CHAPTER 9

CONCLUSIONS

9.1 Introduction

This thesis is a study of the Goulburn Valley as a microcosm in which human social, technological and economic forces have interacted with natural (biophysical) processes to bring about environmental change. The work was undertaken to explain the emergence of apparently avoidable environmental problems (notably waterlogging and salinity), in the hope that the processes of the past might offer insights for the development of more sustainable approaches to resource management in the future.

The major finding is that the present-day problems of the Goulburn Valley have arisen because historical European perceptions of the regional environment failed to match its real or true biophysical nature, and that resource use was ecologically maladaptive as a result. This has been demonstrated through the analysis of historical decision-making concerned with resource use, based on the 'situational interpretation' approach of Berkhofer (1969), as applied within a conceptual framework of the Gouburn Valley as a dynamic, nonlinear socio-agricultural system.

This thesis also shows that theories of systems dynamics derived from the physical sciences are applicable to the study of environmental or bioregional history, and provide a powerful explanatory model for historical decision-making. The Goulburn Valley, as presented in this work, indeed appears to have functioned as a dynamic system, both in Aboriginal times and throughout the period of European settlement, and many of the historical decisions pertaining to resource use conform to recognised archetypes of systemic behaviour (e.g., single- and double-loop learning; shifting the burden)(Parker & Stacey 1995; Senge 1990).

The implications of these findings are that sustainable resource management in the Goulburn Valley (and presumably elsewhere) is contingent upon a holistic understanding of the region, unencumbered by ideology or Utopian visions, and with biophysical considerations as a prime determinant in both regional policy making and on-farm land and water use. The current approach, which has evolved from the salinity management plans of the late 1980s into a catchment-wide resource management strategy, is suggestive of a systemic shift in this direction. However, structural weaknesses still prevail, and both internal (psychological) and external (primarily economic) factors appear certain to remain dominant influences on resource use decision-making in the region into the foreseeable future.

9.2 The human-environment 'dialogue'

Documentation, including both primary and secondary sources, consulted for this thesis reveals that the climate and terrain of the Goulburn Valley, as well as the presence of the Goulburn River, influenced the settlement patterns and resource use activities of the Aborigines and early Europeans, and eventually led to the introduction of irrigation in the region. This, and the widespread clearing of trees, contributed to the present-day problems of salinity and high watertables, which have in turn stimulated new, more holistic approaches to resource use and ecosystem management. These interactions may be seen as an example of the 'dialogue' between humans and the natural environment referred to in the opening chapter, as well as an affirmation of White's (1980, p. 159) postulate that environmental change is an inevitable consequence of human land use.

White (1980, p. 159) observed as a corollary that human-induced environmental change is not always detrimental. In the Goulburn Valley, this appears to have been the case during the period of Aboriginal occupation, as the Pangerang and neighbouring tribes altered the landscape and produced an environment that was capable of supporting their society over a long period of time without any apparent weakening of its productive capacity. More profound changes were brought about by the Europeans, resulting in what Smith (2000, p. 8) describes as tremendous "natural gain" (i.e., negentropy, in the form of an increased pool of resources available for human use), although this has also been accompanied by growing ecological problems that are now detracting from this achievement.

Both of these environmental outcomes (i.e., intentional and unintentional) can be attributed in biophysical terms to the much greater quantitative impacts of the Europeans upon the land, arising from their much greater population size and from the introduction of new technologies and plant and animal species, which have altered the inherent ecological limitations of the region. This thesis also demonstrates, however, that human perceptions have played an equally significant role in the process of environmental change. The present-day Goulburn Valley is thus a product of the ways in which the landscape was envisioned by its inhabitants and administrators, the kinds of relationships that were desired with the land, and the influence of these factors on the ways in which the available environmental information was used.

9.3 Recap of thesis hypothesis: the problem of perception

The hypothesis postulated in Chapter 1 to account for the current troubled state of the Goulburn Valley was that the biophysical environment was historically misperceived - at least during the period of European settlement - and that the resultant maladaptive forms of resource use have been a major cause of ecosystemic stress and instability.

The evidence presented in the main body of the thesis shows that perceptual (or cognitive) failures indeed occurred throughout much of the European history of the region. These appear to have occurred in part because abstract (ideological, cultural, socio-economic) factors assumed an overriding importance in the development of the region's resources, but also because the prime decision-makers - both government policy-makers and landholders - were unreceptive to information that was in disaccord with their resource use goals (a psychological phenomenon known as 'cognitive dissonance')(Mitchell 1979, p. 130).

In systems terms, the critical feedback linkages between the major system components and the biophysical operating environment were largely dysfunctional, so that the metaphorical 'dialogue' between humans and the biophysical environment was largely one-sided. As White 1997, plaintively suggests, the land was 'crying', but in the Goulburn Valley it has only recently begun to be heard. Alternatively, in Norgaard's (1984) terms, the socio-economic development of the region proceeded according to mechanistic and stock-exploitive paradigms, rather than coevolving with the regional ecosystem. This resulted in forms of land and water use that were ecologically maladaptive, contributing to the region's present-day high water-tables, soil and water salinisation, nutrient contamination of waterways, soil structural decline, and other environmental problems, as well as reducing the potential range of developmental options for the future (Norgaard 1984).

9.4 Conceptual framework: the Goulburn Valley as a socio-agricultural system

Support for the above hypothesis was sought through the 'situational interpretation' of evidence pertaining to resource use decision-making in the Goulburn Valley, and by the analysis of the observed behaviour of historical policy-makers and landholders on the basis of the conceptual model presented in Chapter 1 of the Goulburn Valley as a dynamic, nonlinear socio-agronomic system. According to this approach, the various historical phases of settlement discussed in this thesis reflect different structural frameworks and functional relationships resulting from internal and external sources of systemic stress and instability; the resource use priorities of the decision-makers at various times comprise systemic 'attractors'; the transition periods between phases correspond to bifurcation points in the evolutionary path of the system; the motive power for the system is provided by the continual need to import negentropy to maintain system functioning. Each phase of settlement also proceeded within an environment shaped to varying degrees by the previous group of inhabitants.

This conceptual framework was used throughout the thesis to illustrate the functioning of the entire system at various times, and to provide fundamental structural explanations for the observed patterns of behaviour. It is considered that this constitutes a major contribution to the existing body of knowledge pertaining to the Goulburn Valley and the history of resource use in the region. The situational interpretation-systems dynamics model also appears applicable to the study of environmental change in other geographical areas, as well as to other categories of historical analysis, as it provides a general explanatory framework for historical behaviour. It is acknowledged, nevertheless, that this particular study amounts to what Berkhofer (1969, p. 23) describes as "a highly selective account of a postulated past reality" - that is, an interpretation of history based on the available evidence and the chosen conceptual framework. Fitzhardinge (1994) also provides a reminder that the theory of systems dynamics remains a tool for explanation and understanding, rather than natural fact.

9.5 Summary of evidence in support of the hypothesis

That the Goulburn Valley indeed functioned (and continues to function) as a dynamic, nonlinear socio-agricultural system is suggested throughout the main body of this thesis. The narrative also supports Worster's (1990) observation that there is no single rigid theory of causality for environmental change. Time and context are important factors, and natural events (e.g., in the Goulburn Valley, the unprecedented run of wet seasons that coincided with the beginning of the Selection period in the early 1870s, and the equally prolonged cycle of droughts that followed) can be powerful influences on human cognition and behaviour. However, perceptions and preoccupations are also clearly decisive factors in promoting change at other times, and considerable evidence is provided to suggest that this has not only been the case in the Goulburn Valley, but that historical misperceptions have been a major cause of the region's present-day environmental problems.

Aboriginal perceptions of the Goulburn Valley appear to have been particularly attuned to the natural environment, as evidenced by their lengthy and undeniably sustainable stewardship of the region. The systems dynamics model suggests that their social system became adapted through direct feedback mechanisms and structural coupling processes to make both optimal and sustainable use of the region's highly variable resource base (Chapter 3). This adaptation required that the spiritual components of the system were as attuned to the biophysical environment as the Aborigines' day-to-day behavioural activities (hunting, gathering, nomadism), in order that all conscious and unconscious behaviour was directed towards the fulfilment of the primary goal of group survival. This operational structure was facilitated by the fact that, until the arrival of the Europeans, the Aboriginal system was essentially closed, so that external (potentially obfuscating) influences on the internal feedback linkages controlling system functioning were minimal.

The European socio-agricultural system that displaced the Aboriginals was more open, and hence more complex, as it was subject to a variety of abstract ideological, economic and (at the landholder level) personal influences that disrupted environmental feedback processes and directed system functioning away from the biological goal of survival, and hence from sustainable, ecologically-oriented relationships with the land. This occurred in part because the 'European' Goulburn Valley functioned as a regional sub-system within the greater Colonial (later State), national and (ultimately) global socio-economic systems, and the primary system purpose became the extraction of natural resources for export to external markets that were indifferent to local production conditions. All of the region's biophysical complexities were thus reduced to the abstract notion of 'land' as a tradeable source of commodities with no inherent value or functions of its own. Even within the region, however, information that pertained to the biophysical environment was ineffectively channelled and/or processed by landholders, policy-makers or both, either because of geographic circumstances (i.e., the physical, and hence psychological, remoteness of policy-makers from the region in question), cognitive dissonance, or because other internal (psychological) and external (primarily economic) considerations were perceived to be more important than environmental damage - even if this meant losses in productivity.

As a group, and in spite of such ordinances as the Crown Lands Occupation Act of 1836, the squatters were probably least constrained by the officially-mandated systems of resource use that characterised the later phases of settlement in the Goulburn Valley. Through trial-and-error (positive and negative feedback) processes, they were able to devise modes of pastoralism that reasonably reflected the biophysical characteristics of the environments into which they introduced their sheep. As discussed in Chapter 4, these practices were ecologically disruptive and exploitive, but the biophysical limitations of the region were a major consideration in how the squatters managed their flocks, and pastoralism remained the first choice, in terms of land use, of the 'boss cockies' who bought up the holdings of failed selectors in the later 1870s and 1880s (Chapter 5). The squatting system never achieved stability, however, because it conflicted with the loftier agrarian goals of the system's higher-order components (i.e., the Colonial Office and, from 1854, the newly-constituted Victorian Government). The perceived ideological, social and economic imperatives of Victoria in the mid-1800s were sufficiently strong to override the early, vague and unwelcome official knowledge of the Colony's biophysical capabilities that was transmitted to the remote policy-makers in London and Melbourne, and it was soon demonstrated that even the practical misgivings of would-be landholders could be overcome if the land occupancy laws were sufficiently liberalised. As Worster (1994, p. 112) suggests, however, this "kindness" was not without ecological effects, and it also failed to save the selectors from what he describes as "the disciplining hand of natural forces" (Chapter 5).

This bears out the observation that it is hard for people to adapt to a climate they do not fully understand nor fully want to accept, and on the northern plains the conviction persisted among both landholders and officials that the land could and should support agricultural settlement. The obstacle to this vision was a lack of water, but cognisance of the problem was finally taken in the 1880s, as the Victorian Government, spurred on by the enthusiasm of Alfred Deakin, introduced legislative and technical approaches to make use of the abundant waters of the Goulburn River. Unfortunately for the region's later inhabitants, important but unwelcome information (in this case, pertaining to the potentially damaging effects of irrigation on soils and water-tables) was again dismissed. In part, this was because of the opportunity costs associated with the construction of drainage provisions. However, cognitive dissonance also appears to have been a factor, as irrigation was perceived as the epitome of modern scientific agriculture - a practical, technological means of overcoming a profound natural obstacle and transforming arid, minimally productive environments into verdant farmscapes (Chapter 6).

This hubristic attitude persisted into the twentieth century, as visionary engineer-administrators (Elwood Mead, Ronald East) assumed control of the State's all-powerful irrigation authority, the State Rivers and Water Supply Commission (SRWSC). The remaining 'untamed' waters of the Goulburn and other rivers were regulated into an exploitable resource, and the irrigation industry on the northern plains was expanded until almost all land commandable by channels was being watered. This development occurred against the natural inclinations of many landholders, and against economic rationality, and continued even as drainage problems were acknowledged to be worsening on a regional scale (SRWSC 1951). However, the SRWSC's activities were strongly supported by the Victorian Government as it sought to implement new manifestations of its nineteenth century Closer Settlement policies that, it was hoped, would help fulfil the State's longer-term economic development goals while also financing the accompanying irrigation infrastructure. The latter was something of a self-serving argument for the SRWSC - a form of reinforcing feedback that helped the agency consolidate its institutional strength and assume a position as the dominant regulatory component of the entire regional system. As discussed in Chapter 7, this resulted in an unfortunate narrowing of perceptions that reduced systemic flexibility, and hence adaptability to both economic and biophysical changes in the regional operating environment. Ultimately it contributed to what Langford *et al.* (1999, p. 1) describe as a legacy in Victoria of small, barely profitable irrigation farms, a financially unviable irrigation authority, large public debt, and environmental degradation through waterlogging and salinity.

Perceptive (and hence cognitive) failures arising from the suppression of environmental knowledge also occurred at the landholder level, for both external and internal (personal or psychological) reasons. The latter included the desire to save time, money or effort, which led many landholders to opt for 'satisficing' systems of management (e.g., continuous cropping and 'wild flooding'), even when these were recognised as being damaging to the land. Landholders were further swayed from adaptive interactions with the biophysical environment by external factors, including government-mandated resource use provisions (e.g., Selection-era cultivation and land improvement requirements; compulsory water rights), and the economic subsidisation of both inputs (irrigation water; fertiliser; tree-clearing costs) and outputs (horticultural produce). In Hollick's (1990) terms, these distorted the boundaries of landholders' decision-making space (see Figure 4.8, p. 76), such that the crops grown and systems of production employed reflected external considerations that bore almost no relation to the regional farming environment.

It may be concluded accordingly that, because of the above-mentioned distortions and malfunctions in systemic feedback processes, at both the macro- (policy) and micro- (landholder) scale the European modes of resource use that prevailed in the Goulburn Valley largely failed to match either the climatic or the edaphic characteristics of the region, or even, at times, the economic environment in which it functioned. This was a major cause of instability in the overall socio-agricultural system, contributing to the bifurcations and structural adjustments described in the preceding chapters. It was also destabilising for the regional environment, as natural hydrological balances and ecosystemic linkages were disrupted, often irreversibly, to the extent that the productive capacity of the region has now been seriously comprised. This explanation appears to satisfy the original questions behind this thesis (i.e., not only how but why the region came to be degraded), but does not imply that blame need be apportioned for all the mistakes of history. As Powell (1993, p. 17) observes, not only would such an exercise be pointless, but one of the major lessons of this thesis is that all people are constrained by the assumptions and knowledge (or ignorance) of their time, and their actions make sense within the limits of their perceptions.

9.6 The present 'Goulburn Valley' system

The lessons of history remain valid today. As Watson (1969) observed, for people to think themselves free of illusions is an illusion in itself, and in the Goulburn Valley, the new, supposedly holistic approach to the biophysical environment perhaps omits consideration of the "environment of illusions". In other words, although the current salinity management plan for the Shepparton Irrigation Region (SIRLWSMP) has been structurally devised to overcome some of the feedback problems of the past, it has still been formulated within a systemic culture that retains certain hopes and expectations in terms of resource use. The region's landholders thus continue to interact with the biophysical environment in a manner that reflects primary social and economic priorities - including the strong desire to maintain the *status quo* (Chapter 8). The technological (groundwater pumping and drainage) programs that comprise the bulk of the SIRLWSMP, and the scientific research being conducted at Tatura and elsewhere, are aimed likewise at supporting the current (dairying and horticulture-based) system of land and water use on the northern plains.

The Goulburn dryland plan of 1989 was formulated with the similar expectation that the current system of land use (i.e., sheep and cattle grazing) in high recharge areas should not only continue, but that productivity could actually be increased through the use of deep-rooted perennial grasses and clovers to control rainfall percolation to the groundwater. It has since been determined that only widespread tree-planting is likely to be effective in this respect, and that major changes in land use will be required in dryland salinity-affected catchments (Auditor-General, Victoria 2001, p. 131; DNRE 2000). White (1997) and others believe that the salinity management plans for the irrigation areas are similarly misguided, and that significantly greater structural adjustments (including the abandonment of some, if not all, forms of irrigation) will inevitably be required. However, this option remains politically unacceptable at the present time, indicating that both landholders and policy-makers still possess a vision (or perception) of the

Goulburn Valley that is not necessarily in accord with the biophysical capability of the region. (The notion of scaling back irrigation may nevertheless become more palatable with time - particularly if, as projected, the hydrological problems of the region continue to worsen and a re-evaluation of the currently prevailing vision appears warranted.)

Slightly different expectations of what is achievable in the region also appear to be held by different system components. This is suggested by the sometimes-divergent priorities of Landcare groups and Catchment Management Authorities (Chapter 8, page), and by the Victorian Auditor-General's (2001, p. 106) recently expressed concern that the State's present catchment-wide resource use strategies may not be adoptable at the farm level. This situation echoes the conflicting resource use needs and expectations of policy-makers and landholders in the Goulburn Valley and elsewhere at various times in the past, which were indicative of dysfunctional feedback relationships and a major internal cause of systemic stress and instability. The Auditor-General has recommended accordingly that the sharing of information (particularly technical information) within the overall system be improved, and that the regional Catchment Management Authorities undertake more localised investigations of landscape processes, in order that specific solutions may be tailored to particular areas (Auditor-General, Victoria 2001, p. 109).

Another possible weakness in the present systemic structure may be the fact that the (considerable) achievements within the region under the SIRLWSMP to date have been supported by external infusions of funds, and the continued implementation of the Plan appears contingent upon similar high levels of government spending into the future (Sampson et al. 2000). Whether the system will still be dependent on such assistance at the end of the proposed 30-year life of the SIRLWSMP remains to be seen, but the current financial arrangements have some validity if they ease the structural transition towards a more sustainable system of land and water use in the future. Otherwise, the systemic argument suggests that farmers should find alternative ways to adapt and survive (Worster 1994, p. 113). In the Goulburn Valley, this seems likely to entail extensive farm amalgamations to overcome the legacy of small holdings created by the earlier closer settlement policies and price support schemes, as well as possible changes in resource use practices. Any funding available in the future may thus be better spent on helping struggling landholders leave the system (e.g., through the community buy-out of badly degraded holdings) than on supporting farming operations that are otherwise unsustainable. Such a scheme has already been proposed by the Victorian Government for flood-prone parts of the Goulburn Valley with a view to creating a 10,000 hectare riverine wetland and transferring the water rights to other, more viable holdings (Collis 2000). However, economic and environmental rationality may not be sufficient to overcome the desire of individual farmers to remain on their holdings.

The latter point serves as a reminder that landholders are more than automatons - they remain capable of individual resistance to policies that have been endorsed by the broader community, and even in a nonlinear world it seems safe to predict that satisficing behaviour and other, indeterminate psychological factors will always play a role in system functioning in the future. This means, as in past attempts to develop the region according to some prevailing vision, that the Goulburn Valley cannot be driven towards sustainability. The region's landholders, community members, government agencies, and the Government itself, may work towards the achievement of this goal, but none can control the process (Parker & Stacey 1995, p. 4). Success may be more likely if the vision is shared equally by all system components, but the vision of what sustainability actually is (i.e., the most biophysically compatible forms of production, applied to the most profitable crops) must be open to change as the system continues to evolve in response to both internal and external stresses that impinge upon its overall stability.

9.7 The implications of systems dynamics for sustainable development

As suggested throughout this thesis, the 'Goulburn Valley' indeed appears to function as a dissipative, nonlinear socio-agricultural system. It remains poorly adapted to the biophysical environment in which it operates and is vulnerable even to minor changes in its operating conditions if these become amplified by positive feedback. It will also continue to follow an evolutionary path determined more by human volition than environmental constraints, with the degree of structural coupling between the system and its operating environment being determined by the cognitive interactions between them (Chase 1985; Parker & Stacey 1995, p. 6). These interactions will continue to provide the negentropy necessary for system functioning, although different evolutionary paths are likely to offer different outcomes in terms of future success (Swaney 1985). A path promoting rapid initial development may strain certain components in the system or its environment, causing anything from minor disruptions in system functioning to complete instability. An alternative development path might mean slower progress at the outset, but smoother and more sustainable system functioning over the longer term.

Norgaard (1984) maintains accordingly that 'co-evolutionary development', based on ongoing feedback processes between a system and its environment, offers the greatest potential for generating levels of negentropy beyond that necessary to maintain social and ecological systems in their existing states. This surplus may then be directed towards, or may fortuitously result in, a new interaction between the systems. If this proves favourable to the social system, the surplus will be maintained and can be invested in further beneficial change. This equates to the notion of sustainable development, and suggests that the primary goal or purpose of a system desiring to exploit this potential should be to establish and maintain forms of interdependence with its operating environment that enable it to maximise its negentropy, or capacity for growth (Emery 1969, p. 10). In the Goulburn Valley, the Aboriginal system appears to have functioned on this basis, and if the present socio-agricultural system is to do likewise, policy-makers and landholders alike must be fully cognitive of any changes that occur in the biophysical and the economic environments in which the system operates.

Norgaard (1984) points out that the coevolutionary perspective emphasises the uncertainty of the future. The possible courses of coevolution are unknown, as new system components and interactions evolve over time. Parker and Stacey (1995, p. 28) add that making assumptions about future conditions is also relatively pointless, at least in the longer term, because the assumptions themselves will be subject to change. However, this uncertainty need not mean that systems are necessarily limited to adapting to their given environments. To the extent that the laws governing a particular environment are understood, some modifications may be made to the conditions that produce subsequent environments (Emery & Trist 1972, p. 68).

Smith (2000, p. 8, p. 40) suggests, for example, that if constraints to agricultural productivity in Australia are identified and managed, the process of 'natural gain' can go on indefinitely, particularly given the capacity of modern science and computing power to generate information. Some systems theorists have extended this idea into the belief that all external limits to growth are capable of being overcome by human innovation - in other words, the resources available to human societies are potentially unlimited as culture and technology continue to evolve, enabling the process of entropic degradation to be postponed almost indefinitely (Lazslo 1987, cited by Radzicki 1990; Katz & Kahn 1969). Langston (1995, p. 274) cautions, however, that the world is so complex that more information will not necessarily prevent further errors. As technological processes create order, they also cause disorder, and further environmental manipulation may trigger further unforseen and undesirable ecological interactions. (e.g., in the Goulburn Valley, the continued use of groundwater pumping to lower water-tables appears to be aggravating the salinity problem)(Haskew 1996; Mason-Jones 2000).

Swaney (1985) makes the additional point that human technology has become so powerful that it has the potential to disrupt entire life support systems (including the biosphere itself). From this perspective, both the application of technology for marginal increases in productivity and "learning by doing" (which is often the only recourse in a nonlinear world) appear potentially dangerous. Hence, Swaney (1985) argues that humans must utilise their expanding knowledge base to anticipate the consequences of their actions so as to reduce the risk of severe ecological damage.

A further argument against careless technological intervention is provided by Norgaard (1984), who observes that feedback mechanisms that previously operated within ecosystems have, in many cases, been assumed by or shifted to social systems. Examples of this shifting of responsibility include modern agricultural practices, water contamination and treatment, and other environmental problems (e.g., in the Goulburn Valley, rising water-ables and salinisation), all of which require ever more sophisticated technology in order for system functioning to continue. Wilson (1998, p. 270) describes this as the "ratchet of progress", meaning that the more knowledge humans acquire, the more their populations can grow and the more they can alter the environment, whereupon the more new knowledge is required simply for them to survive. From this perspective, advanced technology has become the "ultimate prosthesis", whereas sustainable development may be taken to mean that humans should utilise their knowledge towards expanding resources and improving quality of life for however many people live upon the Earth with minimal dependence on technology.

All of these arguments suggest that the object of technological intervention in the coevolution process should be not so much the incremental pursuit of immediate resource gains, as increasing the probability of securing one of the more, rather than less, desirable "alternative futures" that appear to be available to the intervening system. This view is echoed by Fitzhardinge (1994), who points out that the role of technology is to support established connections between humans and the environment, and that its biophysical impacts occur primarily through its influence on the social system. The development of sustainable resource use systems thus seems less dependent on the development of new technologies than on changing the social structures associated with farming - for example, by overcoming the paradigm that what is produced, and the manner of production, should be determined solely by external commodity markets and the need to maximise profits. Worster (1990) observes, however, that under the capitalist system, ecologically-inspired modes of farming almost inevitably succumb to the pressures of the market economy - and as the Goulburn Valley continues to be dominated by larger economic, political and cultural forces, such a change appears unlikely to occur in the region of its own accord.

Sustainable development appears dependent, in any case, on what Emery and Trist (1972, p. 124) term "adaptive planning" - that is, planning subject to continuous and progressive modification, usually at the instigation of government but with the collaboration of all active system participants. The operating paradigms should be those of nonlinear dynamics - that change is continuous, the results of actions (including the use of new technologies) are inherently unpredictable, and stability, if it occurs, is only a "chance, temporary phase" (Parker & Stacey 1995, p. 50).

The paradox remains that while the efficient conduct of day-to-day activity requires that people work towards a shared vision, coevolution requires that this vision must be constantly questioned as a vital part of the process of change (Norgaard 1984; Parker & Stacey 1995, pp. 50-51). This means that positive and negative feedback processes must operate simultaneously, and implies a systemic structure that is continually capable of adaptation. This, in turn, requires a shift in operational focus away from results or outcomes, which are significant only in the context (temporal, socio-economic, etc.) in which they emerge, and towards the auditable processes which contribute to various outcomes and the extent to which they can be replicated, developed further or modified to bring about desirable change. Also required is the continual generation and dissemination of information regarding resource use opportunities and outcomes. On this basis, a successful system will be one which is open to change but is also capable of constraining the resulting social and economic tensions. Achieving such "order within disorder" requires both institutional structures and behavioural norms that promote adaptability and, in particular, resource use policies that complement, rather than conflict with, biophysical and economic changes in the system's operating environment (Parker & Stacey 1995, p. 77). The reversal of the taxation policy on tree clearing, and the removal of subsidies within the water sector in Victoria are positive steps, as they mark the end of government sponsorship of some of the physical causes of environmental problems (Kellow 1992). The current support for groundwater pumping may also need to be re-evaluated if this is indeed found to be exacerbating salinity problems, and paradigm of irrigated agriculture itself should be subject to free and constant scrutiny into the future.

For the Goulburn Valley, it is to be hoped that the approach to land and water management embodied in the SIRLWSMP indeed indicates the end of the period of untrammelled resource exploitation in the region, and the beginning of a move towards the more sustainable path of coevolutionary development. The return of a measure of decision-making autonomy to the regional community, the emphasis on free information flow between system components, and the review mechanisms that are built into the SIRLWSMP are all positive signs of such a change in the evolutionary direction of the system. This does not mean that the future will be any less challenging for the region's inhabitants than it already appears to be, or that the disturbed hydrological balances can be restored to their former (pre-European) equilibrium. As Langston (1995, p. 271) remarks, there is no 'natural' state to which the ecosystem can be returned - humans have shaped the region for thousands of years, and the decision-makers in the Goulburn Valley must operate within a landscape that is essentially a 'hybrid' product of human aspirations and recalcitrant natural processes. Neither does the goal of sustainability offer any more certainty about what the system might look like in the future. As Dovers (2000) suggests, the Goulburn Valley is "still being settled". The SIRLWSMP and the broader catchment management arrangements within the Goulburn-Broken region may be indicative of a new phase of resource use, but the stability of the socio-agricultural system - and the biophysical environment in which it operates - remain as vulnerable to the forces of both nature and human culture as they ever were. Whether irrigated dairying or intensive horticulture will continue in the region, although of profound interest, is thus beside the point. From the perspective of systems dynamics, the most important question for the region's future is whether its inhabitants will indeed respond to further environmental changes as they occur, and modify their actions to accommodate those changes, or else to maintain some new vision of what the 'Goulburn Valley' should be.

9.8 The need for 'consilience'

This thesis demonstrates, above all, the need for what Wilson (1998) terms "consilience" - that is, the systemic, multi-disciplinary linkage of cause and effect - in the study of human-induced environmental change and in the processes of decision-making that relate to natural resource use. In both instances, the forces or influences at work are, variously, political, social, economic, cultural and psychological as well as biophysical, and all operate at the level of the individual as well as on a broader social scale. This has a confounding (and hence unpredictable) effect on the outcomes of resource use decisions - although as this work also shows, outwardly complex patterns can often be traced back to small, identifiable changes within a system. The forces that generate change do not act randomly, and the theories of nonlinear systems dynamics appear as an authentic principle of nature in the social as much as the biophysical realm. (As Wilson (1998, p. 184) suggests, the distinction between the the social and natural (biological and physical) sciences should thus be considered an academic artifice, as both may benefit in terms of understanding from input from the other.)

The 'consilient' conclusion of this work may be considered accordingly to be that the environmental changes that occurred in the Goulburn Valley over the past 163 years of European occupation are a product of dynamically-interacting natural and human forces; that human perceptions of the region (and hence resource use) were influenced more by exogenous considerations than prevailing biophysical knowledge; that the present-day waterlogging and salinity problems of the region can be explained in terms of these perceptions (and the factors contributing to them), as well as by biophysical processes; and that sustainable resource use in the future is dependent as much on an understanding of human nature as of ecosystem functioning. These generalisations, and the approach by which they were formulated, may also be applied beyond the Goulburn Valley to other regional socio-agricultural systems, and to other dynamic human-environment contexts in which processes of change require a consilient, systemic explanation.

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APPENDIX 1

HISTORICAL RAINFALL RECORDS

Historical rainfall records for several Goulburn Valley locations, as well as for the northern and southern areas of the region as a whole, were obtained from several sources.

The earliest rainfall observations for the region appear to have those recorded at Kaarimba, near Nathalia. These were obtained for the years 1867 to 1910 from Results of Rainfall Observations made in Victoria, 1840-1910 (Bureau of Meteorology, 1912).

Rainfall records for Shepparton commenced in 1877, and were obtained (with some omissions, including the years 1989-96) from the current archives of the Bureau of Meteorology, Victorian Division.

Bureau of Meteorology records for the Upper North and Lower North rainfall districts (see Figure 1) were obtained for the years 1933-98 from various editions of the *Victorian Year Book*.

No complete historical records were found for any single location or district. The data presented on the following page (Table 1b) comprise the averages of all the annual rainfall data available from the above sources for each year between 1867 and 2000, and are considered to provide a reasonable indication of annual rainfall throughout the Goulburn Valley as a whole within this period.

Table 1a: Long term mean annual rainfall in selected Goulburn Valley locations.

	Mean annual rainfall (mm)	Data period	Source
Goulburn Valley	491	1867-2000	Table 1b
Shepparton	501	1877-1986	Bureau of Meteorology
Nathalia	470	1867-1906	Bureau of Meteorology (1912)
Tatura	493	1942-2000	Bureau of Meteorology (2001)
Upper North district	520	1933-1998	*Victorian Year Book*
Lower North district	432	1933-1998	*Victorian Year Book*

Figure 1: Upper and Lower North rainfall districts, Victoria.

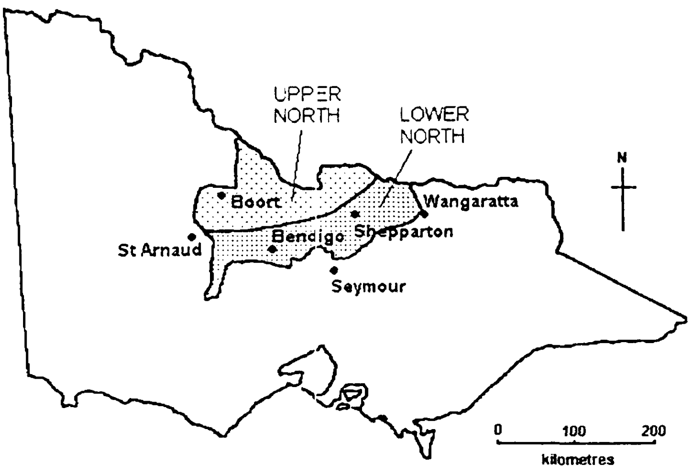

Table 1b: Goulburn Valley rainfall, 1867 to 2000.

Year	Rainfall (mm)	Year	Rainfall (mm)	Year	Rainfall (mm)	Year	Rainfall (mm)
1867	618	1901	342	1935	507	1969	487
1868	388	1902	297	1936	519	1970	536
1869	478	1903	551	1937	353	1971	525
1870	926	1904	474	1938	239	1972	324
1871	580	1905	427	1939	761	1973	899
1872	591	1906	654	1940	251	1974	761
1873	531	1907	419	1941	508	1975	636
1874	621	1908	465	1942	517	1976	306
1875	689	1909	541	1943	293	1977	334
1876	398	1910	499	1944	249	1978	595
1877	415	1911	523	1945	390	1979	454
1878	650	1912	516	1946	471	1980	417
1879	419	1913	467	1947	534	1981	550
1880	518	1914	251	1948	442	1982	206
1881	401	1915	449	1949	551	1983	571
1882	394	1916	712	1950	600	1984	441
1883	387	1917	812	1951	533	1985	463
1884	354	1918	661	1952	595	1986	468
1885	484	1919	384	1953	443	1987	405
1886	448	1920	529	1954	574	1988	586
1887	708	1921	663	1955	707	1989	566
1888	241	1922	381	1956	850	1990	407
1889	658	1923	485	1957	358	1991	451
1890	490	1924	613	1958	548	1992	665
1891	569	1925	379	1959	427	1993	593
1892	429	1926	451	1960	569	1994	278
1893	452	1927	310	1961	389	1995	517
1894	635	1928	544	1962	480	1996	491
1895	305	1929	355	1963	557	1997	334
1896	341	1930	532	1964	520	1998	444
1897	336	1931	593	1965	406	1999	527
1898	391	1932	488	1966	559	2000	529
1899	411	1933	503	1967	245		
1900	456	1934	579	1968	533		

APPENDIX 2

WATER QUALITY CLASSES AND SALT TOLERANCES

Table 2a: Australian Water Resources Council water quality classes.

AWRC water class	Electrical conductivity (microSiemens/centimetre)	Total dissolved solids (milligrams/litre)
Fresh	0 - 800	0 - 480
Marginal	800 - 1,600	480 - 960
Brackish	1,600 - 4,800	960 - 2,880
Saline	> 4,800	> 2,880
Sea water	~50,000	~30,000

Source: Auditor-General Victoria (2001)

Table 2b: Salt tolerances in plants and animals*.

	EC (µS/cm)	TDS (mg/L)	Suitability
Drinking water	< 800	< 480	Good quality drinking water based on taste
Crop suitability	< 650	< 390	For sensitive crops
	650 - 1,300	390 - 780	For moderately sensitive crops
	1,300 - 2,900	780 - 1,740	For moderately tolerant crops
	2,900 - 5,200	1,740 - 3,120	For tolerant crops
	5,200 - 8,100	3,120 - 4,860	For very tolerant crops
	> 8,100	> 4,860	Generally too saline
Dairy cattle	0 - 3,730	0 - 2,240	No adverse effects expected
	3,730 - 5,970	2,240 - 3,580	Should adapt without loss of production
	5,970 - 10,450	3,580 - 6,270	Loss of production; decline in health

Source: Draft Australian and New Zealand Guidelines for Fresh and Marine Water Quality, July 1999 (cited by Auditor-General, Victoria 2001).

** Pasture production declines by about 4 kg/ha for each increment of 1 mg/L of soil salinity above threshold level, and clovers are replaced by grass-dominant swards. Crop yields decrease by 5 to 25 per cent for each 600 mg/L increase in the saturation extract of the soil above the threshold salinity level (ACIL Australia 1983).*

APPENDIX 3

ON-GROUND SALINITY CONTROL WORKS AND ACTIVITIES UNDERTAKEN IN THE SHEPPARTON IRRIGATION REGION, 1990 TO 1999.

Expenditure and community involvement:

* Local communities, including landholders, have spent $270 million on implementing the SIRLWSMP; Governments (State and Federal) have spent over $100 million, or 36 per cent of annual government expenditure for salinity control throughout the State.

* Over 60 landholder and other community action groups have been involved in the implementation process, including 12 Landcare groups in the Goulburn Valley itself. These groups comprise part of the greater Goulburn-Murray Landcare Network, an organisation formed in 1995 to promote and coordinate Landcare works in northern Victoria and assist with the implementation of regional resource management strategies.

Farm Program:

* Over 1400 whole farm plans have been completed (adding to the 540 already completed after incentives for whole farm planning were introduced in 1986/87), representing 131,000 hectares or over 42 per cent of the irrigated area in the Region. The whole farm planning process has also been modified to include environmental and economic considerations, as well as those related to water management.

* The improved water and land management practices suggested in the Plan have also been widely adopted:

  * Over 113,000 hectares have been laser-graded, bringing the total to over 60 percent of the irrigated land in the Region.

  * Micro-irrigation systems have been installed on over 2500 hectares of horticultural land.

  * 2.7 million trees have been planted by landholders, with a further 279 hectares of farmland fenced and planted to native trees and shrubs.

  * Over 2500 re-use systems have been constructed on farms for the collection and re-use of farm runoff (drainage and rainfall). This brings the regional total to over 3400 systems, which collectively trap over 50 per cent of water from the Region.

  * Over 1400 kilometres of new farm channels were constructed; over 1800 kilometres of farm drains were improved.

Surface water program:

* 478 kilometres of community-funded surface drains and 105 kilometres of arterial drains managed by Goulburn-Murray Water have been constructed in the first nine years of Plan implementation, servicing 63,000 hectares of previously undrained land, or 12 per cent of the Region in total. More drains have been designed and are ready for construction. The costs of supplying surface drainage to the region have also been substantially reduced under the Revised Surface Drainage Strategy completed in 1995.

* The surface drainage program has been integrated with the regional Nutrient Strategy and Waterways Programs. The proposed tripling of the area served by drains is required to be accompanied by a 50 per cent reduction in phosphorus contributions from surface drains to the Murray River. This is to be achieved through the development of drainage diversion plans, increased use of natural catchment storages, and further modifications of drain designs to maximise nutrient stripping. Procedures to maintain and enhance

environmental values of wetlands and remnant vegetation have also been adopted in all aspects of the drainage program.

Sub-surface water program:

* 17 public groundwater pumps (protecting 2500 hectares) have been commissioned and 20 others have been planned or are in the process of construction.

* 169 new private groundwater pumps have been installed and 55 upgraded to providing water-table protection for over 24,000 hectares of pasture land as well as water for the irrigation. A further 19 new private pumps were installed and another upgraded on horticultural blocks. Tile drains were also installed on 16 hectares of horticultural land. Groundwater is now a regular source of irrigation water for many farmers, and there is heightened awareness of the need for drainage effluent to be disposed of in winter (aiding dilution). Options for the disposal of saline groundwater on farms (e.g., agro-forestry, low productivity pasture) also continue to be explored.

Waterways program:

* 1999 represented the first full year of works. These are targeted at vulnerable reaches of rivers and streams and include rock beaching projects, gully control structures in tributary waterways, fencing of unstable water frontages, control of woody weeds, removal of large woody debris, and construction of fishways.

Environmental Program:

* Almost 2400 hectares of wetlands on public lands have been protected by environmental works.

* Environmental considerations have been incorporated into all SIRLWSMP programs, so that an additional 1000 hectares of wetlands have been protected in association with drainage works and incentive provided to private landholders to complete works on their properties. Incentive schemes for landholders have also contributed to 172 hectares of tree planting and the protection of 276 hectares of remnant vegetation.

Sources: Fuller *et al.* (1999); Sampson *et al.* (2000); SIRLWSMP (1997)