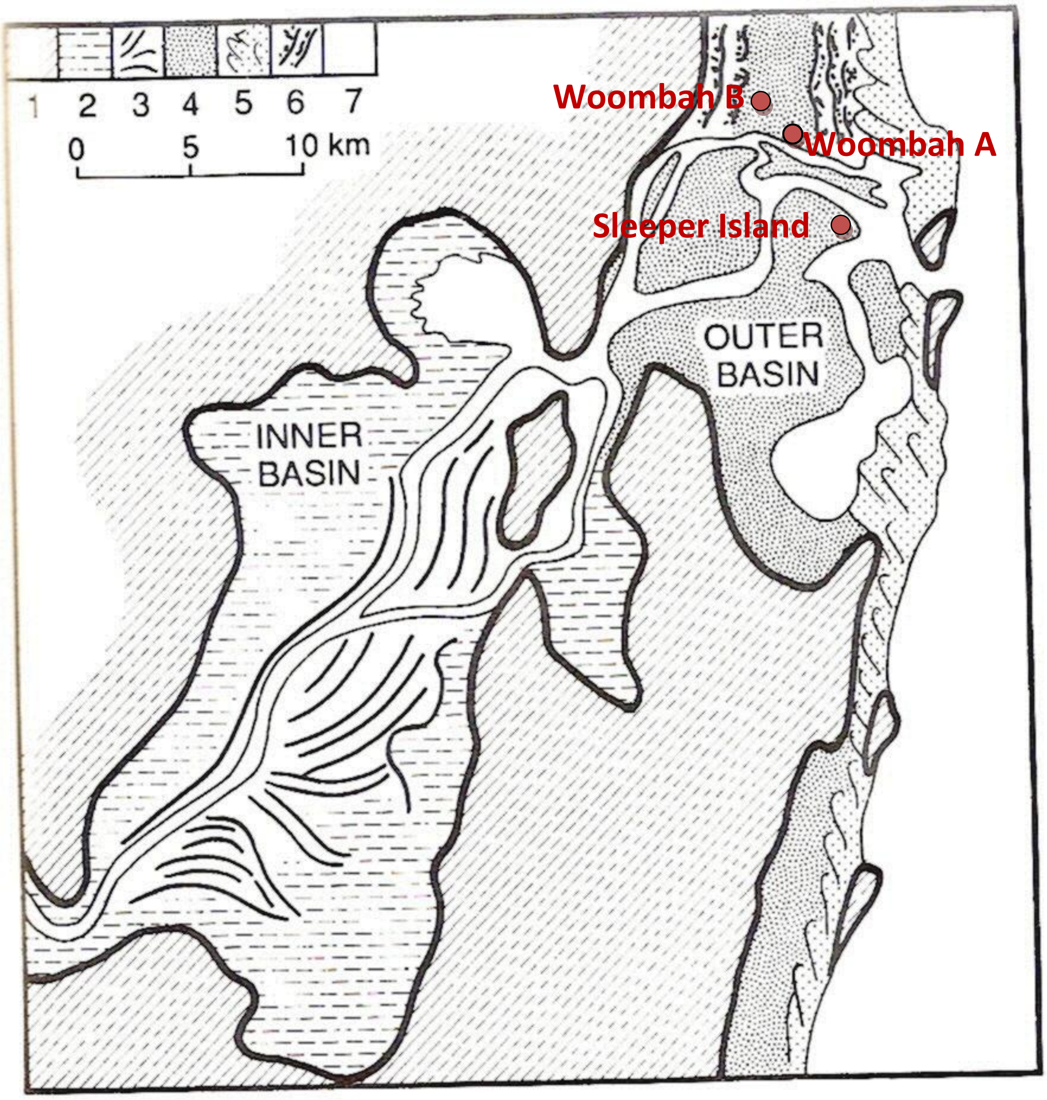


Figure 2.4: Composite estuarine system of the Clarence River showing the location of study sites located within the estuary. Key: 1. Pre-Holocene land surface. 2. Holocene inner basin sediments. 3. Fluvial levee and chute-channel sands. 4. Holocene outer basin estuarine and marine sands. 5. Coastal dune barrier complex. 6. Relict Pleistocene barrier. 7. Estuarine channels and lakes. Source: Carter and Woodroffe, 1994.

Roy (1984; 1994), Roy and Boyd (1996) and Roy *et al.* (2001) recognise four geomorphic zones in south east Australian estuaries. The marine tide delta zone is located in the estuary mouth and is influenced by tidal currents and wave action. Sediments include moderate to well sorted quartzose sand derived from the open coast and minor amounts of mud. High energy environments are restricted to the seaward-most part of the entrance channel, whereas low energy environments are best developed on the delta surfaces and along the inner sides of the barriers. The Clarence River estuary barrier is composed of a soil landscape referred to by Morand (2001) as the Bundjalung Dunefield (see Coastal Sediments and Geomorphology for a description).

Central mud basins, the second zone, consist of dark grey-black mud rich in estuarine shells, foraminifera and organic material (Roy, 1981). The source of this fine silt- and clay-sized sediment is the adjacent river, and it is supplied mainly during floods. Molluscs, polychaete worms and crustaceans are responsible for extensive bioturbation to depths of 15-20 cm, and this has implications for the preservation potential of artefacts (discussed in the following review of taphonomic processes affecting shell material). Central mud basins are found in low energy deeper parts of the estuary as well as in narrow slopes that border their sides.

As an estuary matures its central mud basin reduces in size due to progradation of the fluvial delta. Morand's (2001) soil study showed Clarence delta sediments are present not only on the estuary islands but also on the surrounding mainland. The presence of estuary sediments at the periphery of the Clarence River estuary indicates a relict estuarine landscape. By mapping the distribution of estuarine sediments Morand (2001) has shown that the Clarence River estuary once had a broader range and is thus maturing.

Rivers and streams enter estuaries at the fluvial delta (third zone) and this is a complex landscape containing subenvironments such as river and distributary channels, mid-channel shoals and distributary mouth bars, interdistributary bays, levee banks and crevasse splays. Floodplain sediments are important components of the fluvial and deltaic depositional system – crevasse splays themselves can be reworked (O'Brien and Wells, 1986) and this must be considered when examining the context of Aboriginal shell midden deposits.

The fluvial delta of the Clarence River has an elongated bird's-foot morphology (Carter and Woodroffe, 1994), where progradation of the delta causes outgrowth of natural river levees, forming a finger-like pattern (Whittow, 1984). Due to smaller tidal ranges, the fluvial delta zone in barrier estuaries is less extensive than in drowned valley estuaries. Wind-stress induced water circulation is dominant. Sediment types are variable due to the presence of a number of subenvironments and include clean fluvial sand and gravel in channel beds and on river mouth shoals, medium to coarse moderately sorted sand in small crevasse splays (O'Brien and Wells, 1986), poorly sorted mixtures of sand, mud and organics in levee deposits and mud and organic-rich sediments in marginal embayments and brackish swamps. As an estuary matures its delta front progrades, encroaching on the central mud basin (Roy, 1994). This is evident in the bird's-foot morphology of the Clarence River delta and in the cut-off embayments of Lake Wooloweyah, The Broadwater and Everlasting Swamp.

The riverine channel zone grades downstream into the fluvial delta environment. Roy *et al.* (2001) define the upstream limit of the riverine channel zone as "the maximum landward extent of brackish conditions during droughts" (p. 361). River discharge controls fresh and brackish water conditions in this zone. Sandy point bars occurring at meander bends usually correspond with undercutting and bank collapse of the opposite bank. Incision of riverine channels into relict estuarine muds is common and these channels are now lined with sand. Main sediment types comprise fluvial sand and muddy sand (Rochford, 1951) and are remobilised periodically by flood flows. As an estuary matures its riverine zone migrates seaward, along with the surrounding alluvial plain (Roy and Boyd, 1996).

Morand (2001) identifies two soil landscapes – estuarine/deltaic and estuarine/deltaic-lacustrine – in the Clarence River estuary (Figure 2.6). These soil landscapes both belong to the Clarence Delta physiographic region. The type location for the estuarine/deltaic soil landscape is

Romiaka Island. This landscape includes tidal flats and saltmarshes within the Clarence Delta. Topsoils often contain very high organic matter and these cover unknown depths of Holocene marine sands, clays and muds. Soils are permanently saturated as the region is dominated by tidal activity and saline water. The estuarine/deltaic soil landscape has an extremely low relief of <1 m and simple slopes range from 0-1%. The intertidal (daily tidal inundation, muds and sand flats), supratidal (infrequent inundation, saline watertable at shallow depths) and extratidal zones (inundated in exceptional storm/cyclonic tides) (Isbell, 1996) form extremely low, level tidal flats. Within the intertidal zone soils are deep (>100 cm), saturated Intertidal Hydrosols (Solonchaks); marine sand is also present in this zone. Within the extratidal and supratidal zones soils are deeper (>200 cm) and are composed of poorly drained Sulfidic/Sulfuric Extratidal and Supratidal Hydrosols (Humic Gleys).

The type location of the estuarine/deltaic-lacustrine soil landscape is the western side of The (Clarence) Broadwater. It contains marine and alluvial landscapes of unknown depth with tidal flats, swamps and plain being common landscapes. Elevation is 0-2 m with slopes at 0-1% and local relief is absent. The Broadwater is a large overflow basin formed by progradation of the Clarence River delta (Roy *et al.,* 2001) and water levels are influenced by tides and overland flow. Soils are deep (>200 cm) and are composed of very poorly drained Intertidal and Extratidal Hydrosols (Solonchacks; Humic Gleys). Very poorly drained Redoxic Hydrosols (Gleyed Podzolic soils) are found within limited areas of cattle grazing.

2.1.5.3 *Alluvial sediments and geomorphology*

The Clarence River lowland alluvial plains are present over two fluvioestuarine basins described earlier. The complex, fluvially dominated floodplain of the inner basin (Carter and Woodroffe, 1994) will be the focus of the next section. A brief description of the Alluvial-

Estuarine/Deltaic soil landscape (Morand, 2001) is also included, although the type location for this landscape is located in the outer basin.

Following the Pleistocene-Holocene Postglacial marine transgression vertical and regressive estuarine sediment was capped by alluvium (Roy, 1984). The prograding fluvioestuarine plains behind the coastal sand barrier share facies with the deltaic system. Due to the tectonic stability of the region, the Clarence River fluvioestuarine system is starved of fluvial sediment, thus much of its Holocene sediment originates offshore (Roy, 1984).

The main Clarence channel and its backwater swamps are separated by active channel features with complex chute-channels, crevasse splays and palaeochannels (Roy, 1984). Overbank flood flows contribute significantly to floodplain accretion. Pre-Holocene alluvial facies lie at 8-14 m depth and infilled palaeochannels contain fine textured mildly organic sediments; brackish estuarine facies underlying ~5 m of fluvial beds are present on the Pre-Holocene margins of the active fluvial channel zone. Backwater basins have a thin alluvial cover over organic muds (Roy, 1984).

The Alluvial-Estuarine/Deltaic soil landscape of Morand (2001) is the dominant soil landscape of the Clarence Delta physiographic region. Estuarine/Deltaic and Estuarine/Deltaic-lacustrine soil landscapes are also present in the Clarence Delta region and these have been discussed in the previous section. The type location for the Alluvial-Estuarine/Deltaic soil landscape is Palmers Island, situated in the outer basin of the Clarence River Estuary; other locations include Harwood and Chatsworth Islands and parts of Maclean.

The deltaic plain is extensive (10-15 km wide) and is level to very gently inclined. Holocene marine sediments of undetermined depth underlie 1-2 m of alluvium derived from inland sediments. Relief is 0-3 m, elevation ranges from 1-3 m and slopes are generally 0-3%. Numerous channels create a network of islands within the estuary and abandoned channels and floodways are common. The migrating Micalo Channel/Oyster Channel drainage system has caused erosion on Palmers Island, bringing marine sediments closer to the surface. A terrace scarp commonly separates the main plain from the floodplain.

Soils of the Alluvial-Estuarine/Deltaic (Morand, 2001) landscape are poorly drained with low wet bearing strength at field capacity. They are commonly saline or acidic and subsoils have a high acid sulfate potential. Deep (>200 cm) Melacic Sulfidic/Sulfuric Redoxic Hydrosols consisting of Black Kandosols overlie wet Sulfidic/Sulfuric D horizons.

The Clarence River is laterally constrained until it enters the zone of tidal influence – the site of extensive floodplains; the width of the floodplains greatly expands in this zone to a maximum of ~11 km. The average floodplain width is ~6 km (Huq, 1995). Huq (1995) divides the Clarence River lowland plain between Grafton and Maclean into several floodplain zones based on channel orientation and patterns of the floodplain surface. He further differentiates each floodplain zone into a series of geomorphic units, summarised in Figure 2.4.

Passing through the Grafton-Maclean lowland plain, the Clarence River's main channel is straight to slightly sinuous with occasional anabranches, the most prominent being the South Arm. Moderately well vegetated point and longitudinal bars are present (Huq, 1995). Benches, levees and crevasse splays occur occasionally at channel margins (O'Brien and Wells, 1986; Huq, 1995). The average thickness of fluvial deposits in the Grafton-Maclean floodplain region is approximately 5 m and is influenced by the network of distributary and flood channels; it is not always a function of distance from the main channel. Fluvial deposits are thin to absent in estuarine regions and near valley margins (Huq, 1995).

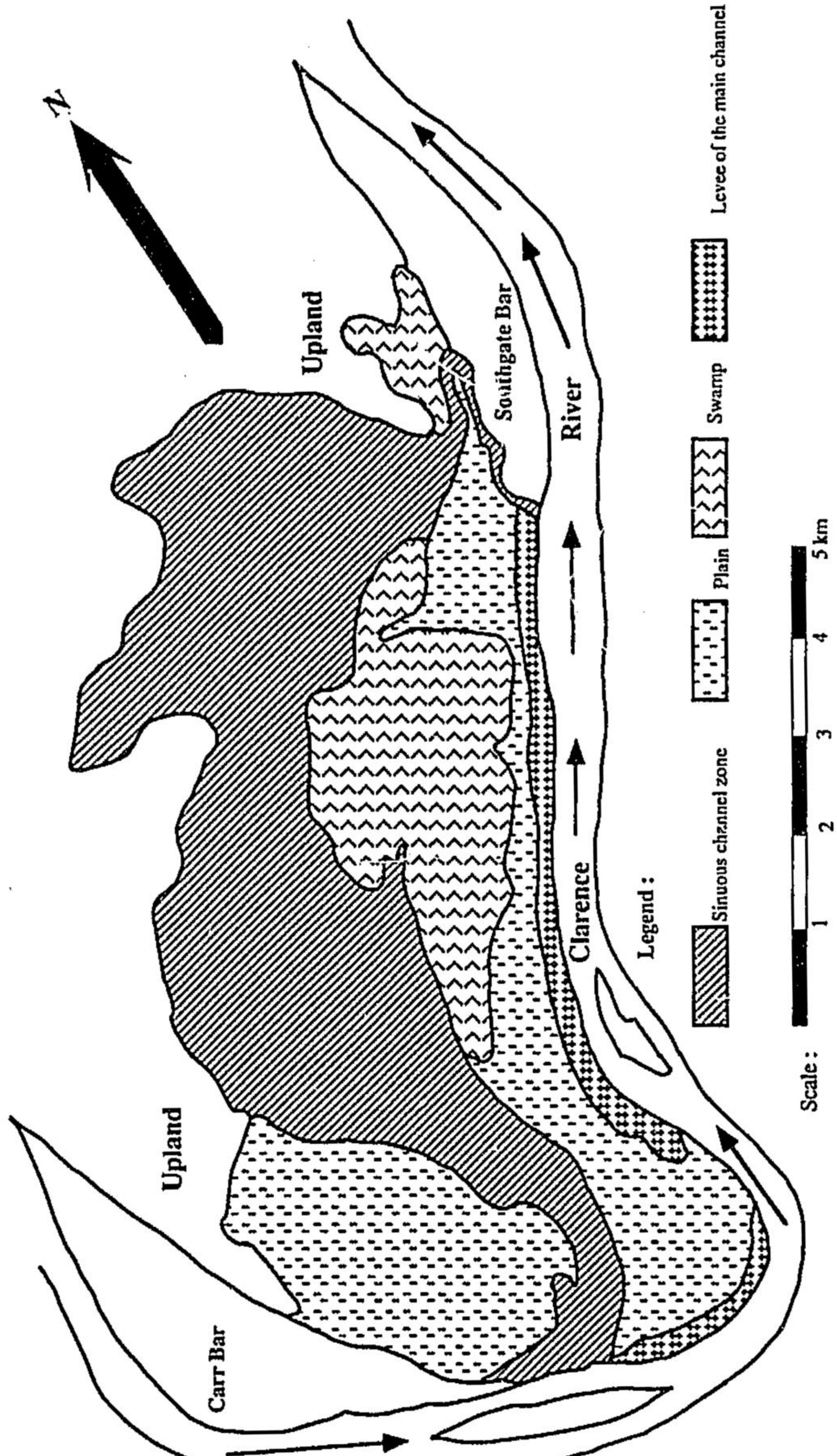


Figure 2.5: Geomorphic subdivisions of the Grafton floodplain.

The type locality for Morand's (2001) Alluvial soil landscape is located along the Maclean-Bluff Point Ferry Road at Cowper. This landscape comprises levees along the main Clarence River channels on the Clarence alluvial plain. Holocene estuarine sediments are overlain by fine-grained alluvium composed mainly of clays and silts with some sand lenses. This alluvium is present to depths >2 m. Elevation ranges from 2-6 m, local relief is 1-5 m and slopes are 0-6%. Major levees along the Clarence River channel and smaller levees along tributary channels form undulating to rolling plains. Land is completely cleared and soils are deep (>200 cm), well drained Brown Dermosols and Brown Kandosols. These erodible soils are strongly acidic and have low permeability.

2.1.6 **Local Resources and Land Use**

The Clarence River system is the largest coastal river catchment in New South Wales, spanning an area of 22 700 square kilometres. The majority of the local population and resources are supported by the Clarence River's extensive alluvial floodplain. The catchment is host to more than 250 sugar cane farms and a mill and refinery are located on Harwood Island. The local sugar industry contributes $103 million to the local economy each year (Clarence Valley Council, 2007). Farm land in the Clarence Valley also supports beef cattle, dairying and other general farming and accounts for 81.5% (8 507.5 square kilometres) of the current land use zonings for the Clarence Valley Council (Clarence Valley Council State of the Land, 2007). Aquatic resources are also important to the local economy; the second largest commercial fishery in New South Wales is located in the region and the industry contributes an estimated $27 million to the local economy each year (Clarence Valley Council, 2007). Timber production is also a significant contributor to the regional economy and the region contains both State Forests (199.4 square kilometres) and Joint Venture Freehold Hardwood Plantations (2 890 hectares) (Clarence Valley Council State of the Land, 2007).

The Clarence Valley also contains Protected Lands and land under Voluntary Conservation Agreements, wildlife refuges and land for wildlife (Table 2.1). Protected Lands include National Parks, which account for an area of 78.6 km^2, Nature Reserves, covering an area of 25.6 km^2, and State Conservation areas covering 17.1 km^2. A total of 239.7 Ha of land is under Voluntary Conservation Agreements, while a total of 11 wildlife refuges (12 747 Ha) and 27 other areas of land for wildlife (1 220 Ha) are contained within the Clarence Valley (Clarence Valley Council State of the Land, 2007). Rural Residential, Residential, Urban and Industrial areas only account for 0.81% (80.6 square kilometres; see Figure 2.5) of the current land use zonings for the Clarence Valley Council (Clarence Valley Council State of the Land, 2007).

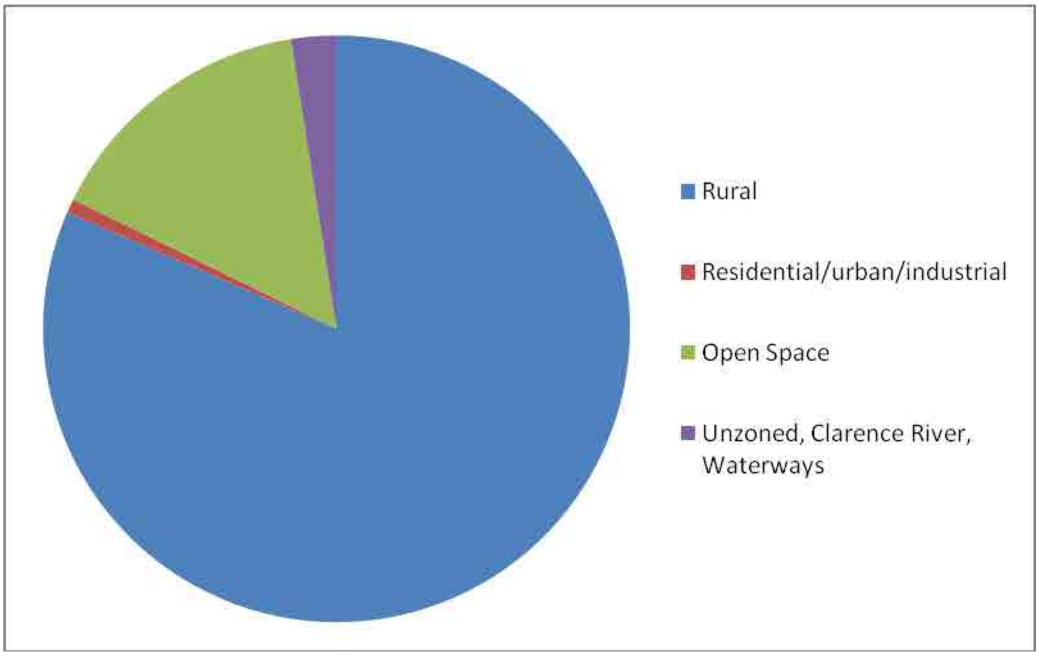


Figure 2.6: Clarence Valley Council current land use zonings. (Data source: Clarence Valley Council State of the Land, 2007).

Table 2.1: Area of Protected Lands, land under Voluntary Conservation Agreements, wildlife refuges and other land for wildlife in the Clarence Valley. (Source: Clarence Valley Council State of the Land, 2007).

Land Type	**Total Area (Ha)**
National Park	78 614
Nature Reserve	27 572
State Conservation Area	17 112
Wildlife Refuge	12 747
Land for Wildlife	1 220
Voluntary Conservation Agreement	240
Total	**237 505**

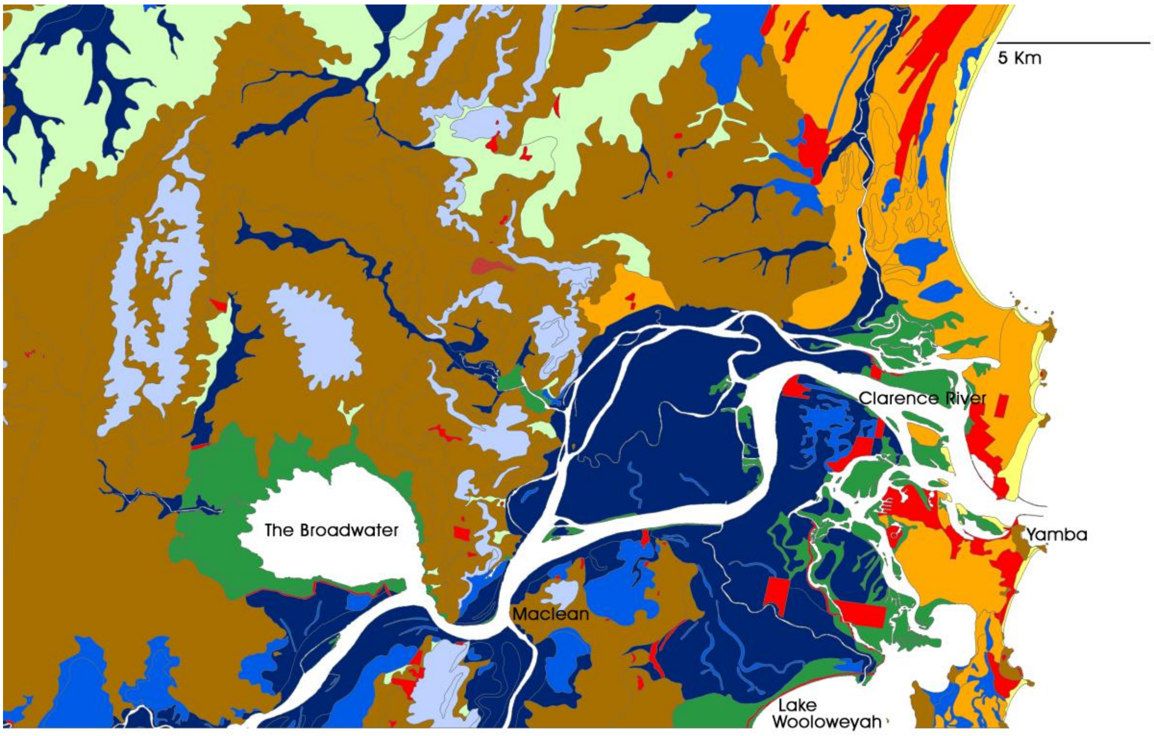
As the majority of the land in the area is used for farming (Figure 2.5), impacts such as loss of riparian vegetation (leading to riverbank erosion and other flood impacts), acid sulphate groundwater, compaction of soils, loss of topsoils and damage resulting from use of farming implements must be considered in the context of the vulnerability of Aboriginal midden sites in estuarine and riverine environments. As only a small amount of land is zoned residential/urban/industrial these may represent future areas of rapid and concentrated growth. Consideration of disturbance associated with industry, construction and increased population density must also be made. As the Clarence Valley is a popular tourist destination, impact on Aboriginal midden sites of such recreational activities as boating, bushwalking, camping and beach four-wheel-driving must also be examined.

Morand observed disturbance in areas of the Clarence Valley during his 2001 soil landscapes study. The following table (Table 2.2) summarises the data presented in this study with regards to observed disturbance in different environments and soil landscapes in the Clarence Valley region. Land use in different soil landscapes is also included. The following map (Figure 2.6) shows general locations of the different soil types.

Table 2.2: Land use by soil type. (Data from Morand, 2001).

Soil Type and Environment	Name and Type Location of Soil Landscape	Land Use	Degradation/ Disturbance
Alluvial	Cowper (cw), type location along Maclean-Bluff Point Ferry Road and includes parts of Maclean and Lawrence.	Grazing, sugar cane, seasonal cropping, flood refuge for livestock.	Original open- to closed-rainforest has been almost completely cleared. The Rainforest Reserve at Maclean is the sole remaining patch of original Clarence River floodplain subtropical rainforest. Streambank erosion is present.
Alluvial – estuarine/deltaic	Palmers Island (pa), type location on Palmers Island, soil landscape present on the deltaic plain of the Clarence River downstream of Maclean.	Some grazing, several prawn farms on Palmers Island. Includes villages of Harwood, Palmers Island, Chatsworth and parts of Maclean.	Soil structure decline in cultivated soils, acid sulphate soils widespread at depth >1 m. Area includes SEPP no. 14 coastal wetlands and isolated stands of *Casuarina glauca* (swamp Oak).
Estuarine/deltaic	Romiaka Island (rm), type location on Romiaka Island, soil landscape present on tidal flats and salt marshes within the Clarence delta.	Land generally unused as soils are saline and saturated throughout the year. Crown Reserves, Crown Land and several oyster leases.	Some urban encroachment at Yamba and Iluka. Area includes SEPP no. 14 coastal wetlands.
Estuarine/deltaic – lacustrine	The Broadwater (bd), type location on western side of The Broadwater near Broadwater Creek. Soil landscape includes The Broadwater and relict estuarine sediments surrounding it.	Uncleared swamp and mangrove complex containing some areas of extensively cleared swamp complex. Cleared areas support some beef cattle grazing, whilst uncleared land remains generally unused. The Broadwater is an important fishing ground.	Minimal amount of cleared land, no degradation or disturbance mentioned.
Beach/barrier	Angels Beach (ab), type location on Angels Beach, soil landscape also present at Evans Head Beach, 10 Mile Beach and Yamba Beach.	Predominantly recreational uses. Land includes Iluka Nature Reserve (World Heritage listed) and Broadwater, Bundjalung and Yuraygir National Parks.	Exposed to summer storms which can severely erode and reshape beaches. Beaches prone to severe wave attack during high seas and wind erosion causing blowouts particularly in beach access areas. Bitou Bush and Lantana are firmly established in most dune

			systems. Extensive sand mining has occurred in the past along beaches and hind-dunes. Dunes at Weapons Range have been extensively bombed. during military drills.
Aeolian	Iluka (il), type location at Iluka, soil landscape present as Quaternary sand sheets within the Bundjalung Dunefield and Clarence estuarine plain.	Some grazing and sugar cane between Broadwater and Woodburn. Urban areas at Iluka, Yamba and Broadwater. Includes parts of Bundjalung National Park and Iluka Nature Reserve. Otherwise uncleared lands, including Crown Lands.	Minor sheet and wind erosion in some cleared/urban areas. Bitou Bush and Lantana are common woody weeds. Area includes parts of World Heritage listed littoral rainforest at Iluka Nature Reserve.
Swamp	Angourie (an), includes swamps within transgressive dunes and swales of the Bundjalung Dunefield.	Includes parts of Broadwater, Bundjalung and Yuraygir National Parks and Dirrawong Reserve. Crown Land at Angourie.	No observed land degradation.
Alluvium	Brushgrove (bh), includes parts of the alluvial plain of the lower Clarence River. A variant (bha) occurs as a sand mass on Munro Island.	Beef and dairy cattle grazing, sugar cane.	Original open- to closed-forest has almost completely been cleared (see Cowper).
Alluvium	Calliope (cp), includes narrow, elongate swamps along flood chutes and distributary channels on the Clarence alluvial plain.	Mostly unused, some grazing.	Original closed-forest (swamp forest) completely cleared.
Lacustrine/chenier plain	Wooloweyah (ww), lacustrine/chenier plain bounding the west and south sides of Wooloweyah Lagoon.	Generally unused, some beef cattle grazing and sugar cane.	Acid sulphate soils.



KEY

WOODBURN SOIL LANDSCAPE

SEDIMENT TYPE

- AEOLIAN
- ALLUVIAL
- BEACH
- COLLUVIAL
- DISTURBED TERRAIN
- EROSIONAL
- ESTUARINE
- RESIDUAL
- STAGNANT ALLUVIAL
- SWAMP
- TRANSFERRAL

Figure 2.7: Locations of Morand's (2001) soil landscapes in the study area.

2.2 SITE FORMATION PROCESSES AND THE SYNTHESIS OF A GEOARCHAEOLOGICAL FRAMEWORK

2.2.1 **Introduction**

The current project focuses on understanding site formation processes acting in different geomorphic settings in the Clarence Valley. Such an understanding is essential if effective site- and environment-specific conservation guidelines and practices are to be implemented. Site formation processes are physical, chemical, biological and anthropogenic factors which not only act to preserve a site, but which also cause it to degrade (Ward and Larcombe, 2003). Central to the study of site formation processes is an understanding of the local geomorphic and anthropogenic factors which potentially disturb sites, as outlined in the previous section, and knowledge of how these factors act on a site. This section reviews literature on site taphonomy and links it with its causes.

2.2.2 **Site Formation Processes**

Figure 2.7 provides an outline of the contexts in which transformations, or taphonomic processes, occur at an archaeological site. It can be seen that site formation is affected by cultural and natural transformations, although Waters (1992) does not appear to acknowledge post-burial contexts. These are, in fact, of great importance in the Clarence Valley (see 'Local Resources and Land Use') and, indeed, the majority of cultural sites. Human activity may exacerbate natural processes, such as erosion, deposition and deflation, and may also cause other hazards such as acid sulphate groundwater and soil compaction.

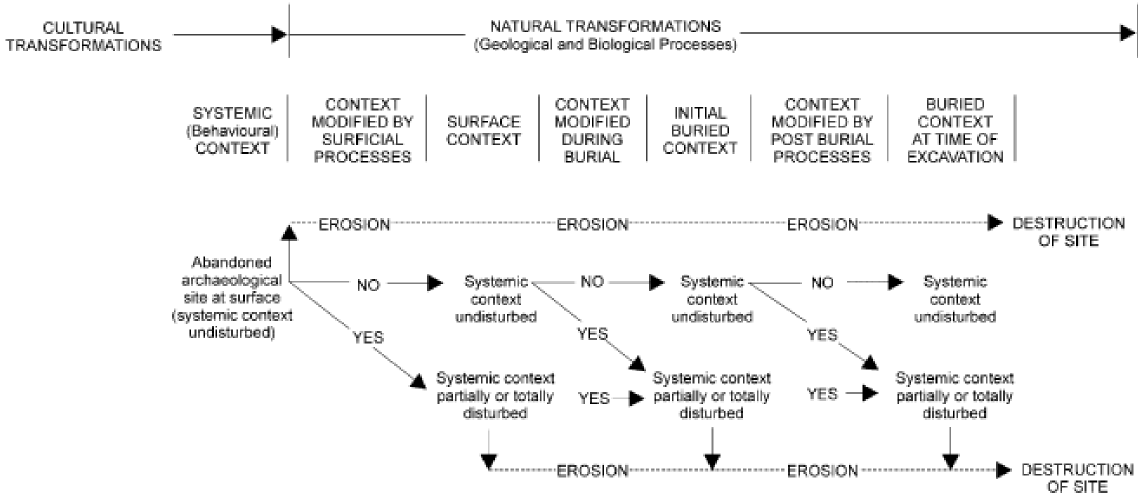


Figure 2.8: A flow chart for site formation. Source: Ward & Larcombe, 2003.

Another important point when considering anthropogenic and environmental factors involves separating the initial cultural context of a site from taphonomic, anthropogenic and environmental processes. Patterns produced as a result of natural formation processes may be mistaken for cultural patterning; this biases interpretation of site function, spatial organisation, chronology and stratigraphy (Erlandson and Rockwell, 1987). Tanner (2005) highlights some of the problems:

- Change of environmental setting: past shellfish may have lived in a habitat different to that of today. An understanding of the palaeodistribution of species and the palaeoenvironment at the time of deposition can effectively remedy this problem.
- Size of excavation/sampling strategy: samples from a single occupation horizon need to be taken from the whole site for a proper representation of site variability. As the focus of the current project involves site conservation strategies such as stratigraphic correlation (from small cores) between cores and with cores from the surrounding non-archaeological sediment, and accurate stratigraphic diagrams drawn from vertical exposures, are sound methods for assessing the integrity of, and variation within, a site.

- Temporal resolution: the more time represented in a single occupation layer the greater the overprint of patterns. Effects of environmental change and human behaviour merge and become difficult to isolate. Thorough stratigraphic studies and ^{14}C chronosequences of a site can aid in determining whether it has been reworked.

Sandweiss (2003) highlights the usefulness of archaeological deposits in palaeoclimatic reconstructions if their integrity can be shown to have remained intact. Sites along the Peruvian coastline with long occupation histories contained well preserved and easily dated sediment, soil signatures of past conditions and marine fauna providing a geochemical record (Sandweiss, 2003) for oxygen isotope studies and amino acid racemisation chronology. Studies of palaeoclimatic conditions and climate conditions since European occupation can help build a picture of susceptibility of Aboriginal midden sites in the Clarence Valley to climatic factors.

The study area, situated along the coastal reaches of the Clarence Valley, is host to a variety of coastal environments including coastal dunes and areas of the Clarence River floodplain adjacent to the Clarence River, estuary and associated swamps. Following is a review of aeolian disturbance processes and disturbance processes associated with alluvial landscapes. Bioturbation is considered separately due to its important in a variety of landscapes.

2.2.3 **Aeolian Processes**

The beach/barrier landscape of the northern NSW coastline is highly susceptible to wind erosion, resulting in blowouts (Morand, 2001). Coutts (1972) describes blowout deposits. A blowout can occur in the side of an unconsolidated sand dune and has the effect of scattering the material contained within the dune over its eroded face. Such surface collections of material are of limited value as chronological and cultural associations among the material have become obscured. (Goldberg and MacPhail, 2006) consider deflation the principal risk for an archaeological deposit in a windblown area. Exposure to wind erosion of unconsolidated or very loosely consolidated deposits containing clasts of various sizes can result in the formation of lag deposits (Garner, 1974). Fine-grained sediment is removed by deflation, leaving behind those clasts too heavy to be transported by the action of wind (Ahnert, 1998). Thus, lag deposits can form from either anthropogenic or natural shell accumulations. Characteristics of lag deposits include segregation of larger or heavier particles (Bloom, 1978), erosional interclasts and imbricated specimens, and condensed and concentrated shell accumulations (Grazhdankin & Seilacher, 2002). Wave-sorting can also produce lag deposits, as it is able to remove finer sands, therefore concentrating heavier material (Millard, 2003).

Rick's (2002) study of coastal dune middens on San Miguel Island, California, USA, found that wind can significantly disturb subsurface deposits to a depth of at least 200 mm. Field observations led Rick (2002) to suggest some key features of deflated midden deposits, although he acknowledges that artefact movement by aeolian processes in dune environments is very complex. Key features include: a higher density of more fragmented shellfish in upper strata, exhibiting angled, faceted, polished and etched surfaces primarily on the side of the shell exposed to the wind, and the presence of charcoal in lower layers of the deposit while it is absent in upper strata. Erlandson and Rockwell (1987) also note that wind abrasion may obscure features of artifacts valuable in determining their use at a particular site or sites.

Frederick, Bateman and Rogers (2002) used optically stimulated luminescence (OSL) dating to gauge the integrity of a site in the sandy uplands of east Texas. OSL results ruled out *in situ* weathering by demonstrating that the unconsolidated sands contained in the deposit had been exposed to significant sunlight prior to mid-late Holocene deposition. Chronostratigraphy is another useful dating technique when assessing site integrity. In an undisturbed midden it would be expected that the ages of shell would show they have accumulated over time (Stone, 1995). If shells of different ages are found at random within a deposit (that is, the deposit has an anomalous chronostratigraphy) it is likely to have been reworked (Erlandson and Rockwell, 1987; Stone, 1995).

2.2.4 **Storm Reworking**

Storm activity can cause disturbance in coastal and alluvial landscapes. Whilst wave erosion is common as a result of summer storm activity along the northern NSW coastline (Morand, 2001), flood discharges and raised estuarine water levels can disturb sites located on river banks. Shick (1987) suggests deposits found in high energy conditions, such as the beach/barrier landscape of the Clarence coastline, are likely reworked. But it is important to assess each site individually, as the degree of reworking will vary between sites (Shick, 1987) and may be related to factors such as amount and nature of dune vegetation, frequency of storm events and frequency of use for recreation.

Hughes and Sullivan (1974, Hons) characterise a midden that has been reworked by storm event(s) as containing shells of species and sizes not thought to have been eaten by Aborigines, water worn shells, rounded pebbles, pumice and marine shell grit with no sorting of material between layers. Rarely are rounded pebbles >5cm in diameter found in undisturbed middens, particularly if the type of rock is unsuitable for use in the manufacture of implements (Hughes and Sullivan, 1974). Pieces of pumice too large to be blown by the wind are common in wave reworked middens and the marine-derived shell grit found in such deposits is usually sub- to well-rounded as a result of abrasion in the surf zone (Hughes and Sullivan, 1974). In contrast, Statham (1892) argues that the presence of pumice within a shell assemblage indicates it was contemporaneous with a period of volcanic activity. Large floods may reverse alluvial sedimentary sequences, thus producing a unit with reversed grading, coarsening from silts to sand or gravel (Brown, 1997); they can also lead to the formation of gravel fans (Goldberg and MacPhail, 2006).

2.2.5 **Other Alluvial Processes**

It is not easy to generalise about the effects of geomorphic processes on archaeological sites in alluvial and wetland locations; variations in sediments and stratigraphy cause variable groundwater transmission rates (Brown, 1997). Meandering and avulsing channels create lateral variability due to movement of sediment (Guccione *et al.,* 1998). Hydrologic events also cause vertical movement of sediment. Sediment type, volume and movement all affect the integrity of archaeological sites in alluvial environments.

Although channel avulsion causes lateral variability in the stratigraphy of floodplain sites (Brown, 1997) it can cause the river course to become abandoned and thus protected from erosion, as is the case with Late Prehistoric (0.5 – 1.0 Ky) archaeological sites located along the Red River, Arkansas, USA (Guccione *et al.,* 1998). In locations meander migration and aggradation have produced overlapping scroll bars sites may be both laterally extensive and vertically stratified (Brown, 1997).

In their study of site preservation along the Red River, Arkansas, Guccione *et al.* (1998) found landforms to be obvious and, as such, geomorphic relationships were more useful than radiocarbon dates in determining the age of landforms and archaeological sites. The formation of diagnostic landforms is controlled by the meandering, migration and avulsion of the Red River and flooding of older floodplain areas deposited a veneer of younger overbank sediment. In such cases Guccione *et al.* (1998) recommend the age of land surfaces be used only as a minimum date for their associated landform. Guccione *et al.* (1998) suggest that vertical floodplain changes may not be as significant as lateral changes in channel position for archaeological site preservation along actively meandering and avulsing rivers such as the Red River, Arkansas.

The integrity of sites located in fluvial contexts is related to the tempo, magnitude and duration of hydrologic events (Petraglia and Nash, 1987). Such events affect the movement of sediment and associated artefacts. Wood and Johnstone (1978) define movement of archaeological materials downslope as 'graviturbation'. The process is fundamentally related to gravity and occurs with the aid of wind, flowing water and trampling (Erlandson and Rockwell, 1987). Stratigraphic anomalies and patterned distributions of artefacts and archaeofauna can be a result of graviturbation (Erlandson and Rockwell, 1987).

Sheetwash is common on slope crests and can transport dissolved and fine-grained loads (Goldberg and MacPhail, 2006), possibly biasing the archaeological record by removing finer and lighter constituents. Sheetwash also has the potential to rework archaeological deposits, thus affecting site integrity. Colluvium, forming slope deposits, is generally massively bedded and poorly sorted and at the slope bottom it is deposited as laminated, water-lain sediment (Goldberg and MacPhail, 2006). The colluvial footslope/valley bottom interface is characterised by interdigitation of colluvial and alluvial deposits – such locations may be identified as poorly sorted silts interfingering organic-rich clays (Goldberg and MacPhail, 2006). The stratigraphy of archaeological sites buried at such locations needs to be carefully interpreted.

After conducting experiments on hydrologic disturbance of stone artefacts Schick (1987) found such disturbance affected the assemblage composition and spatial configuration of stone artefacts. He identified greater proportional losses with successively smaller artefacts and this biased the record, leaving behind a seemingly higher proportion of cores and heavier artefacts. Trends in spatial configurations include:

- relatively core-rich deposits in vicinity of original site
- downstream deposits containing high proportions of debitage – spatial gaps within final deposit

- downstream gradation (coarse to fine)
- changes in material associations
- ‘stretching’ of site downstream
- reconcentration of site materials downstream (mirrors flow regime and sediment movement in river)
- cementation of site materials in fine-grained sedimentary substrates. Cementation of artifactual materials within substrate without evidence of burial by influx of fluvial or lacustrine sediments per se. Wetting and drying of sediments during and after bouts of rain had cemented artifacts fairy solidly within the drying muds.

Preservation and site integrity are closely related to the rate and intensity of erosion and deposition. At sites where erosion has been dominant since the time of occupation the preservation of sites is unlikely (Guccione *et al.,* 1998). Sites which are covered quickly, however, are more likely to be preserved. The erosional environment can be helpful to researchers in that it has the potential to expose deeply buried sites (Guccione *et al.,* 1998) although management of sites that are susceptible to erosion then becomes a pressing issue. Due to shifting stream beds is it unlikely to find intact human artefacts, other than those associated with intrusive features, in contemporary meander channel deposits (Guccione *et al.,* 1998). In such settings archaeological prospecting should be aimed at palaeochannels (Guccione *et al.,* 1998) and topographically elevated areas such as channel islands or banks and parts of the floodplain some distance from a channel (Schick, 1987). Guccione *et al.,* (1998) found in their study of archaeological sites along the meandering Red River, Texas, that vertically accreted overbank deposits were the dominant type of surficial deposit associated with cultural material. Laterally accreted channel deposits were rarely associated with archaeological sites. Channel deposits in the area showed an overall fining upwards trend. This may indicate slower deposition rates than the vertically accreted sediment which may have covered archaeological sites rapidly, preserving their integrity.

Organic-rich soils (A Horizons) can start to form once alluviation decreases or stops because the rate of soil development on floodplains is inversely proportional to the rate of overbank deposition (Brown, 1997). These palaeosols are useful in determining past floodplain conditions. Mature soils may not form at sites with continually high rates of deposition but such sites have the advantage that it is easier to distinguish multiple occupations, as they will be distinctly separated by sediment. Conversely, sites with low rates of deposition show multiple occupations that are hard to distinguish from one another (Goldberg and MacPhail, 2006).

Floodplain stripping is another geomorphic characteristic indicative of disturbance in an area. Floodplain stripping can occur as a result of secular hydrologic regime change from a drought-dominated regime (DDR), where flood frequency and magnitude are relatively lower, to a flood-dominated regime (FDR), characterised by frequent, high magnitude floods (Warner, 1997). Warner (1995) argues these natural changes are based on secular shifts in climate, but have been further complicated by effects of European settlement such as removal of dense floodplain forests and direct channel modifications. Both of these processes have occurred in the Clarence River estuary, with only small areas of original vegetation (for example, Iluka Nature Reserve) remaining, and the construction of drains on many of the estuary's islands (Morand, 2001).

Warner (1997) determined that the Clarence catchment contains a wide variety of stripped surfaces. These predominantly comprise convex bank bars and chutes. The convex bank chutes commonly occur across meanders but are sub parallel in some instances. Chutes channels occur as a result of high level flood flows passing across an extensively alluviated meander apex; incision of fine alluvium down to basal gravels can be seen (Warner, 1997). Bar gravels are exposed, having been exhumed from under fine alluvium. Another field indicator of floodplain stripping is the presence of extensive surface spreads of gravels and sands, often 5-10 m thick. Hummocky relief on floodplain surfaces, however, is often a result of localised erosion rather than floodplain stripping (Warner, 1997).

2.2.6 **Bioturbation**

Bioturbation is an extremely important taphonomic processes acting in a variety of environments. An understanding of the mechanisms of bioturbation, and the disturbance it causes, is essential when interpreting archaeological sites. Bioturbation affects the structure and maturity of soils, and influences a wide variety of sites including mounds, stable upland sites and floodplain terraces and flats. The activity of bioturbating agents is retarded under certain conditions.

Bioturbation can be defined as “the interaction between animals, plants and soil materials during which soil fabric is altered by additive or subtractive processes” (Grave and Kealhoffer, 1999; P. 1240). Animals participate in numerous processes of soil formation including mounding, mixing, forming and backfilling voids, forming and destroying peds, regulating soil erosion, movement of water and air, decomposition of plant litter, nutrient cycling and biota and production of special constituents (Hole, 1981). Both exopedonic (outside the soil) and endopedonic (inside the soil) animals influence archaeological site formation processes (Hole, 1981).

The presence of deep burrowing earthworms can affect soil structure and infiltration, impacting on soil surface segregation (Shuster, Subler and McCoy, 2000). Mackay and Kladivko (1985), Blanchart (1994) and Ketterings, Blair and Marinissen (1997) have observed earthworm activity to improve water filtration in soils however Shuster *et al.* (1999) have observed a process by which earthworm activity degrades the soil surface. Surface crusts or seals can form when the amount of surface coarse organic matter, which protects the soil surface, is reduced. A lack of surface coarse organic matter also increases exposure of the soil surface to weathering.

Stein (1983) used the Carlston Annis mound in Kentucky, USA, as a case study in recognising bioturbation caused by earthworms. An archaeological site in which surface-casting species are present is likely to exhibit a concentration of larger objects beneath the surface, as fine-grained matrix is brought to the surface by the activity of these earthworms. The activity of subsurface-casting species mixes the matrix of a deposit below the surface only (Stein, 1983) and this can cause homogenisation of a deposit (Erlandson and Rockwell, 1987). In both cases earthworms are responsible for reworking the matrix of a deposit, distorting the archaeological record. Erlandson and Rockwell (1987) also note that surface-casting earthworm action causes selective removal of fine sediment beneath large objects resulting in their burial. Objects found out of context, for example buried burnt rock lacking associated elements such as charcoal, ash or fire pit features, are indicative of bioturbation (Erlandson and Rockwell, 1987). Burrowing action of subsurface-casting species and subsequent accumulation of castings can also bring heavier archaeological material to the surface (Erlandson and Rockwell, 1987). Deposits affected by bioturbation often present a bimodal distribution of coarse and fine material (Erlandson and Rockwell, 1987).

Other larger burrowing species such as rodents create easily detectable burrows which, after abandonment, fill with material from a different soil horizon and can thus be easily recognised (Stein, 1983). The burrows of smaller species such as earthworms, ants, crickets and spiders are less easily detected (Stein, 1983) and may require, in addition to the observations mentioned in the previous paragraph, analyses of soil morphology. Grave and Kealhofer (1999) used several techniques to investigate the role of bioturbation at the Omkoi 14 earthwork complex in northwestern Thailand. Firstly, the results of a radiocarbon analysis were used to establish the onset and rate of sediment deposition. Secondly, sediment macro- and micromorphology was used to identify and assess the extent of percolation and insect and root activity. The upper stratum contained randomly distributed clasts and charcoal, while the lower stratum contained charcoal fragments oriented horizontally. Comparison of these strata indicated the lower stratum was undisturbed by bioturbation while the upper stratum was disturbed. Insect burrows and galleries were identified as extending both horizontally and vertically through the deposit and were infilled by faecal pellets. Orange clay infilling of burrows was also observed, indicating termite activity. Mixing of the A and B soil horizons was evident. Comparison of thin sections from the disturbed and undisturbed strata also highlights the effects of bioturbation in the disturbed stratum at Omkoi 14 (Grave and Kealhofer, 1999). Relatively coarse well-sorted grains were evident in undisturbed areas, while fine, poorly sorted sediments were characteristic of areas where termite galleries were present. The thin sections also showed evidence of percolation of fine water-borne sediments. The lower part of pore spaces show clay coatings forming crescentic laminations (Figure 2.8).

Balek (2002) also studied thin sections from bioturbated soil. Thin sections taken from the Sangamon Soil in western Illinois show faecal pellets and biogenic sorting of mineral grains by size (Figure 2.9). Fining in grain size can be seen with increasing distance from the faecal pellets. The Sangamon Soil forms part of a stable upland site and Balek's (2002) study shows even apparently stable sites located away from forms of geomorphic disturbance can be susceptible to biological disturbance.

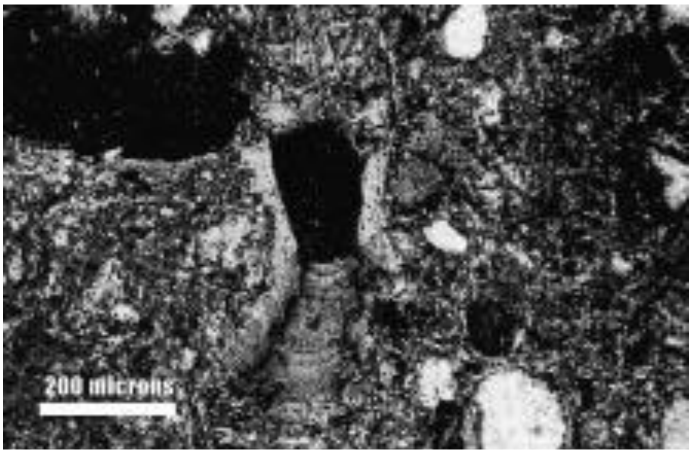


Figure 2.9: Percolation of fine sediments is indicated by the presence of crescentic laminations on the clay coating under the pore space in the centre of the image. Source: Grave and Kealhoffer, 1999).

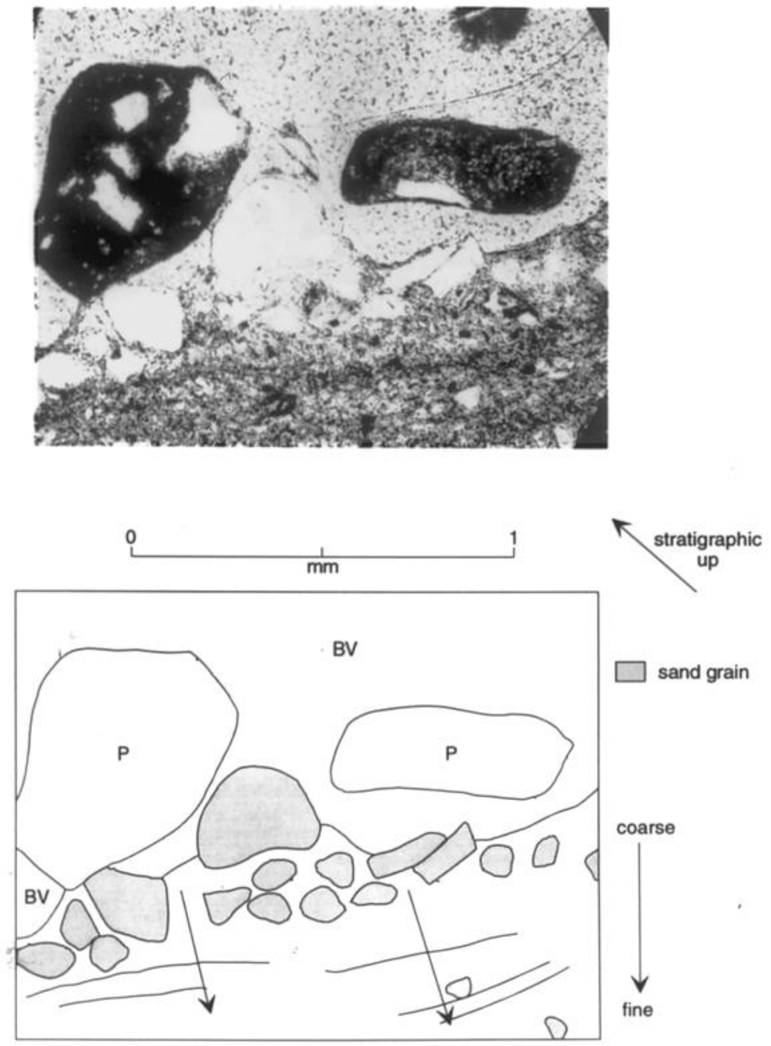


Figure 2.10: Thin section taken from the Sangamon Soil in western Illinois showing biogenic sorting of mineral grains by size. Source: Balek, 2002.

The third technique employed by Grave and Kealhofer (1999) to investigate bioturbation at Omkoi 14 involved an analysis of phytoliths. Each sample contained a full range of phytoliths sizes which suggests the sediment column has been churned by bioturbation. If the sediment had been unaffected by bioturbation it would be expected that phytoliths may be sorted by their size, mirroring the distribution of other sediment particles in the undisturbed stratum.

There are several conditions which exacerbate or retard bioturbation due to earthworm activity. High annual precipitation and temperature (Nye, 1955; Maldague, 1964), as well as mixed or loamy textures and high organic matter input (Brown, 1997), are conditions preferred by earthworms. Brown (1997) suggests that in alluvial environments the locations most densely populated by earthworms are generally terrace surfaces and floodplain flats. High sedimentation rates and very acidic (pH <3.5) and permanently waterlogged conditions inhibit earthworm activity (Brown, 1997).

Knowledge of the habitats of bioturbating agents, coupled with analysis of stratigraphy and soil morphology, is essential when assessing an archaeological site for biological disturbance.

2.2.7 **Synthesis of a Geoarchaeological Framework**

As shown in the studies outlined above, there is a need within archaeological and broader earth science research for a practical geoarchaeological framework. Geoarchaeology can be defined as "The application of geological and geomorphological techniques to archaeology and the study of the interactions of hominins with the natural environment at a variety of spatial and temporal scales" (Brown, 2008, p278). The core characteristic of geoarchaeological studies is the use of geomorphic techniques to place site formation processes into a regional context, thus allowing comprehensive interpretation of the cultural material they contain. Apparent information loss at a site can be investigated in terms of the processes which caused it; this information is often vital for accurate representation within archaeological reconstructions.

Various recent studies have refined highly useful geoarchaeological techniques to reinterpret and add to the volume of knowledge at archaeological sites around the world. Ward *et al*. (2006) integrate archaeological evidence from rock shelter and open site excavations in the Keep River region in north western Australia, after finding depositional and postdepositional processes cause differences in artefact assemblages and occupation chronology.

Reinterpretation of surface stone artefact scatters in western New South Wales, Australia, in a geomorphic context has yielded much useful archaeological information (Fanning *et al*., 2009; Fanning, Holdaway and Rhodes, 2008; Fanning and Holdaway, 2001). Fanning and Holdaway (2001) measured the horizontal integrity of surface artefact scatters through the application of experimental geomorphic studies based on the movement of nonartifact clasts on hillslopes. This technique allows postdepositional movement of stone artefact scatters on very low slope gradients to be determined over a much larger area than archaeological quantification techniques such as refitting and analysis of microdebitage. Fanning and Holdaway (2001) found horizontal postdiscard movement of stone artifacts on low gradient land surfaces to be minimal, and suggested the broader application of this technique in assessing integrity of surface artefact scatters world-wide.

The geoarchaeological study of Fanning *et al*. (2009) demonstrates the use of geomorphic techniques to build a chronological framework for artifact surface scatters in western NSW. By placing the deposits in a regional geomorphic context, they show that variability in erosion and deposition leads to a variability in land surface age. This information facilitates reinterpretation of the age of surface artifact scatters, showing that artifact deposits which appear to have similar characteristics are not necessarily of a similar age. This study also highlights the reason why the archaeological record of the south east Australian arid zone is rarely found in buried deposits but is rich on the surface.

Geoarchaeological techniques have also been used to resolve ancient settlement patterns in central Tonga. Dickinson and Burley (2007) have shown that a number of geomorphic and geologic factors have influenced the ancient population distribution of central Tonga. Volcanic islands were a source of lithic resources and also the origin of tephra blankets which formed over the non-volcanic limestone islands. Weathered tephra blankets formed rich agricultural soil on these non-volcanic islands, and their terrigenous sand is was a resource used in the making of Lapita ceramics. Forearc uplift and subsidence influenced the diverse morphology of the non-volcanic limestone islands; configuration of evolving shorelines was influenced by Last-Interglacial and mid-Holocene sea level highstands (Dickinson and Burley, 2007). Also in the Pacific islands region, Anderson *et al.* (2006) have linked the sedimentary history of Fiji's Sigatoka Dunes with Fijian archaeological theory. They have shown that OSL and radiocarbon age determinations support the stratigraphic interpretation of the archaeological sequence of three stable dune phases associated with periods of Late Holocene dune stability.

Several recent studies in North America also effectively use geoarchaeological techniques to obtain greater archaeological resolution. Punke and Davis (2006) addressed the lack of evidence of inland migration of humans from initial colonisation of the northwest coast of North America by interpreting subregional tectonomorphic processes along the tectonically active Oregon coast. They found preservation and accessibility of Pleistocene stream terrace deposits is largely influenced by local, upper-plate tectonic structures; identification and understanding of these processes and structures better informs archaeologists as to the possible locations of cultural sites within coastal river valleys in tectonically active areas.

Interpretation of sedimentary structures and grain size distribution to resolve the interaction of aeolian, fluvial and local runoff processes in the arid-land Colorado River Corridor has been undertaken by Draut *et al*. (2008). Results show aeolian deposition has been a significant preservation agent over the last millennium, and that since the construction of the Glen Canyon Dam the absence of sediment-rich floods has reduced the preservation potential of cultural sites located in this area.

Cremeens and Lothrop (2009) studied the distribution of regolith materials and associated soil characteristics to interpret the stratigraphic context of eroded Native American shell middens containing multiple occupation events. Understanding the geomorphic processes affecting the vertical distribution of shells at the site allows for a more thorough interpretation of the cultural material. Also in West Virginia, USA, Cremeens, MacDonald and Lothrop (2003) showed that archaeological materials buried in weakly developed soils of the upland landscapes of the unglaciated Appalachian Plateau provide evidence of short periods of landscape stability in between catastrophic storm events. In addition to using geomorphic techniques to expand our understanding of the context and scope of archaeological sites archaeological information, such as that found by Cremeens, MacDonald and Lothrop (2003) can be integrated into the broader scientific data pool. In this case the authors suggest its application to conceptual models of temporal occurrence and classification of mass movements in co-alluvial settings. Similarly, a geoarchaeological study of the sedimentary record of an archaeological mound in Kinet Hoyuk, Turkey, used artifacts to characterise and date sedimentation in the area. Beach and Luzzadder-Beach (2008) found that artifacts from the mound, as it grew, had eroded into the strata of the surrounding alluvial plain, thus providing further information on the possible time period of erosion and deposition of alluvial sediments.

Ghilardi *et al*. (2008) further highlight the application of chronostratigraphic data in the interpretation, and reinterpretation, of archaeological material. They combine chronostratigraphic data, archaeological evidence and ancient literary sources to reconstruct landscape evolution and shoreline displacement during the past 5 millennia on the Thessaloniki Plain, Greece. Results obtained from the chronostratigraphic data led to a re-evaluation of landform definitions in the ancient literature and, thus, a reinterpretation of the mid-late Holocene landscape.

A practical geoarchaeological framework involves the synthesis of geomorphological techniques for analysing chronostratigraphy, hillslope erosion, regional erosion and deposition rates and sedimentary, geologic, tectonomorphic and pedogenic processes. The recent publication of many geoarchaeological studies incorporating analyses facilitated by these techniques highlights the importance of understanding site formation processes within regional and subregional geomorphic contexts. Previous study of archaeological sites in and around the Northern Rivers region of New South Wales has focussed on site survey and largely ignored site formation processes. The synthesis of a practical geoarchaeological framework facilitates in-depth study of site formation processes at recorded and previously unrecorded Aboriginal shell midden sites.

2.2.8 **Previous Archaeological Studies and Identification of Potential Research Sites**

Several archaeological surveys have been undertaken in the Maclean region but these are largely focused on National Parks land (Starling, 1974; Mcbryde, 1982; Byrne, 1985; 1986; James & Conyers, 1995). While Starling's (1974) survey was the most comprehensive, providing tabulated lists of site type, contents, dimensions and map references, recommendations concerning the conservation of sites were minimal. Although admitting dune middens in the Angourie Point – Iluka area (directly east of Maclean) have the potential to be easily disturbed, Starling (1974) states that their location in a National Park affords them protection. This may be true for human impacts such as recreation and development, however natural processes causing dune destabilisation, such as aeolian sediment movement (Rick, 2002) and storm events (Hughes & Sullivan, 1974) still have the potential to alter or destroy vulnerable sites. Reducing the impact of these processes through careful monitoring and stabilisation of dunes is essential to reduce site vulnerability.

Byrne's (1985) report targets Aboriginal sites in the Ulmarra Shire adjacent to the Shire of Maclean. As a proportion of this land is located outside the area of National Parks, he suggests the activities most damaging to Aboriginal sites will be related to agriculture and construction in riverine areas and sand mining and development of coastal villages in coastal zones. Byrne (1985) also notes that the most common sites located in sensitive areas within the Ulmarra Shire are shell middens, and that these sites are vulnerable to the action of natural forces such as wind and wave action in addition to those aforementioned.

A large number of recorded midden sites situated in the foredunes and inner barrier dunes within Maclean Shire are likely to have been reworked, or are vulnerable to reworking (Byrne, 1986; James & Conyers, 1995). Some deposits have become deflated as a result of the action of wind eroding the sediment in which they have been deposited, and others may have been reworked due to storm events or covered with sediment from the Clarence River estuary (Byrne, 1986). While burial of a cultural deposit by estuarine sediment can assist its preservation (Brown, 1997), a rise in water level can also displace shell and artifacts (Byrne, 1985). Identification of vulnerable and reworked sites in these areas is essential if effective conservation methods are to be developed. Other likely agents of disturbance affecting Aboriginal shell midden sites in the Maclean Shire include sand mining, levee construction, agricultural practice (leading to acid sulfate soils which potentially degrade shells), recreation/tourism, urban development, drainage works and animal damage including bioturbation (Byrne, 1986; James & Conyers, 1995).

James & Conyers (1995) undertook an extensive review of Aboriginal sites recorded in northeastern New South Wales as part of a NRAC funded Aboriginal Archaeology Project. They found, however, that records for many of the sites were sub-par, limiting the amount of information that could be gained from them. Twenty one percent of recorded Aboriginal shell middens showed signs of disturbance due to the agents mentioned in the previous paragraph. James & Conyers (1995) also highlight the need for further study in northern New South Wales both to ascertain whether or not significant disturbance has altered Aboriginal midden deposits and to discover new archaeological deposits. They suggested that the value of disturbed sites may be reduced and therefore the conserved sites may represent a skewed sample. The survey of previously unsurveyed land will no doubt yield Aboriginal sites, decreasing the bias of sampling that exists primarily along the open coast.

Several means were employed when identifying potential sites for research. Firstly, consultation with local Aboriginal communities identified midden sites known to be under threat from erosion. Secondly, the National Parks and Wildlife Aboriginal Sites Register (Aboriginal Heritage Information Management System, or AHIMS) contains information on midden sites and their locations. After consultation with local Aboriginal communities it was found there were site locations registered with National Parks and Wildlife of which they were unaware; consequently, they were enthusiastic to assess risk and implement conservation measures at these locations. Previously unrecorded sites known to the Yaegl Local Aboriginal Land Council were also included in the study and registered with the National Parks and Wildlife Service. Studies discussed above have included some of the sites logged in the register and several impacts have been identified. Further study of the nature of these and other impacts allows the formulation of effective site- and environment-specific conservation guidelines in consultation with local Aboriginal communities. Table 2.3 identifies the study sites and summarises the age range of each midden deposit based on information available from previous archaeological (Woombah sites A and B; McBryde, 1982) and geological studies (Sleeper Island, Plover Island, Minnie Water and Wooli; Troedson and Hashimoto, 2008). The following chapter presents general information, including land use, geomorphology, vegetation and cultural material, on the study sites.

Table 2.3: The study sites, their geomorphic context and age.

SITE	GEOMORPHIC CONTEXT	AGE RANGE	REFERENCE
Woombah A & Woombah B (WA and WB)	Riverbank and creekbank, respectively. Adjacent to the deposits in McBryde's (1982) Woolpack Creek study.	2600-3000 BP; 1400-1800BP	McBryde, 1982.
Sleeper Island (SI)	Estuarine plain.	Holocene	Troedson and Hashimoto, 2008.
Plover Island (PI)	Exposure of Coramba Beds (Figure 2.1). Adjacent shell middens located in coastal barrier foredunes.	Carboniferous bedrock (source material for stone artifact quarry, see Chapter 3); Holocene coastal barrier dunes.	Troedson and Hashimoto, 2008.
Minnie Water (MW)	Rocky Point headland an exposure of Coramba Beds. Midden deposit spans sediment stratigraphically overlying this bedrock as well as adjacent coastal barrier dunes.	Carboniferous bedrock; Holocene coastal barrier dunes.	Troedson and Hashimoto, 2008.
Wooli (WL)	Coastal barrier.	Holocene.	Troedson and Hashimoto, 2008.

3. SITE DESCRIPTIONS

3.1 SLEEPER ISLAND

3.1.1 **Land Use and Geomorphology**

Sleeper Island is a small (~8 km^2), flat, low-lying island located in the Clarence River estuary (S29°24.609’, E153°19.540’, Figures 3.1, 3.2, 3.3). It is connected to Palmers Island by a cement bridge (Figures 3.4 and 3.6). The portion of Palmers Island adjacent to Sleeper Island is privately owned and is used predominantly as a cattle farm. Evidence on Sleeper Island suggests cattle from the adjoining farm are let onto the island periodically (Figure 3.4, box). Sleeper Island is separated from Palmers Island by a tidal channel 5-7 m wide and the cement bridge which connects the two islands has prevented the flow of water from one side of the channel to the other. Stagnant pools of water can be seen on either side of the bridge (Figure 3.7).

The banks of Sleeper Island are eroding and face daily inundation at high tide. At low tide the western bank of the island falls sharply into the water with only minor sediment deposited from the estuary (Figure 3.8, arrow). The position of this bank in relation to the flow of water in the estuary may account for the lack of observed sedimentation, in an effect similar to that seen on the outside bank of a river meander. The eastern bank, however, shows a much greater exposure of sediment at low tide (Figures 3.1 and 3.9). Deposition due to the position of the bank in the estuary channel may also account for this observation, having a similar, depositional effect as flows on the inside bank of a river meander. Movement of sediment (erosion and deposition) as a result of this and other mechanisms may have changed the shape of the channels between the estuary islands, altering flows and thus impacting on bank erosion (see Chapter 7). Although sedimentation rates and loads may vary between the east and west banks of Sleeper Island bank erosion is considered to be the major geomorphic factor impacting on this island. A subsequent site survey performed two years after the initial investigation showed the bank has been undercut by a further 0.6 m at the site of the midden deposit.

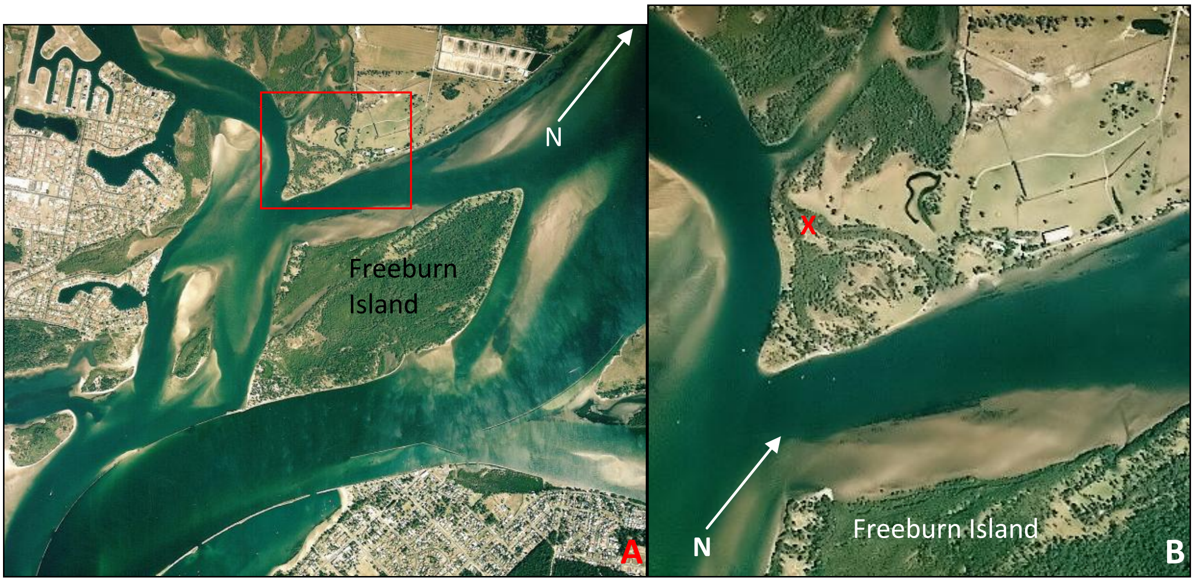


Figure 3.1: A: Aerial photograph of a section of the Clarence River estuary showing Sleeper Island (box). **B:** Close up of Sleeper Island showing location of Aboriginal shell midden (X).

Figure 3.2: Sleeper Island, adjacent to Palmers Island, showing locations of core samples. Scale = 1:5,600

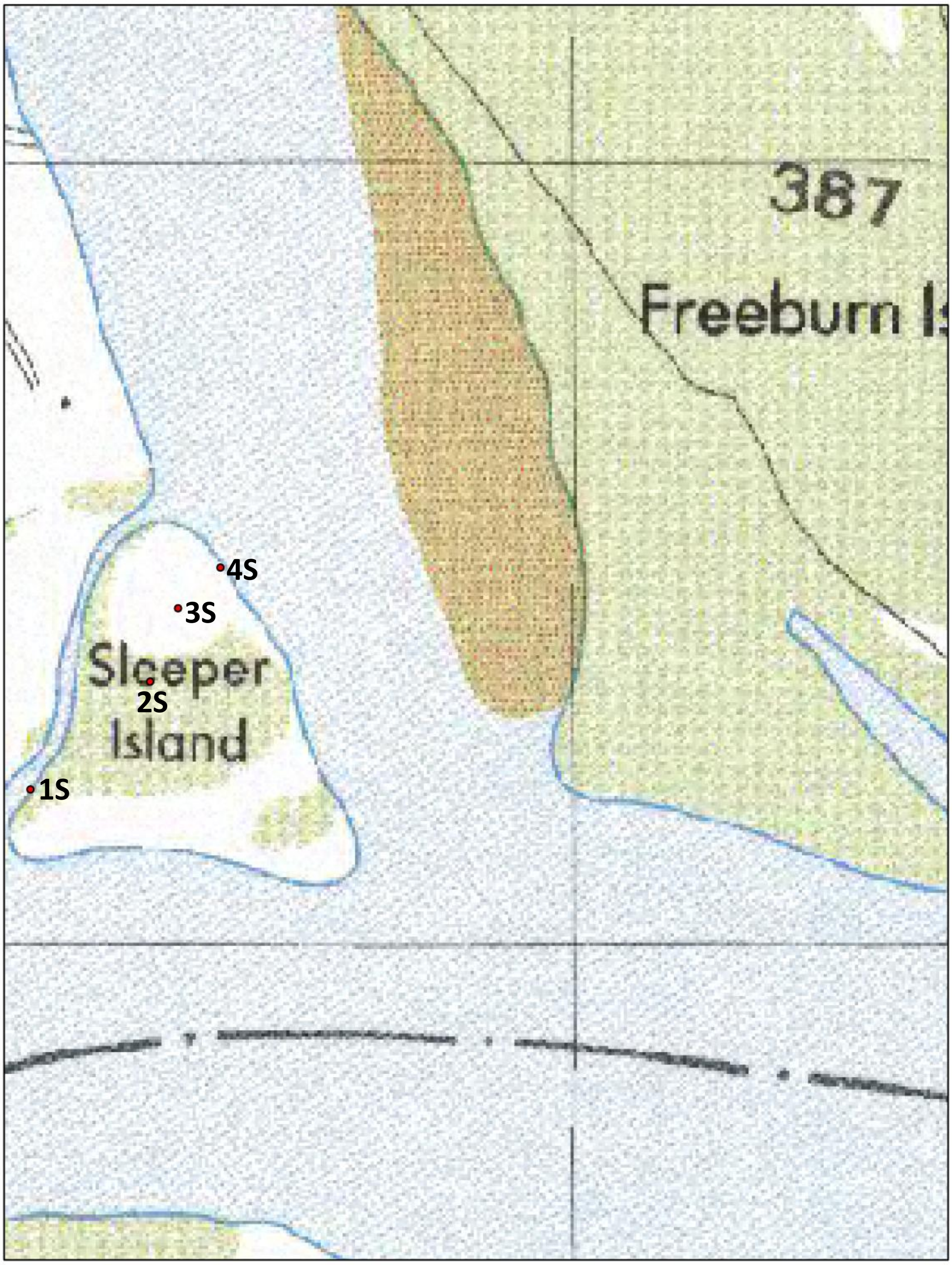


Figure 3.3: Topographic map of Sleeper Island, adjacent to Palmers Island, showing locations of core samples.

Scale=1:5,600

Figure 3.4: Cattle hoof prints on Sleeper Island.

Figures 3.5 & 3.6: Bridge connecting Sleeper and Palmers Islands.

Figure 3.7: Pooled water in the channel between Sleeper and Palmers Islands.

Figure 3.8: West bank of Sleeper Island, showing bank erosion.

Figure 3.9: East bank of Sleeper Island.

3.1.2 **Vegetation**

Vegetation on Sleeper Island comprises native and exotic species. Mangroves are present in and around channels. Many propagules were observed on the eastern, southern and western beaches of the island however the banks are devoid of mangroves. Water couch covers the whole island from the centre to the banks. *Casuarina* is the most common tree on the island. Some large bottle brush and Cyperaceae are also present. Exotic vegetation includes *Cinnamomum camphora* (Camphor Laurel), *Amyema* sp. (mistletoe), *Ipomoea* sp. (Morning Glory) and *Datura ferox* (Common Thorn Apple). Volunteers from the local Aboriginal community are systematically removing these weeds.

3.1.3 **Cultural Material**

There is one cultural deposit on Sleeper Island – an Aboriginal shell midden. The deposit lies 0.30-0.40 m below the soil surface and the dimensions of its exposed face are 0.10 m X 22.5 m long. The vast majority of the cultural material has eroded out of the deposit, which sits in a channel bank (Figure 3.10), and coring suggests the thickness of the *in situ* deposit is negligible at ~ 0.10 m (Figure 3.11). The contents of the midden include bivalve and gastropod molluscs, a vertebrate jawbone and stone tools (see Chapter 6, Plates 1, 6 and 7). A small piece of charcoal (1.50 X 1.50 cm) was found *in situ* in the channel bank deposit.

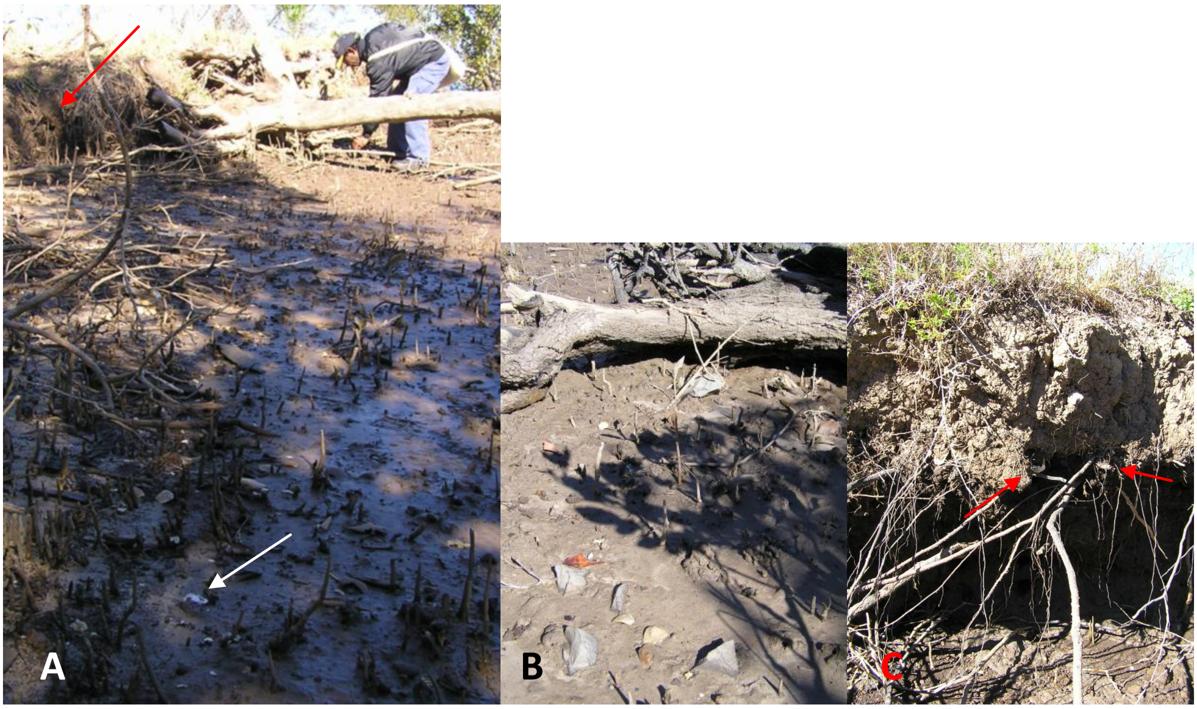


Figure 3.10: A: Site of the cultural deposit on Sleeper Island. Red arrow indicates *in situ* deposit and white arrow indicates lag deposit. **B:** Part of the lag deposit showing stone tools. **C:** Part of *in situ* deposit with arrows showing shell material.

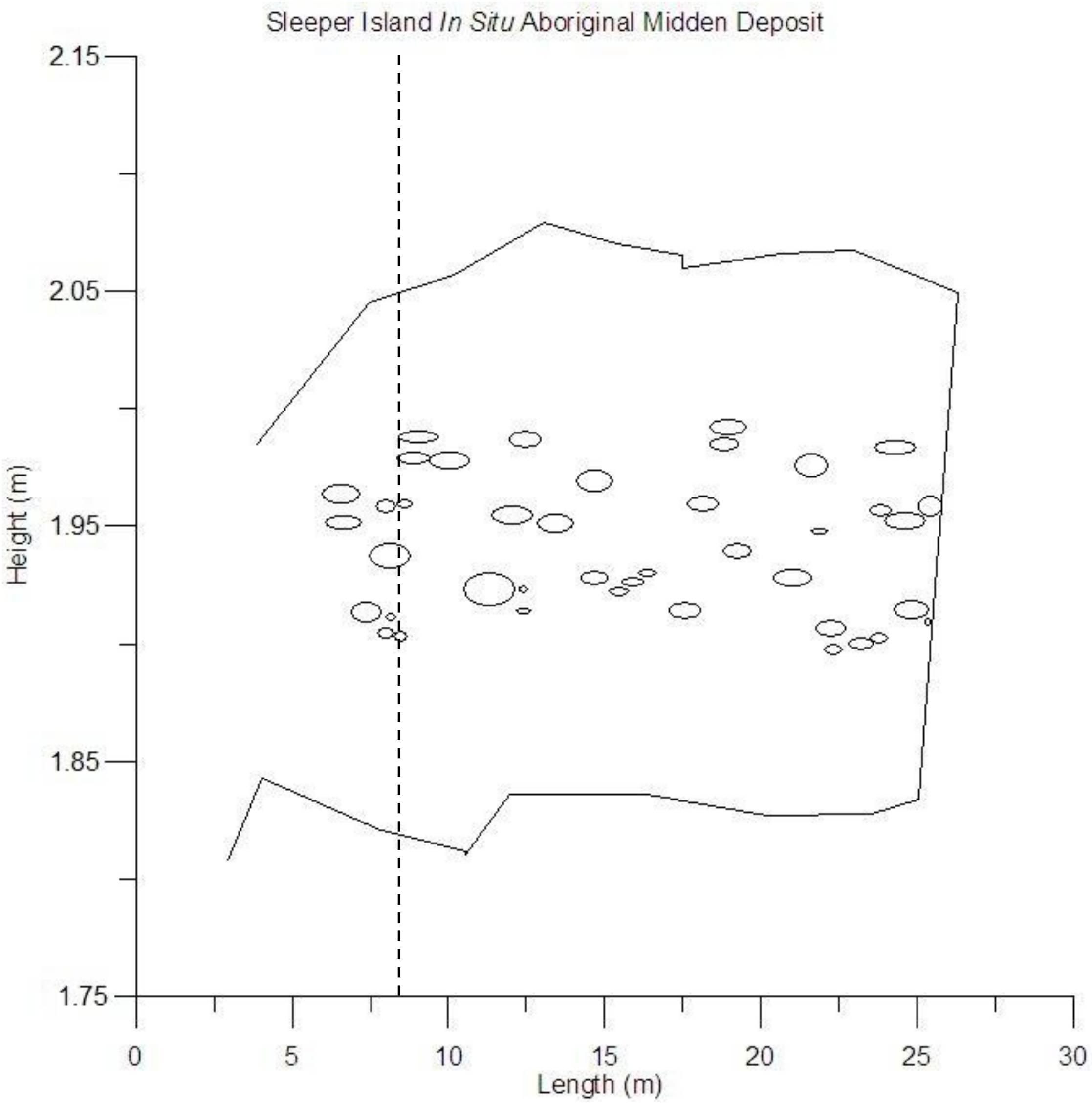


Figure 3.11: Sleeper Island *in situ* Aboriginal shell midden deposit. Dashed line shows the location of core 1S.

3.2 WOOMBAH

3.2.1 **Land Use and Geomorphology**

The Woombah midden complex is located at S 29°22.075', E 153°17.328' on the northern bank and floodplain of the Clarence River estuary's North Arm (Figures 3.12, 3.13, 3.14). It is referred to as a midden complex as there are many discrete Aboriginal shell middens in the area (Roger Mehr, DECCW, personal communication). This study focuses on two deposits – the first, referred to as Site A, is a riverbank *Crassostrea* deposit and the second, Site B, is a creek bank midden exposure (Figures 3.12, 3.15, 3.16, for full species composition details refer to Chapter 6, Biological and Taphonomic Analyses). In addition to these shell deposits there is a thin layer of fragmented shell covering parts of the area (see A_p layer, core diagrams W1a-W5b – Appendix 1). This shell material is clearly reworked.

Although the site B creek bank midden is identified with a sign put in place by the local Aboriginal community and Council, this is a fairly recent addition. The surrounding land is privately owned and has supported orchards and cattle in the past, however it currently does not support crops or livestock. The source of fragmented shell material in the A_p layer is clearly a result of the use of farming equipment. At the eastern end of the study area soil containing fragmented shell material from the A_p layer has been piled into mounds for use as bike jumps. As this shell material was most likely sourced from previously degraded material on the property it is unlikely this activity has caused disturbance to *in situ* cultural material.

The topography of the area is flat, as both deposits are situated on a floodplain. The floodplain at Woombah extends landwards (north) from the channel ~150 m before reaching a gently sloping levee. Directly north of this levee is a 50 m wide tract of trees and a road which runs parallel to the riverbank and levee. The tract of trees marks the northern limit of the study site. The riverbank marks the southern boundary of the study site, while the eastern limit of the site is a small creek running perpendicular to the main channel, and the creek bank site B marks the western boundary (Figures 3.17 & 3.18).

3.2.2 **Vegetation**

The majority of the floodplain within the study area is covered by domestic lawn. Tall, native grasses and reeds grow in the area immediately bordering the creek bank site B and the creek itself supports mangroves. Mangroves also line the riverbank and the creek at the eastern edge of the study area. The tract of trees marking the northern edge of the study site contains Eucalypts, ferns and Lantana.

3.2.3 **Cultural Material**

Both the site A and site B deposits contain only shell material (see Chapter 6 for species list, Plate 1). No artifacts were found at these sites, although other sites in the Woombah midden complex were found to contain artifacts (Mcbryde, 1982). The deposits occur at approximately the same depth. Site A is a riverbank deposit containing almost solely *Crassostrea* shells. It is located in the northern riverbank of the North Arm of the Clarence River approximately 20 m west of the eastern border of the study site. Shell material is eroding from the deposit and forming a lag at its base (Figure 3.15, 3.16). The exposed shell lens extends from 0.48 m to 0.67 m depth; its length is ~30 m.

Site B is a midden exposure present in both banks of the narrow (2.0 m wide) creek marking the western border of the study site. The southern end of the deposit lies 40 m north of the riverbank and the deposit extends north along the creek ~32 m. Coring on either side of the creek bank has shown the *in situ* deposit to extend 10-12 m east of the eastern creek bank and 3 m west of the western creek bank. Cultural material is found between 0.07 and 1.2 m depth in the exposed creek bank and between 0.00 and 0.24m at its eastern extent. At the western extent of the midden shell fragments are found at a depth of 0.00-0.35 m and whole shells from 0.35-0.65 m. It is possible the original deposit extended much further than this, and that the impact of farming machinery has disturbed large areas of it.

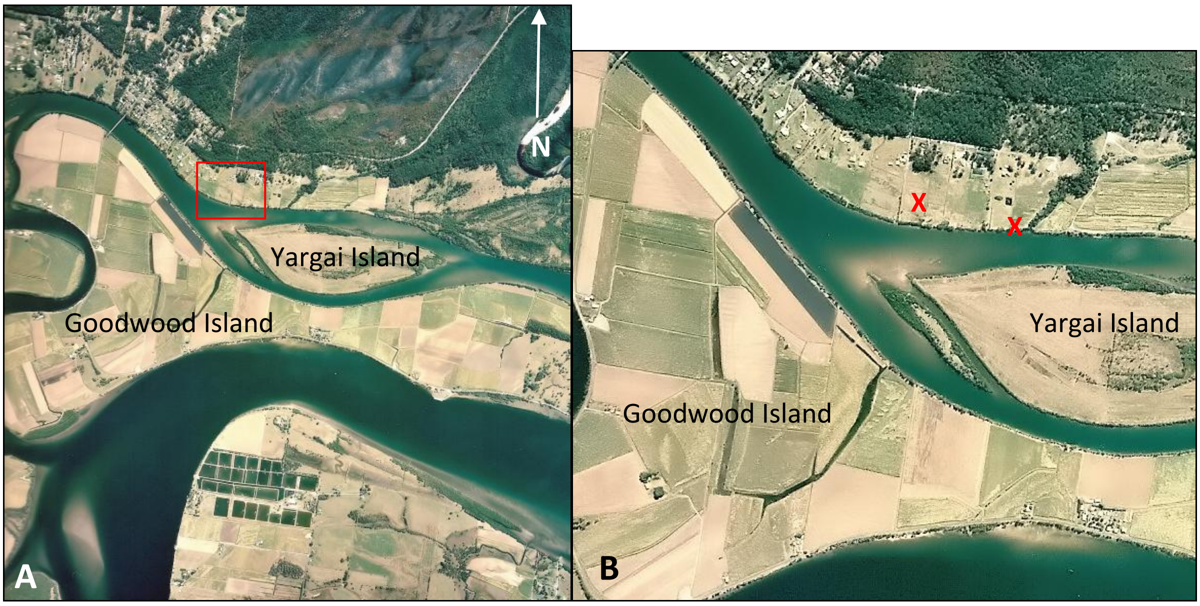


Figure 3.12: A: Aerial photograph of a section of the Clarence River estuary showing the Woombah study site (box). **B:** Close up of the Woombah study site showing locations of the Aboriginal shell middens (X).

Figure 3.13: Close up of red box in Figure 3.10A showing the location of core samples. Scale = 1:4,000

Figure 3.14: Topographic map of Woombah sites A (east) and B (west), showing the location of core samples.

Scale = 1:4,000

Figure 3.15: Section of Woombah Site A riverbank deposit. Scale= 0.50 m.

Figure 3.16: Shell material eroding from the Woombah Site A riverbank deposit.

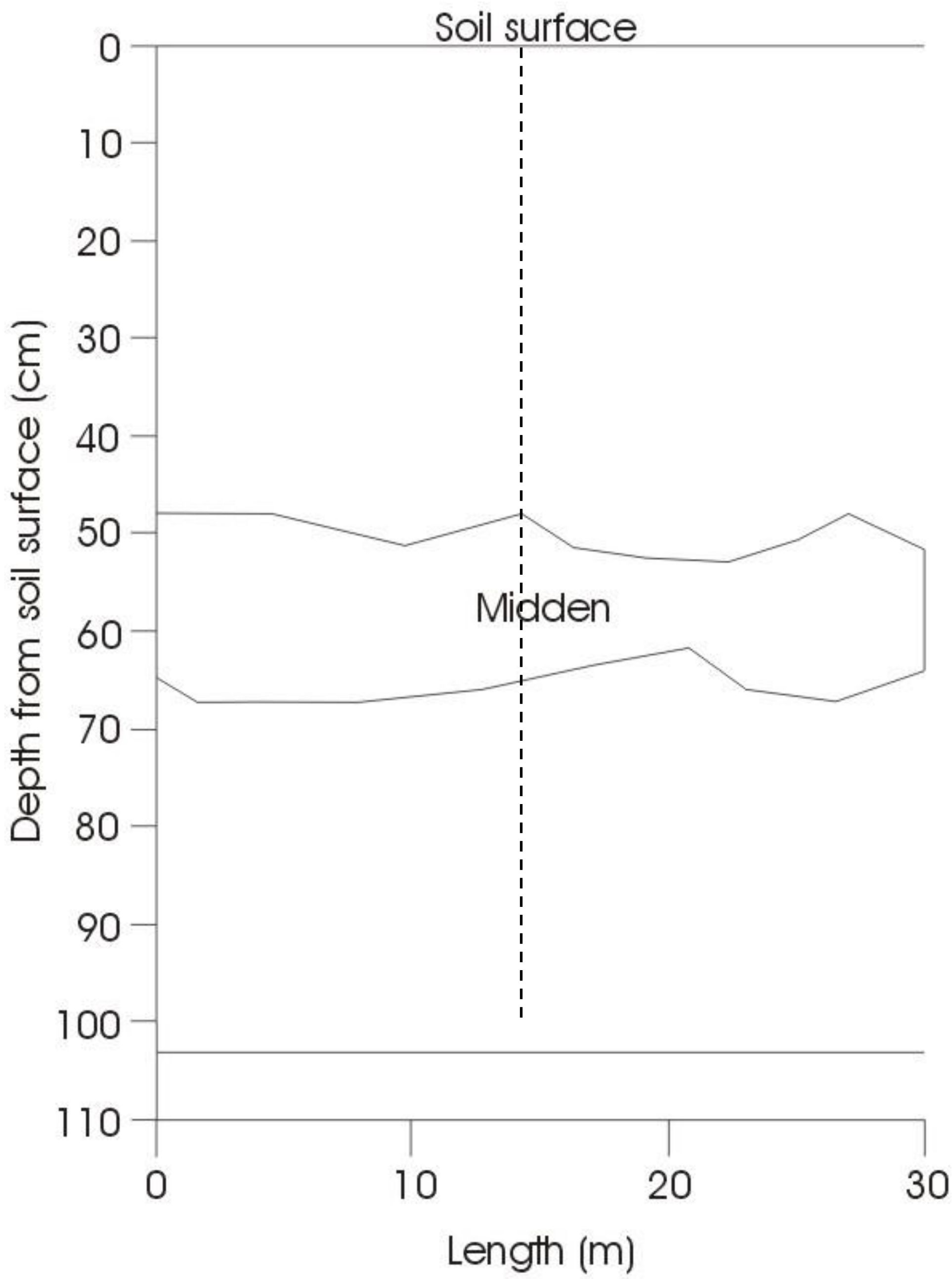


Figure 3.17: Woombah Site A Aboriginal midden deposit. Dashed line shows the location of core 5A.

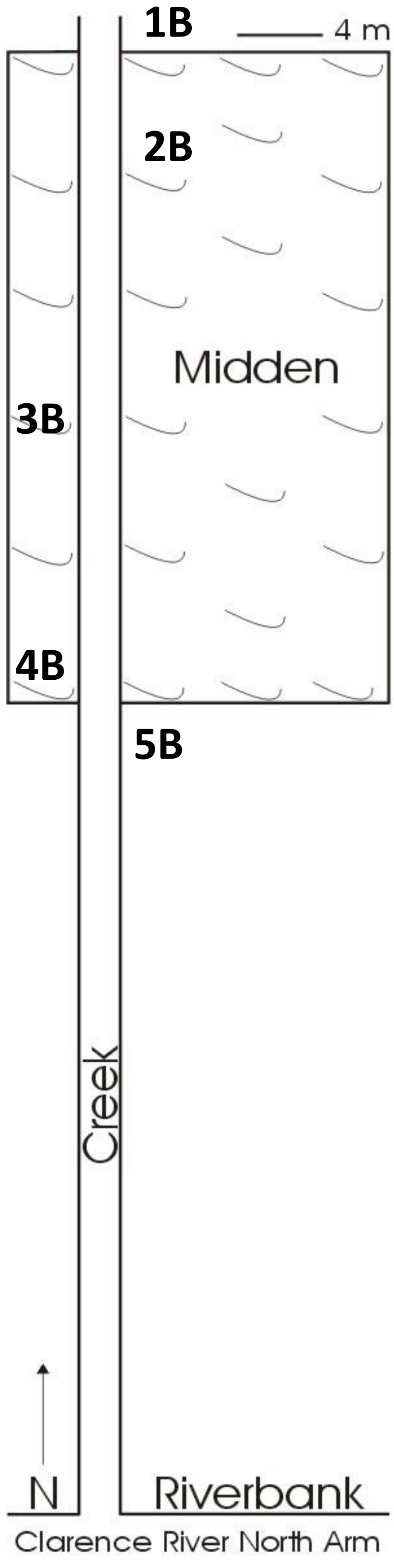


Figure 3.18: Woombah Site B Aboriginal midden deposit.

3.3 PLOVER ISLAND

3.3.1 **Land Use and Geomorphology**

Plover Island is a small (~8,324 m^2), rocky island located on the north side of the mouth of the Sandon River (S 29°40.335', E 153°19.811', Figures 3.19, 3.20, 3.21, 3.22, 3.27) and connected to the mainland by a tombolo. It has a maximum elevation of 7.1 m above present sea level and is exposed to winds around its entire circumference. The adjacent beach and camping ground are located south of Broom's Head, a small but popular surfing and holiday destination. Plover Island, the Sandon River camping area and surrounds are located within the Yuraygir National Park and access to the north side of the mouth of the Sandon River is via a 10 km unsealed road connected to Broom's Head road. Access to Sandon Village, which is located on the south side of the Sandon River, is restricted to a 12 km 4WD track which can be accessed from the Illaroo camping ground north of Minnie Water. Access to Plover Island from the south side of the Sandon River is by boat only. Recreational fishing off the rocks at the base of Plover Island is a popular local activity however this usually requires people to walk around the base of the island rather than over the top of it where the cultural deposits are located. Narrow walking tracks around the island indicate the island is also used for recreational walking and sightseeing (Figure 3.23).

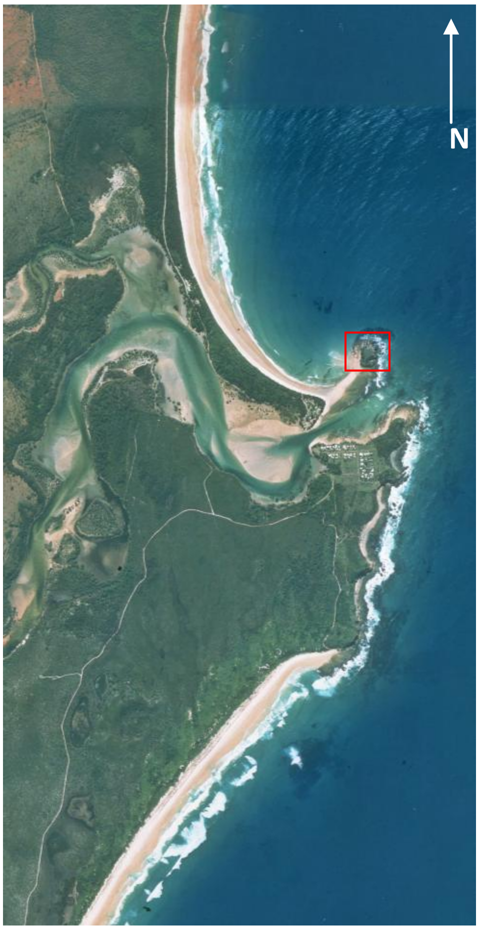


Figure 3.19: Aerial photograph of the mouth of the Sandon River showing Plover Island to the north (red box).

Figure 3.20: Close up of Plover Island showing the locations of the *in situ* stone artifacts (red cross), surface scatter (white cross) and managed Aboriginal shell midden deposit (black rectangle).

Figure 3.21: Plover Island showing the location of core 1P (red dot). Scale = 1:4,000

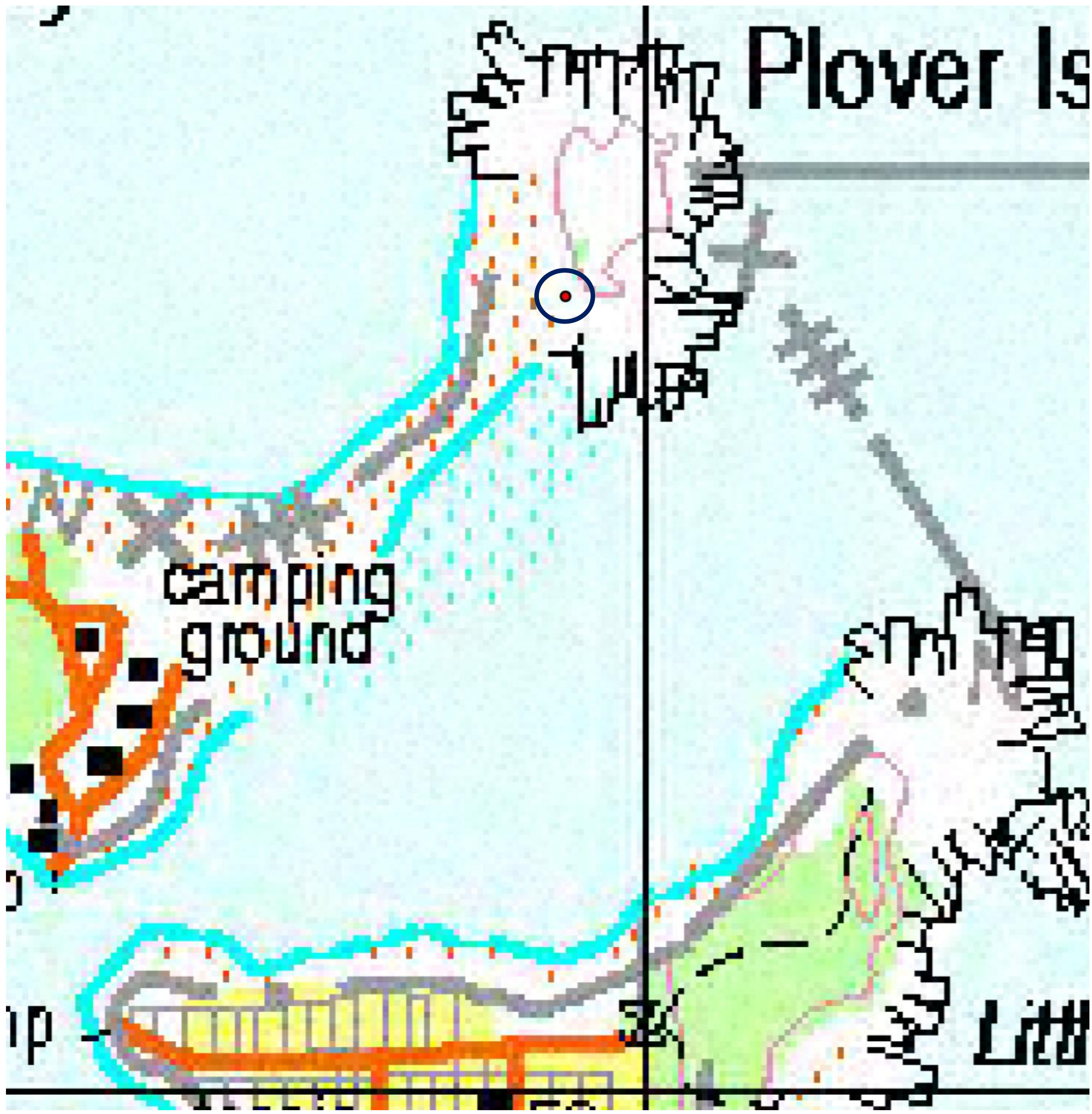


Figure 3.22: Topographic map of Plover Island showing the locaton of core 1P (circled red dot). Scale = 1:4,000

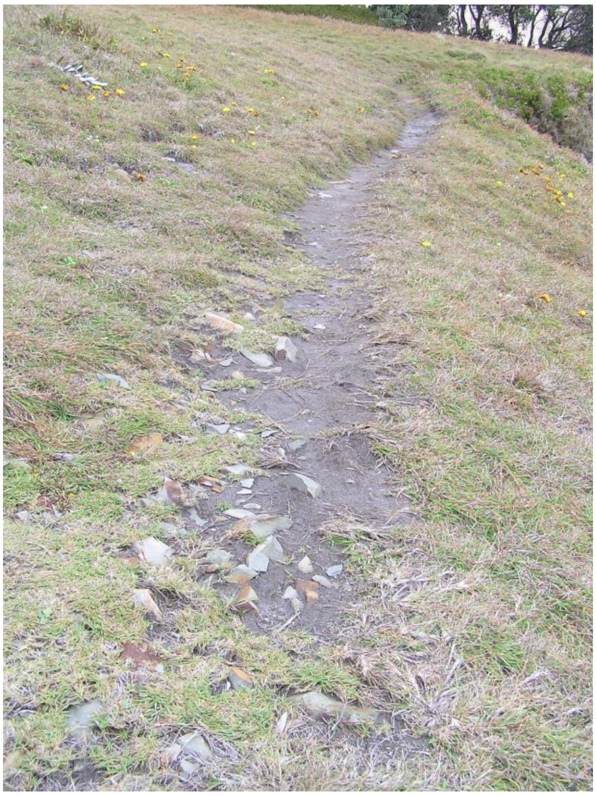


Figure 3.23: Walking track worn partially through the surface scatter of Aboriginal stone tool artifacts on Plover Island.

3.3.2 **Vegetation**

A thin layer of soil (Appendix 1 – core diagram PI) supports grasses, shrubs and small trees on Plover Island. Grasses (Poaceae) are shorter and thicker towards the seaward side of the island and shrubs are virtually absent here. This suggests the prevailing winds come from an easterly direction; their first point of contact with land is the seaward side of Plover Island. Shrubs and small trees are present around the north, west and south edges of the island and include *Acacia* sp., *Casuarina* sp., *Banksia integrifolia*, *Pandanus pedunculatus* and *Scaevola calendulacea*. A climber, *Stephania* sp., is also found with these shrubs and trees.

3.3.3 **Cultural Material**

Plover Island is the site of an Aboriginal stone quarry. Some stone artifacts are found in an *in situ* lens on the western side of the island (Figure 3.20, red cross; Figure 3.24, Plate 5) but most cultural material, including stone cores and flakes, is found in a surface scatter on the opposite side of the island (Figure 3.20, white cross; Figure 3.25). The *in situ* stone artifact exposure is 7.70 m long and sits at a depth of 0.35-0.43 m. The surface scatter is present as an arc following the shape of the eastern side of the Plover Island and is ~20.00 m long and 1.50 m wide (Figure 3.21). The surface scatter is partially covered with thick grass and partially exposed where a walking track has been worn around the perimeter of the island. Plover Island constitutes part of the Coramba Beds (Troedson and Hashimoto, 2008; Figure 2.1), predominantly comprising lithofelspathic wacke (Geoscience Australia, 2008). Stone artifacts from the Aboriginal quarry on the island share this lithology.

A lag deposit containing very well-rounded shells and cobbles is present at the base of the island on its north side (Plate 5). The origin of this deposit is uncertain as no *in situ* material has been found on the island above this deposit (see Chapter 6 for further discussion). The soil is clearly exposed around the circumference of Plover Island and is devoid of shell material.

An Aboriginal shell midden is present in the dunes adjacent to Plover Island in very close proximity to the Sandon River camping area (Figure 3.20, black box). Members of the local Yaegl Aboriginal community have been involved in the protection and preservation of this site by constructing retaining walls, revegetating dunes and advising new locations for campsites (Figure 3.26). A sign has also been erected informing campers and other tourists of the significance of the area to Yaegl people. The work done on this midden is a prime example of the effectiveness of a grass roots approach including community consultation and involvement. While the midden at Sandon is considered stable with a very low susceptibility to destruction, the quarry on Plover Island is in need of further management and thus comprises one of the study sites of this project. Even though it is not strictly a shell midden site the presence of a midden site in close proximity to the Aboriginal stone quarry on Plover Island ensures the area retains its significance as an important Aboriginal cultural site of multiple resource use.

Figure 3.24: *In situ* stone artifact lens, Plover Island. Dotted line indicates position of core 1P.

Figure 3.25: Portion of the stone artifact scatter on Plover Island.

Figure 3.26: Retaining wall at the Aboriginal shell midden site, Sandon River camping ground.

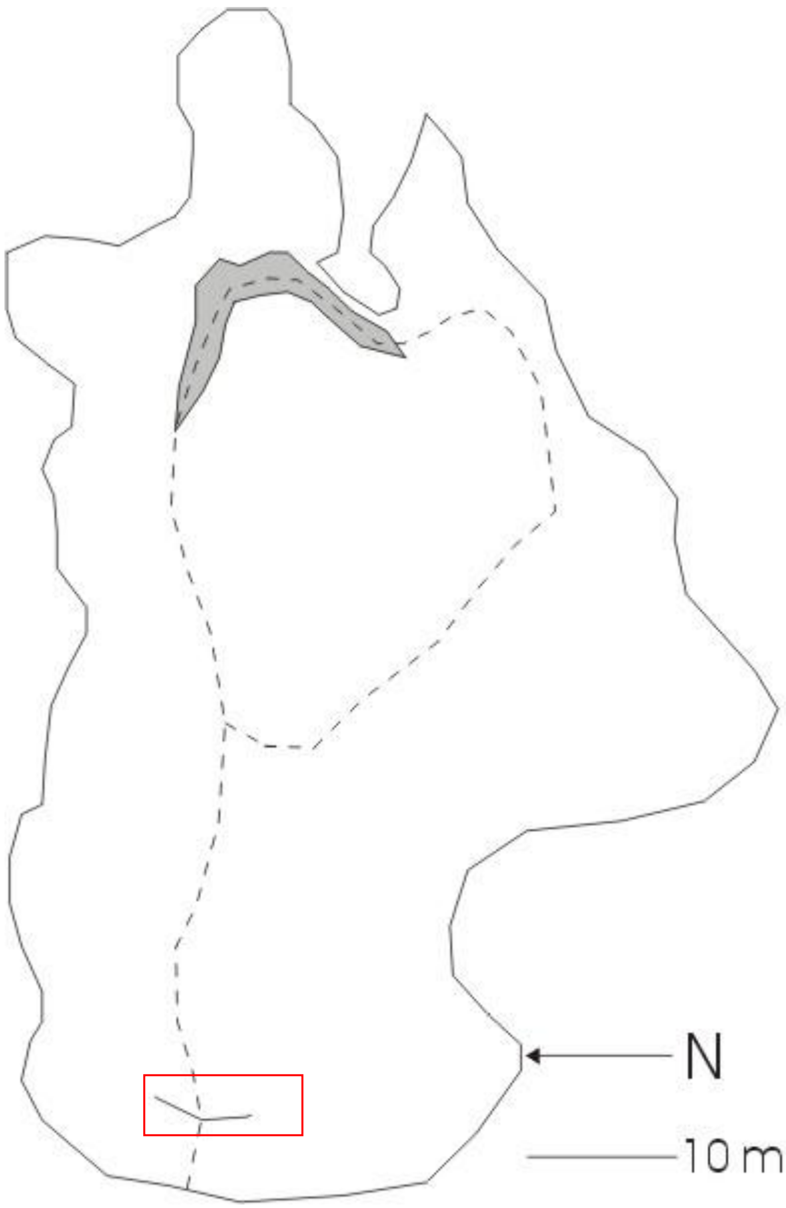


Figure 3.27: Plover Island, showing the location of the *in situ* artifact deposit (red box) and the surface artifact scatter (grey shaded area). The dotted lines show the walking track around the island.

3.4 MINNIE WATER

3.4.1 **Land Use and Geomorphology**

Rocky Point is a small rocky outcrop located at the northern end of the beach at Minnie Water (S 29°45.882', E 153°17.847', Figure 3.28A). The outcrop lies adjacent to beach foredunes forming an arc with a south to east orientation (Figures 3.28B, 3.29, 3.30). These dunes reach a maximum elevation of ~20 m above present sea level and extend ~1.6 km south along the length of the beach. The study site is located 1 km north of the town of Minnie Water and 500 m and 1.3 km from the main beach access points. Rocky Point is located within Yuraygir National Park; the Ilaroo camping ground, also located within Yuraygir National Park, lies 1 km north of the study site. Minnie Water can be accessed via the 15 km sealed Minnie Water Road or the 25 km unsealed 4WD track from Sandon. Access to the beach on the north side of Rocky Point is confined to a narrow walking track through the foredunes 10 m west of the rocky outcrop. Although access to Minnie Water is better facilitated than Sandon and Plover Island, both the Ilaroo camping area and the village of Minnie Water are small and this limits access to the area. Day trips from surrounding areas are possible however these areas are also considered holiday destinations and many of them are relatively small as well. Many of the houses at Minnie Water are holiday rental properties and so an increase in patronage is seen during peak periods such as school holidays.

Figure 3.28: A: Aerial photograph of Minnie Water showing the study site (X), town (T), Ilaroo camp ground (C) and beach access points (arrows). **B:** Close up of Rocky Point. Box indicates the location of the midden deposit.

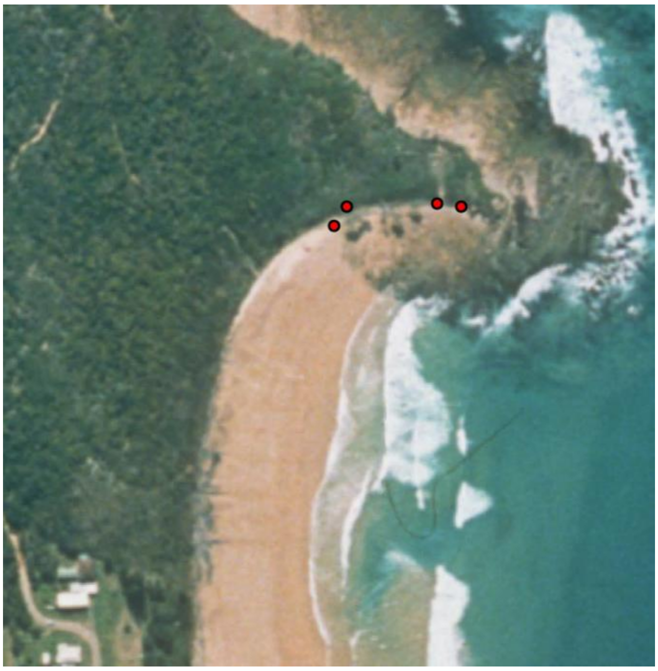


Figure 3.29: Rocky Point Headland (Minnie Water) showing the locaton of core samples. Cores 1MW to 4MW run west to east. Scale = 1:4,000

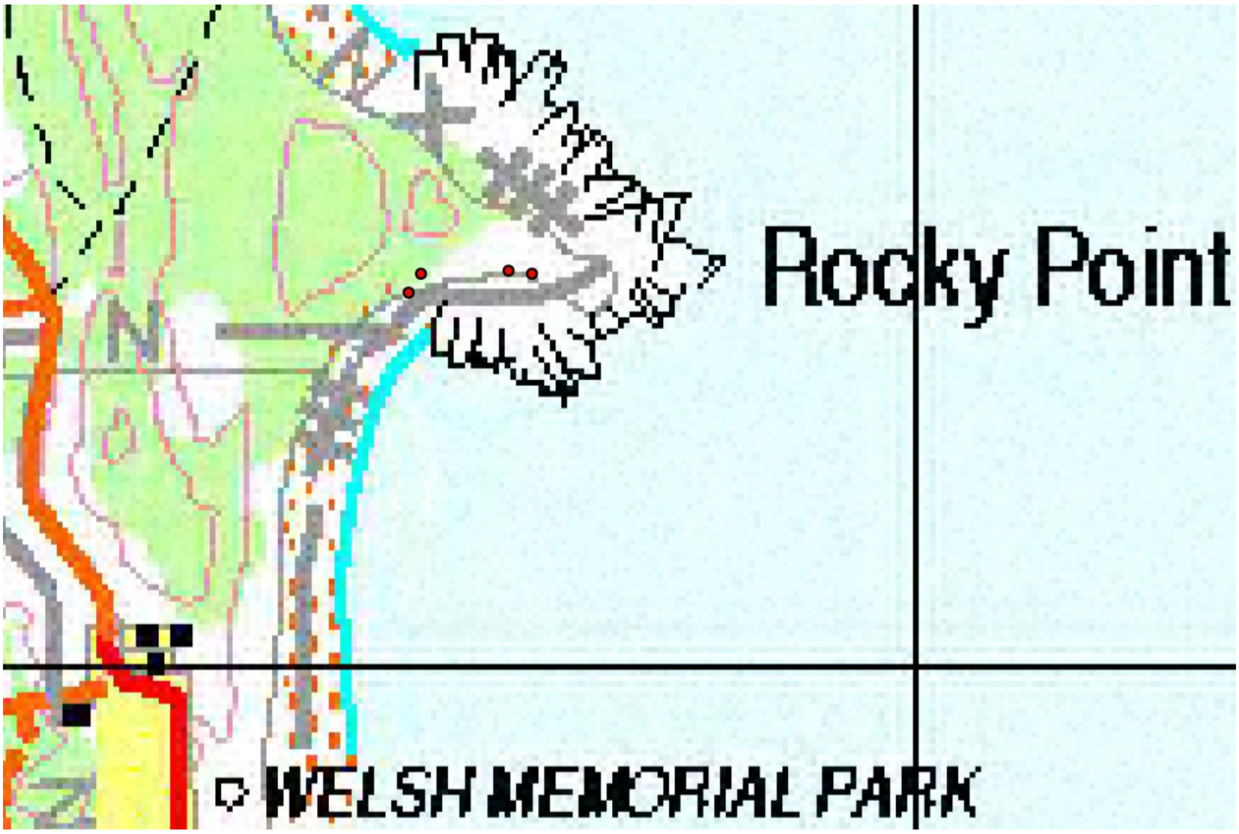


Figure 3.30: Topographic map of Rocky Point (Minnie Water) showing the location of core samples.

Cores 1MW to 4MW run west to east. Scale = 1:4,000

3.4.2 **Vegetation**

Vegetation is present on the Minnie Water foredunes, although the density of coverage is variable. Vegetation present at the Aboriginal shell midden site is similar to that seen at Sandon and Plover Island and likely reflects the similar environmental conditions in the two areas. Vegetation includes grasses (Poaceae), *Casuarina* sp. and *Banksia integrifolia*. The density of trees and shrubs increases from the base to the top of the foredunes. The patchy distribution of trees and shrubs in the dunes closest to the rocky outcrop becomes more uniform with an increased density further away from Rocky Point. Grass coverage is also variable and decreases towards the base of the dunes.

3.4.3 **Cultural Material**

An Aboriginal shell midden deposit (Figures 3.31, 3.32, 3.33, 3.35 & 3.36) containing a variety of gastropod shells is found at the base of the foredunes adjacent to the rocky outcrop at Rocky Point, Minnie Water (see Chapter 6 for species list, Plates 2 and 3). Shell material is eroding out of the exposed face of the deposit and forms a lag deposit at the base of the dunes. The 85.3 m long X 0.09-0.92 m thick X 0.35 m deep *in situ* deposit also contains gravel and pebbles, and shell material appears well-worn, suggesting the deposit may have been reworked by storm waves (see Chapter 6 for further discussion). A stone core was found in the exposed face of the *in situ* deposit (Figure 3.34).

Figure 3.31: A: A section of the exposed face of the midden deposit at Rocky Point, Minnie Water. **B:** The eroding face of the midden deposit showing the lag deposit at its base.

Figure 3.32: Location of the midden deposit at Rocky Point, Minnie Water.

Figure 3.33: Well worn *in situ* shell material at the Rocky Point midden. Scale: 1.5 cm = 1 cm.

Figure 3.34: *In situ* stone core showing points of percussion (red circle). Scale bar = 2 cm.

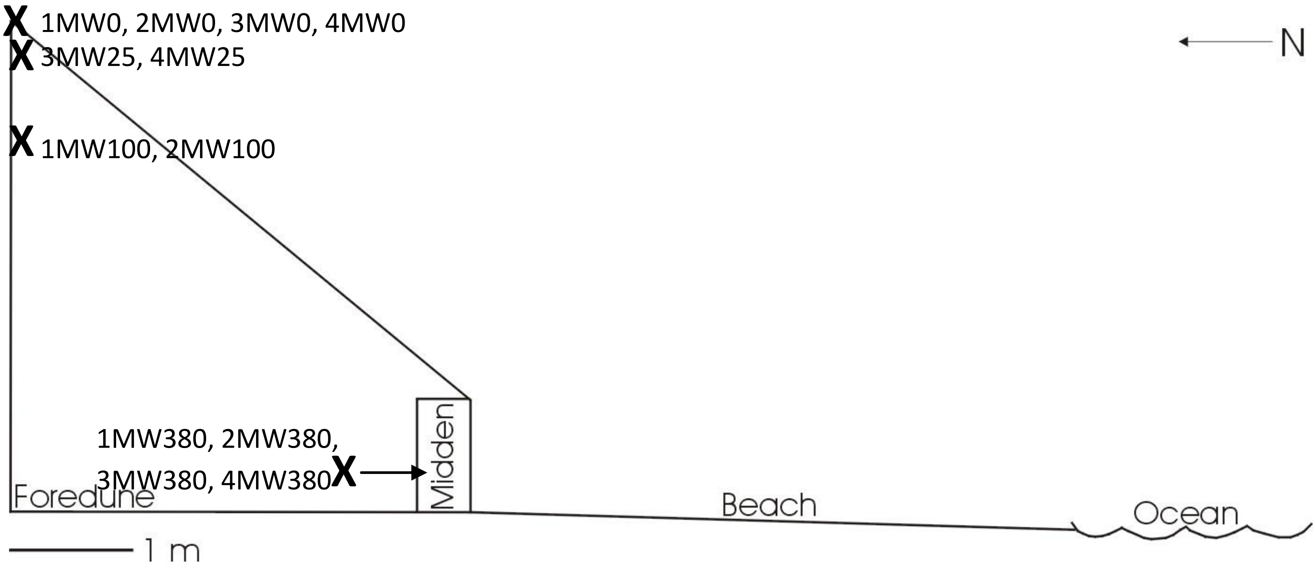


Figure 3.35: Cross section of the location of the Minnie Water Aboriginal midden. Sediment samples were taken at depths of 0 cm, 100 cm and 380 cm for cores 1MW and 2MW and 0 cm, 25 cm and 380 cm for cores 3MW and 4MW.

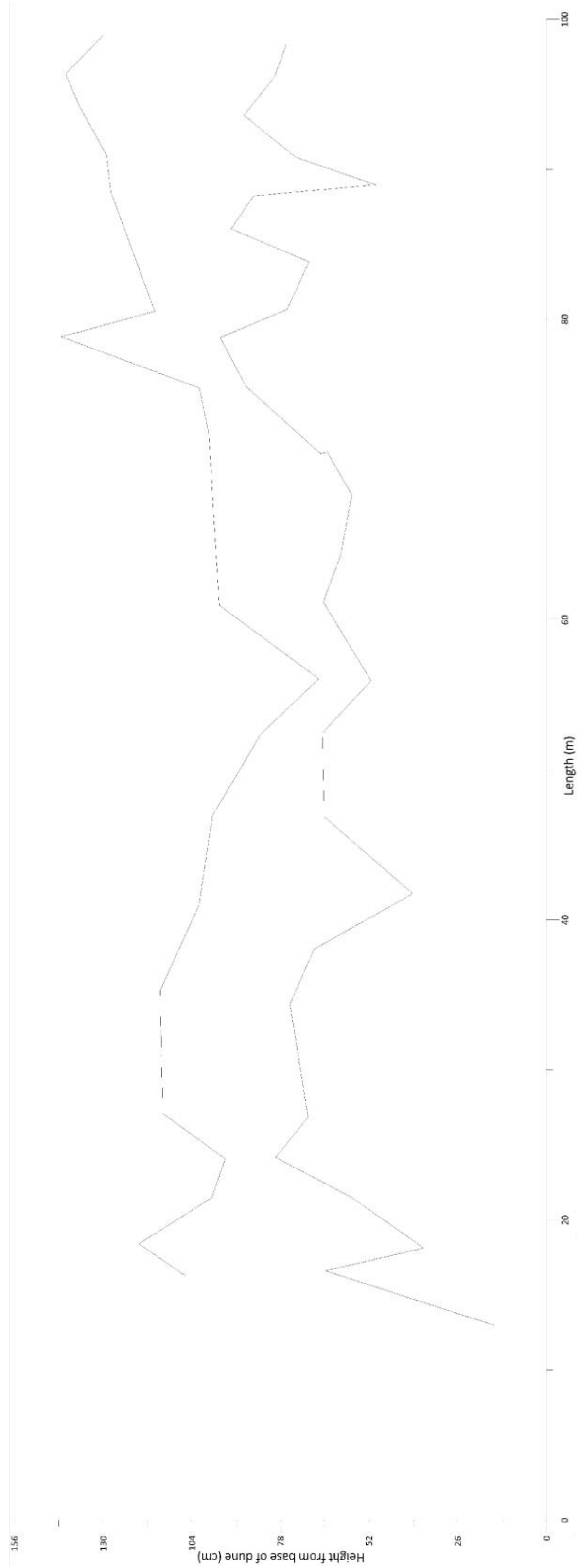


Figure 3.36: Minnie Water Aboriginal midden deposit.

3.5 WOOLI

3.5.1 **Land Use and Geomorphology**

The Aboriginal shell midden deposit at Wooli is located along a section of the western edge of Harold Lloyd Park, Wooli (S 29°52.475', E 153°15.885', Figures 3.37, 3.38). It is orientated north-south and is buried under well-vegetated, gently sloping land which runs parallel to the riverbank of the Wooli River. The width of the river is 100 m at this point and an entrance for small watercraft and people wishing to fish and swim is present over the northern edge of the deposit. This is currently not causing any disturbance to the midden, although continual use will likely erode the surface, potentially exposing the midden deposit underneath. Land use in the vicinity of the midden is recreational however a large portion of the deposit is buried under soil and a thick layer of vegetation on the fringes of the public park so it is unlikely to be continually walked over. Twenty two centimeter deep burrows (Figure 3.39) ranging from 0.05-0.15 m in diameter are scattered along the western side of the midden, although the amount of shell material that has been disturbed is very minimal (see Erosion discussion, Chapter 7). The burrowing agent/s is/are unknown but magpies and bandicoots have been suggested (Clarence Valley Council, personal communication). Wooli can be accessed via sealed Wooli Road from the Pacific Highway north of Coffs Harbour, Grafton or Maclean. As is the case at Minnie Water, many of the houses are holiday rental properties and so an increase in patronage is seen during peak periods such as school holidays, although Wooli has a larger permanent population than Minnie Water.

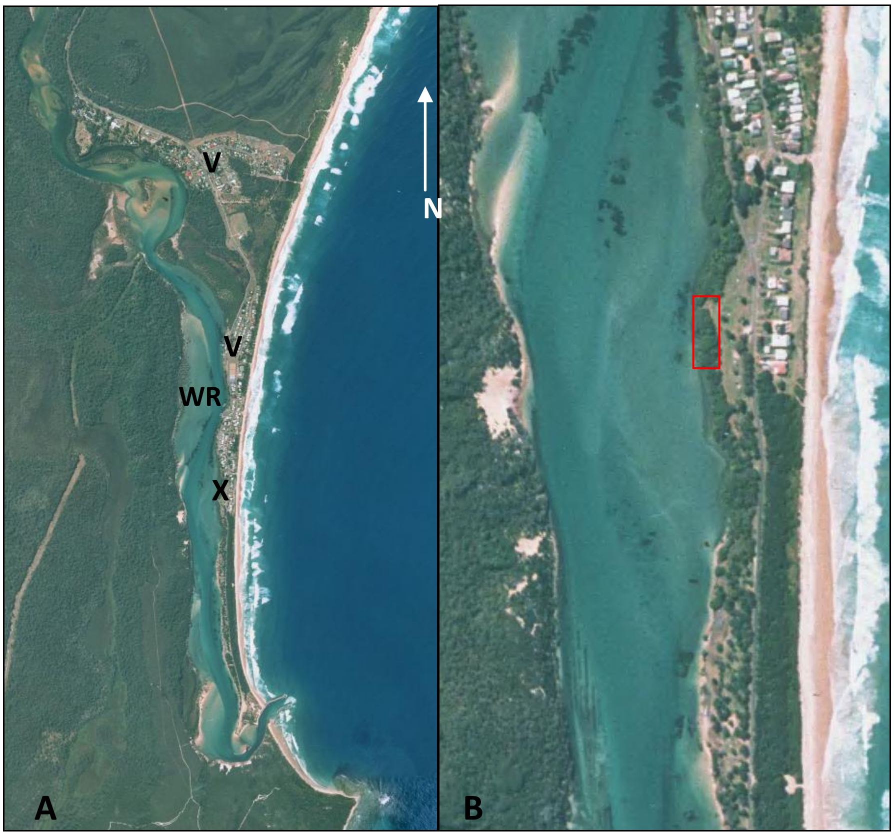


Figure 3.37: A: Aerial photograph of Wooli showing the study site (X), the village of Wooli (V) and the Wooli River (WR). **B:** Close up of Harold Lloyd Park. Box indicates the location of the midden deposit.

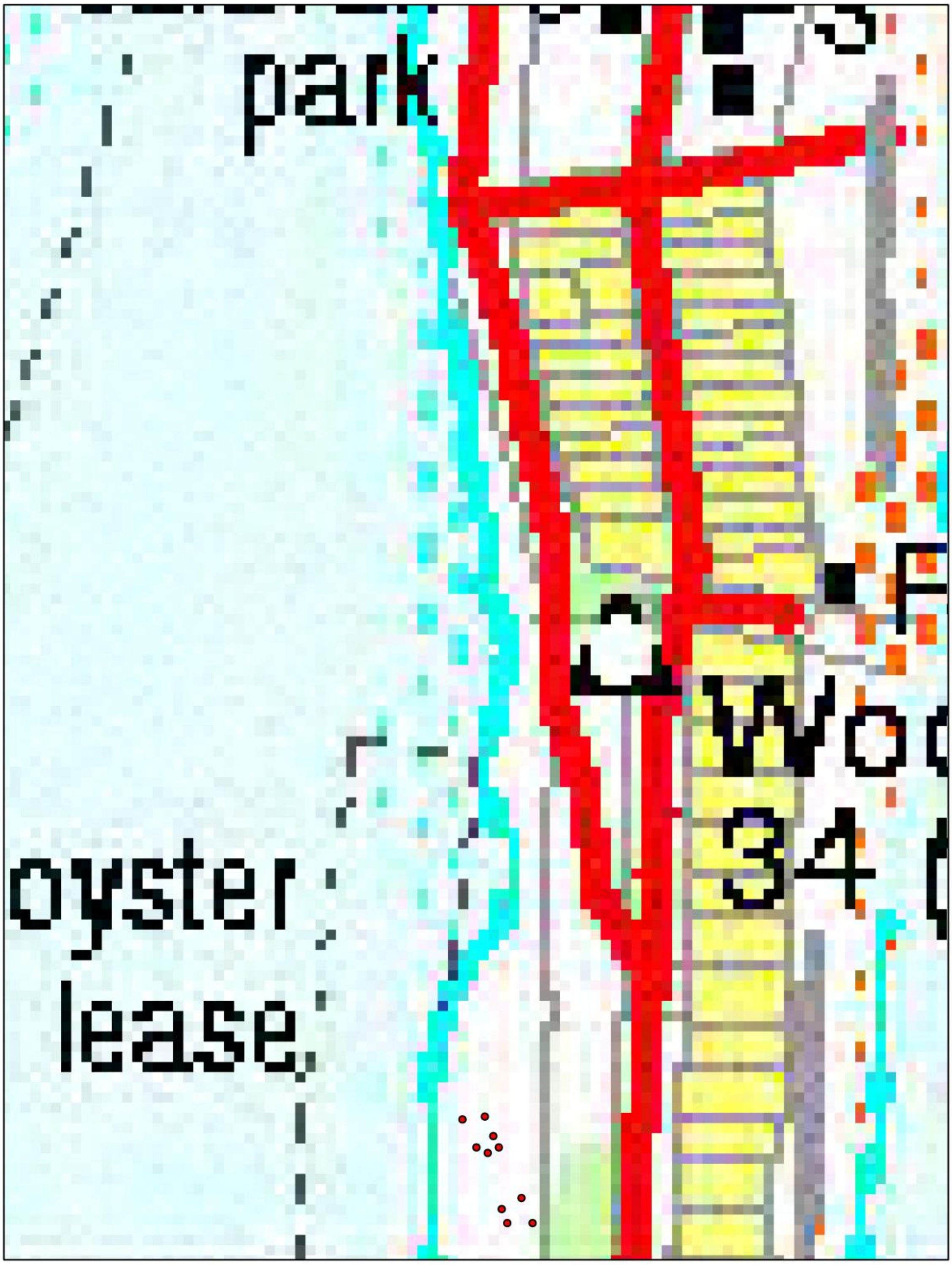


Figure 3.38: Topographic map of the Wooli study site showing the locaton of core samples. See Figure 3.42 for core labels. Scale = 1:1,600

3.5.2 **Vegetation**

The vegetation present on top of the midden deposit comprises exotic species, the most prevalent being Lantana and Buffalo grass. The adjacent, gently sloping riverbank supports dense mangrove growth. The soil lying above the midden deposit is well protected against erosion by thick vegetation coverage, thus protecting the underlying deposit. If the removal of the exotic vegetation is undertaken steps must be taken to ensure rapid re-planting of suitable species in order to preserve the soil which is protecting the midden.

3.5.3 **Cultural Material**

The Aboriginal shell midden at Harold Lloyd Park (Figures 3.40, 3.41 & 3.42) is present at a depth of 0.25 m and reaches a depth of 0.41 m at its thickest point. The deposit extends over an area of ~157 m^2. The major shellfish species present are *Anadara trapezia*, *Pyrazus ebeninus* and *Saccostrea glomerata* (see Chapter 6 for a complete species list, Plate 4). No artifacts were found in the material sampled from the 10 trenches which were dug through the midden for collection of sediment and cultural material. The next chapter outlines the methodology used in this research project. It includes field and laboratory techniques and formulation of the erosion hazard assessment methods.

Figure 3.39: A burrow through the Wooli Aboriginal shell midden showing cultural material which has been brought to the surface as a result of the burrowing process.

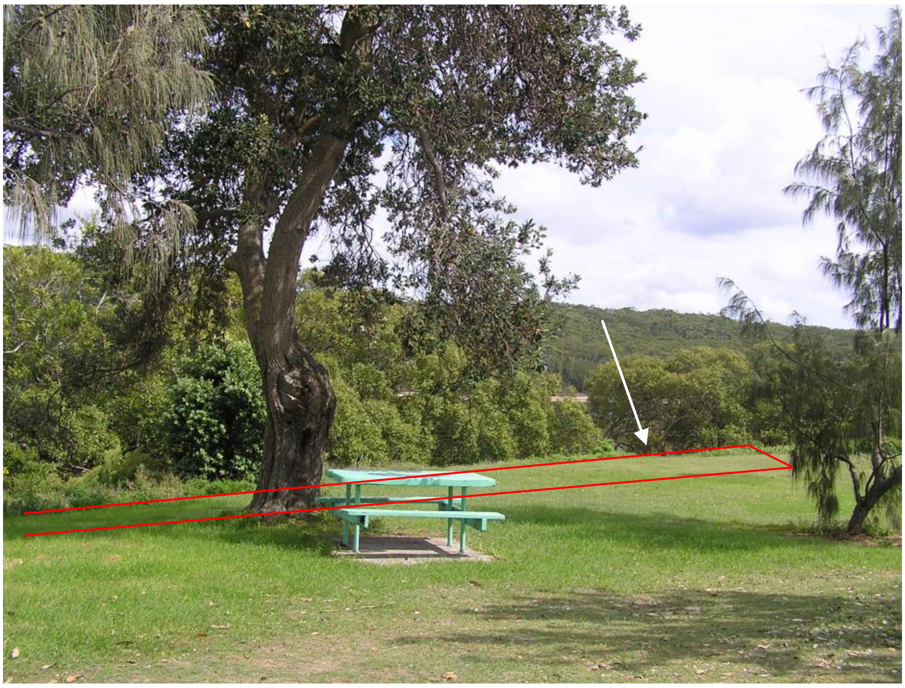


Figure 3.40: Photograph of the northern end of Harold Lloyd Park, Wooli. The arrow points to the boat access area discussed above. The approximate position of the northern section of the midden deposit is shown in red. The Wooli River is situated behind the mangroves.

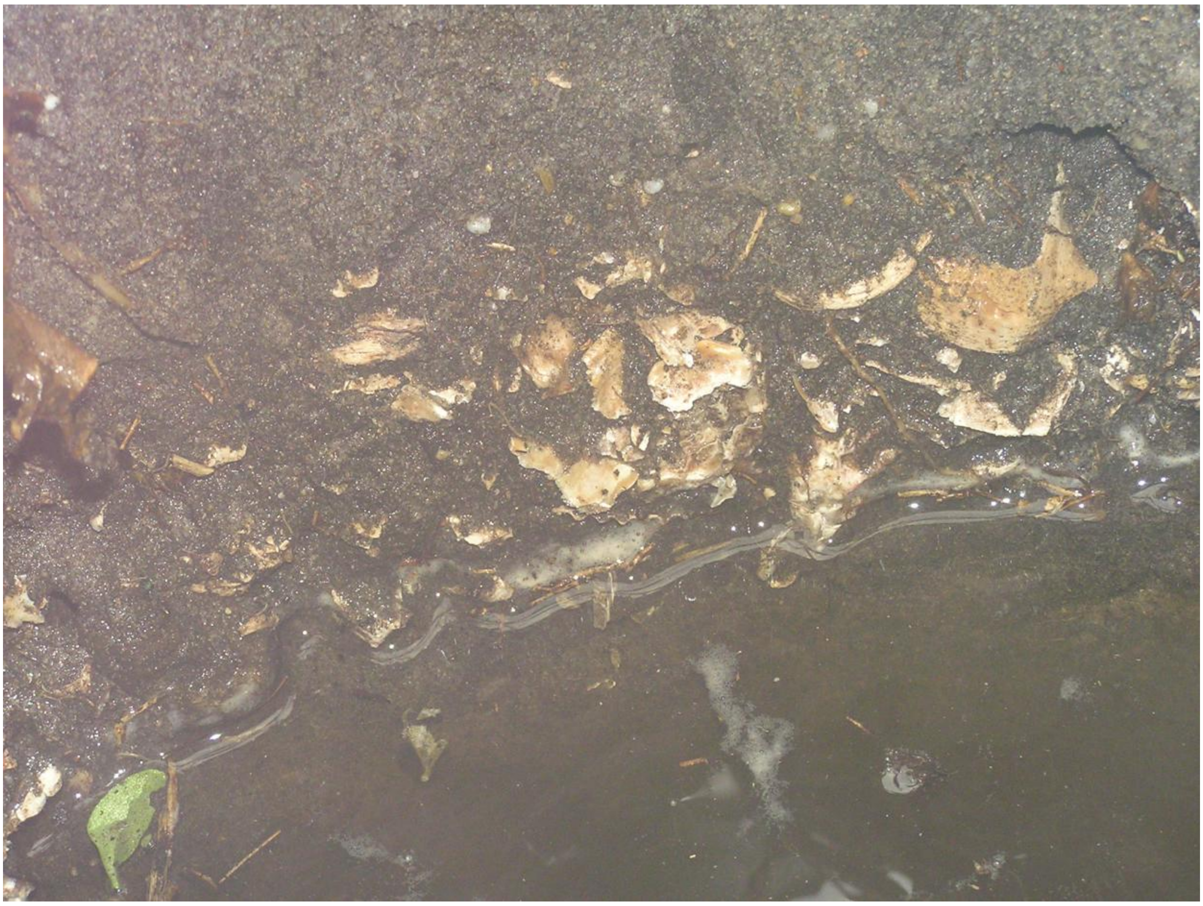


Figure 3.41: Photograph of a section of one of the trenches dug for sample collection at Harold Lloyd Park. Note the high watertable due to the recent floods (mid-2009). Scale: 1 cm = 2 cm.

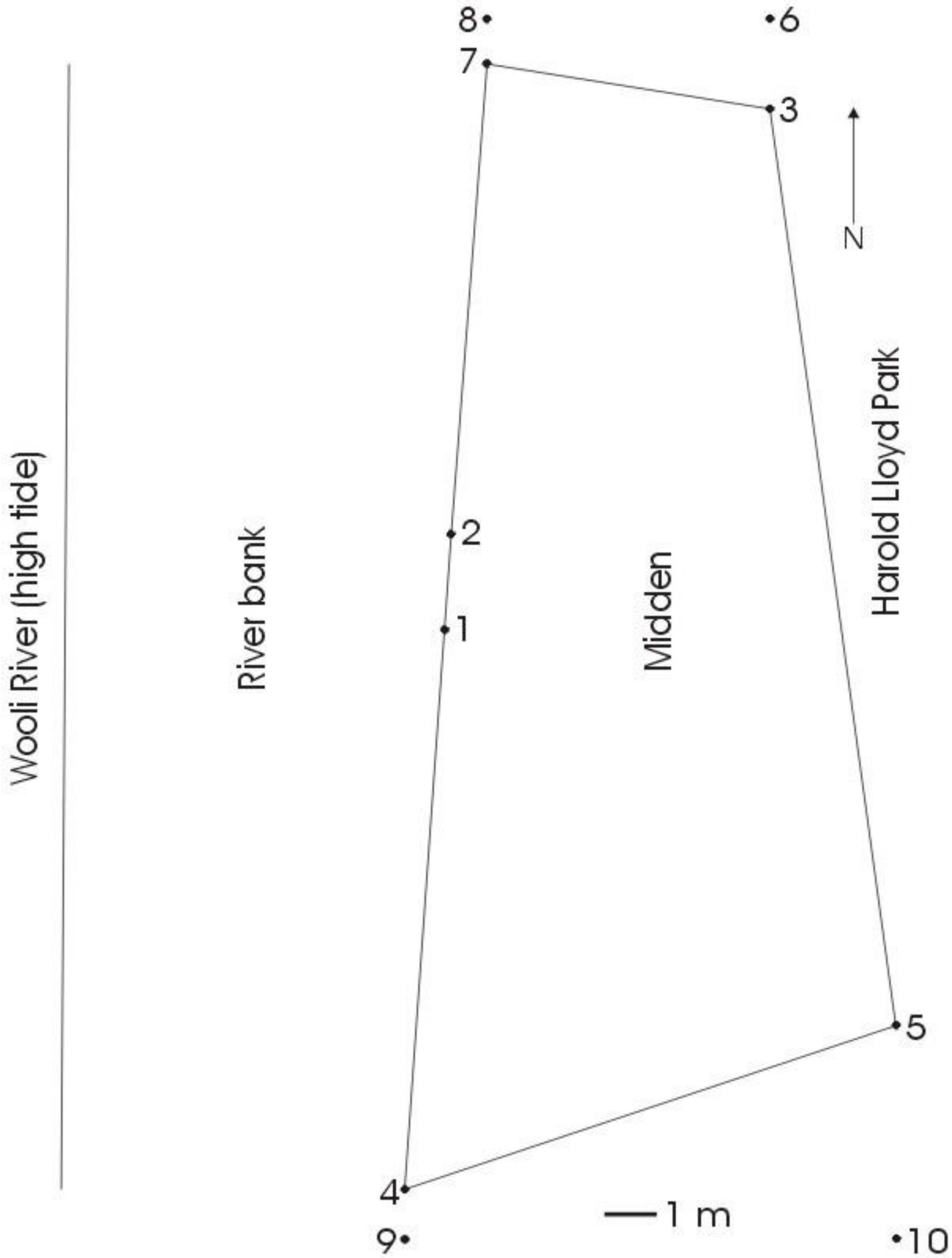


Figure 3.42: Plan view diagram of the Wooli Aboriginal midden deposit showing the locaton of core samples.

1=1WL, 2=2WL, 3=3WL, 4=4WL, 5=5WL, 6=6WL, 7=7WL, 8=8WL, 9=9WL, 10=10WL.