CHAPTER 1

INTRODUCTION

1.1 Introduction

Landscapes are chronicles of history. With skilful interpretation, they can reveal past geological events, paleo-climatic shifts, and evolutionary changes in floral and faunal associations. They may also reflect evidence of changes that have occurred within human time scales - whether millennia or less than a decade - as consequences not only of geological and ecological processes, but of human intervention.

Human societies have been long assumed to be influenced by their environments, but the idea of environments as "social constructions" (White 1980, p. *xix*) or "cultural achievements" (Worster 1994, p. x) is relatively new. The nineteenth century American environmentalist George Perkins Marsh was perhaps the first to assert, in *Man and Nature* (Marsh 1965; first published 1864), that humans were responsible for shaping nature in significant and often devastating ways. Marsh recognized that natural systems were particularly altered by human technology - whether the plough, the axe, the traction engine, or large scale irrigation and land reclamation projects. Marsh observed further that environments created by technology were often quite different from what had been intended, and degraded soils and weed-infested fields, though unanticipated, were frequent consequences of conscious human manipulation. Marsh did not discuss the role of humans in introducing new species of plants and animals to previously closed ecosystems, but this is an equally significant form of ecological intervention and may not always be detrimental. Such introductions may be purposeful (exotic crop species, domesticated livestock) or accidental (weeds, insect and rodent pests), but both may have unanticipated and far-reaching environmental consequences.

Man and Nature was widely read at the time of its publication, and helped fuel a forest conservation movement in Australia in the 1860s (Powell 1976, p. 55 ff.). Marsh's ideas about humans as the agents of environmental change were largely forgotten for the first half of the twentieth century, however, until they were rekindled in the 1950s (Thomas 1956). It slowly came to be acknowledged in the meantime that human societies are more than the passive products of their environments. The environmental historian Donald Worster borrows from the 1930s ideas of the German philosopher Karl Wittfogel in describing the relationship between humans and nature as "an ongoing spiral of challenge-response-challenge, where neither nature nor humanity ever achieves absolute sovereign authority, but both continue to make and remake each other" (Worster 1985, p. 22). Worster adds that the human responses to environmental challenges usually take the form of technological developments that help to overcome the natural limitations to human achievement. New environmental challenges arise in the form of human-induced erosion problems, for example, or declining soil fertility, or weed or pest infestations, or they may occur as 'natural hazards' such as droughts and floods.

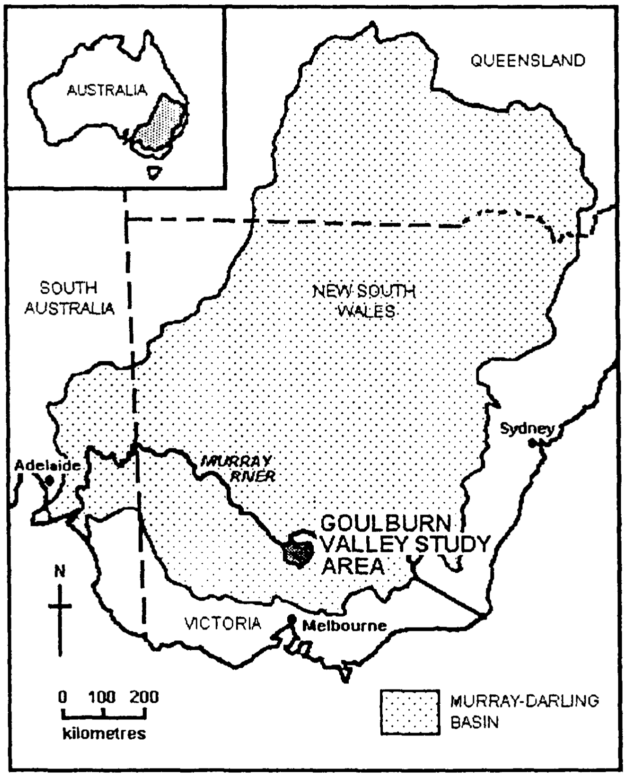
The challenge-response spiral has been described by Worster (1994, p. xi) in its simplest terms as a process of "discovery and adaptation" that arises from a "dialogue" between culture and nature. The dialogue or feedback process tends to be complicated, however, by the distorting effect of environmental perception. This was explained technically by Brookfield (1969, p. 53) to mean that "decision-makers operating in an environment base their decisions on the environment as they perceive it, not as it is. The action resulting from the decision, on the other hand, is played out in a real environment." The landscapes in which history unfolds, in other words, are both "real" and profound, and "not real," but projections or artefacts of historically-conditioned human expectations and hopes. Real environments obviously affect human societies, but perceived environments can nevertheless be more influential, and become the environments to which societies attempt to adapt. Both societies and environments may become unstable as a consequence, and as Worster (1994, p. xi) observes, a region can be quickly degraded by the processes of nature, by new technological breakthroughs, or by human folly.

1.2 The purpose of the study

This study is a systemic, multi-disciplinary examination of the historical relationships between humans and their environment in a particular region in south-eastern Australia known as the Goulburn Valley. The study documents the various changes wrought in the natural (biophysical) environment of the region as a result of human occupation and resource use activities, and the consequences of these changes for the region's inhabitants. It also examines the ways in which human expectations and ideas of the natural world have influenced these relationships, in an attempt to account for the seemingly inevitable emergence of potentially avoidable environmental problems. The natural history of the region is intertwined accordingly with a broader social and political narrative. The overall approach has been to consider the Goulburn Valley as a dynamic socio-agricultural system, while the hypothesis presented is that, throughout its European history, historical perceptions of the biophysical environment have rarely been in accord with the real or true nature of the region, and that this has been a significant source of systemic and environmental stress and instability.

As the geographical focus of the study, the Goulburn Valley is an important irrigated agricultural region in the State of Victoria, Australia (Figure 1.1). The original regional inhabitants were Aborigines, but since the late 1830s the Goulburn Valley has been occupied by increasing numbers of Europeans, who came initially as 'squatters' (pastoralists), later as 'selectors' (yeoman farmers), and, from the 1890s, as irrigationists. By Australian standards, the region has enjoyed great economic prosperity as a result of agricultural development, particularly in the twentieth century, but it is now increasingly subject to a range of environmental problems, most significantly land and water salinisation, that threaten the viability of

Figure 1.1: Location of the study area.



agricultural production in the future

The purpose of this thesis is to explain the causes of these environmental problems. Many of the biophysical processes involved have been long known, but this study attempts to provide a full understanding of them in a historical socio-political context. It is not intended to apportion blame for historical errors, as what should have been done in terms of land and water use in the Goulburn Valley is ultimately of less interest than what was done, and why.

1.3 Research method and materials

The approach taken in this thesis has been to document and discuss the social and environmental changes that occurred during the various phases of human settlement in the Goulburn Valley, and to relate these changes to the historical factors contributing to official and land-user perceptions of the regional environment and their resultant behavioural actions.

The basic 'data' is presented in the form of a narrative review of published and archival information, including both historical sources and contemporary interpretive studies. Historical literature was searched for references pertaining to the biophysical environment of the Goulburn Valley (including descriptions of the vegetation, soils, water resources, and general landscapes), and to land use within the region.

Sources included primary documents from explorers and travellers, early settlers, scientists and government officials, as well as numerous secondary sources including local histories, pamphlets and guides for prospective settlers, gazetteers and other books for armchair geographers, and parliamentary and other official papers published for the information of the general public. Since almost all sources were written for purposes other than specific environmental reporting, the information obtained tended to be incidental to the main focus of each document and the search procedure was necessarily opportunistic. Environmental observations also tended to be influenced by the subjectivity of the observers, although this was identified where possible, and indeed contributed to the understanding of how the Goulburn Valley was perceived by its historical inhabitants.

Graphical sources, including early survey maps held in the collection of the Department of Natural Resources and Environment and in the State Library of Victoria, were also examined. These provided some information on changing vegetation cover in the Goulburn Valley, although most historical maps indicated only the general localities of timbered areas and open grasslands, without specific annotations concerning vegetation type.

Twentieth century sources included soil survey reports, descriptions and maps of regional land systems (including objective information on climate, soils, physiography, vegetation and land use), annual reports and journal articles published by Victorian Government departments, parliamentary papers, and articles published in accredited scientific and academic journals.

A broad range of contemporary interpretive studies in Victorian history and historical geography was also consulted. as much of the information of relevance to this thesis has been covered previously, and in greater detail, by other authors.

The narrative component of the thesis is supported by an analysis of the complex relationships between human-induced environmental change and environmentally-induced social change, in an attempt to explain the observed patterns of resource use behaviour within each phase of settlement. This was undertaken using a systems approach incorporating basic theories of feedback relationships and nonlinear dynamics as a means of linking environmental perceptions to biophysical phenomena in space and time. The Goulburn Valley has been treated accordingly as a microcosm in which socio-political, technological, economic and personal factors have all operated to influence human perceptions of, and interactions with, the natural environment, with the interrelationships between these elements providing the explanatory key to environmental change. This is believed to be a new application of the theory of nonlinear dynamics, which was originally developed within the physical sciences (meteorology, fluid dynamics), but has been recently adapted by economists and social scientists as a means of modelling or explaining complex human organisational behaviour (e.g., Loye & Eisler 1987; Parker & Stacey 1995; Radzicki 1990; Senge 1990). It has also been applied towards the understanding of biological systems and holistic 'deep ecological' relationships (e.g., Capra 1996). In this instance, it has been employed to explain the complex relationships between humans and their environment, both real and perceived, and provides the underlying conceptual framework of this thesis.

It is hoped that this work provides, as a result, an enlightened perspective on the current troubled state of the Goulburn Valley. Moreover, the social and environmental interactions identified within the region should have broad implications for a much larger part of Australia. The factors that influenced human activities in the region were similar to those in many other parts of Victoria, and, indeed, the important changes that occurred in the Goulburn Valley occurred across much of the Murray-Darling Basin, the large agriculturally important region of south-eastern Australia of which the Goulburn Valley is a part.

The lessons to be learned from the Goulburn Valley, in terms of natural resource appraisal, land and water use and environmental degradation, could thus be applicable across a much wider area. Accordingly, this study should be of value, not only in providing an understanding of the success and failures of land and water management in the Goulburn Valley, but in the development of general sustainable resource use policies for the future.

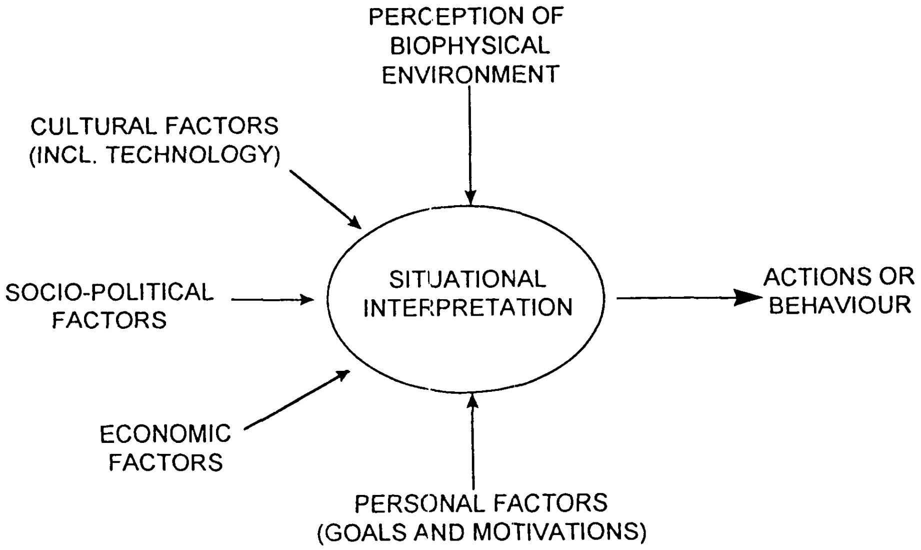
1.4 Conceptual framework

1.4.1 Environmental perception and situational analysis

How the natural (or biophysical) environment of a region is perceived by its inhabitants is a major theme of this thesis and, as suggested in the introduction, it involves much more than the physical act of seeing. To use Brookfield's (1969, p. 53) definition, the perceived environment is the entire 'surface' on which decision-making concerning natural resource use is based, and includes "natural and non-natural, visible and non-visible, geographical, political, economic and sociological elements." In a practical sense, it can be equated with resource appraisal, which at any given time in history is determined not only by the natural endowment of a region but by a society's needs and wants, as well as technological, cultural and economic factors. Sauer (1952, cited by Pigram 1972) observed accordingly that "natural resources are in fact cultural appraisals", and the perceived environment may be considered similarly - as a model of the real environment constructed from culturally-filtered information.

The perceived environment is thus not an objective feature of the world, but a subjective psychological phenomenon which may change - or not - in the light of new information, and which may be quite specific to each individual (Pigram 1972). This means that reconstructing historical perceptual environments can be problematical. Brookfield (1969), a geographer, points to the difficulty of identifying quantifiable taxa, since those normally employed to characterise real environments, such as biophysical or economic indicators, may have no relevance to a perceived environment. Berkhofer (1969), a historian, offers an alternative, 'situational' approach. This is a method of historical analysis which studies "the behaviour of the whole human being in reaction to the totality of the situation as interpreted by the organism in question" (Berkhofer 1969, p. 33). The basic data are the actions undertaken in relation to a situation, meaning that study is focused on dynamic processes rather than objects or individuals, and on overall situational responses rather than selected or predetermined components. The observer can nevertheless attempt to account for behavioural manifestations in terms of goals, motives, biophysical factors and the societal arrangements that contributed to the actor's assessment of the situation (Figure 1.2). This requires, necessarily, that the observer provide empirical evidence to support his or her interpretation of the situation.

Figure 1.2: Situational interpretation (after Berkhofer 1969).



In the Goulburn Valley, the environment was historically perceived at both 'official' and 'popular' levels throughout most of the period of European settlement (Heathcote 1965; Powell 1970a). This compounds the study of environmental perception, as historical resource use policies were based on governmental or bureaucratic perceptions of the regional environment, while actual resource use was based on the perceptions of the settlers themselves, who were obliged to operate within a regulatory framework but also made resource use decisions on the basis of other (e.g., economic, cultural and personal) factors (e.g., Hollick 1990; Pigram 1972, 1977). Powell (1970a, p. xx) observes that official and popular appraisals were sometimes directly opposed, while the overall character of settlement and land use at various times was largely the product of the interplay between them.

Berkhofer (1969) suggests that one means of implementing situational analysis to overcome this problem is to use systems theory as a basis for a conceptual model to explain various historical actions. This entails the study of basic organisational patterns and interrelationships that influence behaviour. A systems approach has been adopted accordingly in this study, since it allows for the real environment, factors contributing to environment perceptions at both official and popular levels, and the resultant resource use activities in the region to be linked in such a way that the interactions between them can be studied over time and the resultant actions understood in a holistic historical context.

1.4.2 Systems theory and nonlinear dynamics

A system is an integrated whole whose essential properties arise from the relationships between its parts. Alternatively, it is a pattern or configuration of ordered relationships, the nature of which depends on the system: a biological system, for example, might be based on the transfer of oxygen or adenosine triphosphate (ATP), while human social and political systems are connected by flows of 'information' or ideas (e.g., Brookfield 1969; Capra 1996, p. 27). These systems are examples of thermodynamically 'open' systems, in which matter (or energy or information) continually enter from, and exit into, the external environment in which the systems operate[1]. System functioning involves the transformation of inputs into outputs (including intellectual products), which provides energy to reactivate the cycle, thereby enabling the system to maintain its internal structure and preventing the accumulation of entropy, which would otherwise bring about eventual system disintegration[2] (e.g., Katz & Kahn 1969).

The analysis of systems involves tracing the patterns of energy exchange, or, in social systems, of the behavioural activity of people to produce some output, and ascertaining how the output is translated into energy which reactivates the process and thereby maintains the system. This requires that the system components (including subsystems) be identified along with the boundaries of the system and the nature of its interactions with the external or operating environment (Berkhofer 1969; Katz & Kahn 1969). A systemic model of the Goulburn Valley is presented at the end of this chapter, but as Capra (1996, p. 37) notes it is the relationship between the system components, rather than the components themselves, that are important and provide the key to analysis. These are discussed throughout the later chapters of this thesis.

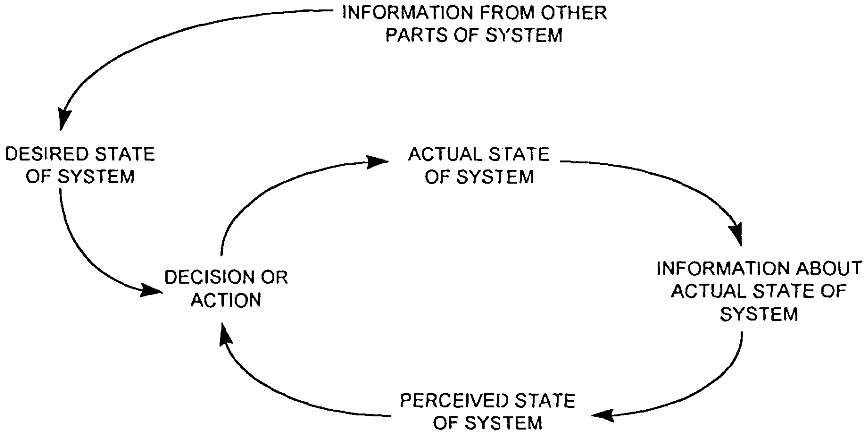
The most general and fundamental property of all systems is the interdependence of their components. In complex, multi-levelled systems, such as ecosystems or human societies, all components are interconnected by a vast and intricate network of 'feedback' relationships. As depicted in Figure 1.3, these are abstract cybernetic linkages which convey information about the outcome of any process or activity

---

[1] 'Closed' systems, by contrast, have no contact with external phenomena, and tend to function in a state of thermodynamic equilibrium (e.g., von Bertalanffy 1969).

[2] Entropic process is a universal law of nature in which all forms of organisation move towards disorganisation (i.e., in biological systems, death)(Katz & Kahn 1969)

Figure 1.3: Simple feedback loop (after Radizicki 1990).



of circular causality, and may be either negative (stabilising, or balancing) or positive (destabilising, or reinforcing). Negative feedback means that a change to a component in the system leads to consequences in which the change is ultimately offset or cancelled out. This has a 'dampening' effect on the system which, in the absence of disturbances from the external or operating environment, will cause a system to move towards a stable point or equilibrium, in which the components of the system interact with one another and with the external environment in relatively constant fashion (e.g., Berkhofer 1969, p. 181; Feibleman & Friend 1969; Parker & Stacey 1995, p. 7, p. 26). Systems operating on negative feedback thus tend to be adapted to the circumstances in which they exist, but are inflexible (and hence prone to disintegrate) if external conditions change significantly. Positive feedback, by contrast, reinforces change by widening the gap between actual and intended outcomes. Systems incorporating positive feedback loops thus tend to function in a state out of equilibrium with their external environment. Positive feedback is exemplified by the 'vicious circle,' although it also allows for systemic development and adaptation if environmental conditions change. Natural systems, such as ecosystems, comprise multiple examples of both kinds of feedback, which collectively enable a system to remain stable after a disturbance, thus conferring flexibility in a world that is constantly changing (Capra 1996, p. 302).

Natural systems are particularly complex because of their numerous components, which are usually systems in themselves. This is also true of human societies and political and economic systems (Loye & Eisler 1987; Radzicki 1990; Parker & Stacey 1995). Such complexity characterises these systems as nonlinear, meaning that events or actions may have multiple possible outcomes. These may occur in different parts of the system, or over time as the effects become amplified by interdependent positive feedback loops. Simple linear explanations of causality are generally inadequate for such systems, as the direct links between causes and effects often become obscured (Capra 1996, p. 298; Rappaport 1977; Senge 1990, p. 71). Small external disturbances or the actions of an individual component can also lead to large and unforseen changes in the behaviour of an entire system, as small changes build on themselves. This phenomenon is known in theories of nonlinear dynamics as the 'butterfly effect' (after the quasi-serious suggestion that eddies created by butterflies can affect entire weather systems). Radzicki (1990) suggests that it is evident in social systems throughout history, as the extraordinary actions of individual people have led to technological breakthroughs and substantial social changes.

The presence of positive feedback loops means that nonlinear systems generally exist in a state far from equilibrium - that is, they remain unadapted to the environment in which they operate, as the interactions between the system and the environment are constantly out of balance (Feibleman & Friend 1969; Parker & Stacey 1995, p. 6). Such systems nevertheless possess a capacity for self-maintenance (an essential feature if they are to exist for any conceivable length of time), and are characterised by a stable organisational structure. This is determined by the internal purpose of the system (rather than by external impositions), and is maintained thermodynamically by the continual flow of energy or information from the external enviroment, while overall system functioning is controlled by the various negative and positive feedback loops (Capra 1996, p. 167; Loye & Eisler 1987; Radzicki 1990). Systems of this type (self-regulating, open, operating far from equilibrium) are known in the field of nonlinear dynamics as 'dissipative systems', as they maintain and sometimes increase their structural complexity at the expense of greater disorder (or entropy) in the environment in which they operate. (Such systems are thus said to import 'negentropy' - i.e., negative entropy)(e.g., Chase 1985; Swaney 1985)

Capra (1996, p. 189) likens dissipative systems to "islands of order in a sea of disorder". Examples include such natural phenomena as whirlpools and tornadoes, as well as living systems, which obtain highly ordered food resources from their external environment for metabolic purposes and dissipate less complex waste products in return. Social and economic systems may also function as dissipative systems - for example, when new information is discarded as humans form expectations or preconceptions (Parker & Stacey 1995, p. 26; Radzicki 1990). Chase (1985) notes that the law of entropy prevents dissipative systems from existing at constant levels of output and systemic complexity for any significant period, as the supply of available inputs is inevitably reduced by the system, leading to its eventual collapse through entropic degradation. This law also appears to apply to social systems, suggesting that even if a fixed or lower level of output (and hence of structural simplicity) is volitionally chosen, eventual resource limitations will require that knowledge and technical ability advance so as to generate the necessary negentropy for system functioning to continue. In this way, system complexity necessarily increases (Chase 1985).

Dissipative systems can also be defined in terms of attractors (Radzicki 1990). In spatio-temporal terms an attractor is a point, or set of points, that defines the evolutionary path of a dynamic feedback system. Nonlinear systems may have several attractors, which may be of different types, including 'normal' (the equilibrium point of a system), 'periodic' (causing repeated or cyclic behaviour), or 'strange' (or 'chaotic') attractors. The latter occur between the boundaries of stability and instability and are responsible for complex or unpredictable system behaviour, as a system may switch abruptly to a new attractor if its initial attractor becomes unstable or if another attractor emerges (Parker & Stacey 1990, p 18; Radzicki 1990). Attractors serve nevertheless to constrain the behaviour of dynamic systems and contribute to their structural stability. Capra (1996, p. 136) observes accordingly that the qualitative analysis of a dynamic system essentially consists of identifying its main attractors - which in the context of this thesis equate to the (combinations of) factors influencing environmental perceptions of the Goulburn Valley during the various phases of settlement.

The switch to a new attractor generally occurs when system variables are pushed past some threshold level or tolerance limit (variables being single-dimension parameters or, in social systems, components of perceptions, such as values or needs)(Berkhofer 1969, p. 181; Parker & Stacey 1995, p. 17; Radzicki 1990). This may occur as a consequence of external disturbances to the system, amplifying positive feedback, or shifts in the dominance of certain loops within the system (e.g., as new goals are introduced, or new technologies are discovered) (Radzicki 1990). Such events cause the system as a whole to become unstable and approach a critical stage, known as a bifurcation point, at which relationships between components begin to break down. A period of uncontrolled, 'chaotic' behaviour may then occur, after which new feedback loops form, such that a new system (or systems) with a new structure emerges. A bifurcation point is thus a 'threshold of stability' (Capra 1996, p. 191) at which a dissipative system may either collapse or progress through to one of several new possible structural orders. This is an evolutionary process, and according to Loye and Eisler (1987), critical bifurcations in history have occurred when significant shifts in human consciousness or social structure have occurred in the wake of major conflicts. On a grander scale, Capra (1996, p. 232) observes the striking pattern in the evolutionary biology of the Earth of repeated catastrophes (bifurcation points) followed by intense periods of growth and development. A suggested example is the catastrophe that caused the extinction of the dinosaurs 66 million years ago, which paved the way for the evolution of primates and, ultimately, humans.

The current structure of a dissipative system amounts to a record of previous bifurcations, or structural changes, and of previous interactions with the external environment. The existing structure also determines the new structural options available after a bifurcation, but does not necessarily specify the particular reorganisations that will occur, or the evolutionary path that will be taken (Capra 1996, p. 182, p. 220; Radzicki 1990). In natural systems, an "irreducible random element" exists at each bifurcation point, so that not all structural changes will necessarily be adaptive to the external environment of the system and further bifurcations may ensue. The range of developmental options available in each instance may nevertheless include systemic structures that are potentially adaptive to changed environmental conditions (Capra 1996, p. 236). In social systems, by contrast, the existence of human will permits the volitional selection of particular developmental paths, although the choice remains limited by the range of feasible paths consistent with existing technological or cultural parameters (Chase 1985).

Rappaport (1977) notes that not all structural changes need occur as a result of bifurcations. Slow changes in parameters or variables within a system may trigger minor functional adjustments (i.e., reorganisations of feedback loops) while the system attractors remain relatively constant. Such systems are 'structurally stable', as their basic characteristics remain unchanged (Capra 1996, p. 136).

Ongoing structural changes that occur in response to environmental changes comprise an adaptive process that Capra (1996, p. 218) terms 'structural coupling'. This may be considered a form of systemic learning and is characteristic of all living systems, whether biological or social. Not all systems are structurally coupled to the environment in which they operate, however, as not all environmental changes bring about structural changes. As Capra (1996, p. 267) observes, it is the organism or system, rather than the environment, which determines which stimuli will bring about a structural response. This is because not all changes in the environment can be detected, or are of relevance or interest to the system. In other words, many disturbances do not cause structural changes because they are 'foreign' to the system and are not perceived because the system is not attuned to them (hence 'information' is not the same as 'knowledge')(Capra 1996, p. 267; Katz & Kahn 1969). Structural coupling is thus a cognitive process in which both the perceptions and actions of a system are reflected in the resultant structural changes. Cognition in this sense corresponds to Berkhofer's concept of 'situational interpretation', in which systemic behaviour is seen as a manifestation of the various factors influencing the perception of the environment (biophysical and otherwise) in which the system operates (Berkhofer 1969).

The adaptation or otherwise of a system to its operating environment is thus a process of cognition. As Rappaport (1977) observes, this is essentially cybernetic, as information perceived by the system concerning stressful changes to system components or aspects of the external environment initiates behavioural responses aimed at ameliorating those changes. Corrective actions may involve the elimination of the stressor, compensatory adjustments, or major changes within the overall organisational structure of the system. These are adaptive if they contribute to the ability of the system to maintain itself in the face of further perturbation (which will inevitably occur as environmental conditions constantly change to varying degrees). Maladaptations may also occur, however, if anomalies occur in the cybernetic structure of the system that impede its responsiveness to stress. Rappaport (1977) identifies simple forms of maladaptation as breaks in feedback loops, impediments to the detection of variables outside critical ranges, excessive delays in information transmission, loss or distortion of information in transit, and the failure of regulatory components to interpret the signals being received. This latter problem may particularly occur in social systems, in which regulatory structures tend to be hierarchically organised, and may be exacerbated by scale (i.e., the number of nodes through which the information is required to travel). Rappaport (1977) observes accordingly that while adaptive processes have cybernetic characteristics, not all that is cybernetic is necessarily adaptive. This has implications for the study of the Goulburn Valley, as the hypothesised mismatches between the real and perceptual environments are postulated to have resulted in various systemic maladaptations, and may be considered accordingly as a fundamental cause of the region's present-day environmental problems.

1.4.3 A systemic model of the Goulburn Valley

The theories of nonlinear system dynamics outlined above offer a powerful explanatory framework to support the 'situational approach' to historical analysis proposed for this study. On this basis, the key to understanding historical perceptions of the Goulburn Valley and the resultant environmental changes in the region appears to lie in the interactions of the various historical inhabitants with the biophysical environment, and in the adaptiveness or otherwise of the various structural changes that occurred within the regional socio-agricultural system during the various phases of settlement.

The system itself is proposed to consist of the cybernetic relationships between an official or policy-making component and a collective of landholders operating within the geographical region of Australia known as the Goulburn Valley. The two major system components are each subsystems in themselves, with the official component including various government agencies, as well as colonial, State and Federal Governments and, in some case, influential individuals responsible for certain historical policies. Although more anonymous, each landholder also represents a distinct management unit (i.e., a farm) within the overall collective 'landholder' component of the system.

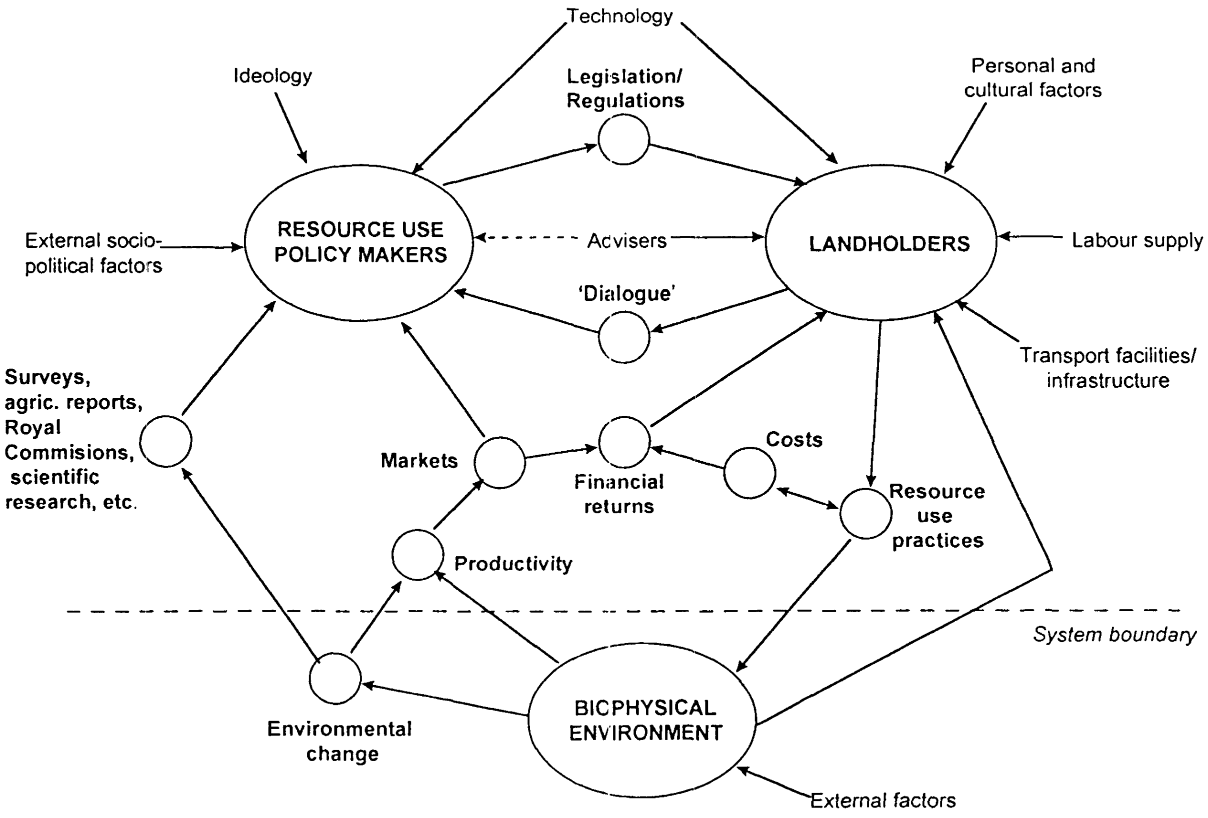
The regulatory structure of the system is hierarchical, with the official (higher order) component primarily responsible for regulating relations among subordinate components in order to promote the general goals of the system (Rappaport 1977). Landholders occupy the lowest order and regulate specific or material variables. They are thus responsible for the direct interactions between the system and the biophysical environment. As Rappaport (1977) notes, however, the operations of lower order components are generally guided by goals or considerations established from 'above', which in the Goulburn Valley tended to occur in the form of either official directives or market economic demands. It can also be observed that in proceeding from lower to higher order components, the degree to which operations are determined by environmental or other technical factors tends to diminish in favour of more abstract concerns, such as ideological matters (Rappaport 1977). This was the case in the Goulburn Valley, where system goals (and resultant land use policies) were strongly influenced throughout the nineteenth and early twentieth centuries by agrarian idealism.

Direct interactions between landholders and the regional environment occurred primarily in the form of pastoral and agricultural operations, including, from the 1880s onwards, irrigated horticulture and dairying. Material and energic inputs to the system thus included solar energy, soil, water, natural and introduced pasture and crop species, and introduced domestic animals; outputs included wool, meat, milk, grains, fruits and other forms of agricultural produce, as well as waste products including the effluent from irrigation farms. Other systemic transactions with the biophysical environment were informational in nature. These also involved landholders, but also government agents, surveyors, engineers and scientists at various times, with the appraisals of each group contributing to overall perceptions of the region at both official and popular levels.

Feedback relationships within the system, and between the system components and the biophysical environment of the Goulburn Valley, were complex, involving different types of regional appraisals and direct and indirect forms of information transfer. Not all loops were fully functional, which contributed to systemic stresses and maladaptive interactions with the biophysical environment. Stresses also arose from internal conflicts over system goals between officials and landholders within the region.

The overall conceptual model of the Goulburn Valley as a socio-agricultural system can be depicted graphically as follows (Figure 1.4), and provides the basis for the study of the environmental history of the region throughout its European history (i.e., from the 1830s to the present), as presented in this thesis. A different model necessarily applies to the period of Aboriginal occupation, since the various population groups that inhabited the region, although structured hierarchically into several organisational levels, were all essentially self-governing, without separate administrative or policy-making bodies (see Chapter 3). As with European landholders in the ensuing chapters, Aboriginal society is treated accordingly in this study as a collective - and hence single - social component in terms of its interactions with the biophysical environment.

Figure 1.4: Conceptual model of the Goulbum Valley as a socio-agricultural system.



CHAPTER 2

THE STUDY AREA

2.1 Geographical overview

For the purposes of this study, what is referred to as the 'Goulburn Valley' is an area of the State of Victoria, Australia, which comprises the northern third of the catchment of the Goulburn River (Figures 2.1, 2.2). Despite its name, the region is not so much a valley as an area of flat, relatively featureless riverine plain. It is predominantly rural in character, and approximately two-thirds of the land is irrigated with water derived from the Goulburn River.

The study area extends across approximately 2,500 square kilometres, and essentially comprises the Shepparton and Central Goulburn irrigation areas of the greater Shepparton Irrigation Region (SIR)(Figure 2.3). To the west, it extends almost as far as the Campaspe River; to the east, it is bounded by the East Goulburn Main Channel; northern boundaries are formed by the Murray River and Broken Creek; the Waranga Basin storage forms part of the southern perimeter. In local government terms, the region includes the City of Greater Shepparton, as well as parts of the Shires of Campaspe, Moira and Strathbogie[1]. West of the Goulburn River, the region also encompasses much of the County of Rodney (Figure 2.4), which was a designated Statistical District of northern Victoria until 1978, and is the source of most of the historical agricultural statistical information cited in this thesis[2].

Principal population centres within the Goulburn Valley include the cities of Shepparton, Mooroopna and Kyabram, the towns of Murchison, Tatura and Nathalia, and various smaller hamlets including Ardmona, Congupna, Girgarre, Katandra, Merrigum, Stanhope, Tongala, Tallygaroopna, Undera and Wyuna. The region also includes over 4,300 irrigation farms (held predominantly under freehold title), and has a current total population in excess of 100,000 people (Goulburn-Murray Water 2001).

The original inhabitants of the region were Aboriginal people, but from the beginning of European settlement (which occurred from 1838 onwards) the region has been subject to increasingly intensive agricultural development, including the introduction of irrigated agriculture from the late 1880s. The natural ecosystems of the region have been altered extensively as a result, particularly in terms of hydrology, while many economic and social benefits have been realised, both locally and nationwide.

---

[1] Prior to 1994, when the organisation of local government in Victoria was revised, the region included the City of Shepparton, Shire of Rodney, and parts of the former Shires of Shepparton, Waranga, Nathalia, Numurkah, Deakin and Goulburn (Figure 2.4).

[2] In 1978, when revised statistical divisions were adopted in Victoria, Rodney was incorporated into the Goulburn Statistical Division (*Victorian Year Book* 1979).

Economically, the Goulburn Valley is one of the most significant agricultural areas in the nation, and because of the abundance and variety of primary produce grown in the region during the twentieth century, it has been described as both the "garden" and the "foodbowl" of Australia (McLennan 1936, p. 31; SIRLWSMP 1997). Irrigated agriculture and the processing of agricultural produce provides the mainstay of the regional economy, with annual economic output in the greater Shepparton Irrigation Region (including some districts outside the study area) being in the order of A$4.5 billion (SIRLWSMP 1997).

The dominant physical feature of the region is the Goulburn River, which has been the major geographical influence on the settlement history and economic development of the Goulburn Valley, as will be seen in subsequent chapters of this thesis. The river is approximately 560 kilometres long from its source near Woods Point, in the snowfields of the Central Victorian Uplands, to its confluence with the Murray River near Echuca (Figure 2.2). From Eildon Weir to Echuca, the distance is 430 kilometres, and the river flows through open farmland along much of this length. Upstream from Seymour, the valley narrows; downstream from Nagambie the river meanders across a wide, open floodplain.

In terms of both length and annual discharge (3 million megalitres), the Goulburn is the largest of Victoria's rivers, and is a major tributary of the Murray River, contributing 11 per cent of that river's stream flow (GWQWG 1996). The Goulburn Valley thus forms part of the much larger Murray-Darling Basin, the agriculturally vital region of Australia which spreads over one-seventh of the continent (see Figure 1.1, page 3). Although more fertile and climatically temperate than the rest of the Murray-Darling Basin, the Goulburn Valley shares some of the environmental characteristics of the Basin as a whole, including predominantly flat terrain, low rainfall and runoff, variable river flows (now managed by dams and irrigation), fragile soils of low fertility, unproductive native vegetation, and an unpredictable climate. The settlement history of the Goulburn Valley is also typical of the broader region: encouraged by government idealism, Europeans cleared much of the land in order to farm it, and then developed irrigation schemes, based on the diversion of snowmelt from the Great Dividing Range, to provide them with an assured water supply. The result, for both the Goulburn Valley and the Murray-Darling Basin as a whole, has been great regional economic prosperity, but also a deteriorating resource base and potentially reduced agricultural productivity in the future (e.g., Lawrence & Vanclay 1992).

Figure 2.1: The Goulbum Valley study area.

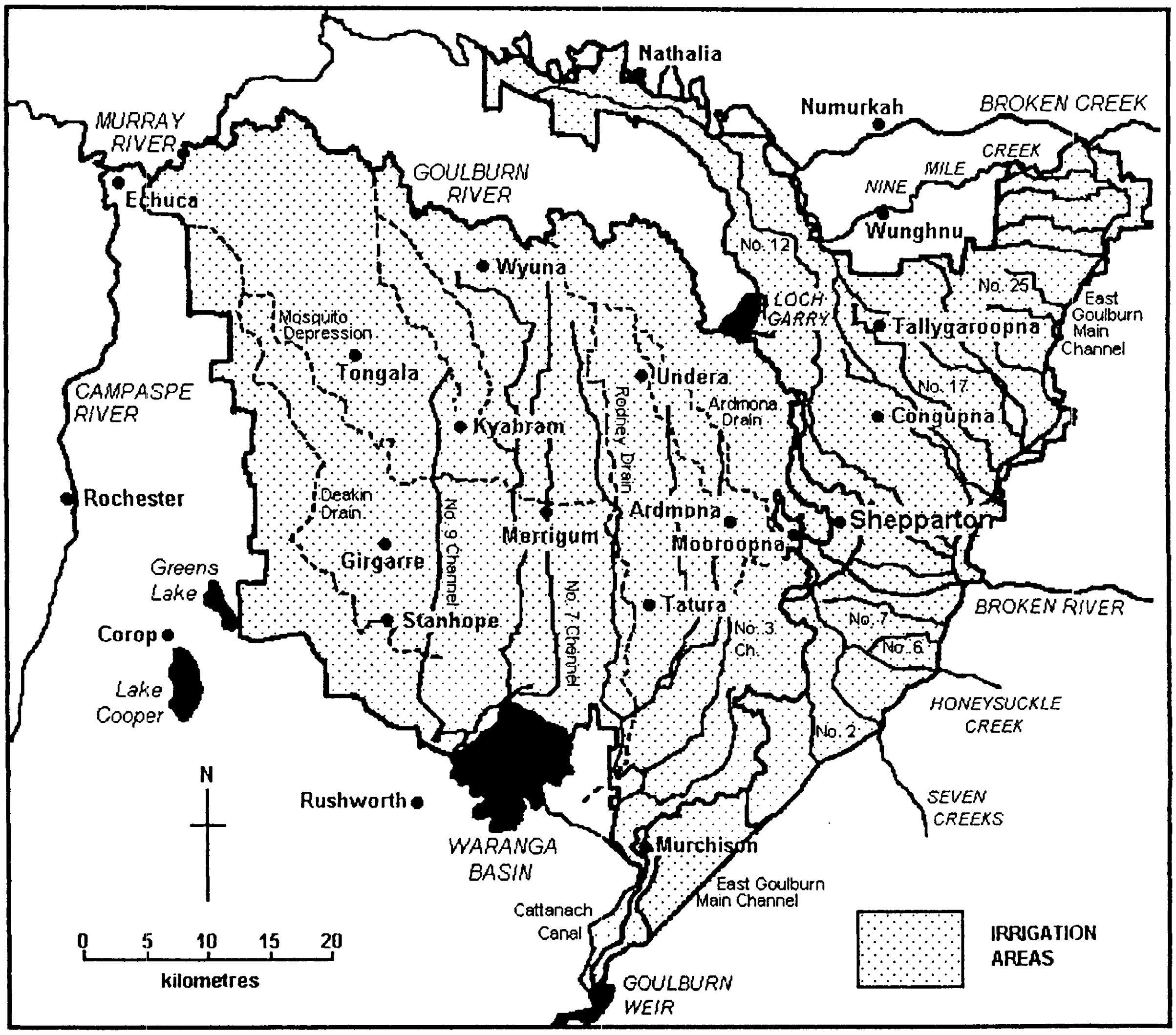


Figure 2.2: Location of the study area within the Goulbum-Broken catchment.

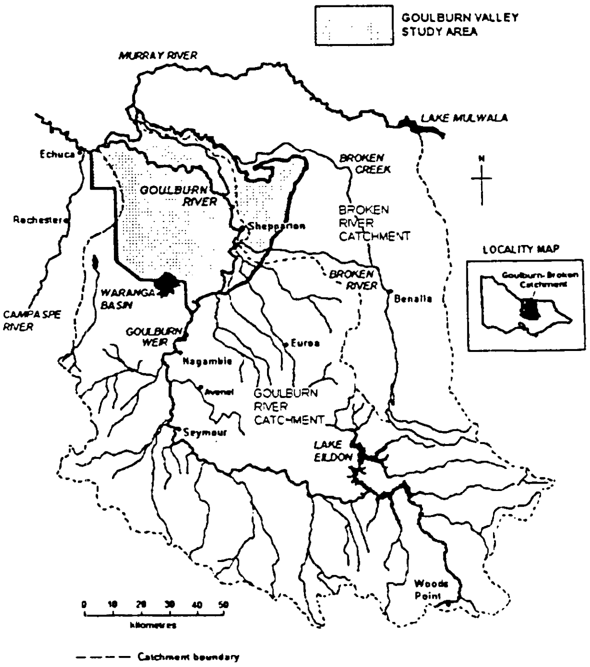


Figure 2.3: Irrigation areas within the Shepparton Irrigation Region (SIR).

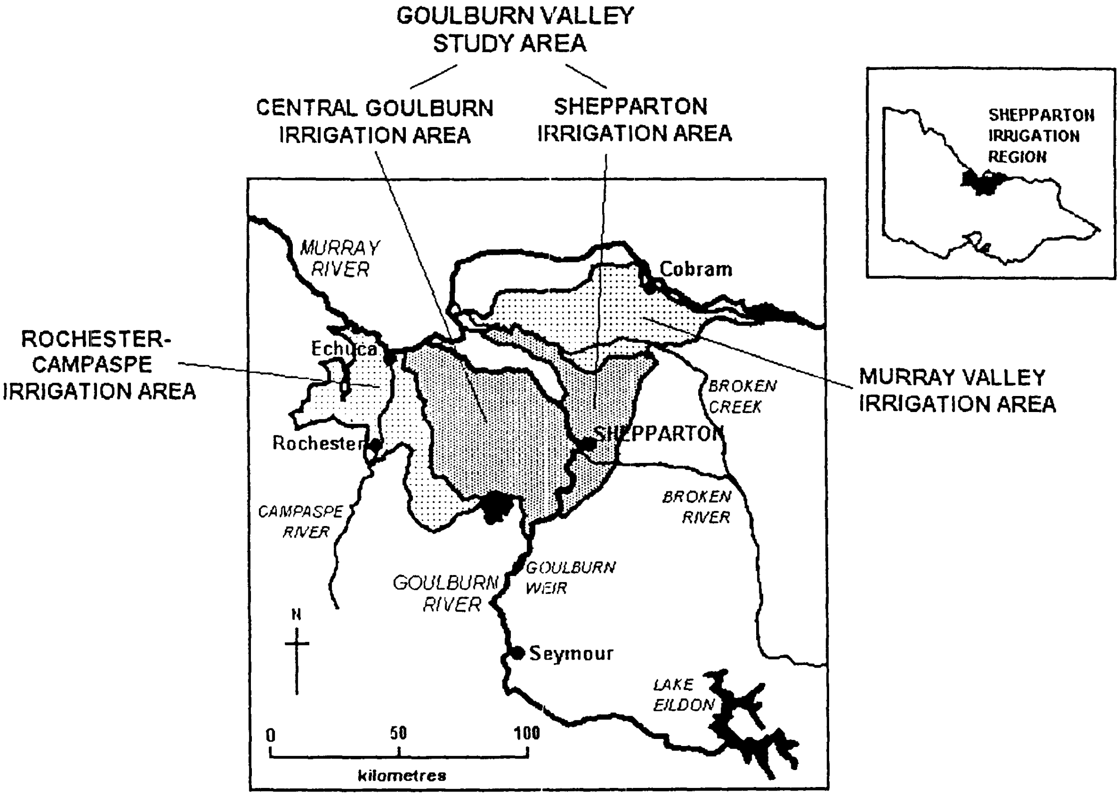
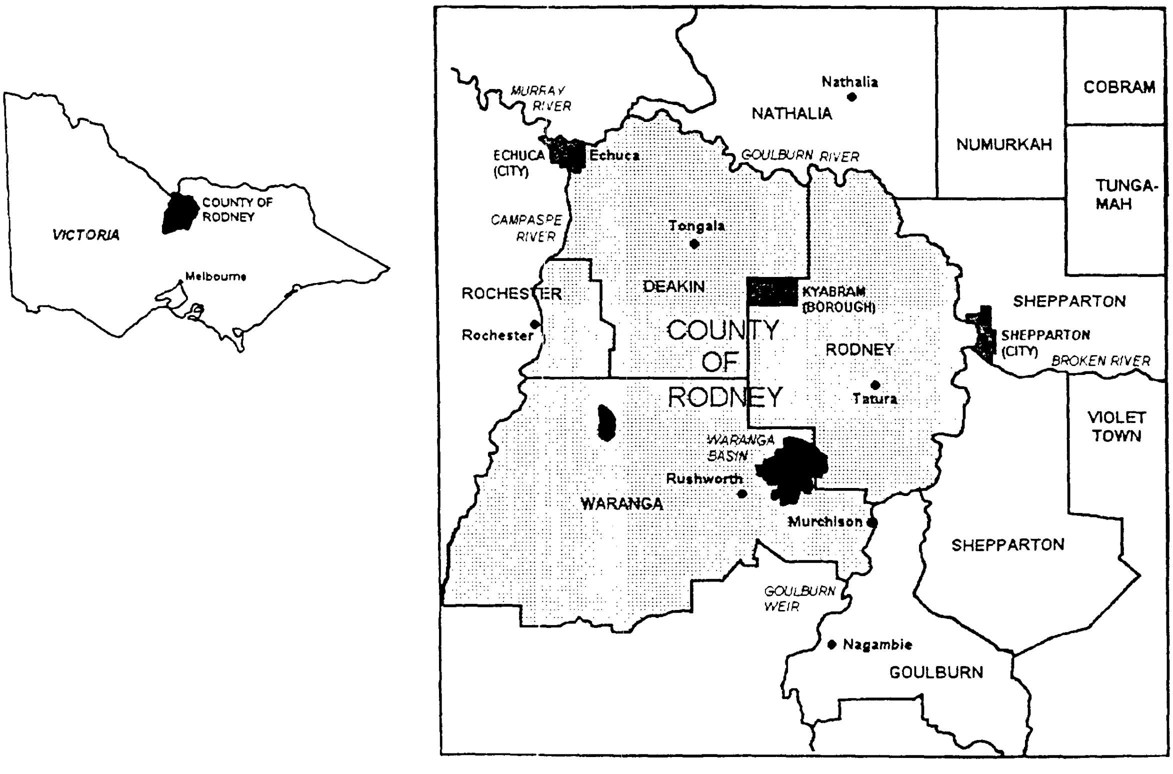


Figure 2.4: County of Rodney and former (pre-1994) local government districts in the Goulburn Valley.



2.2 The biophysical environment

2.2.1 Geomorphology and geology

In geomorphic terms, the Goulburn Valley comprises an area of Riverine Plain in the eastern part of the Murray Basin (Figure 2.5). It consists of a flat[3] and topographically relatively featureless landscape formed from a thick sequence of Quaternary alluvium laid over subsided Tertiary sediments and Paleozoic bedrock. The most outstanding geological feature is a complex of stream channels, both ancient and recent, which correspond to three distinct phases of fluvial activity within the present day Goulburn River catchment. These channels attest to the importance of water in the geomorphic history of the region (Bowler 1990), and they have also had a profound influence on both agricultural land use and present-day hydrological problems, as will be seen in later chapters of this thesis.

The Murray Basin as a whole arose as a distinct tectonic and depositional unit in the Early Tertiary (Lawrence & Abele 1988). It was inundated by the sea several times during that geological period, after which large rivers flowed across the resultant depositional plains from the southern highlands. These carved deep valleys that slowly filled with coarse alluvial sands and gravels, as drainage was occluded in the Late Tertiary by geological activity to the west (i.e., the laying down of sediments in what is now the Mallee, in association with the final retreat of the sea from the western Murray Basin). During subsequent depositional periods, the river courses were buried at depths of 60 or more metres below the surface. Known as the Calivil Formation by geologists, and 'deep leads' by early miners, these ancient channels are of minor significance to the present-day landforms of the Goulburn Valley, but they are hydrologically important as they provide highly permeable underground conduits for groundwater draining away from the highlands towards the north (Figure 2.6)(Macumber 1978a). Hydrological intake areas of the Goulburn Valley include the entire highland tract of the Goulburn River, and the 'deep lead' system extends northwards through Nagambie, Arcadia, Toolamba and Shepparton, where it has a width of approximately six kilometres (Macumber 1978b).

The alluvial sediments that overlay the Tertiary formations in the Goulburn Valley are subdivided geologically into the older and more extensive Shepparton Formation, and the younger Coonambidgal Formation (Jenkin *et al.* 1988). The Shepparton Formation is an extensive depositional plain, 80 to 120 metres thick, comprised of Quaternary alluvial clay, silt, sand and gravel derived from the adjacent uplands and deposited by a system of 'prior streams'. Unrelated to the present-day rivers that traverse the riverine plain, these streams flowed over 30,000 years ago and can be traced as shallow meandering depressions flanked by low levees that have been eroded to varying degrees (Jenkin *et al.* 1988). Bowler (1978) notes that the gravel-filled channels of eight such streams or their remnants can be identified

---

[3] From Echuca to Shepparton, a distance of 60 kilometres, elevation varies by only 18 metres, and similar, extremely low gradients are maintained throughout the region (Bowler 1978).

below ridges of aeolian sand and clay deposits on the plains between the Goulburn and Campaspe Rivers (Figure 2.7). The prior streams arose at a time when the riverine plain was a vast internal drainage basin, and their courses changed at various times as a result of climatic changes (Jenkin *et al.* 1988). Flow rates slowed with decreasing gradients and increasing aridity, while cycles of flooding produced depositional patterns of coarse 'meander floodplain' sediments immediately adjacent to natural levees, and finer 'cover floodplain' sediments further from the stream courses (Figure 2.8). The oldest sediments were eventually buried, the permeable 'meander floodplain' sediments becoming sub-surface aquifers that traverse the present-day landscape at depths of up to 30 metres (Figure 2.9) (Gutteridge *et al.* 1970). Some of these aquifers are filled with fresh water, others (usually older and deeper) tend to be saline, the salt having been contributed by rainfall over several million years at annual rates of up to 40 kilograms per hectare (cited by Barr & Cary 1992, p. 221).

Some areas of the Shepparton Formation are overlain by the more recent Coonambidgal Formation, which was deposited between 30,000 and 8,000 years ago by rivers that are considered 'ancestral' to the present day river systems and flowed within valleys eroded into the existing flood plain (Ife 1978; Jenkin *et al.* 1988). In the Goulburn Valley, these ancestral rivers may be traced as linear deposits of sediment up to 20 metres thick, and they tend to be closely associated with the present day Goulburn River, with the exception of the most northerly reaches that were affected by tectonic activity along the Cadell Fault during the Pleistocene (Bowler 1978). The deposits of the Coonambidgal Formation reflect this activity, as well as the influence of earlier landforms, such as the alluvial ridges built up by the prior streams. These posed barriers to subsequent drainage, and contributed to the deposition of the Coonambidgal Formation. Changing climatic conditions, including a major glacial period (which began prior to 35,000 years ago and peaked around 18,000 years ago before waning again) also played a role in the deposition process. According to Jenkin *et al.* (1988), the morphological characteristics of the various stream systems suggest that the climate was relatively dry prior to 30,000 years ago (i.e., during the deposition of the prior streams), while the depositional features of the Coonambidgal Formation reflect a period of higher stream flows and runoff, indicating that the prevailing climate was probably wetter than both previously and at present.

Lesser climatic oscillations also occurred during the deposition of the Coonambidgal Formation, resulting in three distinct fluvial phases associated with variations in stream discharge, as well as localised patterns of soil type reflecting the underlying sediments (Bowler 1978; Gutteridge *et al.* 1970). The oldest of these phases (Phase I, also known as the Green Gully-Tallygaroopna complex) was formed over 30,000 years ago, when the streams were fast flowing and relatively straight, and carried large volumes of sand and gravel. Their courses can now be traced as linear sand and gravel ridges. The second (Phase II, or Kotupna) flood plain dates from between 30,000 to 15,000 years ago, and comprises most of the river flats between Shepparton and Mooroopna. This Phase is also characterised by high sediment loads. The most recent Phase (also known as the Goulburn complex) dates from about 15,000 ago, when drier climatic conditions prevailed. The channels of this complex are narrow and sinuous, and carried silts and clays rather than coarser sediments. The present day Goulburn River, which dates from about 8,000 years ago, meanders along this third ancestral river depression, at a level of three to four metres below the level of the surrounding flood plain (Bowler 1978; Ife 1978).

Figure 2.5: The Murray Basin (after White 1997).

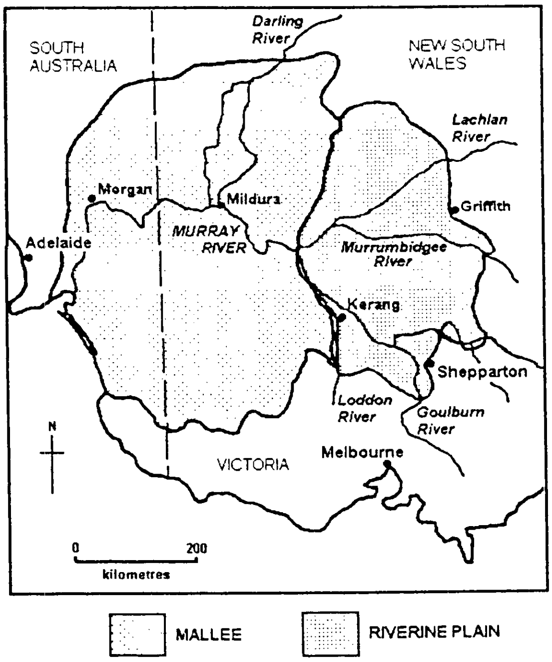


Figure 2.6: 'Deep leads' (Calivil Formation) under the Riverine Plain (from Macumber 1978a).

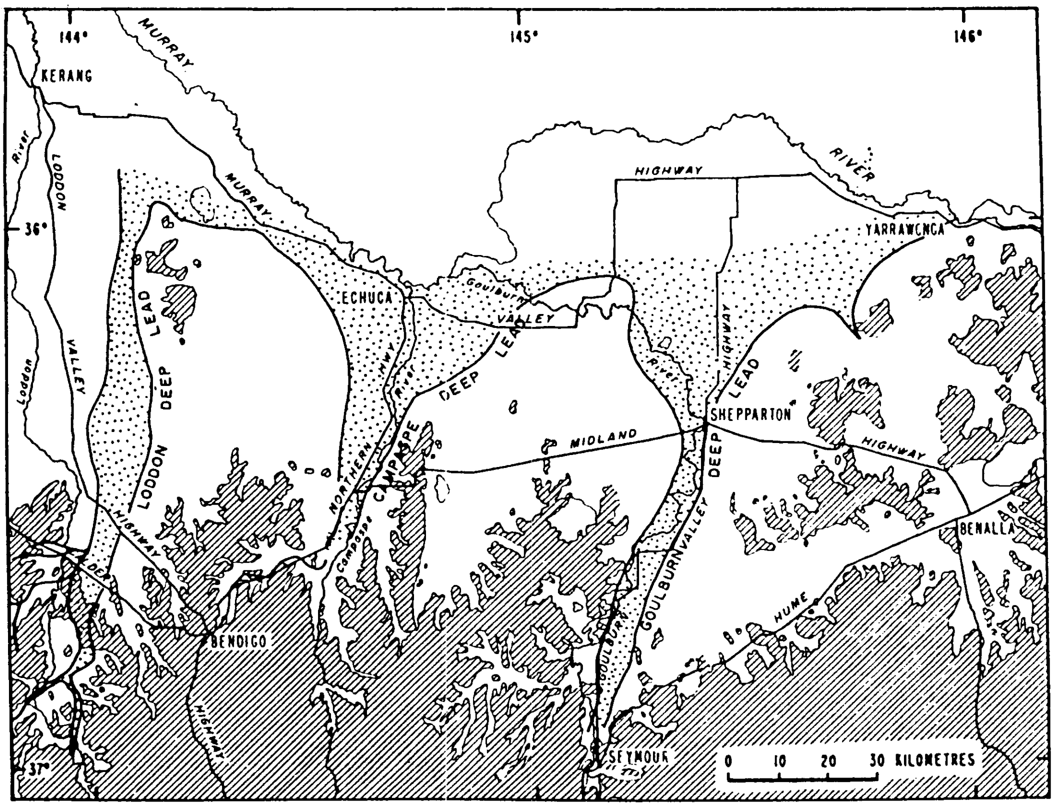


Figure 2.7: Geomorphic map of the Riverine Plain between Shepparton and Echuca (after Bowler 1978).

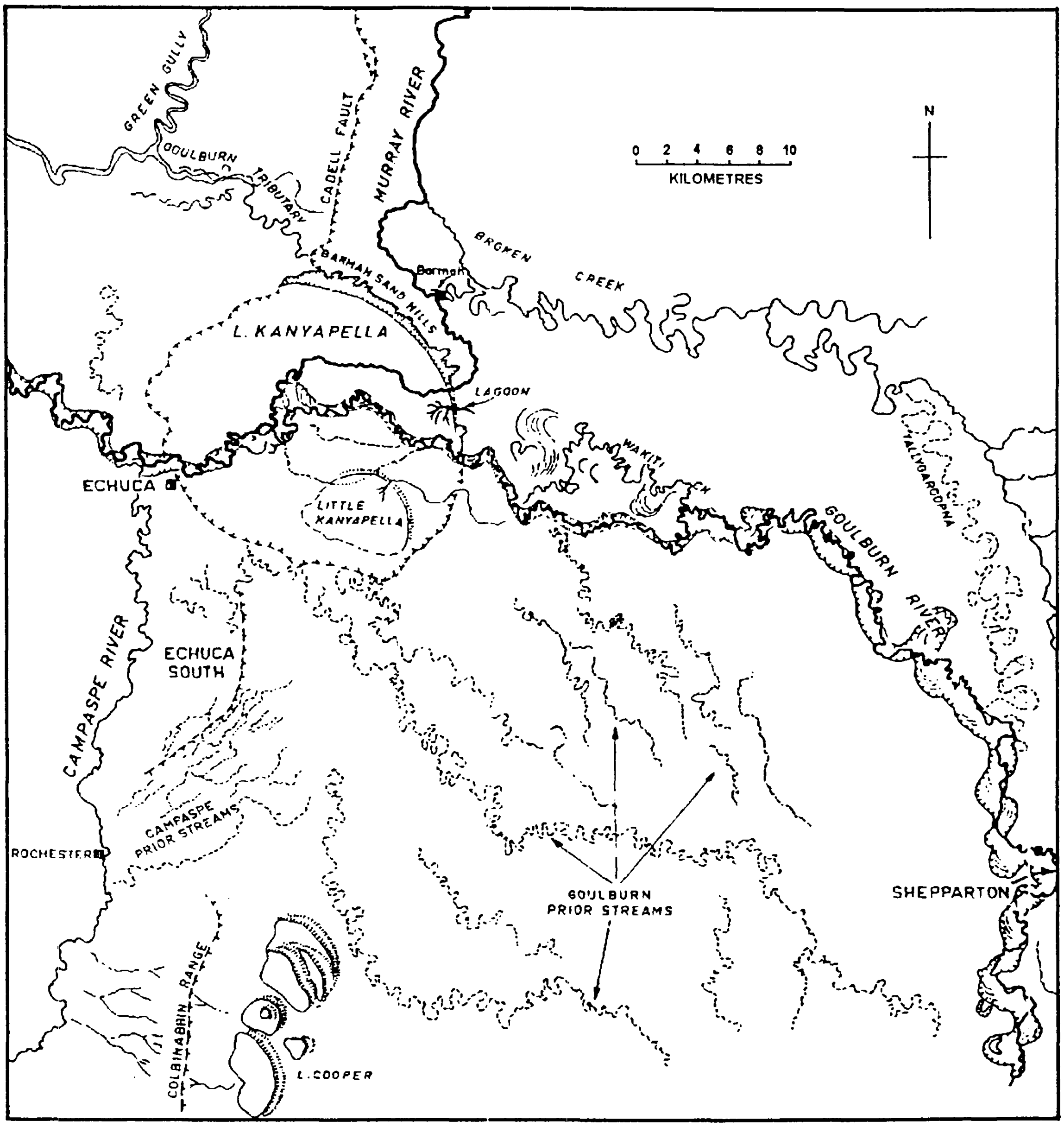


Figure 2.8: Prior stream depositional patterns (after Gutteridge *et al.* 1970).

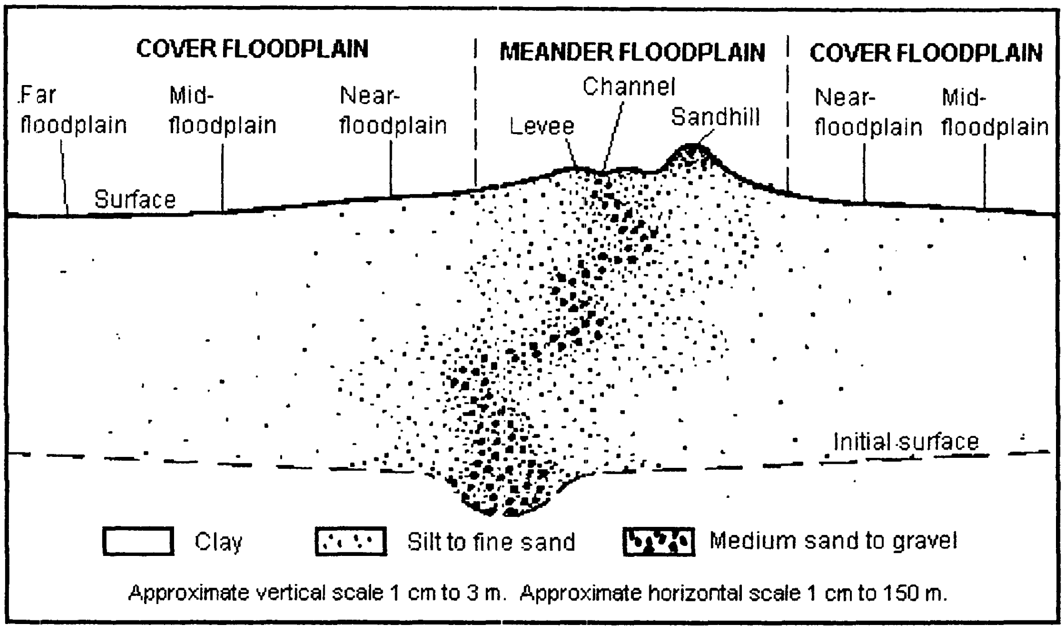
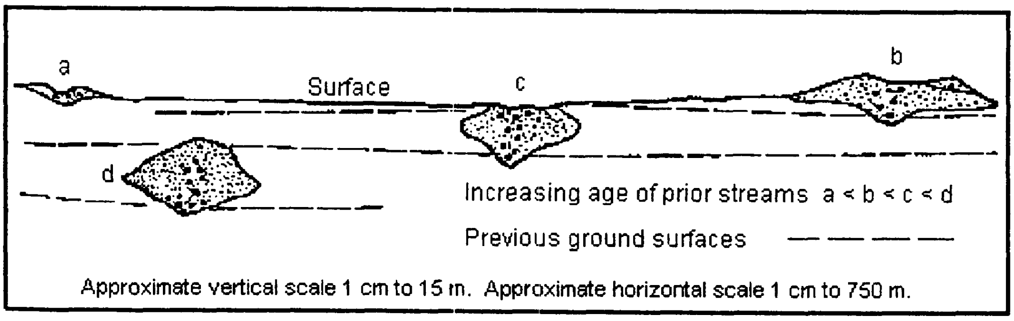


Figure 2.9: Development of prior stream landscapes and aquifers (after Gutteridge *et al.* 1970).



2.2.2 Soils

The distribution of soil types on the Riverine Plains is strongly associated with geomorphology; however, most Goulburn Valley soils are classified as red-brown earths (Skene & Freedman 1944; Skene & Poutsma 1962). These are duplex in profile, with loam or sandy-loam upper horizons overlying heavier clay subsoils of generally low permeability. Heavier, more uniform-textured grey clay soils also occur in low-lying parts of the regional landscape and on flood plains, while soils on the alluvial plains east of the Goulburn River are more typically grey to grey-brown calcareous soils. All are of low to moderate fertility and require additions of phosphorus for agricultural uses[4]

Within the red-brown earth soils of the region, significant variations in soil physical characteristics occur in association with prior stream influences (Figure 2.10). These have also determined patterns of irrigated land use. The meander floodplains, for example, tend to comprise more elevated tracts of the landscape, with coarse, better-drained soils that are suitable for intensively irrigated horticultural and dairying enterprises (Gutteridge *et al.* 1970, p. 21). Horticulture came to be practised around Shepparton in particular, as this district contains a higher proportion of meander floodplain sediments than other areas of the riverine plain, due to its location at the head of the fans of the prior Goulburn River system. Prior stream meander floodplains also occur in small areas around Tongala, Stanhope and Kyabram, where intensive horticulture and dairying are similarly practised (Gutteridge *et al.* 1970, p. 271, p. 283). Heavier, cover floodplain soils otherwise predominate in the western parts of the Goulburn Valley and are used primarily for extensive mixed-farming and sheep-grazing. These soils are relatively impermeable, having shallow A horizons overlying impermeable clay B horizons, and are particularly prone to surface waterlogging during floods or as a result of excessive irrigation (Gutteridge *et al.* 1970, p. 21, p. 271; Skene & Poutsma 1962). They are also characteristically sodic (i.e., high in sodium), and are susceptible to clay dispersion, and hence structural degradation, under irrigated conditions (e.g., Rengasamy & Olsson 1991, 1993; see Chapter 7).

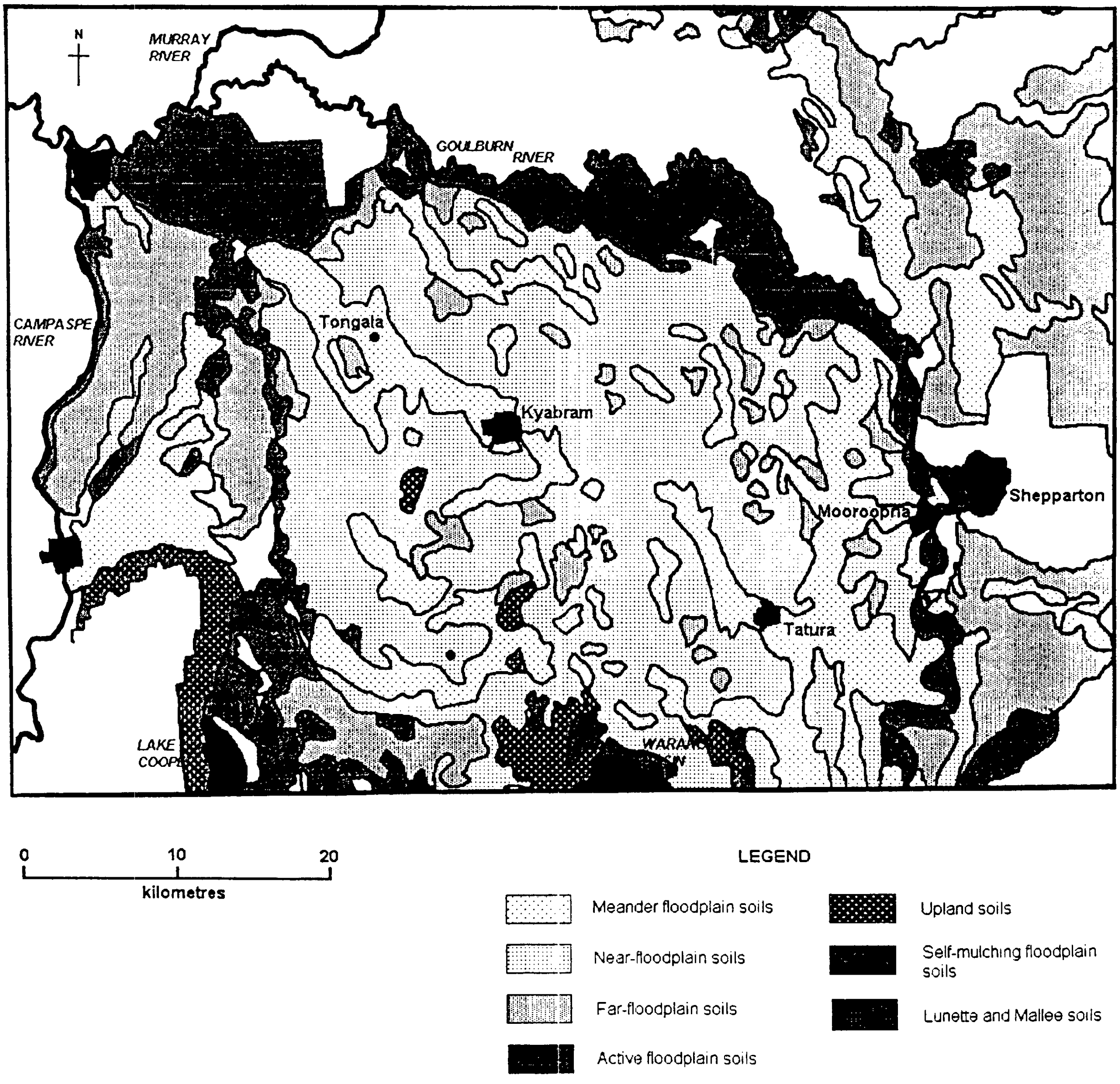
The natural hydrological characteristics of the Riverine Plain soils have been modified by irrigation, as have patterns of salinity (Gutteridge *et al.* 1970, p. 21). The natural distribution of salinity on the plains tends to increase downstream along the prior streams, in association with increasing fineness of soil texture. Salt accumulation is also greater to the west as prevailing winds have brought salts from the sea and from Mallee-area lakes and lunettes. Lower salinities occur adjacent to ancestral river courses as a

---

[4] Low fertility is characteristic of Australian soils in general, and can be attributed to the unusual geological stability of the continent. Bowler (1990) notes that Australia has been remarkably free of volcanic or mountain-building activity compared to other continents in recent times, and the main topographic elements in southern Australia, the Dividing Range and adjacent plains, have been present for at least 20 million years. White (1997, p. 47) adds that in its drift northward from Antarctica, Australia has escaped large-scale glaciation, even during Ice Ages. Soil formation rates are thus extremely slow compared to the natural processes of weathering and leaching, and the soils of the continent have been considered for this reason to be a non-renewable or 'fossil' resource (Flannery 1994, p. 78).

result of leaching and deposition processes. However, as will be seen in later chapters, these natural patterns have been disturbed by human influences primarily associated with irrigation development.

Figure 2.10: Soils of the Goulburn Valley (after Gutteridge *et al.* 1970).



2.2.3 Climate

The regional climate is described as Mediterranean (or 'temperate hot summer'), and is characterised by hot summers and cool wet winters and springs. Average temperatures on the northern plains range from 14°C minimum to 31°C maximum in summer, and from 3°C minimum to 13°C maximum in winter (Figure 2.11). Maximum temperature ranges vary markedly between seasons, however, and temperatures may exceed 38°C at times from October to the end of March, generally in association with a dry, turbulent northerly or north-westerly wind. In winter, frosts occur frequently between May and August, and hail storms are a regular occurrence during spring (Land Conservation Council 1983).

Rainfall varies across the Goulburn River catchment as a whole, averaging more than 1200 millimetres per year in the Central Highlands above Lake Eildon, and decreasing to the north (Figure 2.12). Within the study area, average annual rainfall ranges from 450 to 550 millimetres annually, and is approximately one-third of annual evaporation. Rainfall is more uniform throughout the year than in other regions of the State, but is heaviest and most consistent in the winter months. Summer precipitation may also be substantial but is usually insufficient to maintain plant growth because of high temperatures and evapotranspiration rates (Figure 2.11). Summer rain usually comes from storms, which tend to be heavy but of short duration, and little moisture actually infiltrates into the soil (GWQWG 1996; Land Conservation Council 1983, p. 58). Growing seasons, which in Victoria correspond to the period when rainfall exceeds one-third of potential evaporation (Connor *et al.* 1987), are of about six months duration on the northern plains.

Rainfall also varies substantially from year to year (see Appendix 1), and the region is usually subjected at least once each decade to both droughts and floods. In 1982, for example, a year of severe drought, the Goulburn Valley received only 40 to 50 per cent of annual average rainfall for the region (Land Conservation Council 1983). Serious flood events also continue to occur (most recently in 1993), despite the heavy regulation of river flows (see below). As discussed by White (1997, p. 37), the overwhelming climatic influence in Australia is the *El Nino* Southern Oscillation (ENSO) phenomenon, which tends to occur in two- to eight-year cycles and is responsible for non-annual climatic changes that may more be more significant than the regular seasonal cycles. Powell (1989, p. 30) notes that this climatic irregularity has been "the bane of European settlement" in Victoria and, as will be seen, the unreliability of water supplies has been a recurring influence on the course of human settlement in the Goulburn Valley.

Figure 2.11: Mean monthly climatic averages at Tatura (Source: Bureau of Meteorology 2001. Data recorded at the Institute for Sustainable Irrigated Agriculture, 1942-2001).

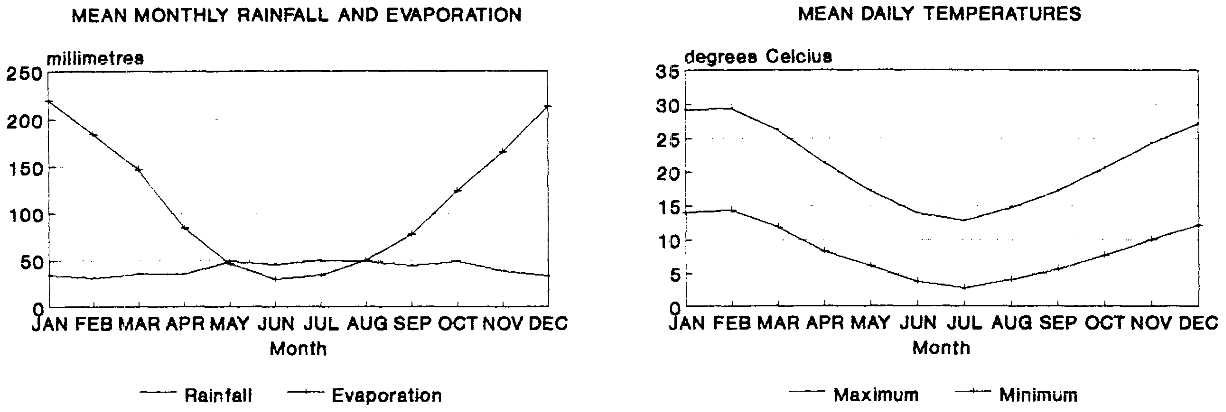
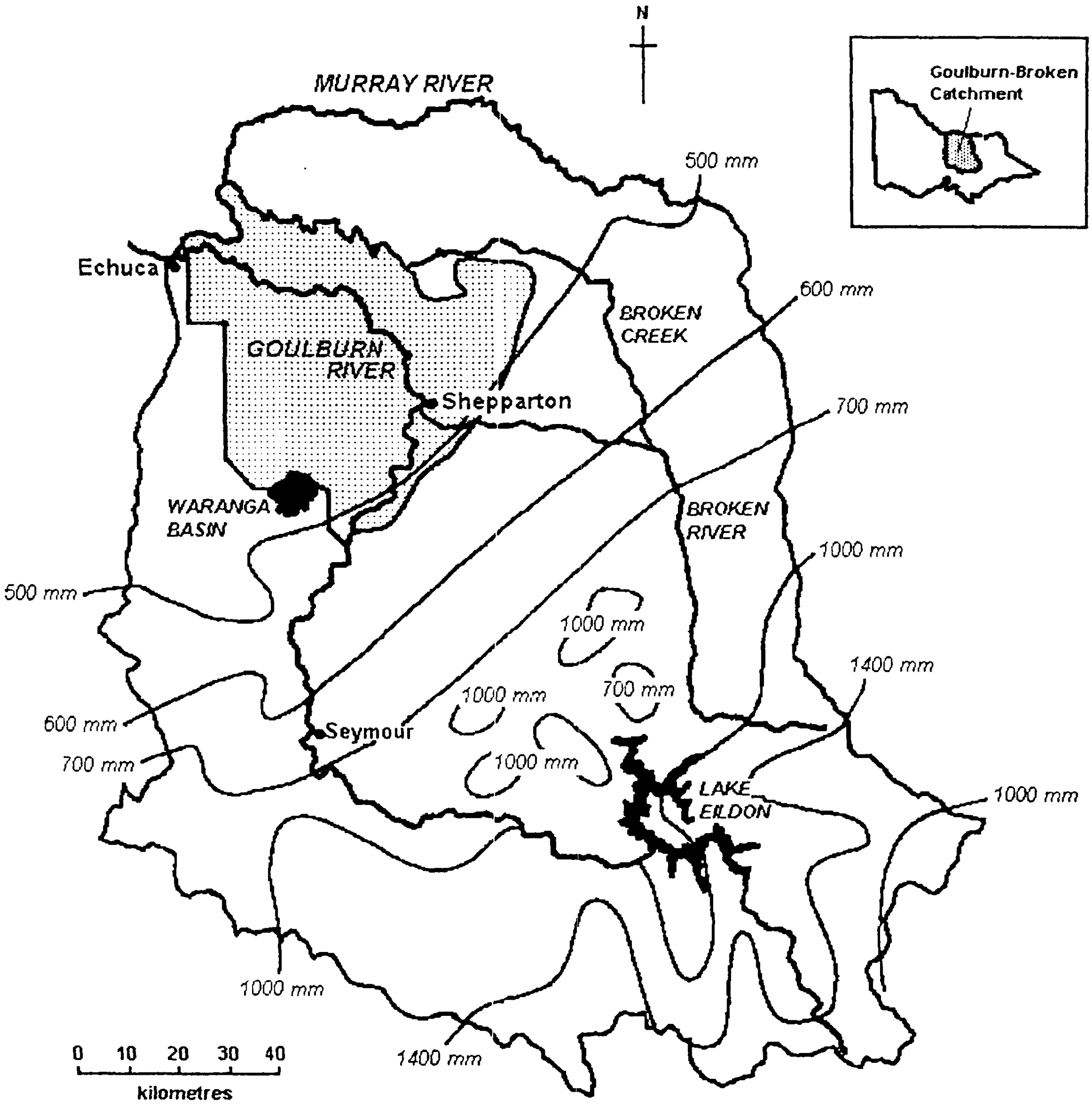


Figure 2.12: Mean annual rainfall across the Goulburn-Broken catchment.



2.2.4 Water resources

The Goulburn Valley lies in what Powell (1989, p. 34) describes as a zone of 'balanced' (as distinguished from 'excess' or 'deficit') water resources. That is, rainfall is adequate to sustain the natural vegetation, with little remaining as surface runoff. The Goulburn River and various perennial streams flowing through the region originate in the wetter highland districts, and are characterised in their natural state by highly variable flows. The Goulburn River, before the building of the weirs, alternated from a slow moving stream during drought periods to a raging torrent in flood times (e.g., Morvell 1983, p. 10).

River flows have since become highly regulated, and the water resources of the Goulburn River are among the most developed in Victoria (Landcare Victoria 1993, p. 8; State of the Environment Report 1991, p. 189). Water from the Upper Goulburn catchment, including snowmelt, is stored in Lake Eildon and released downstream in summer to the Goulburn Weir and Waranga Basin storages (Figure 2.2; Table 2.1). Winter flows account for 33 per cent of the total annual flow of the river below Lake Eildon, while summer flows have been increased to 23 per cent of the annual flow (Figure 2.13)(GWQWG 1996; Land Conservation Council 1983, p. 67). Over 91 per cent of the water released from Lake Eildon is diverted at the Goulburn Weir for irrigation purposes, although the controlled inundation of floodplain wetlands and riverine red gum forests within the region has also become a catchment management priority in recent years (GBCMA 1999; Goulburn-Murray Water 2001; MDBMC 1998). Supplies for irrigation are diverted to the eastern sector of the Goulburn Valley by the East Goulburn Main Channel (capacity 2447 ML/day), and to the west (including districts beyond the Goulburn Valley) by the Cattanach and Stuart Murray Canals (each of 3670 ML/day capacity). The total surface water resources of the system are around 3.2 million megalitres, of which the exploitable yield (after evaporation and other losses) is 72 per cent (Land Conservation Council 1983, p. 64). Within the study area, total annual water rights amount to over 560,000 megalitres, although water deliveries for irrigation generally exceed this figure (Table 2.2). Below the Goulburn Weir, regulated average annual river flow averages 1.3 million megalitres (or less than half of the pre-regulated flow) (GWQWG 1996), including 395,000 megalitres and 75,000 megalitres contributed respectively by the Broken River and Seven Creeks tributaries.

In addition to surface water resources, groundwater is pumped to supplement both urban and agricultural supplies in various parts of the region, though predominantly in the irrigation areas. Within the Shepparton Groundwater Management Area (an area of 35,000 hectares), a volume of up to 200,000 megalitres is licensed annually for extraction (Goulburn-Murray Water 1999). Throughout the Goulburn Valley as a whole, water quality and yields are highly variable, depending on the type of aquifers exploited. Groundwater supplies are recharged by infiltration of rainwater, river water and irrigation water (Land Conservation Council 1983, p. 70; Landcare Victoria 1993).

Figure 2.13: Goulburn River flow patterns (after Land Conservation Council 1983).

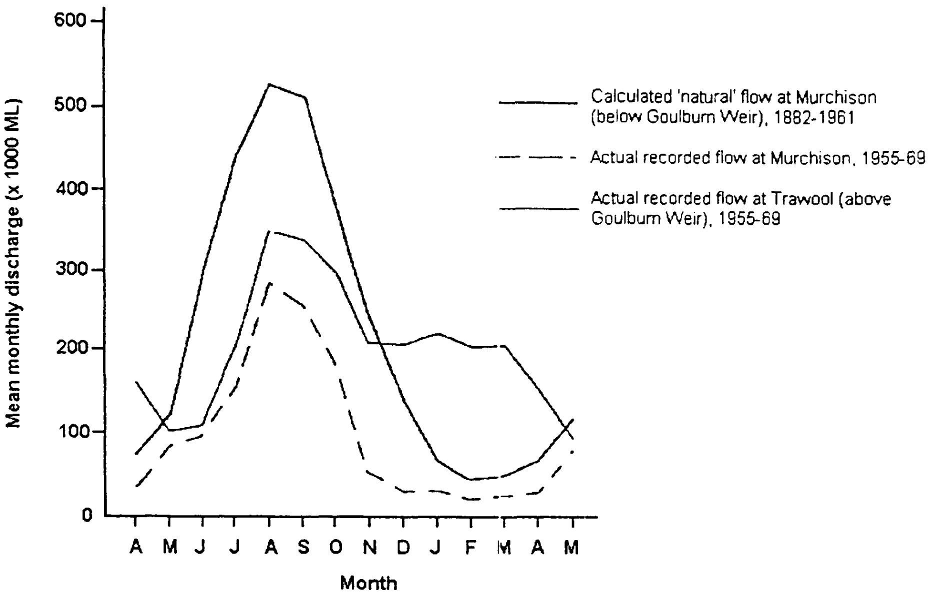


Table 2.1: Water storages within the Goulburn River system.

Storage	Date of construction	Date of enlargement	Capacity (ML)
Goulburn Weir	1891	–	25,000
Waranga Basin	1905	1917, 1926	411,000
Lake Eildon	1927	1935, 1955	3,390,000
Greens Lake*	1968	–	32,750

Sources: Goulburn-Murray Water (2001); Land Conservation Council (1983, p. 66).

** Off-stream storage (i.e., catchment from rainfall and floodwater runoff only).*

Table 2.2: Water supplies to Goulburn Valley irrigation areas.

	Shepparton Irrigation Area	Central Goulburn Irrigation Area	Goulburn Valley Total
Total area	81,750 ha	173,053 ha	254,803 ha
Area irrigated	51,000 ha	113,106 ha	164,106 ha
No. of irrigated holdings	1,500	> 2,800	> 4,300
Length of distribution channels	754 km	1460 km	2214 km
Length of drains	441 km	661 km	1102 km
Water right	181,743 ML	385,180 ML	566,923 ML
Water deliveries (1998-99)	174,904 ML	410,623 ML	585,527 ML

Source: Goulburn-Murray Water (1999, 2001).

2.2.5 Vegetation

The Goulburn Valley was originally forested over almost its entire area (Powell 1967; *State of the Environment Report* 1991). Prior to European settlement, the plains were characterised by open savannah woodlands maintained by Aboriginal fires (see Chapter 3), while denser forests grew along the rivers and in the foothill areas to south. Tree communities throughout the broader catchment area varied according to climate, soil, drainage and topography, but on the riverine plain vegetation consisted primarily of red gum-box woodland, with the distribution of particular associations being determined by drainage. River red gum (*Eucalyptus camaldulensis*) predominated in flood plain areas and along watercourses, with little undergrowth apart from swamp grasses and rushes. Grey and yellow box (*E. microcarpa, E. mellidora*) communities occurred on sand ridges and better drained soils, and were widespread across the broader plains and southern foothills, in association with occasional communities of white cypress pine (*Callitris* spp.), ironbark (*E. sideroxylon*), buloke (*Allocasuarina luehmannii*) and she-oak (*A. verticillata*)(Conn 1993; Land Conservation Council 1983; Skene & Freedman 1944; Skene & Poutsma 1962).

Native grassland communities on the plains were comprised of temperate shortgrass communities in the far north, dominated by wallaby grasses (*Danthonia* spp.) and spear grasses (*Stipa* spp.). Temperate tallgrass communities dominated by kangaroo grass (*Themeda triandra*) and tussock grasses (*Poa* spp.) also occurred on the plains and foothill areas (Conn 1993; Moore 1959; see Chapter 4). Introduced species are now more common, and include *Bromus* spp. (brome grasses), *Cynodon dactylon* (couch grass), *Dactylis glomerata* (cocksfoot), *Hordeum leporinum* (barley grass), *Lolium* spp. (ryegrass) and *Phalaris aquatica* (phalaris), as well as *Trifolium repens* (white clover), *T. subterraneum* (subterranean clover), and other clovers (Conn 1993).

Almost all freehold land on the northern plains has been cleared of trees for agricultural or pastoral purposes. Most public land supports stands of native vegetation, although this has been modified to varying degrees by logging, bushfires and grazing. Substantial areas of river red gum forests remain near the confluence of the Goulburn with the Murray River, and along the Goulburn River downstream from Murchison (Land Conservation Council 1983, 1990)

2.2.5 Fauna

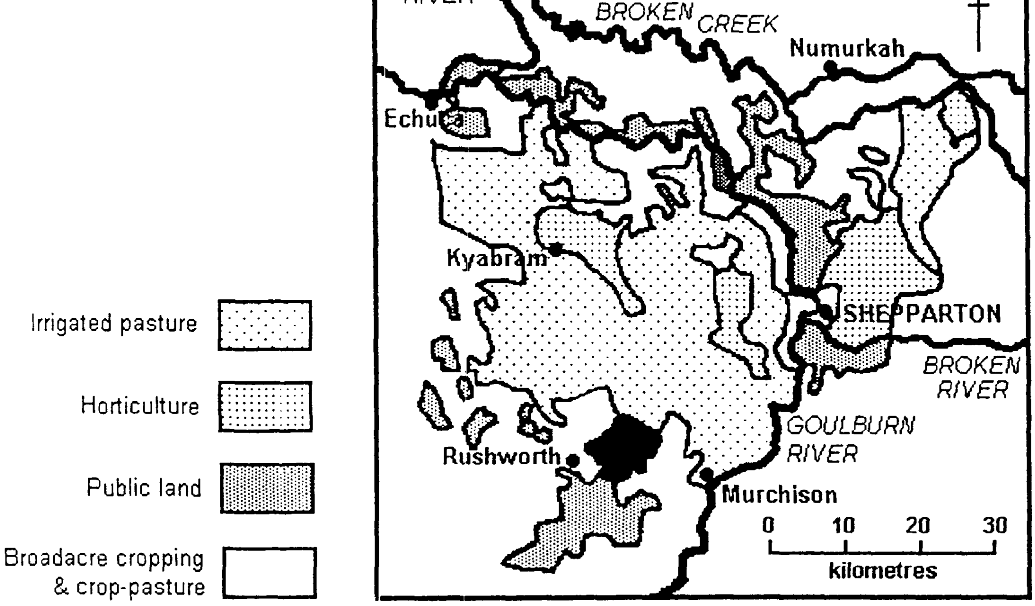
The Goulburn Valley provides a variety of wildlife habitats that support over 30 species of mammals, 130 species of birds, and numerous amphibians, reptiles and terrestrial and aquatic invertebrates. The Goulburn River also supports a diversity of native fish and other aquatic species. The most common native mammals include the common brushtail and ringtail possums (*Trichosurus vulpecula, Pseudocheirus peregrinus*), eastern grey kangaroo (*Macropus giganteus*), platypus (*Ornithorhynchus* *anatinus*), little forest eptesicus (*Eptesicus vulturnus*) and water rat (*Hydromys chrysogaster*). Other native species, such as the koala (*Phascolarctos cinereus*) and squirrel glider (*Petaurus norfolcensis*) were formerly common in the region but are now either rare or endangered (Land Conservation Council 1983; Landcare Victoria 1993; SIRLWSMP 1997). Notable introduced species include the European rabbit (*Oryctolagus cuniculus*), brown hare (*Lepus capensis*), cat (*Felis catus*) and house mouse (*Mus musculus*).

2.2.6 Present-day land use

Generalised land use in the Goulburn Valley is shown in Figure 2.14. East of the Goulburn River (i.e., within the Shepparton irrigation area), dairying and horticulture (mostly stone fruit) are the most common forms of irrigated land use, although over half of the irrigated farms, including a significant number of 'hobby farms' close to Shepparton, are mixed cropping and grazing enterprises. West of the Goulburn River, dairying is the most common enterprise, covering 46 per cent of the land area. Cropping and grazing comprise a further 48 per cent, and horticulture (stone and pomme fruits) 6 per cent (Goulburn-Murray Water 2001). Land along the Goulburn River itself remains in the public domain and is primarily forest or wetland areas.

Food-processing industries, including dairy processing plants and fruit canneries, are the major non-agricultural industries in the Goulburn Valley, and produce around 25 per cent of the rural output of the state of Victoria (GWQWG 1996). In the towns, the public sector is a major employer, as are the service and recreational industries (Landcare Victoria 1993).

Figure 2.14: Present-day land use in the Goulburn Valley (after GWQWG 1996).



2.3 Environmental problems

Land degradation and water quality problems of various types have emerged within the Goulburn Valley within the last three decades, and have raised serious concerns about the sustainability of agricultural production in the region. These problems have been widely documented, and are discussed in subsequent chapters of this thesis, but they may be summarised as follows:

Waterlogging and salinity in irrigation areas: Between 35 and 50 per cent of the greater Shepparton Irrigation Region (including some irrigation districts outside of the study area) is currently subject to watertables within two metres of the soil surface (i.e., within plant root zones), and this area is expected to increase into the future (Sampson 1996; Sampson *et al.* 2000). Within the Goulburn Valley itself, the problem is particularly widespread in the Central Goulburn District, west of the Goulburn River. Soil salinisation is an associated and growing problem, as natural salts are brought to the surface by rising groundwaters, and are concentrated by the processes of capillary action and evaporation. The economic losses arising from declining pasture and orchard productivity as a result of waterlogging and salinity are considerable, and a number of major wetland areas in the region are at risk from the intrusion of saline groundwater (Fuller *et al.* 1999). Drainage from the region also contributes to the overall salt load of the Murray River.

Dryland salinity: This is primarily a problem in dryland areas of the Goulburn River catchment (i.e., outside of the study area), although it also poses a threat to the Goulburn Valley as stream base flows and accumulated salt from dryland areas contribute to salinity problems in the irrigation areas. Dryland salinity is also expected to cause substantial rises in salinity levels in the Goulburn and other rivers over the next century, with likely impacts on downstream water users, aquatic ecosystems and biodiversity, and regional infrastructure (e.g., roads and building foundations)(DNRE 2000; Landcare Victoria 1993).

Water quality: Declining water quality is a problem of major significance in the study area, and has contributed to a number of toxic blue-green algal blooms and other nuisance algal blooms in Goulburn Valley storages and waterways in recent years. Such occurrences are symptomatic of the general contamination of water resources within the region by nutrient runoff, agricultural chemicals, industrial pollution and other land degradation processes (GWQWG 1996; Landcare Victoria 1993).

Soil structural decline: This is a particular problem of red brown earth soils in cropping and orchard areas, where repeated cultivation and flood irrigation has destroyed soil aggregates held together by soil organic matter, leaving a hard-setting surface that is impermeable to water, restricts seedling emergence, and is highly prone to sheet erosion (Landcare Victoria 1993; Skene & Poutsma 1962; *State of the Environment Report* 1991, p.397). Decades of irrigation, in association with inadequate drainage provisions, has also exacerbated the sodic nature of the Goulburn Valley soils, causing clay particles to disperse upon wetting and adding to the general problems of soil structural decline (Rengasamy & Olsson 1993; see Chapter 7).

Vegetation and fauna: Remnant native vegetation on both public and freehold land is considered to be at risk, as the natural understorey has been severely modified by grazing and pest animals, fire and weeds, and dieback of the remaining ageing and isolated trees is widespread and severe. A number of animal species in the region are also rare or endangered, due to the destruction or fragmentation of habitat areas (Landcare Victoria 1993).

Pest plants and animals: These have been described as 'perennial' problems in the region (Landcare Victoria 1993). Over 100 species of noxious weeds occur in the study area, including Patersons Curse (*Echium plantagineum*), Blackberry (*Rubus fruticosus*), Skeleton weed (*Chondrilla juncea*) and various thistle species (Land Conservation Council 1983, p. 338). A variety of non-noxious weeds also contribute to losses in agricultural productivity. The worst pest animals are rabbits, which have aggravated soil erosion and stream siltation problems throughout the region for over a century. Native species, including kangaroos, wallabies, cockatoos and galahs (*Cacatua* spp.), are considered to be significant agricultural pests. In waterways, European Carp (*Cyprinus carpio*) are a problem because of their tendency to destroy vegetation and muddy the water during feeding, to the detriment of native fish species (Land Conservation Council 1983, p. 114).

All of these biophysical problems represent an economic cost to the Goulburn Valley, whether direct (e.g., mitigation or reclamation costs) or indirect (reduced agricultural production), and extensive research and land and water quality management programs have been directed in recent years towards their containment, if not their solution. Conservation of remnant native habitat areas and wetland ecosystems has also become a focus of regional environmental management strategies (GBCMA 1999). Ironically, most of the above problems were preventable, at least in theory, as many of the basic physical processes of environmental degradation were understood throughout much of the twentieth century, if not earlier, and early warning signs were often evident before the problems became widespread. Understanding why the remedial responses were not more timely is one of the reasons that this study was undertaken, and the socio-political as well as the physical causes of the environmental problems in the Goulburn Valley will be discussed in the remainder of this thesis.