

3 Geomorphology and Land Systems

This chapter provides an overview of a system for characterisation of land based on the integration of several biophysical components. At the broadest level these are geomorphological characteristics, while detailed land systems are correlated with indigenous vegetation and soil types.

GEOMORPHOLOGY AND GEOMORPHOLOGICAL REGIONS

Geomorphology—or physiography as it was previously known—is the study of the Earth’s surface and processes that form natural features such as mountains, plains, coastlines and rivers. These processes may occur in the present or the past and be influenced by land use practices such as the building of dams, irrigation channels or other structures. This section describes geomorphological processes and landforms within the River Red Gum Forests study area.

The River Red Gum Forests Landscape

The diversity of landscapes in Victoria is due to variations in geomorphological processes across regions with different topography, tectonism, geological history and rock lithology, sea level and climate changes (Joyce et al. 2003). The physical landscape on which we live can be divided into regions of similar character in several ways. Previously divisions were based exclusively on landform or physiography. Other characteristics were subsequently incorporated, such as underlying geology, groundwater systems, climate and elevation. More recently land systems have integrated geomorphological and ecological characteristics. Victoria has been divided (starting with Rowan 1990) into geomorphological regions and further subdivided into geomorphological units on a regional or local scale. Land systems form the third tier of this division of physical characteristics.

The statewide land systems and geomorphological regions and units are currently under review by the Geomorphological Reference Group (GRG), coordinated by Department of Primary Industries. The revised scheme encompasses seven geomorphological regions, including four that are found in the study area: Eastern Uplands, Western Uplands, Northern Riverine Plains and the North West Dunefields and Plains. These regions and their component units are shown in Map 3.1. This section describes the geomorphology of the study area broadly and then in terms of its geomorphological regions. Subsequent sections examine the more detailed sub-divisions— geomorphological units and land systems.

Recent geomorphological processes in southeastern Australia have preserved the soil horizons, dunes and lake sediments that reveal evidence of past climate and changing landscapes. Sea level fluctuations and climate changes during the Quaternary (1.8 million years ago (Ma) to the present), especially increasing aridity in the Pleistocene (1.8 Ma to 10,000 years ago), had a major impact on inland areas of Victoria, and particularly the study area.

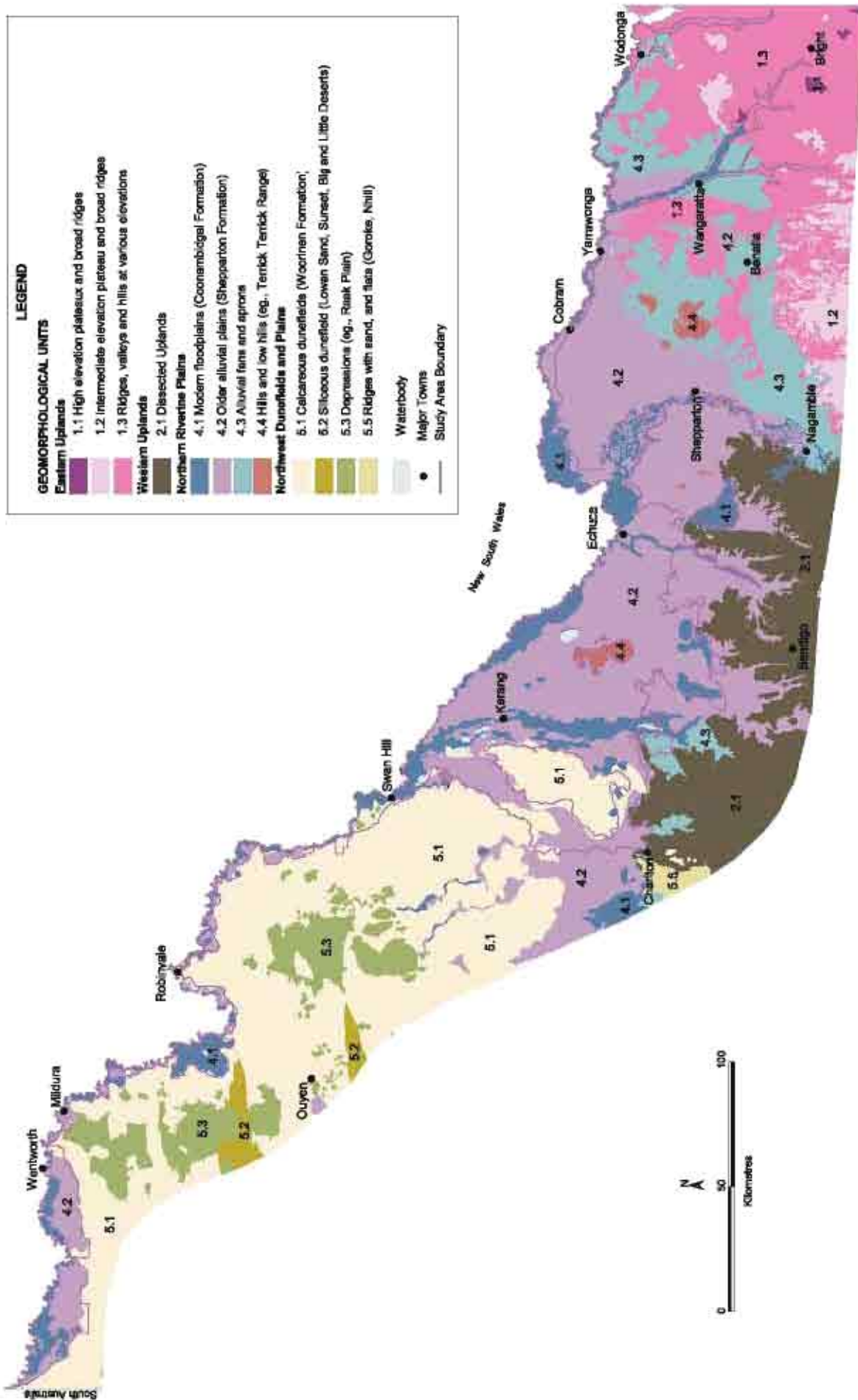
The River Red Gum Forests study area lies in a flat or gently undulating landscape, on the extensive Northern Riverine Plains, that extend inland through New South Wales (NSW). The North West Dunefields and Plains are of relevance in the northwestern part of the study area. Some hilly areas occur in the Eastern and Western Uplands along the southern and eastern edges of the study area.

Geomorphological features of importance in the study area are the lunette-fringed lakes and entrenched meander belts of the river system. Lunettes are crescent-shaped dunes formed by wind-blown (aeolian) movement of sand and clays from dry lake-floors. The larger the lake, the greater the dune source area and hence the largest lunettes form on the down-wind side of many of the biggest lakes across the Northern Riverine Plains during dry climatic phases. In some places the changing climate has left only the lake floor and lunette as evidence of formerly much more extensive bodies of water (Lake Kanyapella, Lake Bungunnia and Hattah Mega-lake—described below). Source-bordering dunes are formed in a similar manner to lunettes and often occur on the northeastern side of large point-bars (see Box 3.1, Figure 3.1) in the major rivers that were deflated and transported locally by aeolian or wind-blown processes during dry climatic phases. These wind-blown deposits are important cultural sites and may contain Aboriginal artefacts or burials such as those at the Willandra Lakes World Heritage Area (Lake Mungo) in NSW.

The present-day river system of the Northern Riverine Plains is the remnant of an older, more extensive system initiated in the Eocene 55–35 Ma (Macumber 1978). Major landforms include streams that leave the major rivers and re-join again downstream (anastomosing anabranches) forming large islands (Gunbower, Lindsay, Wallpolla and Mulcra Islands), large complex wetland and billabong systems (Hattah lakes, Barmah–Moira lakes and forest), and river meanders embedded in larger wavelength meanders inherited from ancient faster flowing streams (see Box 3.1).

Older surfaces, such as where bevelling cuts across changes in bedrock, or where distinctive weathering horizons are preserved, are of significant geomorphological interest. Many are related to the regional sedimentary record, particularly the erosion of uplands and major unconformities within sedimentary sequences.

Map 3.1 Geomorphological Units in and adjoining the study area.



Box 3.1 River Meanders

Rivers rarely maintain a straight route, particularly on floodplains. Often a series of bends and loops known as meanders snake across the landscape, reflecting the way in which resistance to flow is minimised and energy spread evenly along the river course (see Figure 3.1). As water rushes past the outer part of a bend, sediment is eroded from the riverbank. With the slower flow concentrated around the inner side of each bend, coarse sediment accumulates and forms an area of shallow water and sandy beaches or point bars. Through this process incremental channel migration occurs and a new floodplain is created by lateral accretion. Channels bend further with migration until the narrow neck of land between one bend and the next is breached (avulsion). A new shorter flow path is created, and the old channel is abandoned to evolve into an oxbow lagoon or billabong. The size of meanders depends upon the underlying geology and the changing speed and volume of water flow. The rate and direction of channel migration, and the degree of floodplain inundation, are affected by tectonic as well as fluvial or river processes.

Compared with other parts of the world, a relatively small proportion of Australia's rivers are meandering, and the meanders of the River Murray are well developed and relatively unaltered by European settlement. Within the study area no single area of floodplain is representative of the whole Victorian Murray. Rather, some areas demonstrate the effect of local tectonic activity (Barmah forest), some suggest the influence of regional tectonism, and others may not be affected by tectonism at all (Gunbower Island, Yarrowonga reach). Some floodplains appear to show rapid oblique channel migration, the traces of which are not masked by flood deposits, and the result is clearly-marked 'scroll plains' such as those of Lindsay Island. In others, the old channels are semi-parallel to the present channel, and migration is slow enough that the present channel crosscuts the palaeochannels (Kings Billabong near Red Cliffs). Other floodplains such as Belsar Island near Robinvale may have more layers of flood sediments, covering any traces of previous channel migration.

Figure 3.1 Air photo showing meander channel features of the River Murray floodplain, Retail Bend and Murray-Kulkynne Park (see Figure 3.2 for location).



The River Red Gum Forests study area, by design, encompasses particular biogeographic regions which mostly carry river red gum or associated vegetation types. Because biological features are strongly correlated with geomorphological systems, the study area mostly encompasses the Northern Riverine Plains geomorphological region (Map 3.1). Only small areas of other regions—the North West Dunefields and Plains, the Eastern Uplands and Western Uplands occur the study area (and Rees 2000; see Rowan 1990).

Northern Riverine Plains

The Northern Riverine Plain is an extensive alluvial plain associated with the Murray River and its tributaries, which extends north from the Western and Eastern Uplands of the Great Dividing Range to the River Murray. It can be divided into an upland fringing slope with low residual hills, a plain crossed by palaeochannels and modern rivers such as the Loddon, Avoca and Campaspe, and the major alluvial terrace and floodplain-infilled troughs of the Goulburn and Murray rivers. Concentrations of lake and lunette systems, such as the Kerang Lakes, Avoca Marshes and Kow Swamp, occur intermittently across its surface.

Much of the plain is made up of Quaternary alluvial deposits of clay, silt sand and gravel (Shepparton and Coonambidgal Formations), forming broad fans extending and widening northwards from the uplands edge. The sediments were laid down in a fluvial system of floodplains and river channels, and in scattered shallow lakes and wind-blown dunes. The deposits extend from upland valleys such as the Loddon and Ovens and coalesce into an almost continuous mantle across the study area. Leveed channels of several ages are present, sometimes forming ridges above the general elevation of the plains, and may have source-bordering dunes. Higher terraces and aprons of uncertain age occur along the southern edge adjoining the uplands. In places, low rocky ridges of older basement rocks, such as the Terrick Terrick hills, rise above the plains.

Features of floodplain evolution and development can be categorised as modern streams, prior streams, ancestral rivers and lakes and lunettes (e.g. Bowler et al. 1978; Pels 1964; Rutherford 1990). Modern streams are the channels and swamps of the present-day river system (described in more detail under 'River Murray Evolution', below), with generally narrow channels and well-defined levee banks and floodplains. Some, such as the Campaspe, have alluvial terraces. Lakes and swamps lie in cut-off meanders or avulsion channels across the floodplains.

Prior streams are the traces of older rivers characterised as low ridges of silt and sand—former natural levee banks—that lie adjacent to shallow, meandering depressions of the former river channels. Often these channels are perched higher than the present floodplain and may be a great distance from present rivers. Typically, prior streams do not carry surface water, except in high flow conditions, and both channels and levees are broken where they have been partly eroded by later events.

Ancestral rivers are old, abandoned channels that lack levee banks, are incised into the surface of the plain,

and are partly filled with alluvium. They are associated with and often crossed by the modern rivers and may act as floodways during high water flow. Many are wider than those of the present-day rivers, have coarse sand and gravel, and have much larger meanders, indicating they formed at times of much greater river discharge. Modern rivers often form a meander within the larger meander pattern of these ancestral rivers.

Lakes on the riverine plain have formed in three ways, as cut-off meanders and abandoned channels, deflation (wind-eroded) hollows, and as tectonic depressions. Many of these lakes are composite and fed by groundwater. Associated with shallow lakes are lunettes, crescent-shaped dunes composed of clay, silt and fine sand typically along the eastern shoreline. Some are single, but many form complex systems that record the gradual decrease in the size of the adjoining lake (e.g. palaeo-Lake Kanyapella, see Box 3.2). Most of the lunette sediment consists of clay and fine sand blown from the lake floor during dry conditions.

The alluvial terraces and floodplains of the modern rivers (Coonambidgal Formation—see Map 3.1) often have source-bordering dunes on the northeastern sides of channels, formed from fine sand deposited by the same river in times of greater flow. Several former courses of the major rivers, such as the Murray and Goulburn, are marked by extensive meander belts and occur in shallow depressions incised below the plains. These features indicate several phases of channel and dune activity, with many dunes forming along the Murray River during the last major dry glacial period. River channels with wide sandy point bars persisted into the Holocene, but formation of dunes along the river ceased as the climate warmed.

The final episode of river deposition after the glacial and periglacial conditions is present along the length of the River Murray and its tributaries. The current channel of the Murray River may be only a few hundred years old in many places. Some areas on the riverine plain, such as between Tragowel and Pine Grove, have only rare channels and no source-bordering dunes. Much of the central and eastern parts of the plain are overlain by a shallow mantle of calcareous wind-blown deposits (or parna) comprising silt and clay aggregates.

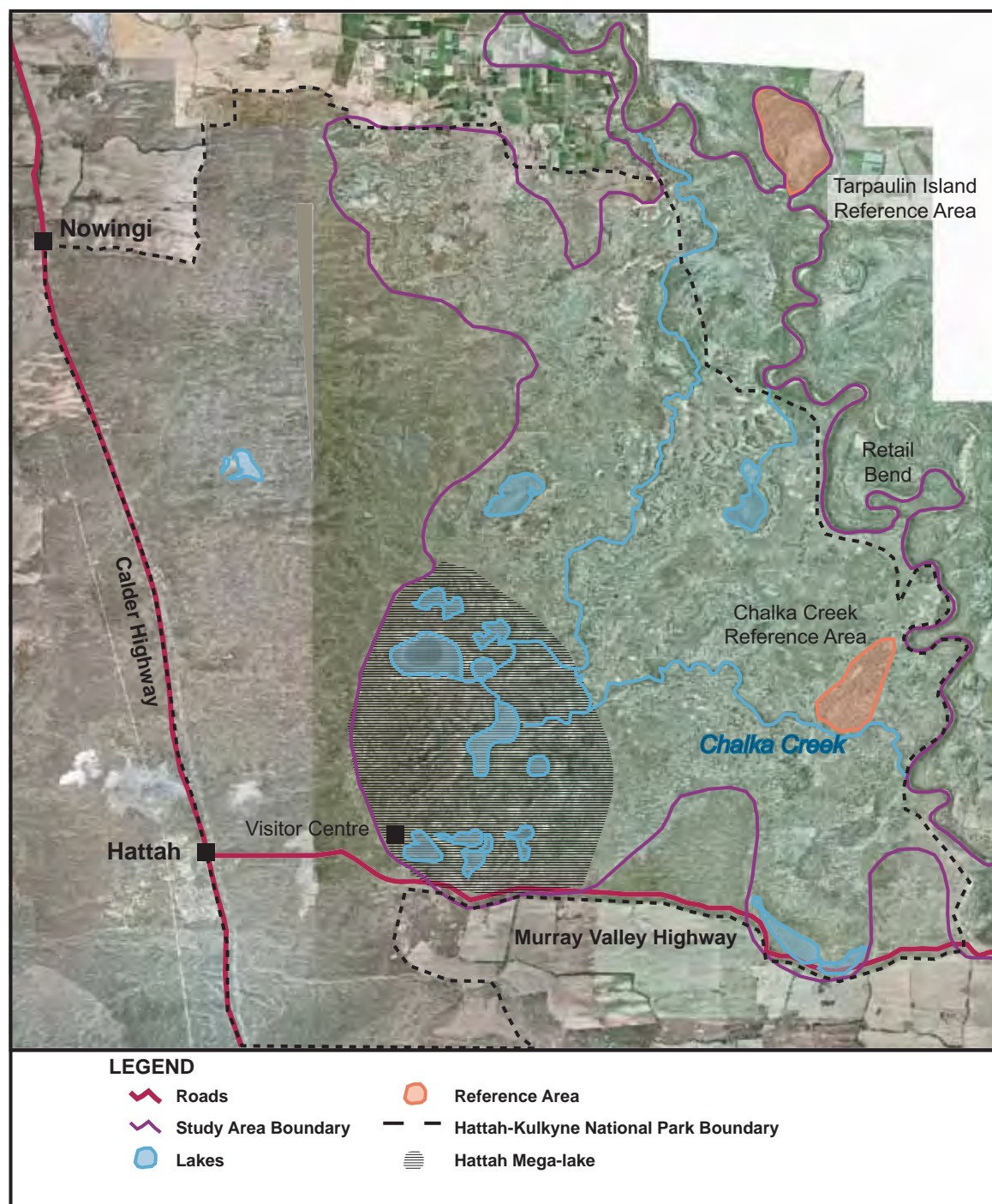
Near Echuca, movement along the Cadell Fault dammed the River Murray to produce palaeo-Lake Kanyapella around 30,000 years ago (see Box 3.2 Bowler 1978; Cupper & White 2003; Page et al. 1991; Rutherford & Kenyon 2005). Other faults (such as the Echuca South Fault) cross the alluvial deposits and alter the earlier leveed stream channels, allowing a chronological sequence of channels to be mapped (see Rutherford & Kenyon 2005). However some previously postulated 'faults' e.g. Leaghur Fault, are now regarded as erosional features, as evidence for displacement or movement cannot be found.

Hattah Lakes is the most extensive lake system along the River Murray, where a series of about 21 interconnected lakes and wetlands formed in a depression at the easternmost limit of the Sunset Country dunefields (Figure 3.2). The lakes are surrounded by longitudinal dunes of the Woorinen Formation and sub-parabolic dunes of the Lowan Sands. Water is supplied to the

lakes by flooding from Chalka Creek:—an anabranch of the River Murray. Several of these lakes lie on the floor of the pre-existing Hattah 'Mega-lake' (in the order of 50 square km in size), which is bordered to the east by a large lunette (Kotsonis et al. 1999; Macumber 1978). The large size of the palaeo-lake, combined with high river discharge in the past, suggests that it contained freshwater, and developed during the pre-glacial wetter climates with significantly more surface water in the Murray Basin. Hattah Mega-lake is entrenched at a topographic level similar to the upper river terrace in this area, and probably developed from an old meander cut-off on this terrace.

Sub-parabolic dunes completely cover the high level terrace at Hattah Lakes and partially cover the Hattah Mega-lake floor, indicating that dune encroachment occurred at similar times to lunette formation and after the drying-out of the lake. The presence of source-bordering dunes and sub-parabolic dunes on the low level terrace suggests a high level of wind activity during deposition of this terrace. The present fluvial regime lacks source-bordering dunes and truncates sandy dunes on older terraces, indicating that dune mobility had ceased when this river system became active about 15,000 years ago. Within the Hattah Mega-lake, this reduction in aeolian activity was accompanied by a

Figure 3.2 Air Photo of the Hattah lakes complex.



change from saline lakes and clay lunette formation to freshwater conditions, as recorded by the presence of freshwater fauna in local midden deposits. Dating of the Northern Riverine Plain landforms has unravelled much of the Late Quaternary climatic history and processes in this region.

Downstream of Hattah the remaining area of the Northern Riverine Plains is represented as an entrenched and more constrained river system containing diverse landforms including anabranches that form large islands such as Lindsay, Wallpolla and Mulcra Islands, as well as meander channels, billabongs, levees and low dunes, with larger overflow lakes and lunettes abutting the semi-arid Mallee region. The area consists of three main geomorphological components: the riverine floodplain (subject to periodic flooding and encompassing numerous oxbow lakes, ephemeral wetlands and active meander belts); broad, flat alluvial plains (infrequently flooded); and alluvial rises or elevated terrace areas that were built up during more arid periods by wind-blown material from the surrounding areas. To the south and flanking the floodplains, lie the North West Dunefields and Plains.

North West Dunefields and Plains

The North West Dunefields and Plains extend north from the edge of the Western Uplands to the margin of the Northern Riverine Plain. In the study area, it occurs only in small peripheral patches west and north of Kerang (Map 3.1). This geomorphological region consists largely of dry, sandy, gently undulating plains with extensive siliceous and calcareous dunefields, becoming more subdued towards the south. Beneath the plains is a low relief bedrock surface, only rarely rising above the plains as low granitic hills (such as at Wycheproof). Rivers in the region, such as the Avoca and Wimmera, rise in the Western Uplands to the south, lose water by evaporation and infiltration as they flow northwards, and do not reach the Murray. Elsewhere across much of the North West Dunefields and Plains there is almost no run-off, except locally after heavy rain. The rivers are linear and relatively fixed, showing little evidence of migration, and are flanked by floodplain and terrace deposits of Pleistocene and Holocene age. Low-lying areas contain saline lake complexes, or freshwater lakes fed by the rivers (e.g. Raak Plain, Avoca Marshes). Clay plains, cemented in places by calcrete, underlie large parts of the dunefields, and salt lakes in the north of the region. Beneath the dune and lake sediments are the curvilinear coastal ridges of the Pliocene Parilla Sands.

There were several separate phases of dune activity comprising siliceous and calcareous dune complexes. A siliceous (Lowan Sand) dunefield (Sunset Country) lies to the south and west of the riverine plain in northwest Victoria and contains both linear and parabolic dunes. The parabolic dunes are often large, with sharp crests, and interspersed with wide sandplains and smaller, often smooth-crested, dunes of variable orientation. The linear dunes are closely-spaced, low and smooth-crested, with narrow, sandy swales. Dunes of both types are oriented east-west to northeast-southwest, parallel to the present dominant wind directions.

The calcareous dunefield forms a large area of the Mallee extending discontinuously from Nhill northeast to

the Northern Riverine Plain, and includes reddish quartz sands (Woorinen Formation). These dunes are vegetated, predominantly linear and oriented east-west, but are not uniformly distributed. In the west quartz sand and carbonate dominate, but in the east, where the dunes have migrated over the clay-rich riverine plain, up to 20 percent clay content is common.

These calcareous dunes and associated palaeosols reflect the alternation of cool and arid conditions with wetter soil forming conditions. The siliceous dunes of the Lowan Sand have a notable absence of clay and carbonate in contrast to the Woorinen Formation dunes.

Large, variably saline lake complexes occupy low areas, such as the Kerang Lakes and the Raak Plain adjoining the study area. These saline lakes are groundwater discharge basins or relict groundwater discharge features, where saline groundwater can emerge and, through intense evaporation, produce hypersaline brines. Sediment is deposited by aeolian input and precipitation from groundwater; typically lake floor sediments are dominated by gypsum.

The freshwater lakes differ from the saline lakes in that they contain fluvial or river sediment and have well-defined elliptical or rounded margins. The eastern sides of most of the lakes have low half-moon-shaped lunette dunes of sand and gypseous silt. Orientation of these lunettes indicates that westerly wind regimes were responsible for their formation, which are thought to have dominated during arid dune-building phases of the Pleistocene.

Eastern Uplands

The River Red Gum Forests study area extends along the King, Kiewa and Ovens rivers into small areas on the northern slopes of the Eastern Uplands (Map 3.1). The Eastern Uplands form part of the broader Great Dividing Range, and are the largest and highest upland areas of Victoria. The region can be divided into two broad areas: the gentler topography of the high plains and the deeply incised valleys of the northern and southern slopes, including some low plateaus.

The northern slopes of the Eastern Uplands consist of steep-sided branching river valleys with thick sediment, separated by high, narrow ridges with mostly young, stony gradational soils caused by the continual movement of weathered material down the slopes. River gradients within the dissected northern slopes are steep, particularly in the upper reaches, but gradually decrease as the valleys widen downstream and enter the study area. River direction is often determined by past geological activity, for example, the Kiewa River follows the north-northwest line of the Kiewa Fault. These northern rivers flow either across the Riverine Plains to join the Murray River (Goulburn, King and Ovens Rivers) or, east of Wodonga, into the Murray directly (Indi (or Upper Murray), Mitta Mitta and Kiewa Rivers).

The lower parts of the river valleys of the northern margin are partially filled with alluvium and have open U-shaped or sometimes angled cross-sections. The alluvial flats are often flooded during late winter and spring in areas where snowmelt contributes to streams. Well-developed alluvial fan aprons have been deposited by ephemeral streams draining the sides of some of the

major valleys. The large, older fans may be cut by subsequent erosion and new fans deposited in the gullies; as many as four 'nested fans' occur in some locations. Paired river terraces are common, and typically several sets can be identified.

Western Uplands

The Western Uplands extend from Kilmore Gap north of Melbourne westwards to near the Victorian-South Australian border. A small area of the Western Uplands occurs in the southern part of the study area near Wedderburn (Map 3.1). The region is low, with an average elevation of about 300 m, which divides drainage areas. The Loddon, Campaspe and Avoca Rivers flow north from these uplands towards the Murray River. The major valleys, terraces and floodplains of the Avoca and Loddon rivers are features of the Western Uplands' northern margin. Between the main valleys, the slopes of ridges and hills are often deeply weathered and mantled by colluvium and alluvium, with fresh to saline springs.

From the northern edges of the Western Uplands two palaeosurfaces extend northwards beneath the Northern Riverine Plain. The Karoonda Surface occurs on the uplands fringe but mostly overlies the Parilla Sands in the Murray Basin, as well as partly underlying the Blanchetown Clay. The Mologa Surface is a highly weathered, low-relief palaeosurface that overlies the upper parts of the Renmark Group and Murray Group within the Murray Basin—see chapter 2 for more details of the formations on which the palaeosurfaces lie.

GEOMORPHOLOGICAL UNITS AND LAND SYSTEMS

In this section, the detailed geomorphological units within each of the four geomorphic regions of the study area are described, before land systems are briefly summarised in the following section.

Geomorphological Units

In total, eight geomorphological units are found in the study area (Table 3.1).

Table 3.1 Geomorphological Units within and adjoining the study area.

Region	Unit	Brief Description	Map symbol
Eastern Uplands	High Elevation Plateaux and Broad Ridges	Subalpine terrain of low relief; source area of major streams and rivers—outside the study area	1.1
	Intermediate Elevation Plateaux and Broad Ridges	Montane terrain of low relief—outside the study area	1.2
	Ridges, Valleys and Hills at Various Elevations	Highly dissected terrain as well as outlying terrain	1.3
Western Uplands	Dissected Uplands	Generally subdued terrain in contact with the plains and dunefields	2.1
Northern Riverine Plains	Modern Floodplains	Present floodplain (Murray valley)	4.1
	Older Alluvial Plains	Shepparton Formation representing the older floodplain extent	4.2
	Alluvial Fans and Aprons	Associated with the erosion of the Uplands and the major river systems	4.3
	Hills and Low Hills	Inliers such as the Dookie Hills and the Terrick Terrick Range	4.4
North West Dunefields and Plains	Calcareous Dunefields	Predominantly linear dunes with various proportions of associated plain or swales	5.1
	Siliceous Dunefields	Adjoining study area only	5.2
	Depressions	Small area north of Swan Hill within study area; larger areas adjoining study area (Raak Plain)	5.3
	Ridges with Sand, and Flats	Adjoining study area only	5.5

Note : Map symbol numbers correspond with those in Map 3.1 and in the text on the following pages.

Northern Riverine Plains Units

The major groupings within Northern Riverine Plains are Modern Floodplains, Older Alluvial Plains, Alluvial Fans and Aprons, and Hills and Low Hills.

Modern Floodplains (4.1) are dominated by the major streams that often have a meander belt below the current plain level, such as those along the Murray, Ovens and Goulburn Rivers. Areas of inundation away from modern channels occur at Gunbower forest, Barmah forest, the Hattah lakes area, Lindsay and Wallpolla islands, Dingee Swamp and the Loddon River fan. There are also young lakes and basins with lunettes such as Kow Swamp, Lake Cooper, Lake Kanyapella depression and Lake Tutchewop.

Older Alluvial Plains (4.2) cover much of the study area, and comprise the extensive elevated plains away from the modern floodplains. This grouping includes plains with leveed channels (prior streams) such as those at Tatura and Naneella, as well as plains with non-leveed channels at Tragowel and Pine Grove. Lakes and depressions with lunettes, such as Lake Mokoan (originally Winton Swamp), are also associated with the Older Alluvial Plains.

At present there is no detailed information below the land systems scale available for significant areas of this group. Future mapping will incorporate work undertaken for irrigation potential in the 1960s and 1970s by the then Department of Agriculture. Unlike the current land systems coverage, the revised scheme will differentiate prior stream and non-prior stream areas, and related cover such as soil associations.

Alluvial Fans and Aprons (4.3) are associated with the elevated areas or uplands as well as the major streams which have deposited material upon leaving the uplands. These areas are quite extensive abutting the study area, but only small areas of low fans carry river red gum or associated vegetation communities. Alluvial fans have formed over much of the middle Broken River catchment (outside the study area) which is bound by the Strathbogie Ranges and the Warby Range, and in parts of the lower Loddon River.

Hills and Low Hills (4.4) such as the inliers of the Terrick Terrick hills and the Dookie hills, interrupt the predominantly flat alluvial plains landscape. Erosion of these hills has provided a source for deposition of coarse-grained material such as gravel and sands, and hence local variations in environment or habitat.

North West Dunefields and Plains Units

The North West Dunefields and Plains includes what was formerly known as the Mallee Dunefields (Rowan 1990) and consists of aeolian or wind-blown dunefields (calcareous and siliceous), basins or depressions, plains and ridge and flat terrain. The revised scheme (based on work by Rowan (1990), particularly that undertaken for the LCC (1987) Mallee Area Review) standardises this geomorphological division to a three tiers system that is used for the remainder of Victoria. The main groupings within the study area are minor occurrences of Calcareous Dunefields, Siliceous Dunefields, and Depressions. The three other major divisions of this geomorphic region occur outside the study area.

Calcareous Dunefields (5.1) consist of aeolian dunefields with various proportions of dune, plains and minor depressions. The dunes decrease in frequency as they approach the River Murray alluvial floodplains. These areas are utilised extensively for cropping due to the moderate to high nutrient status of the soils.

Siliceous Dunefields (5.2) occur in distinct belts alternating from east to west between parabolic and linear dunes. These areas are characterised by low nutrient soils unsuitable for cropping, and have therefore been retained mostly as large tracts of native vegetation on public land that form the large desert parks of the Mallee, including the Sunset, Big Desert and Little Desert National Parks.

Natural depressions or shallow basins (5.3) have formed generally as groundwater discharge areas, which are saline and often gypseous. A notable example is the Raak Depression located west of Hattah, just outside the study area. A small area of this geomorphic division occurs within the study area, to the northwest of Swan Hill. Lunettes associated with these depressions, provide an indication of the past extents of lakes under climatic conditions different to those today.

Eastern Uplands Units

The Eastern Uplands comprises the elevated landscape east of the Kilmore Gap and contain major alluvial valleys such as the Kiewa, Ovens, King, Goulburn, Broken and Murray Rivers that flow out into the Northern Riverine Plain. The area covered by this geomorphological region within the study area is comparatively small, and consists of valleys extending into the uplands. These outliers of the more extensive area of uplands consist of either Palaeozoic sediments or Palaeozoic granites, generally of subdued terrain.

Western Uplands Units

The Western Uplands are elevated regions (generally formed of hard rock) west of the Kilmore Gap. These uplands are generally more dissected and lower than the Eastern Uplands, as well as having a drier climate. The Loddon, Campaspe, Avoca and Wimmera rivers are the main waterways flowing north out of the Western Uplands and towards the Murray River floodplain.

This geomorphological region comprises a comparatively small portion of the study area, consisting of extended valleys into the uplands and as well as outlying units predominantly to the north of Bendigo and Wedderburn. The major divisions within this unit are largely defined by underlying rock lithology which in turn defines hardness and therefore elevation in eroded landscapes. A very small part of the Dissected Uplands (2.1) unit is included within the study area.

Land Systems

Compared to geomorphological units, land systems describe a more detailed level of land information within the geomorphological framework. Land system mapping is used to characterise land in terms of its capabilities, limitation and management requirements, particularly in the context of agriculture use. In addition, prior to the advent of detailed vegetation mapping (e.g. at the ecological vegetation class or EVC level—see chapter 5 Biodiversity), the LCC used land systems as the basis for



recommending representative areas for particular public land uses (typically reference areas and conservation reserves).

Individual land systems have been allocated a key to provide a systematic nomenclature at the statewide level. The land systems set compiled by Rowan (1990) which has been updated (Rees 2000) provides a key for land system description based on geomorphological divisions, landform, surface lithology, geological age, climate (rainfall) and a unit designation. The land systems key is provided in Table 3.2.

As shown in Table 3.2, each land system has a unique range of land components. For example, 4.1 FfQ4-1 indicates that the land system occurs in the Modern Floodplain unit of the Northern Riverine Plains (4.1); it is a Floodplain landform (F), with a fine textured sediment lithology (f) of Quaternary age (Q), has an annual

average rainfall of 400-500mm (4) and is the first designate of this type (1). The tables associated with these statewide land system entries also indicate broad soil and vegetation types as well as a simple assessment of land degradation susceptibilities (Rowan 1990).

A table of the land systems covering the largest extent within the River Red Gum Forests study area is provided below (Table 3.3). Those land systems that comprise a small area have been grouped under broader categories for simplicity. Map 3.2 is an example of a land systems map for an area near Swan Hill. In the northwestern part of this area the interaction of the North West Dunefields and Plains and Northern Riverine Plain may be observed. The modern floodplain occupies the entire floodplain compared to other areas in the southeastern corner of the map where the older floodplain extends laterally and occupies a more elevated or higher level of the landscape.

Table 3.2 Land Systems Key.

Landform		Lithology		Lithological Age		Climate—Av. Annual Rainfall (mm)	
F	Present Floodplain	c	Unconsolidated (coarse)	P	Palaeozoic	2	200-300
P	Plain above flood level	f	Unconsolidated (fine)	M	Mesozoic	3	300-400
D	Dunes	z	Unconsolidated (fine, saline)	C	Cainozoic, undifferentiated	4	400-500
R	Rise	g	Granite and gneiss	T	Cainozoic; Tertiary	5	500-600
L	Low hill	l	Limestone/calcrete (calcareous)	Q	Cainozoic; Quaternary	6	600-700
H	Hill	v	Acid volcanics			7	>700 (temperate)
M	Mountain	b	Basic volcanics			8	>700 (montane)
S	Depression/ Swamp/ lunette complex	m	Metamorphic rocks			9	>700 (sub/alpine)
C	Coastal Complex	s	Sedimentary				

Source: Rees (2000)

Map 3.2 Land Systems for an area near Swan Hill.

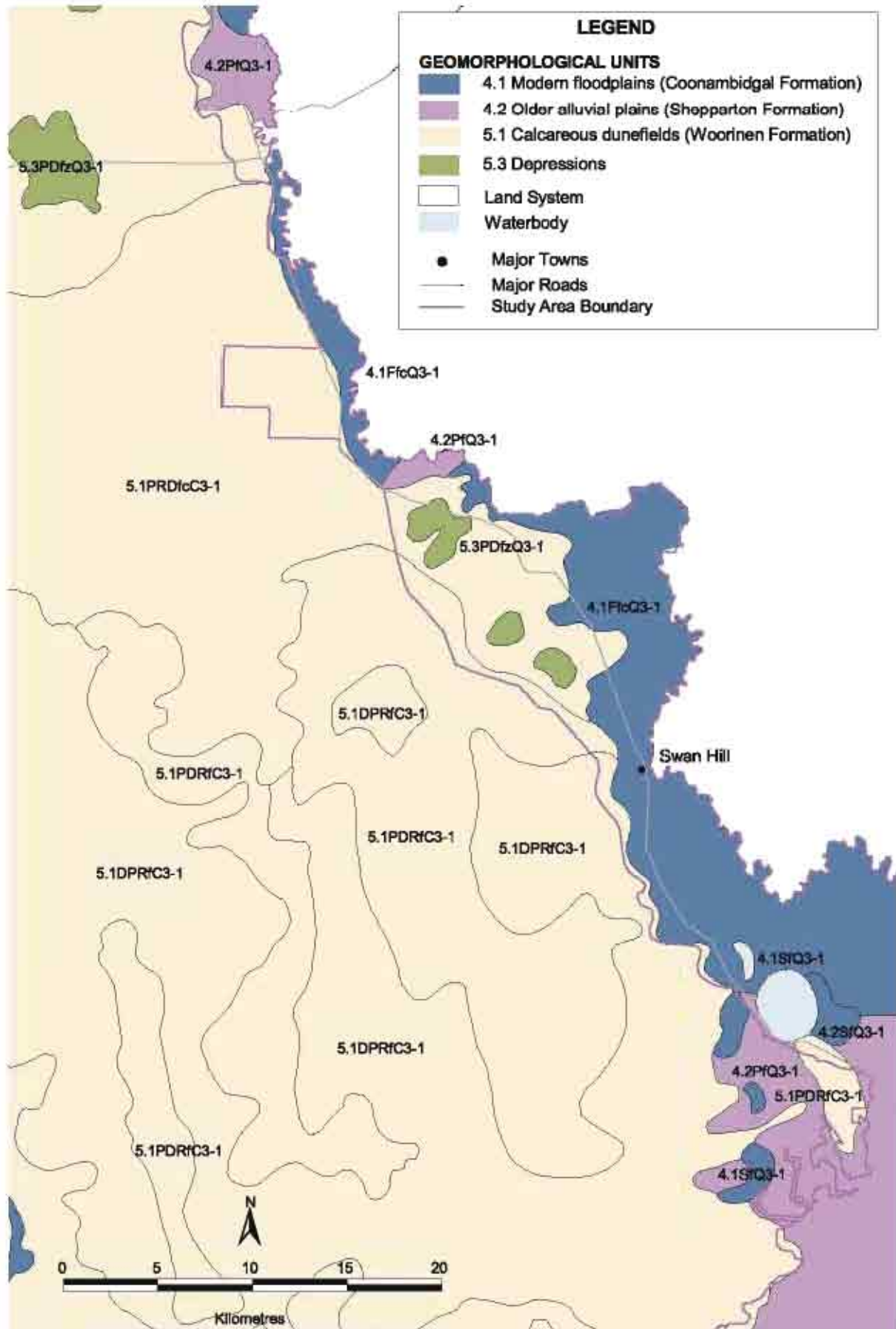


Table 3.3 Land systems in the study area.

Region	Land system
Eastern Uplands	1.1HgmP7-3
	1.1HsP7-5
	1.1HsP7-6
	1.1HsP8-5
	1.1LsP5-1
	1.1MsP8-5
	1.1PfcQ6-1
	1.1PfcQ8-1
	1.1PgP7-4
	1.1RbT7-2
	1.1RsP7-7
	1.3FfcQ7-2
	1.3HgP7-3
	1.3RgP7-4
	1.3RsP7-6
Western Uplands	2.1LmsP3-1
	2.1PfcQ3-1
	2.1Pft4-7
Northern Riverine Plains	4.1DPcfQ2-1
	4.1FDcfQ2-1
	4.1FSfQ3-1
	4.1FSfcQ4-1
	4.1FfcQ2-1
	4.1FfcQ3-1
	4.1FfcQ4-1
	4.1FfcQ5-1
	4.1FfcQ6-1
	4.1PfcQ2-1
	4.1PfcQ3-1
	4.1PfcQ3-3
	4.1PfcQ4-1
	4.1SfQ2-1
	4.1SfQ3-1
	4.1FSfQ4-1
	4.2FfcQ3-1
	4.2PDfcQ2-1
	4.2PfcQ2-1

Region	Land system
	4.2PfcQ3-1
	4.2PfcQ3-2
	4.2PfcQ3-3
	4.2PfcQ4-1
	4.2PfcQ4-2
	4.2PfcQ4-5
	4.2PfcQ4-6
	4.2PfcQ5-3
	4.2PfcQ5-4
	4.2PfcQ5-5
	4.2PfcQ6-5
	4.2PfcQ7-2
	4.2PfcQ4-1
	4.2PfcQ5-1
	4.2SfQ2-1
	4.2SfQ3-1
4.3PfcQ4-8	
4.3PfcQ4-9	
	4.3PfcQ6-3
	4.4LfbP4-1
	4.4LgP3-1
	4.4RsP4-2
	4.4RsP4-5
	5.1DPRcfC2-1
	5.1DPRcfC3-1
	5.1DPRfcC3-1
North West Dunefields and Plains	5.1DPRfcC2-1
	5.1DPRfcC3-1
	5.1DPcfQ2-1
	5.1FSfQ3-1
	5.1PDRfcC3-1
	5.1PDfcQ2-1
	5.1RPDfcC2-1
	5.1PRDfcC3-1
	5.1PfcQ3-1
	5.3PdzQ3-1

EVOLUTION OF THE MURRAY RIVER

Across the floodplains, evidence of older streams and channels suggest that much more water flowed in the past than the present day. The Murray River itself occupies a channel of varying age and character. Some sections are relatively recent, being constructed on recent floodplain and stream sediments, and having a typically straight and narrow character (e.g. through the Barmah–Millewa forest; see Figure 3.3). Sections within the ancestral river have meanders with large wavelengths and a convoluted and often tortured path to the sea (Figure 3.4). This river is both ancient— with origins over the last 50 million years— and relatively modern (Macumber 1978).

Much research has been undertaken on the geomorphology and hydrological processes that have shaped the Murray River (e.g. Bowler & Magee 1978; Currey & Dole 1978; Macumber 1978; Pels 1964).

The greatest influence on the river character has been the capture of the main channel by large tributaries (i.e. Goulburn and Ovens Rivers) and movements of cross-cutting faults such as the Cadell Fault extending between Deniliquin and Echuca (see Figure 3.3 and Box 3.2). Currey and Dole (1978) divided the Murray into five geomorphic tracts from its source to the Victorian border as shown in Figure 3.4. Rutherford (1990) built on Currey and Dole's model, describing the current path of the river and the key elements and adding the South Australian Gorge and Swamp tracts.

The preservation of these complex ancient streams is an important geomorphological feature of this region. They have persisted largely because of a lack of tectonic activity in southeastern Australia over the last 30 million years. Climate has also played a significant role, with limited weathering or erosion over the last few million years.

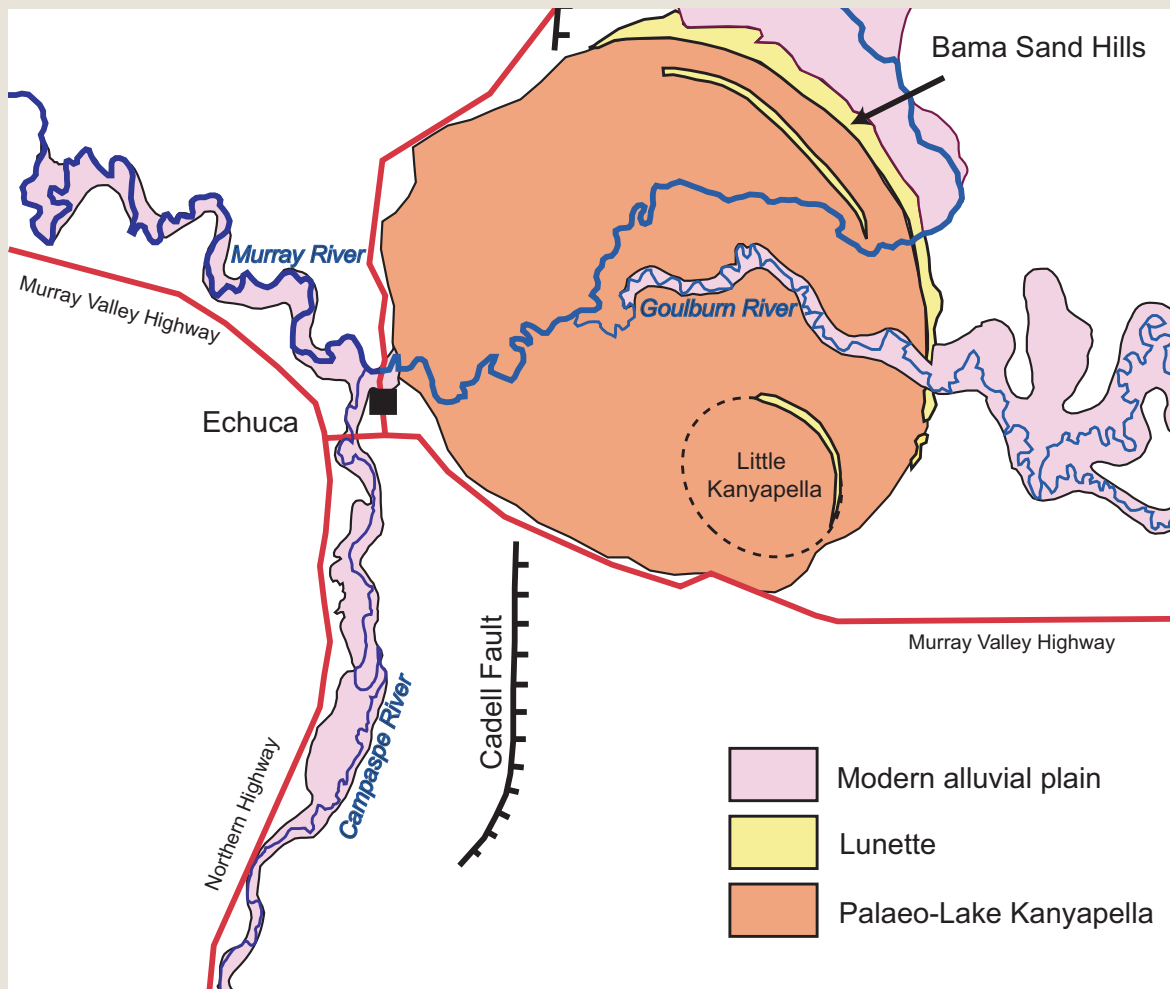
Box 3.2 Barmah Area Geomorphology

The Barmah-Millewa river red gum forests are unique in the Australian landscape. This broadly triangular floodplain forest has developed as a result of the interaction of ancient river drainage patterns and palaeo-levees, and the rise of the Cadell Fault Block (Figure 3.3). Today we observe a narrow channel of the River Murray at the Barmah Choke, cutting through sediments of older river and dune deposits. These dunes rise up to 25 m above the flat floodplain and provide evidence of once extensive lakes formed by the damming of the river system. The largest of these is Bama Sandhill formed on the eastern and northeastern edge of Lake Kanyapella. This landform is now cross-cut by the Cadell Fault, and both the Murray and Goulburn Rivers. Other palaeo-lakes with lunettes are Little Kanyapella and Barmah Lake-Bucks Sandhill, forming part of the associated lunette created as the lake dried periodically. Movements on the Cadell Fault have probably occurred several times during the evolution of the riverine plain.

Dating of channel sediments suggest that the first movement was more than 30-35,000 years ago (Bowler 1978; Page et al. 1991; Rutherford & Kenyon 2005).

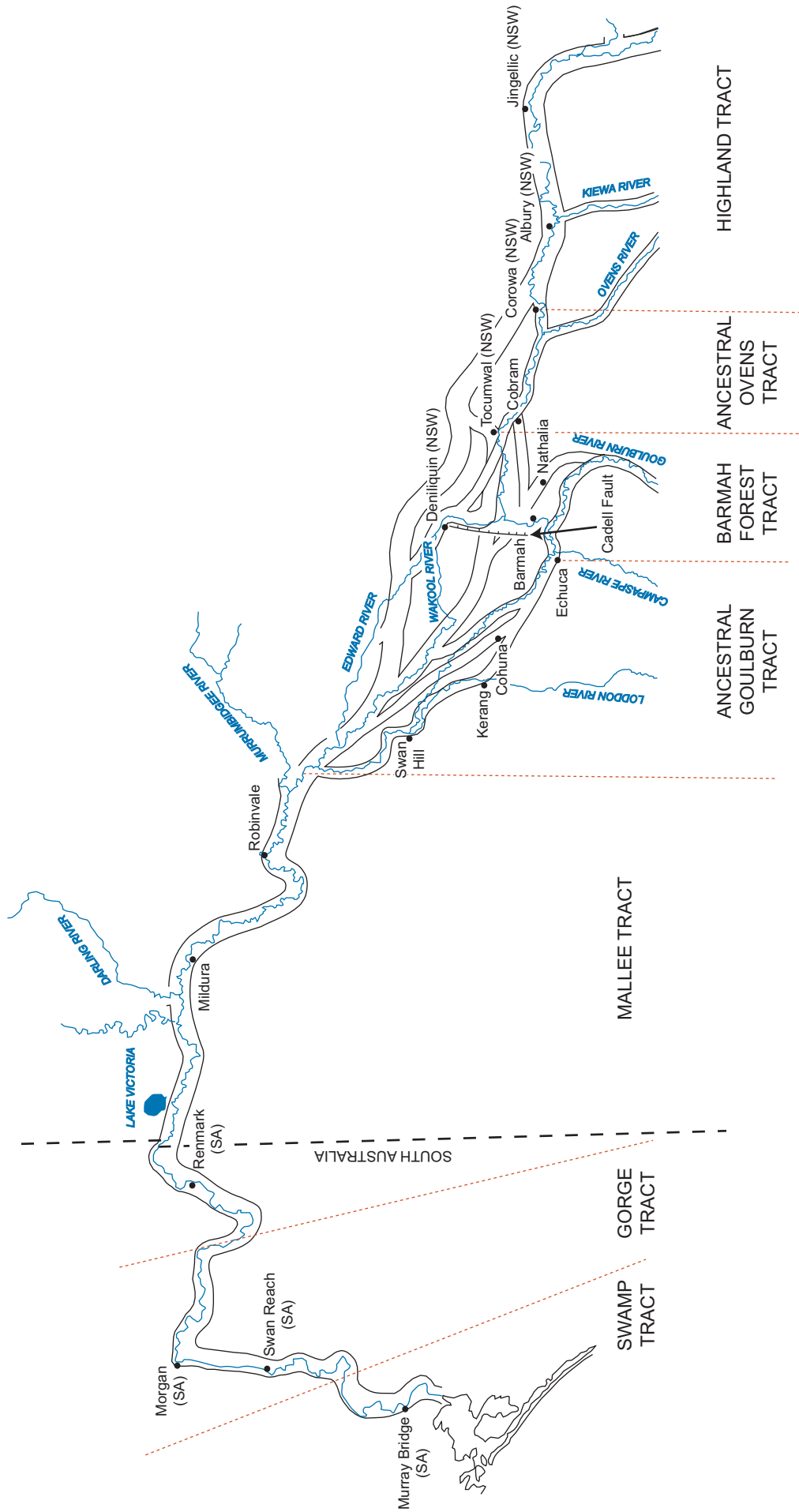
In the past the main channel of the River Murray has occupied various alternate courses including Bullatale Creek, Gulpa Creek, Green Gully and the Edward River, and entered the existing channel through the Mallee at Wakool Junction. It was not until perhaps 8000 years ago that the Goulburn captured the main Murray flow when the lunette bordering Lake Kanyapella was breached. This event is geologically very recent and overlaps with the presence of Indigenous people in the area. Traditional stories of a great flood and the breaching of the lunette may reflect this geological event (Atkinson 2005). As a consequence of this unusual hydrological arrangement between the two rivers, the Murray in this region acts as a tributary of the Goulburn and in times of high flow, the Goulburn will back up water in the Murray and cause flow to run 'upstream'.

Figure 3.3 Map of Palaeo-Lake Kanyapella and Cadell Fault near Barmah



Source: modified after Rutherford and Kenyon (2005); Barberias (1983)

Figure 3.4 Geomorphological tracts of the River Murray.



Source: modified after Currey and Dole (1978); Rutherford (1990)