CHAPTER 2: GENERAL GEOLOGY OF THE COAST

2.1 INTRODUCTION

The coastline of the study area is approximately 300km in length, stretching from Gingin in the North, to Cape Leeuwin in the south (Figure 2.1). Beaches generally face northwest or southwest and are dominated by a series of exposed limestone cliffs and headlands, rock platforms, extensive dune systems and sandy beaches.

The coastline within the study area is composed of two main geological units (i) the Tamala Limestone; and, (ii) the Safety Bay sand. Both of these formations belong to the early Pleistocene to Holocene Kwinana Group (Playford *et al.*, 1976). They have been mapped at a scale of 1:50,000 by the Geological Survey of Western Australia (GSWA) in their Urban Geology Series and more recently in their Environmental Geology Series (Gozzard, 1989).

2.2 GEOLOGY

2.2.1 Tamala Limestone

The Tamala Limestone (LS1 on the Environmental Geology sheets) consists of coarse to medium-grained calcarenite, composed mainly of foraminifera and mollusc fragments, with some detrital quartz sand (Playford *et al.*, 1976). This limestone (otherwise known as the Tamala Eolianite) was formed from the cementation of the Spearwood Dune System by calcium carbonate (Playford *et al.*, 1976).

The Spearwood Dune System is a late Pleistocene formation (120ka) that comprises a series of coast-paralleling limestone ridges that were originally deposited as a transgressive sheet of coastal sand dunes (Gozzard and Smurthwaite, 1988). As sea levels fell, the shoreline retreated to the west. Shore parallel lines of dunes marks the successive position of the coast during this period. From 120 ka – 6.5 ka, the sea level was lower than the present day and a series of coast-paralleling islands and submerged reefs mark this lower sea level (Playford *et al.*, 1976).

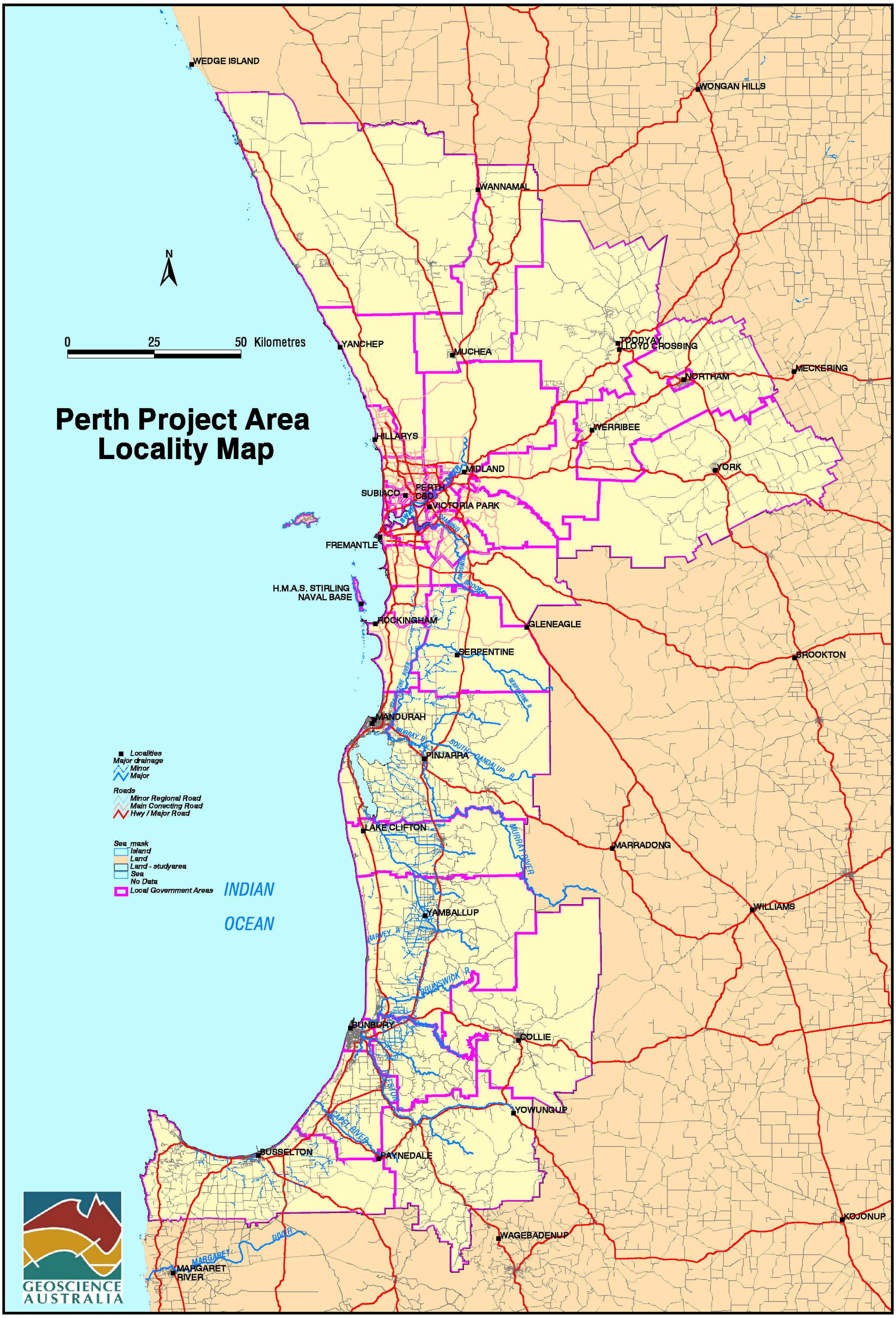

Figure 2.1: Location of the Perth study area is highlighted in yellow.

Paleosol (or fossi soil) layers, calcrete duricrust layers and calcified root structures are common features within the limestone. All three features are interlayered with the limestone and were developed during periods of sub aerial exposure.

Paleosol layers are light to dark brown in colour and can be up to 2 m thick, representing a hiatus in dune formation. They are unstratified, fine-grained calcareous soils that contain land snail shells and fossil cocoons of Weevils (Gordon, 1997). These periods of soil development allowed plants and trees to establish themselves within the dunes. The longer the hiatus in dune formation, the more extensive the vegetation.

Calcrete duricrust formation is a common feature of carbonate weathering and also forms during a hiatus in the dune building process. The duricrust forms when calcium carbonate from shells, is leached from the underlying layers of limestone and redeposited at the surface. The surface deposition of calcium carbonate forms a hard indurated caprock above the fossil soil layer, leaving the underlying limestone weak and friable. This calcium carbonate depleted layer weathers rapidly under the indurated caprock leaving hard calcrete casts and moulds of fossil roots as prominent features. This is known as the Zone of Roots (Gordon, 1999) and can be seen in extensive outcrops along the coastal fringe (Figure 2.2).

Figure 2.2 Hard calcrete casts and moulds of fossil roots can be seen in this outcrop of Tamala Limestone at site 6 (see Appendix A).

2.2.2 Safety Bay Sand

The Safety Bay Sand overlies the Tamala limestone and is Holocene (< 10 ka) in age. It occurs along the length of the study area and includes all of the modern dunes along the coastline. The beach ridge plain around the Rockingham area, as well as sand still being deposited are also a part of this unit.

The Safety Bay sand has an average calcium carbonate content of over 50% and is made up of shell fragments (mainly foraminifera and molluscs) with variable amounts of quartz and minor feldspar. This poorly to moderately consolidated sand can be weakly cemented below the dune surfaces, marking the first stage in conversion to eolianite (Playford *et al*. 1976).

The Environmental Geology map series produced by the GSWA has subdivided the Safety Bay sand into many different units based on their physical and mechanical characteristics. Only three of these subdivisions however occur along the coastline of the study area. These units are referred to as S1, S2 and S13 on the Environmental Geology maps and can be described as below:

S1 is most commonly found forming flat to gently sloping sandy beaches along the coast (Figure 2.3). The sand is calcareous fine to medium-grained, sub-rounded quartz and shell debris of eolian origin. This unit is not vegetated and has an elevation ranging from 0 – 25 m ASL (above sea level).

S2 also consists of fine to medium-grained, sub-rounded quartz and calcareous shell debris of eolian origin. This unit however, is most commonly found forming large undulating dunes with moderate to steep slopes ranging from ~10^{o} to >20^{o} (Figure 2.3) These vegetated dunes have an average elevation between 20 – 60 m but can reach heights of 140 m along the Naturalise coast.

S13 is predominantly found on beach ridge plains forming low (< 10m) undulating dunes. The unit consists of well sorted, medium-grained calcareous sand with rounded quartz and shell debris of eolian origin. The sands are variably thick and overlie limestone at relatively shallow depth.

Figure 2.3 Profile of Mindarie Beach in the City of Wanneroo. This beach is a typical example of the relationship between S1 and S2 Safety Bay Sands. S2 forms large dunes backing the gently sloping S1 beach.

2.3 COASTAL STABILITY

2.3.1 Introduction

The world's coastlines are dynamic systems in a constant state of flux. Through the process of erosion, transportation and deposition, the shape of the coastline changes, often slowly but sometimes very rapidly. The interaction between rock, water, wind and vegetation is responsible for the dramatic landforms we see along the coast today. Unfortunately however, these dynamic interactions can result in hazards that put our communities at risk.

2.3.2 Tamala Limestone

The Tamala Limestone is a soft porous rock that is highly susceptible to solution from weakly acidic water such as rainfall, seawater and groundwater. The carbonic acid in these waters causes the dissolution and removal of calcium carbonate in solution, resulting in a loss of carbonate from the limestone (Murck *et al*. 1997). This process is known as Karst weathering and occurs mainly along fractures and openings within the limestone rocks. Over time, large volumes of rock can be dissolved away, forming voids and zones of friable sand within the limestone. Sinkholes, caves and underground drainages are also characteristic of this type of weathering.

In conjunction with Karst weathering, which diminishes the structural integrity of the limestone, the unit is also vulnerable to mechanical weathering from wind and wave action. Wave action at the base of a cliff gradually erodes the limestone, undermining the cliff and developing an overhang (Figure 2.4). This process of erosion continues until the overhang becomes sufficiently undermined and collapses.

Rainfall can often be the trigger for an overhang collapse, such as the one at Gracetown in 1996. In a report to the Gracetown coroner, F.R. Gordon (1997b) stated that 'the eolianite cliff face has the capacity to absorb 30-40% water with the more sandy materials having higher absorptive capacities'. It was his view that 'the trigger for the rockfall was the heavy rainfall of the 27th and the antecedent days driving into the face, which increased the weight of the rock and sand mass by up to 40%'.

Figure 2.4 Wave action at the base of this cliff has initiated the development of an overhang.

Overhangs can also be developed from the action of wind, rainfall impact and salt spray erosion. These forces have the most impact on the softer more friable layers such as the Zone of Roots, therefore accentuating the differences between the layers of hard indurated caprock and the underlying Zone of Roots.

As the Zone of Roots weathers, the hard calcrete fossil roots are accentuated as the surrounding leached material is removed through erosion. Infilled solution pipes extending into the ZoR can act as columns to the caprock and provide support which may allow a large area to be eroded before collapse occurs (Gordon, 1997c).

2.3.3 Safety Bay Sand

Dunal systems formed by the Safety Bay Sand (S2), can be particularly hazardous if they are subject to erosion. The foredunes along the coastline are comprised of loose, unconsolidated sand with a natural angle of repose averaging around 30^0. When this angle of repose is increased due to erosion, the dune may become unstable and subside, therefore creating a hazard for people visiting the beach.

Erosion of dunal systems can occur through several processes. The first agent of dune erosion is that caused by wave action upon the seaward margin of a foredune (Figure 2.5). This natural process cuts into the base of the dune, increasing the angle of repose and exposing a crumbling cliff of sand. This process can dramatically increase the risk of collapse and is most common during winter storms.

Figure 2.5 The natural angle of repose for these dunes has been steepened to almost 90^o due to erosion.

Human impacts on the dune systems are a major cause of instability. The popularity of beaches for recreational activities means that human impact is inevitable. The stability of coastal sand dunes relies heavily upon the existence of vegetation. Dune vegetation acts as a barrier to surface wind speed, trapping blown sand and holding it in place. When vegetation is removed from the dune systems, erosion increases, as does the risk of subsidence. The direct impact of people on the dunes is primarily through trampling that occurs as people walk from the carpark over the dunes to the beach. This type of activity destroys the vegetation cover and may lead to the formation of blowouts or mobilise dunes that were previously fixed.

Other human activities that destroy the natural stability of dunes include horse riding, 4W driving, housing and industrial development, as well as digging into the foot of the dune. Recently, two children have been killed and two injured in Australia by digging or tunnelling into sand.

In each case of erosion, it is possible for a collapse to occur and hence there is a risk of injury or loss of human life should that collapse occur at a time when members of the public are present.