PART IV

ANALYSIS AND CONCLUSION

Preface

Part IV (Chapters 11-12) contains an analysis of the AEH approach.

The discussion in Chapter 11 draws together evidence and insights from Chapters 8, 9 and 10 to explain why planners and policy makers in the Murrumbidgee Irrigation Scheme did not learn from the past. While the conclusions are necessarily somewhat speculative, they are intended to stimulate discussion about the range of issues that policy makers, today, ought to consider in comparable human-environment systems.

Chapter 12 concludes the thesis with an evaluation of AEH approach and the development of operational guidelines for future studies. It identifies some areas of current debate in NRM where AEH studies could be usefully carried out.

Pioneers on the Murrumbidgee Irrigation Areas (Water Conservation and Irrigation Commission 1913)

Settlers spraying fruit trees in the Yanco Irrigation Area (Water Conservation and Irrigation Commission 1914)

CHAPTER 11 ANALYSIS OF THE AEH STUDY

11.1 Introduction

This chapter is organised around a discussion of why planners and policy makers in the Murrumbidgee Irrigation Scheme did not learn from the past. Here I draw together evidence and insights from Chapters 8, 9 and 10. The discussion is aimed at the development of plausible dynamic hypotheses. Although it is not possible to say why a particular person at a particular time did not learn some specific thing, it should be possible to identify generic patterns of behaviour that were likely to have been contributing factors to the failure of a community to learn from the past.

The account of irrigation development in Chapter 8 focused on what scientists, engineers and policy makers understood about the effects of intensive irrigation in northern India. It covered the period from the 1820s to the 1890s. By the 1870s there was already a serious irrigation salinity problem in northern India, which had followed the construction of new irrigation canals. In some areas salt efflorescence appeared more rapidly than in other areas and was more serious. Thanks to the work of geologists and chemists (Medlicott 1863 and 1880; Anderson 1863 [quoted in Whitcombe 1972]; Center 1880; Leather 1897a and b) scientific understanding of salinity was reasonably advanced by the end of the century. But learning from experience in the policy community remained poor. Nevertheless, India was potentially an important source of knowledge concerning the dangers of irrigation salinity. Policy makers in the Australian colonies *could* have learnt from the past.

In Chapter 9, the scene is south-eastern Australia in the final decades of the nineteenth century. Unlike India, south-eastern Australia offered Europeans no pre-existing examples of indigenous irrigation. The 1880s and 1890s was a period when scientists and men on the land were observing and learning about their new bio-physical environment. They were experimenting with irrigation techniques and learning about local soils and groundwater. A few gentlemen farmers were communicating their observations to scientists at the meetings of the Royal Society of NSW (e.g., T.K Abbot 1880, W.E Abbott 1880, Abbott 1884). It was a time when the colonial governments of Victoria and New South Wales were gathering scientific data. Scientists were becoming aware that, in south-eastern Australia as much as in India and the western USA, salt could become a serious problem. Policy makers in the Australian colonies *should* have learnt from the past.

Chapter 10 covered a much larger period of irrigation development than Chapters 8 or 9. It traced development of the first intensive irrigation scheme in Australia, the Murrumbidgee

Irrigation Scheme. Formally begun in 1906, the scheme presented government and policy makers with many difficulties during the first two decades. The historiographic evidence assembled in this chapter indicates that MIA policy makers *did not* learn from the past.

While Chapters 8, 9 and 10 may each be regarded as a self-contained narrative, collectively they describe the evolution of scientific knowledge and the growth of experience in irrigation operations that were vital for successful long-term irrigation in south-eastern Australia. When useful lessons from the past were available, including some from the very recent past in Australia, why did MIA planners not take advantage of them? Why did they not pay more attention to the danger that salinity would accompany intensive irrigation? What were the impediments to their learning from the past?

It is useful to keep in mind two phases of the MIA development. The first phase covers the period from the Lyne Royal Commission (1884-1887) to the inauguration of Yanco Irrigation Area in July 1912. Throughout this time the NSW Government and the community were gathering the necessary data, and considering a range of measures for water conservation and irrigation development. Following the McKinney-Gibson proposal in 1903, attention started to focus on an intensive scheme served by the Murrumbidgee River. Serious planning specifically for the MIA began in 1906. In this earlier period lessons from the past could have provided crucial guidance. The second phase extends from 1912 when the MIA was an operating system. While opportunities to learn from the past were always available, the community of policy makers, scientists and farmers now had new opportunities to learn from their own experiences under operating conditions. As the scheme evolved it became more complex, and the task of learning more difficult. (Note that, because MIA players had opportunities to learn from their own experience and the experience of others (the past), in this chapter I use the phase 'learning from experience' to cover both activities.)

11.2 Dominance of Specific Worldviews

Individuals' mental models of how the world works will influence which issues they pay attention to and which they ignore. Understanding mental models (worldviews or policies) can reveal how a particular worldview can become entrenched and dominant. The focus of this section is particularly on the way in which the engineering view of irrigation development came to be entrenched in, and dominated, the development of the MIA.

The CAP model (see Chapter 4) shows that, in order to isolate generic patterns of behaviour, it is necessary to look at a number of cases. The historiographic studies presented in Part III have provided evidence from three cases: India, Mildura and the MIA. The evidence presented, which reflects the quality and availability of primary material, varies across the three cases. Nevertheless, 12 characteristics of developments in these places are summarised in Table 11.1.

Table 11.1:
Comparison of irrigation developments in India, Mildura and MIA

Characteristic	*India 1870s*	*Mildura 1890s*	*MIA 1910s*
Stated aim of development	Crops to provide famine relief locally, and for export	Chaffeys' commercial interests, government land settlement	Drought insurance for pastoralism, and new land settlement, nation building
Influence of economics	Strong economic focus	Essentially a land-development scheme, with strong focus on profit	Strong economic focus
Planned social benefit	To serve pre-existing and new agricultural communities	To create agricultural communities	To create agricultural communities
Attention to bio-physical (landscape) features	Received poor consideration	Received poor consideration	Received poor consideration
Influence of engineering	Focus on water delivery, dominant in development and operation	Focus on water delivery, dominant in development and operation	Focus on water delivery, dominant in development and operation
Influence of science	Land reclamation on a small scale once salt problem evident	Appear to have been no scientific studies before or during	Some attempts to identify soils before; experiment farm to identify best crops
Experience in operating irrigation	Small-scale irrigation existed long before British built canals	Small irrigation works elsewhere in Victoria from 1880s	Small private attempts, and proto-irrigation schemes
Knowledge of salinity	Known to occur in other parts of the world, and in north India before British schemes	Known to occur in other parts of the world. Saltbush a known indicator of saline land in Mallee country.	Known to occur in other parts of the world, and to have been a problem in Mildura. No attempt to clarify situation in MIA.
Planned use of irrigation	Staple grains, and export crops (indigo, cotton, sugarcane)	Horticulture (grapes and citrus)	Mixed horticulture, agriculture and dairy
Type of farmer/ settler	Indigenous rural peasantry experienced in agriculture, but not in intensive irrigation	No experience in agriculture and horticulture	No experience in agriculture and horticulture
Management institution	Irrigation branch of Indian Public Works Dept	Chaffey Brothers Limited	Water Conservation and Irrigation Commission (NSW Govt)
Attention to agricultural sustainability	Ignored	Ignored	Ignored

A comparison shows considerable similarity, notably the influence of economic and engineering factors; scant attention to bio-physical factors in the face of knowledge of salinity; minimal experience on the part of settlers who would use irrigation; and no attention to agricultural sustainability. From these similarities it appears that there was a general tendency for engineering and short-term economic considerations to drive irrigation development, and for the long-term sustainability of the agricultural enterprise to be neglected.[1]

In particular, the data suggest that in India, Mildura and the MIA policy makers did not learn from the past about salinity because irrigation development was squarely under the control of engineers. Engineers held positions of influence in all three jurisdictions, and were not concerned with the long-term problem of over-watering (waterlogging and salinity). In the late nineteenth century several British engineers with field experience in water conservation and irrigation from India were working for government agencies in Victoria and New South Wales.[2] Some had been employed on the massive Ganges Canal system. In addition, government and community worldviews were generally influenced by wild optimism, unconstrained by facts, concerning the economic and agricultural prospects of Australia (Powell 1989).

The traditional engineering view is captured in the words of McKinney. He did acknowledge that, with early attempts at intensive irrigation in India, poor irrigation practices caused saline efflorescence to spread in some instances, but in relation to New South Wales he wrote (McKinney 1892:15):

> The statement that artesian water is fatal to vegetation is generally baseless. Even if the cumulative effect of the water should in some instances prove temporarily injurious, new land could be cultivated while the old recovered. So far, this cumulative effect is only a fear. Artesian water is extensively used in American irrigation.

In one case McKinney actively rejected the concerns expressed by the scientist, William Dixon. Dixon (reported in David 1893:437) said:

> All the salts held in solution in water . . . would gradually accumulate in the soil and render it absolutely sterile as has been the case in some places in India. This effect might not be noticed or act injuriously for ten, twenty, or fifty years, but under the conditions stated it is sure to come sooner or later according to the quantity of matter held in solution.

It seems that McKinney (1893:400) knew the risks associated with irrigation when, describing some cases in India, he said that:

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[1] Rose (1988) has argued that in the majority tradition of engineering education, engineers were biased against the inclusion of public policy concerns in their work. There are signs that this bias is changing, as evinced by the recent emergence of 'green engineering'. Nevertheless, some argue that the above tendency is still widespread (Postel 1999, WCD 2000).

[2] The civil engineers identified in NSW include H.G. McKinney, David McMordie, F.A. Franklin and Arthur Ritchie; and in Victoria George Gordon, W.W. Culcheth and John D. Derry.

> . . . irrigation was adopted as the best of a choice of evils ─ possible privation on the one hand and probable injury to the land on the other. A similar choice of evils may have to be met sometimes in the western districts in this Colony.

He appears to have understood groundwater dynamics (McKinney 1895:548):

> This rise in the level of the underground water has doubtless a tendency to carry up the salts in the subsoil; but admitting all this, it is necessary to state that some writers have exaggerated the mischief done, and have quite overlooked the compensating benefits conferred.

In India, H.B. Medlicott, Superintendent of the Geological Survey, had observed the influence of engineers in irrigation development, and knew their views on salinity. He told the *Reh* Committee (NWP 1879, 218-309, Index No 115, para 21):

> I have never known a canal officer [engineer] to speak rationally on [salinity], i.e., with a knowledge of the many conditions involved in the production of *reh*. I do not mention this to blame any one. A man cannot give what he has not got; and it is hard for a professional man to disown a knowledge imputed to him. The responsibility rests with higher authorities who had not intelligence to see that the *reh* question is not primarily one of engineering.

Under such conditions it was difficult for a change of worldview to occur. This observation supports the basic hypothesis embodied in the CAP model that there is a natural tendency for managers to adhere to their existing operational models and policies. This tendency will be particularly strong when narrowly focused technical experts play a dominant role in policy development.

In Figure 11.1 the loop labelled *Traditional Engineering View* (R1) is a reinforcing loop that represents what has long been a characteristic approach to irrigation development. As the historical study in this thesis has shown, in India, Mildura and the MIA there was an engineer-driven preoccupation with policies for water delivery. This preoccupation led to a strong focus on the construction of canals and infrastructure. Expanded infrastructure then enabled an increase in the amount of water delivered to farms. More water meant that now crops grew in new districts where previous conditions had made agriculture or horticulture impossible and, in other areas, crop yield increased. These results, which typically persisted in the short-to-medium term, encouraged adherence to the dominant engineering view of irrigation development. As long as there was no challenge to this view the system remained locked into the traditional engineering view.

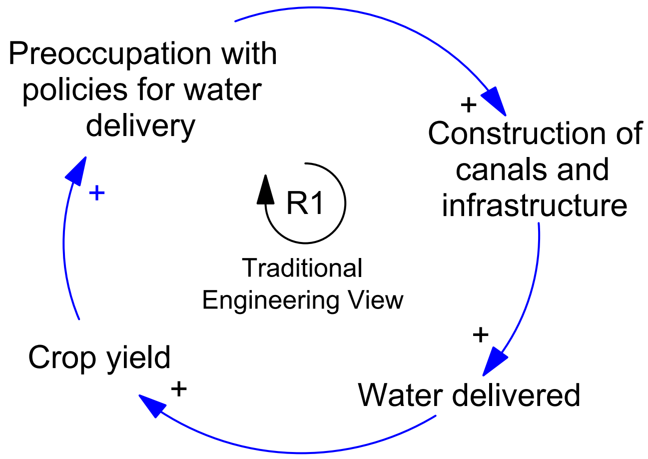

Figure 11.1: Observed dynamics. The dominant approach to irrigation is locked into a traditional engineering view by positive feedback. See text for discussion.

According to the CAP model an alternative worldview could only be generated by the same people when the learning loop operates. Lock-in to the traditional engineering view of irrigation development inhibits learning. This inhibition leads to rejection of possible lessons from the past. Therefore, in order to learn from the past, it is necessary to break the hold of the traditional engineering view. If this can be done, then it should be possible to shift the system over to a new state (Figure 11.2).

In Figure 11.2 the loop labelled *Policy Learning* (R2) is a reinforcing loop that illustrates the effect of advances in irrigation science. The operation of this loop can best be understood by starting at the variable labelled *Understanding of problems of irrigated agriculture*. As understanding grows, either as a result of direct or past experience, the hold of the traditional engineering approach is weakened. This weakening in turn reduces the community's preoccupation with water delivery, and thus increases focus on water usage and a call for more sustainable practices. As the need for better understandings of groundwater and soils increase, research increases. Note that, as defined here, 'water delivery' means getting water to the farmer in useful quantities. 'Water usage' means careful application of water guided by an understanding of crop moisture needs, the ability of various soils to retain water, the effect of irrigation on groundwater levels, and salt diffusion.

A system, like that in Figure 11.2, with two opposed positive feedback loops will be bistable. That is, an increase in the strength of one loop will result in a reduction in the strength of the other. Such a system will automatically lock into a state where one or other of the loops dominates. Once locked in it will not move to the alternate state without the impact of some triggering event.

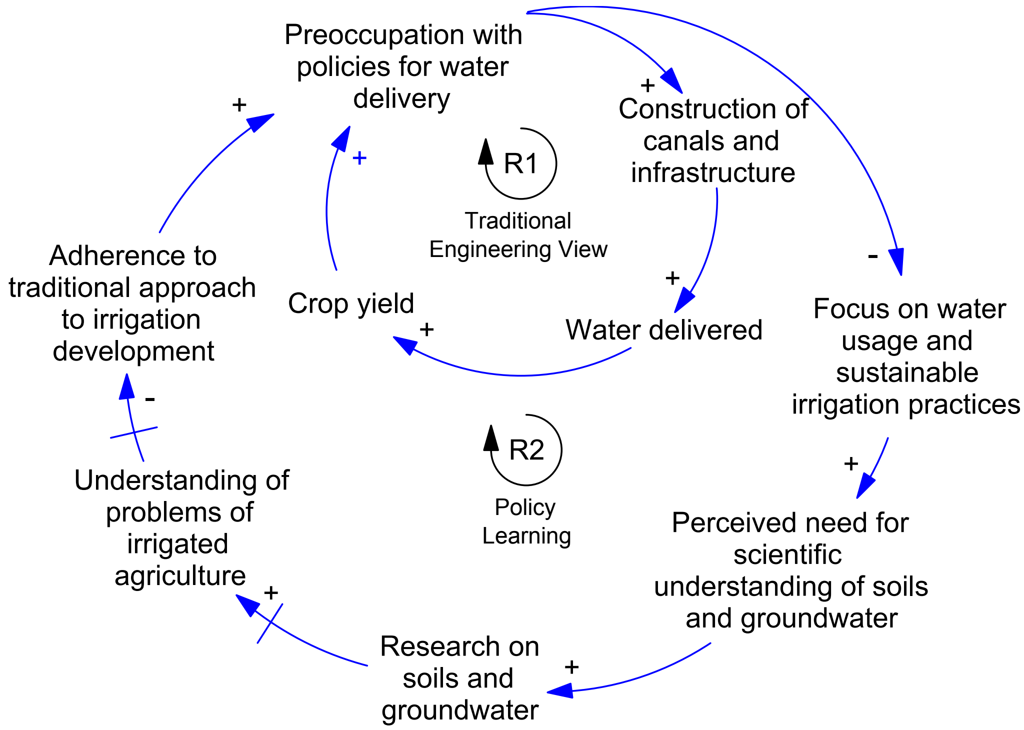

Figure 11.2: Suggested bistable system. R1 and R2 are positive feedback loops that oppose each other. An increase in preoccupation with water-delivery policies will increase the strength of loop R1 and decrease the strength of loop R2. A decrease in preoccupation with water-delivery will have the opposite effect: decrease the strength of R1 and increase the strength of R2. Such a system will tend to lock into a state where one or other of the loops dominates. In irrigation practice this tends to be loop R1, the traditional engineering view. Note that 'water usage' means applying water scientifically guided by an understanding of crops, soils and groundwater. See text for discussion.

In the period 1885-1912 in New South Wales over-watering presented no immediate danger because irrigation was not yet conducted on a scale where waterlogged soils and salinity were likely to occur. Consequently the necessary events did not arise to trigger a change in the prevailing operating models and policies. Policy makers had no opportunity to learn from their own experience. They could have learnt from the past (from other people's experience) by considering the history of irrigation in Mildura and India, but the dominance of the traditional engineering view (with the tendency of engineers to dismiss salt as a problem) would have made this history seem irrelevant.

The CAP model indicates that learning is triggered only when persistent patterns of failure are detected (see Figure 4.6). This suggests that the traditional engineering view of irrigation will dominate until it is recognised that an exclusive focus on water delivery and maximum production can easily lead to a failure of the whole enterprise. This triggering effect is represented in Figure 11.3 by the negative feedback loop labelled *When to learn?* (B1). The preoccupation with policies for water delivery leads to a strong focus on the construction of canals and infrastructure. Expanded infrastructure then enables an increase in the amount of water delivered to farms, but then, with a delay, the effects of over-watering become evident. Then crop production begins to decline, in the short term from waterlogging, and in the longer term from soil salinisation. The reduction in crop yield caused by waterlogging and salinisation weakens preoccupation with water delivery and, thus, increases the focus on water usage and sustainable practices. This process can lead to an increase in the strength of loop R2 and a corresponding decrease in the strength of loop R1.

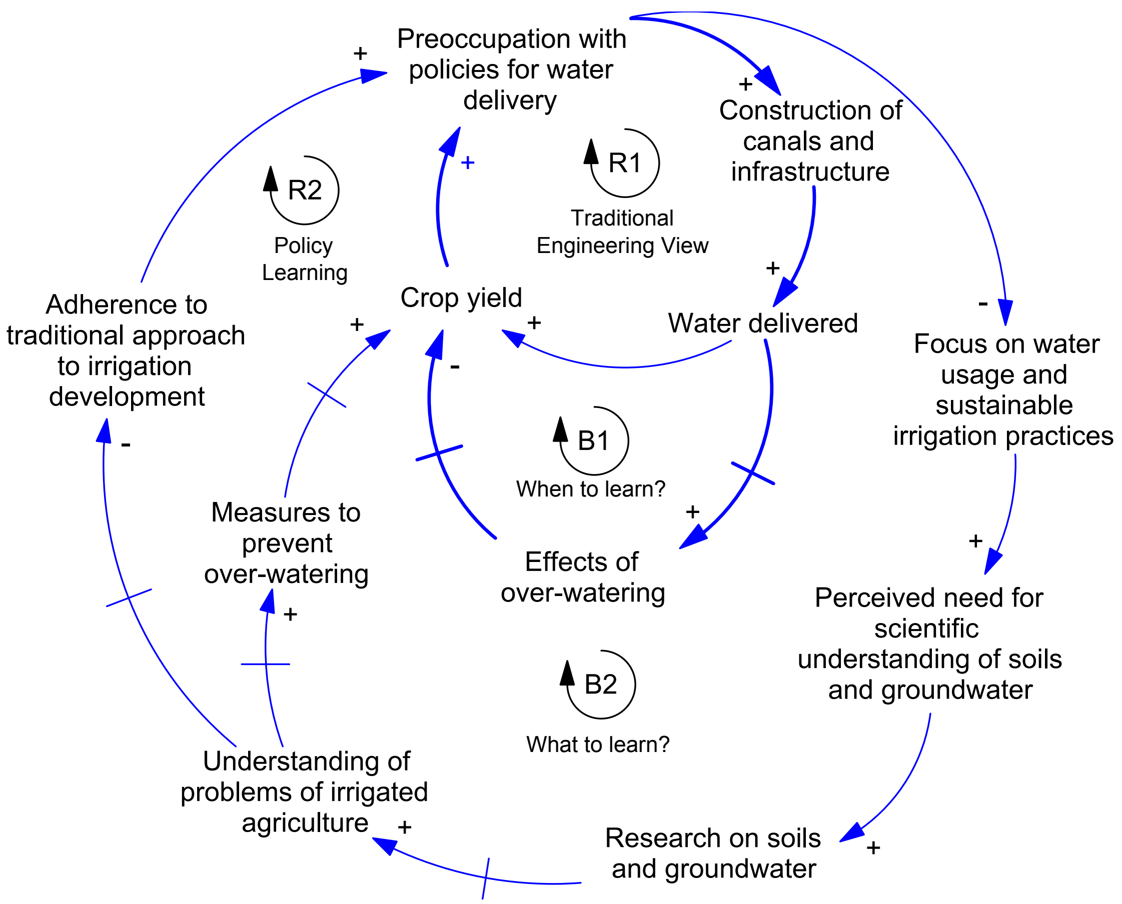

Figure 11.3: The policy learning system. The loop B1 provides the trigger (poor crop yield) to move the system from the R1 state to the R2 state. The loop B2 indicates the learning that must take place to counteract the problem associated with over-watering in B1. There will be delays at many points before a successful transition takes place. See text for discussion.

The CAP model suggests that for effective learning to occur policy makers must recognise that the production problems have been caused by over-watering. This may not be the case, if irrigation science (crop science, hydrology, soil science) has not developed far. Thus, a precondition for loop R2 to become dominant is that irrigation science has developed to the point where the consequences of over-watering are understood, and it is known *how* to prevent it. This effect is represented in Figure 11.3 by the negative feedback loop labelled *What to learn?* (B2). Following the triggering event in loop B1, the focus on sustainable irrigation practices (viz., to avoid over-watering) increases. This will produce a need for understanding of soils and groundwater, and research will follow. In time the community will have a better understanding of the problems of irrigated agriculture, particularly of measures to prevent over-watering. In the longer term, measures to counteract rising watertables and soil degradation help to sustain crop yield. There will be delays in loop B2, depending on the rate at which irrigation science develops.

Once scientists gained a clearer understanding of the capillary potential of soil water, and the concept of field capacity became important, by the 1920s, irrigation science was in a better position to help shift adherence away from the traditional approach to irrigation.

The feedback effects produced by loops B1 and B2 have the potential to move the whole policy learning system from the R1 state to the new R2 state. This process requires sufficient time for effects to accumulate to push the system in R1 close to the transition threshold, then to move it into the new state in R2. Loop dominance has changed.

Figure 11.4 illustrates these effects schematically. The graph shown in panel (a) represents the time-dependence of production from irrigated crops. Once irrigation begins, production increases steadily until the effects of over-watering become evident. It then levels off before declining, in a classic overshoot-and-collapse scenario. Because of the delays inherent in the system, production will typically fall to low levels before a new approach begins to take effect, and then production will begin slowly to rise again. In panel (b) the solid line represents the traditional engineering view corresponding to dominance by the R1 loop in the causal-loop diagram. The dashed line represents a new approach as a result of policy learning corresponding to dominance by the R2 loop in the causal-loop diagram. The dot-dash line shows the underlying cause of a shift in loop dominance from R1 to R2. When crop yield begins to decline (an unintended effect of the policies associated with a traditional engineering view), it acts as a trigger to learning. B1 corresponds to the CAP question *when to learn?* and B2 corresponds to the CAP question *what to learn?*. They lie in a transition zone where the strength of R1 is weakening, and R2 is beginning to grow in strength.

In the case of irrigation development, with long timescales for changes to occur and become visible, learning from the past is essential. Once the effects of over-watering appear, especially

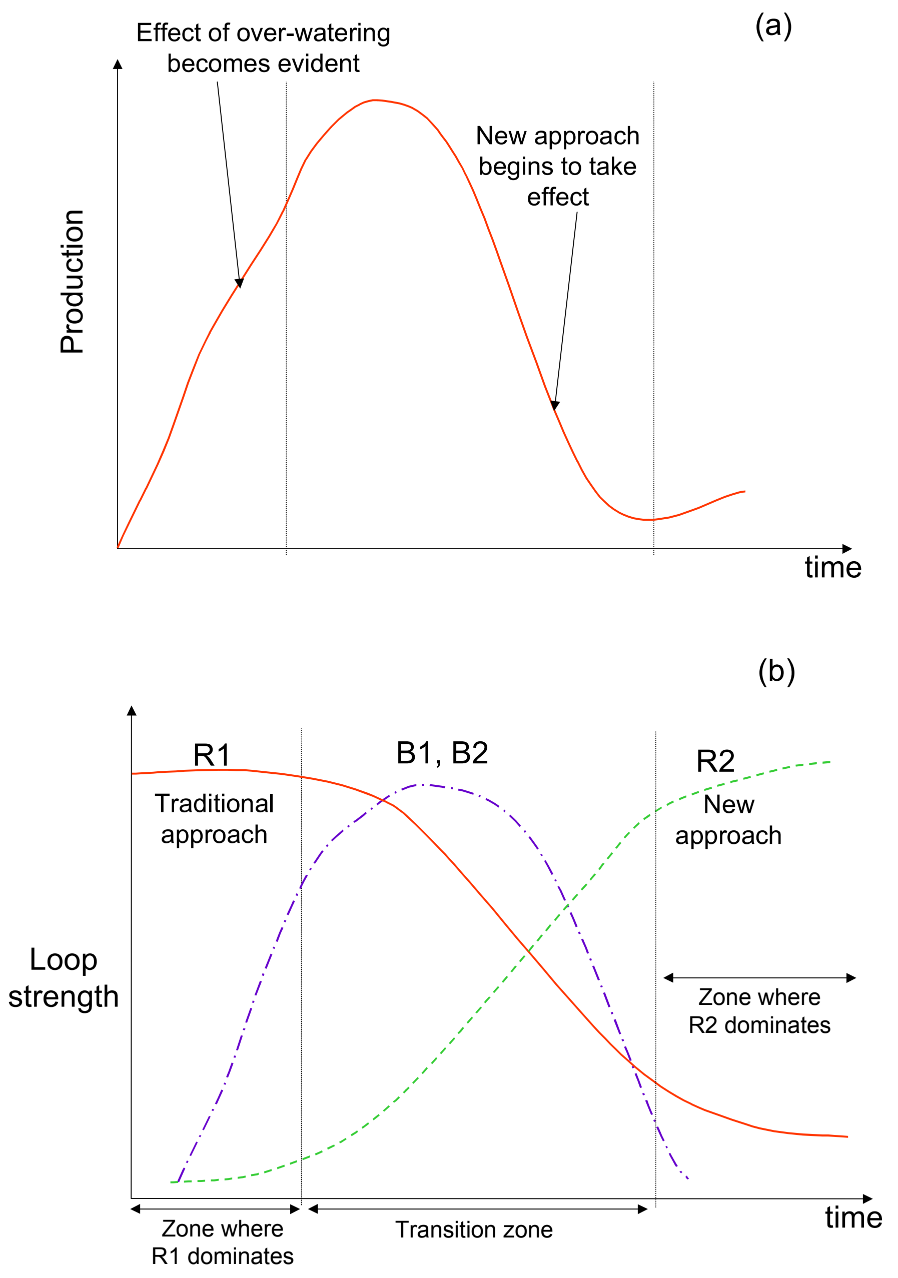

Figure 11.4: Schematic diagram showing dynamics of the policy learning system. In panel (a) the horizontal axis shows elapsed time from the inception of irrigation. The vertical axis shows production from irrigated agriculture. In panel (b) the horizontal axis shows elapsed time from the inception of irrigation. The vertical axis shows the strength of the loops in the causal-loop diagram in Figure 11.3. In both panels the time scale is the same, and vertical lines divide time into three zones. The traditional approach (R1) is dominant in the first zone. In the middle is a transition zone, before the new approach (R2) dominates in the last zone. See text for discussion.

salinisation, they cannot be reversed or removed quickly. Under the particular bio-geophysical and social conditions that existed in India and Mildura, salt appeared relatively quickly. In the MIA the process was slower; salt first appeared there in 1931, then the problem increased steadily over decades. When long timescales are involved, learning from the past can provide advance warning of problems. In practice learning from the past is much less likely to occur than learning from experience, because someone else's failure does not capture the attention and refocus the mind like personal failure does. Moreover, in learning from the past at least two cases are necessary to be sure that a generic pattern has been seen. Therefore, the learning process takes time, attention, deliberation and good scientific reasoning. Under typical NRM conditions, past and present policy makers are unlikely to follow this path.

11.2.1 Generic pattern

Figure 11.5 generalises the behaviour shown in Figure 11.3. The diagram takes the same form as Figure 11.3. The loop R1 represents the reinforcing effects of any traditional entrenched worldview or policy. Loop B1 provides the trigger event, and B2 the focus of the new approach, that can prompt a shift in the dominance from R1 to a new approach in R2.

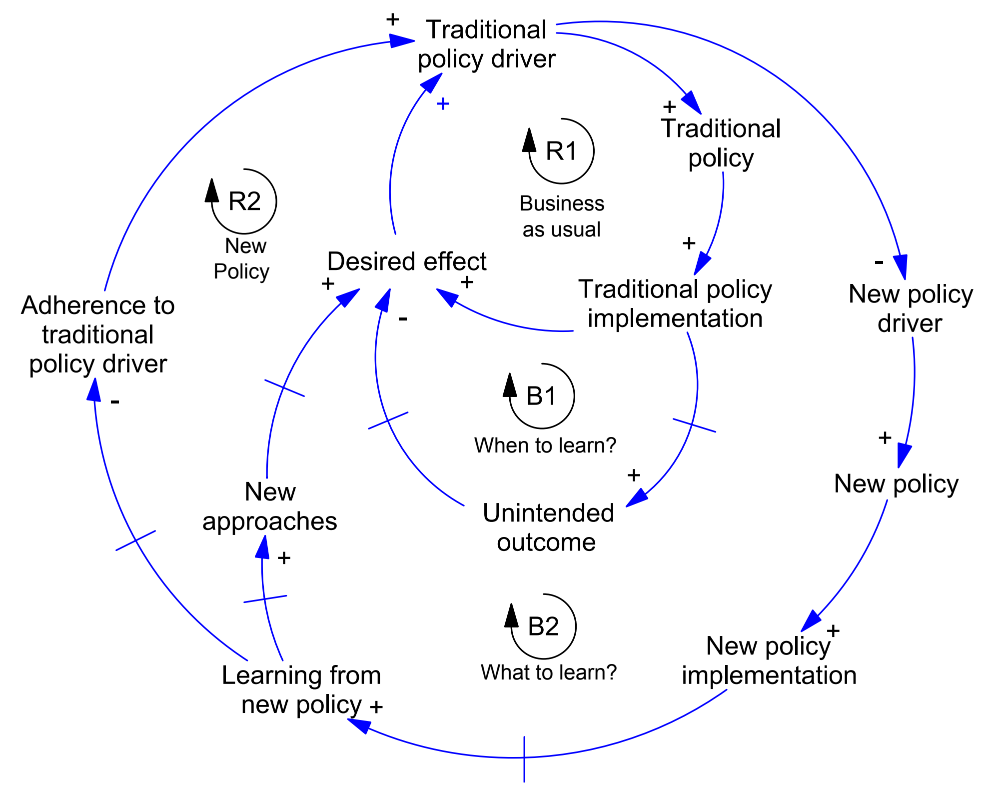

Figure 11.5: The generic bistable system. The pattern of behaviour underlying the requirements for a shift in policy dominance. If feedback loops B1 and B2 do not operate, then the system will remain locked into loop R1, and managers and policy makers will not learn. See text for discussion.

11.3 Decision-driven Complexity

Cowper (1987) noted that, in the critical planning years of 1906-1910, the NSW Government was more focused on avoiding another land scandal, than on the agricultural and social aspects of the MIA development. This attitude seriously distorted the decision-making process and produced unwanted results. Some of the policy decisions made at the time had profound long-term effects on the MIA. They stand out because of the complex web of unintended outcomes that they created. Three examples are examined below. They relate to the land acquisition and development program adopted in 1910; to social policy concerning the selection of settlers; and to economic policy concerning the gazetted capital value of farms. By examining the feedback dynamics, it will become clear that policy makers were making the system more complex faster than they could comprehend the effects of their decisions. Under such conditions learning from experience was difficult.

11.3.1 Program of land acquisition and development

The original plan of 1906 for development of the MIA was to begin at Mirrool. Mirrool was the area with first-class land, and 'contained a large area of Crown Land and holdings which would present no difficulties in the way of resumptions' (Cowper 1987:25). In 1910 the NSW Government departed from the original land-acquisition program to avoid a potential land scandal involving Samuel McCaughey. There was public anger at the prospect that a private landowner stood to make a large profit by subdividing and selling blocks along the path of the Main Canal. Land scandals were still fresh in the public and political minds. The report of a Royal Commission into the affair involving Crick, Minister for Lands (1901-4), had been published in 1906, and the *Sydney Morning Herald* had constantly attacked the Liberal Premier Carruthers for his handling of the scandals at the time. Therefore, the desire to avoid another land scandal led the Liberal Government of C.G. Wade in 1910 to buy *North Yanco* at the lower pre-1910 valuation. Because *North Yanco* was located on second-class land, the land in this holding had not been ear-marked for early development. Nevertheless, in 1910 the government completely reversed its policy, and development of Yanco began.

In Figure 11.6 the loop labelled *Yanco Development* (B1) is a balancing loop that illustrates the short-term effects of this policy change. Once *North Yanco* was resumed, it added to the scheme a vast amount of land (97,354 acres or 240,380 ha) that was not producing revenue, but adding to the government's interest burden. The government needed to generate a cash flow quickly by land development. Therefore, it chose to develop the Yanco area before Mirrool. As development proceeded, more blocks became available, the number of operating farms increased, and provided much-needed revenue. In theory the government would then have had a steady cash flow, and a balanced operation in which revenue received from rents and charges of operating farms could provide funds for the staged development of the MIA.

The loop labelled *Soil Quality* (R1) is a reinforcing loop that illustrates feedback effect that worked to undermine the policy underlying loop B1. Development of farms in the Yanco area, with its second-class land, decreased the average soil quality of farms in the MIA. As more farms were located on inferior soil, the average productivity in the scheme declined. Settlers found it very difficult to make a living, and to meet their financial commitments (rent, water rates, and repayment of loans used to purchase equipment and to cover other initial expenses). Their inability to meet these commitments produced a shortfall in expected government revenue. This delayed effect counteracted the desired effect of the Yanco development.

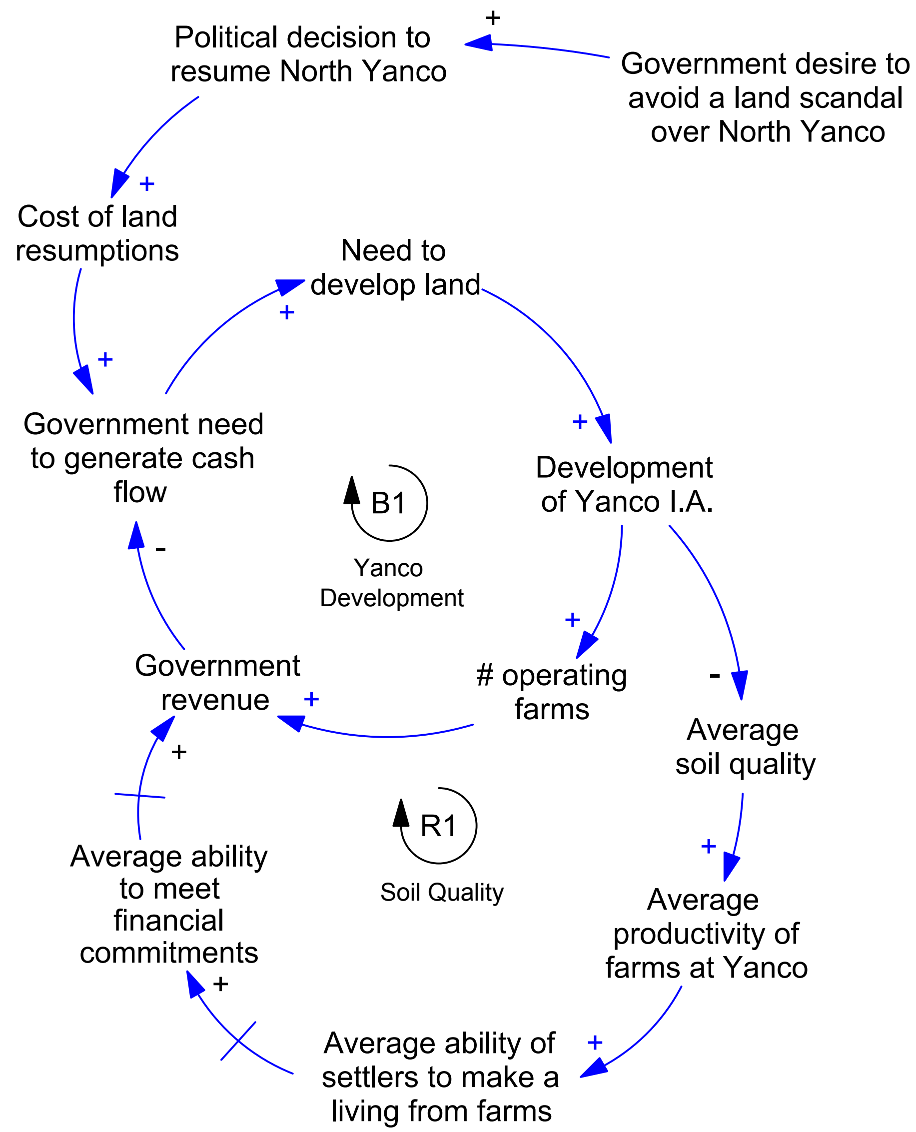

Figure 11.6: Land acquisition and development. Loop R1 is an unintended response to the decision (B1) in 1910 to develop the second-class land at Yanco. The decision increased the complexity of the MIA scheme on many levels. Note the delays marked on the causal links. See text for discussion.

The decision to resume *North Yanco* was driven by political issues, and its development ignored the bio-physical realities of the second-class land. It produced unintended and unwanted outcomes, including considerable hardship for farming families.

11.3.2 Choice of settlers

Initially the NSW Government was committed to a policy of taking only settlers with appropriate farming experience and with cash reserves to help them through the early years. But this policy, though sound, had to be relaxed owing to the lack of such people who wanted to take up blocks in the MIA in 1912. Thus, the government was forced to accept less suitable settlers. This action caused serious problems in the case of both the initial settlers (under closer settlement) in 1912-14 and war veterans (under soldier settlement) in 1920-1925.

World War I (1914-1918) made the initial conditions even worse, and the MIA stagnated. Both farmers and a much-reduced government service struggled with the continuing problems that had been generated by a flawed land-development program, and by short-sighted economic and social policies. In 1916 the Commonwealth and State Governments began planning for the resettlement of veterans under the Soldier Settlement Scheme. The NSW Government was forced to look to the MIA as a source of rural land, because there was little Crown Land available elsewhere, and insufficient funds for new land acquisitions. Soldier settlement imposed additional burdens on the MIA during a time of extreme economic and social hardship caused by war.

Soldier settlement policy was a version of the earlier closer settlement policy, but directed to the specific needs of a post-war society. It offered a means of rewarding men who had served their country during wartime, many of whom had few skills. Like closer settlement, soldier settlement was also driven by an age-old belief in the 'agrarian ideal', illustrated in the life of the yeoman farmer. Rural settlement was seen as 'a vehicle for influencing the type of society' that Australia wanted (Williams 1975:61), and soldier settlement fitted in with this ideal. It aided the task of nation building.

In practice soldier settlement had serious disadvantages. Most returned soldiers, like the original MIA settlers, had insufficient financial resources to carry them through the initial lean years. The dynamics shown in Figure 11.7 came into play again. A former Labor Prime Minister, J.C. Watson, described a fundamental difficulty with soldier settlement policy: 'The problem of settling returned soldiers on the land is, in the main, the problem of settling the moneyless man in a calling which requires capital' (quoted in Fedorowich 1995:148). In addition, most returned soldiers, like the majority of Australians, were urban dwellers and had no experience on the land. In 1925 the NSW Government no longer accepted soldier settlers without experience or capital. Learning from the past was taking place in this context.

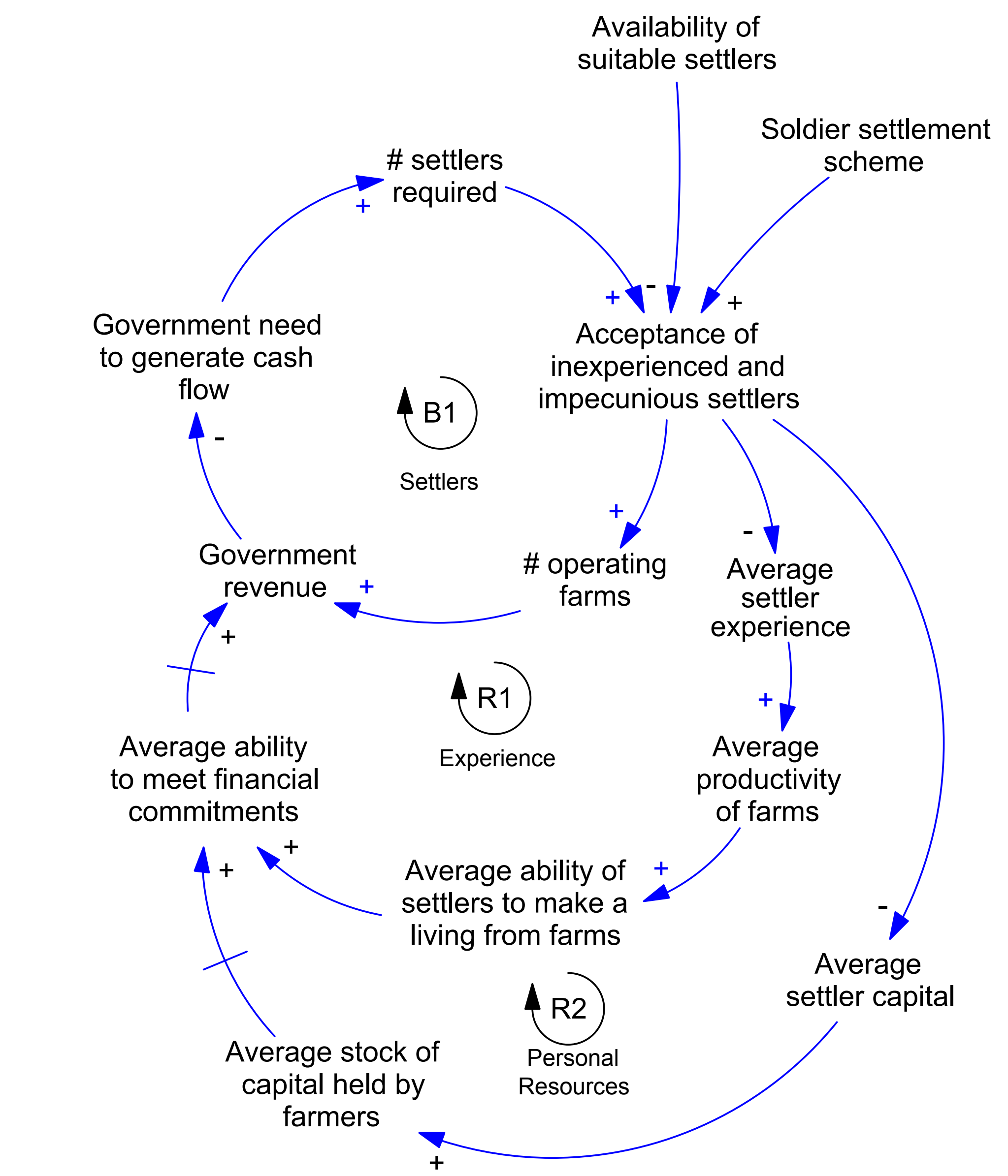

Figure 11.7: Suitability of settlers. Loops R1 and R2 are unintended consequences of decisions (B1) to lower the requirements of prospective settlers, both under closer settlement and soldier settlement. These decisions increased the complexity of MIA operations. Note the delays marked on the causal links. See text for discussion.

In Figure 11.7 the loop labelled *Settlers* (B1) is a balancing loop that represents the government's new policy of accepting settlers with little experience and money. Again, as the need for government to generate a cash flow increased, the number of settlers required for the MIA increased. In turn, because of a lack of suitably qualified settlers, the government was forced to accept inexperienced and impecunious settlers which produced the required increase in the number of operating farms. In the short term, at least, some operating farms contributed to government revenue.

The settlers who arrived at Yanco I.A. had several counts against them: poor soils (Figure 11.6), poor advice about plantings, little or no farming experience, and inadequate financial reserves. Loops R1 and R2 capture the effect of the latter two characteristics.

The loop labelled *Experience* (R1) is a reinforcing loop that illustrates the unwanted effects associated with acceptance of inexperienced settlers. In the 1910s New South Wales had considerable experience in the pastoral industry, but experience in agriculture was low, and even lower in irrigated farming. Ideally, as the fraction of experienced farmers increased, the fraction of successful farmers would have increased, and by diffusion raised the level of collective experience. But this did not occur (Langford-Smith 1966, Cowper 1968, Lloyd 1988). As collective experience remained low, average farm productivity did not increase, and many settlers were unable to make a living from their farms. (Poor soil quality also contributed.) As their prospects grew worse, their ability to meet their financial commitments declined. This, in the longer-term, reduced government revenue from the MIA.

The financial resources that each settler could draw on were especially important for survival during the period before a farm reached full production and could reliably generate income. In fact, many settlers did not have anything like a reasonable reserve of funds (some £300 to £500), and did not survive (Langford-Smith 1966).

The loop labelled *Personal Resources* (R2) is a reinforcing loop that illustrates the unwanted effects associated with acceptance of settlers with inadequate cash reserves. As the number of impecunious settlers increased, the average stock of capital held by settlers decreased. The ability of settlers to meet their commitments declined, and, in time, government revenue from the MIA declined below expectation.

11.3.3 Gazetted capital value of farms

Growth of the MIA was influenced by two significant factors. First, because the MIA was classified as 'a government industrial undertaking' it was required to make a profit. Second, the government land valuer had emphasised that the financial success of the scheme depended on the land being taken at the rate of 24,500 acres (60,500 ha) per year. For the former reason, there was strong pressure on the government to keep valuations of land artificially high. The valuations had been determined by the cost of land acquisition, interest on State loans, subdivision surveys, road construction and maintenance, canal and drainage construction, administration, promotion, instruction of settlers, activities on demonstration areas, and losses

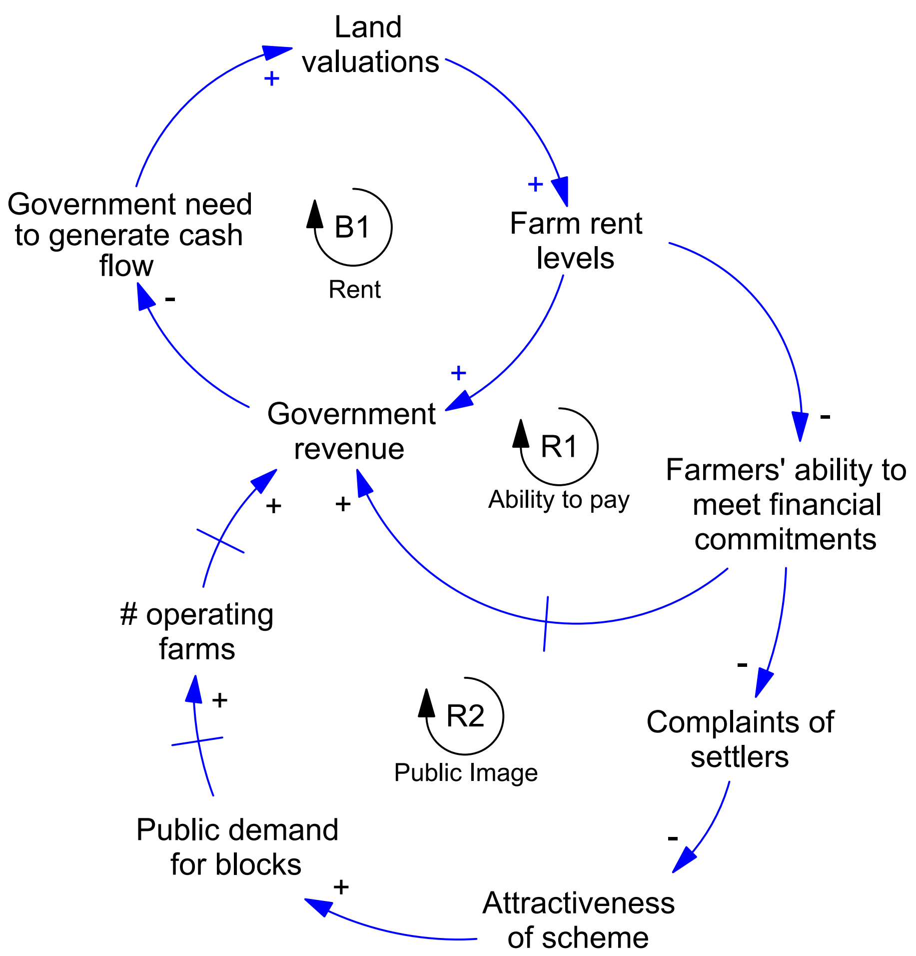

Figure 11.8: Gazetted capital value of farms. Loops R1 and R2 are unintended consequences of decisions (B1) to keep land valuations artificially high. These decisions increased the complexity of the MIA scheme. Note the delays marked on the causal links. See text for discussion.

on WCIC local factories (butter, canning and bacon). This was the published version of the 'method' for valuing farms (*Irrigation Record* 15 March 1913), and used to promote the scheme. It failed to disclose that the 'method' included the cost of Burrinjuck Dam, the railway within the MIA, the Main Canal, and Berembed Weir. It was not until 1926, in a legal test case (*The Stark Case*) that the NSW Land and Valuation Court found that the WCIC had greatly over-valued the MIA land. The Court determined that the WCIC could not maintain its assets at a fictitious standard, and had to cut its losses.

In Figure 11.8 the loop labelled *Rent* (B1) is a balancing loop that illustrates the short-term effects of land valuations. As the need increased for the government to generate a cash flow, the gazetted capital value of land was driven up. Since the capital value determined the rent level from operating farms, rents in turn were set artificially high. Because these funds went into government revenue, and provided resources for the next stage of MIA development, the government was committed to keeping valuations high.

The loop labelled *Ability to pay* (R1) is a reinforcing loop that illustrates the unwanted effects associated with the policy of keeping land valuations high. As the rent for operating farms increased, farmers' ability to meet their financial commitments declined, and in time the revenue received by government from settlers also declined.

The loop labelled *Public Image* (R2) is a reinforcing loop that illustrates a set of further unwanted effects associated with the policy of keeping land valuations high. Initially, when the number of farms was relatively small, the burden of rates and charges was disproportionately large for the existing farmers. Settlers complained. Their complaints reduced the attractiveness of the MIA to new settlers and thus reduced the public demand for blocks. Ideally, the popularity of the scheme should have inclined more settlers to take up blocks, and thereby increased the number of operating farms that could have contributed to revenue. Because that was not the case, the whole scheme remained economically fragile for many years.

The pressure on government that was underlying the behaviour in Figure 11.8 was an outcome of the situations described in the two previous diagrams. The combined effects of all three government decisions (Yanco development, inexperienced and impecunious settlers, and high rents) caused a steady growth of complexity in the whole scheme. The extent of this complexity becomes clearer when the three diagrams are combined. The wider view of the system, presented in Figure 11.9, shows that there were common variables shared among the three issues. They were *Government revenue, Number of operating farms* and *Farmers' ability to meet financial commitments*. Complexity arises because of the tight coupling between the sub-systems. Strong feedback effects operated in and between these sub-systems, and produced behaviour that delayed, diluted or defeated policy makers' attempts to achieve their desired goals.

The steadily increasing complexity in the MIA drove up the difficulty of managing the development, and seriously hampered policy makers and managers' ability to learn from experience.

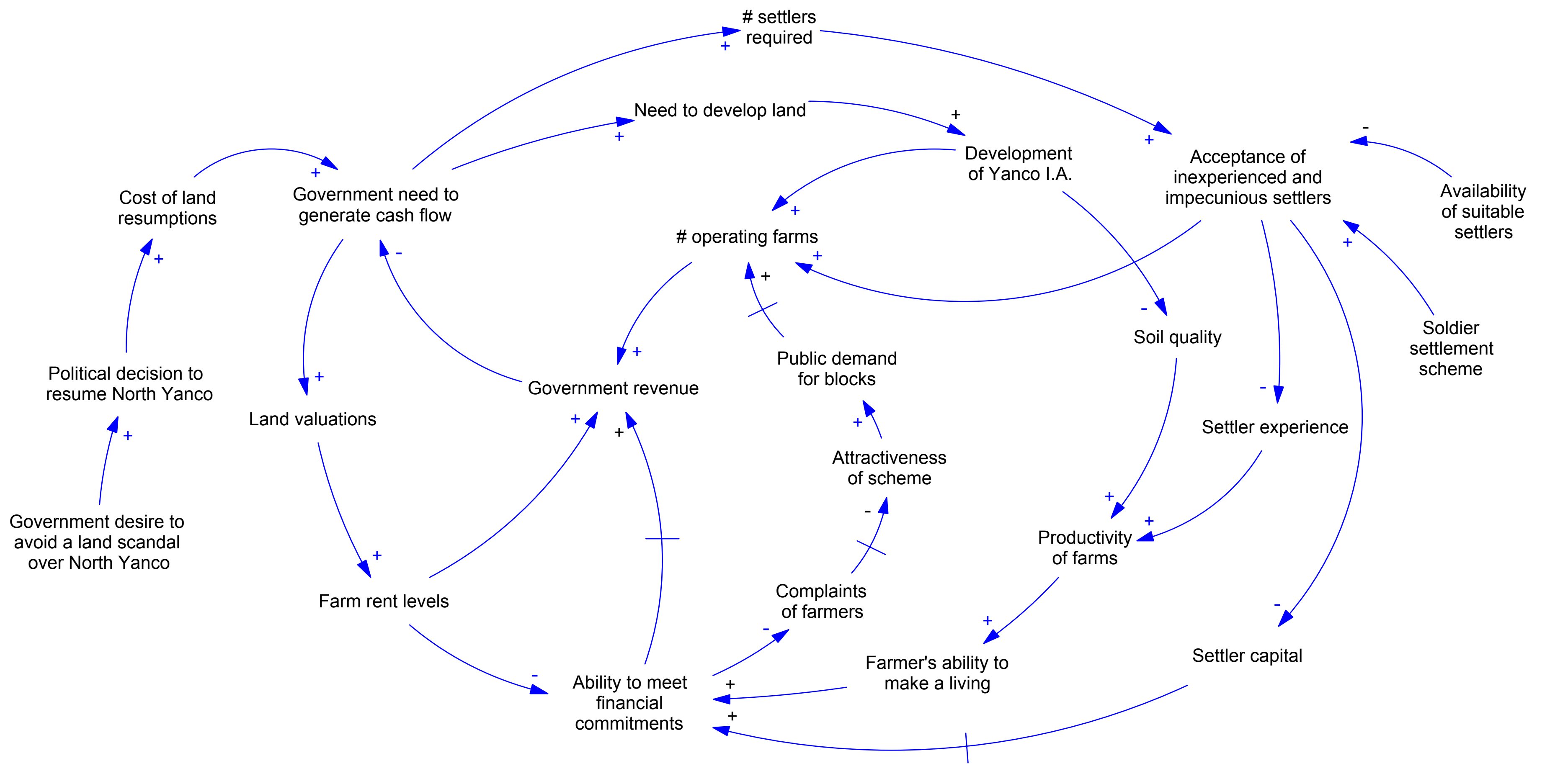

Figure 11.9: A wider view. The combined effects of Yanco development, inexperienced and impecunious settlers, and artificially high rents produced detail and dynamic complexity, and a corresponding difficulty to learn from experience. See text for discussion.

11.3.4 Other sources of complexity

Three other notable cases of decision-driven complexity should be mentioned:

In 1910 the McGowan Labor Government insisted that the MIA blocks be designated as leasehold, to prevent a repeat of history. They wanted to avoid the situation where freehold tenure had allowed a privileged few to own large pastoral estates in the nineteenth century. However, because leasehold tenure denied small farmers access to bank finance, it increased their financial distress. When the *Savings Bank (Amendment) Act, 1914*, was passed, settlers on irrigation blocks could obtain loans from the Government Savings Bank. In practice, the way the Act was administrated left little actual cash for farm development, because outstanding debts were first deducted from the loans. The government had badly misperceived the feedback effects.

The WCIC established no satisfactory mechanism for dealing with farmers' grievances, whether they were complaints about the capital value of the blocks, their inability to obtain finance, the unsuitability of farms to grow lucerne, or the delay in introducing the *Local Government Act, 1919*, to the MIA. In many cases settlers' grievances were made worse by the piecemeal approach of government. Short-term fixes were applied, complexity increased, and the ability to understand the system that the WCIC was trying to manage became more difficult.

On a general level, the structure of the policy environment and the policy culture in New South Wales shaped early decisions about irrigation development. The NSW Public Service in the nineteenth century was modelled on the system of government administration in England, rather than being allowed to evolve naturally 'as a home-grown adaptation to local needs and conditions' (McMartin 1983). The resulting administrative structure reflected non-systemic worldviews that caused policy fragmentation. Policy fragmentation, in turn, encouraged types of agriculture and patterns of environmental exploitation that the Australian environment could not sustain. As shown in Table 11.2 this situation has persisted from 1880 to the present. Government decisions about institutional arrangements continue to contribute to policy fragmentation and the consequent operational complexity of NRM.

Table 11.2:

Institutional NRM Structure in New South Wales (1880-2004)

Land	Forests	Water	Soils
1880-1981 Dept Lands[1]	1882-1887 Forest Conservancy Branch, Dept Mines[2]		
	1888-1889 Forest Conservancy Branch, Dept Lands	1887-1892 Water Conservation Branch, Dept Mines[3] (moved Oct 1892)	
	1889-1892 Forest Conservancy Branch, Colonial Secretary's Office		
	1892-1893 Conservation of Forests, Dept Mines & Agriculture[4]	1892-94 Water Conservation Branch, Dept Public Works	
	1893-1897 Conservation of Forests, Dept Agriculture & Forests	1894-1896 Water Conservation Branch, Dept Mines (moved June 1896)	
	1897-1909 Forests Branch, Dept Lands	1896-1911 Water Conservation Branch, Dept Public Works	
	1910-1916 Dept Forestry	1911-1913 Murrumbidgee Irrigation Trust	
	1916-1976 Forestry Commission of NSW	1913-1976 Water Conservation and Irrigation Commission (WCIC)	1938-1944 Soil Conservation Service, Dept Mines and Forests
	1944-1975 Forestry Commission, WCIC, and Soil Conservation Service brought together in Dept Conservation under Minister for Conservation		
1981-1984 Dept Local Government and Lands	1976-1992 Forestry Commission of NSW	1976-1986 Water Resources Commission, Dept Water Resources	1976-1991 Soil Conservation Service, Dept Agriculture
1984-1991 Dept Lands		1987-1992 Dept Water Resources	

Table 11.2 (continued)

Land	Forests	Water	Soils
1992-1994 Dept Conservation and Land Management	1992-2004 Dept Conservation and Land Management (policy) and State Forests of NSW (commercial)	1992-1994 Dept Conservation and Land Management	1992-1994 Dept Conservation and Land Management
1994-2004 Dept Land and Water Conservation		1994-2003 Dept Land and Water Conservation[5] and State Water (commercial)	1994-2004 Dept Land and Water Conservation
2004- Dept Lands	2004- Dept Primary Industries[6] (policy) Primary Industries Trading (commercial)	2003- Dept Infrastructure, Planning and Natural Resources and State Water (commercial)	2004- Dept Lands

[1] Dept of Lands separated from Dept of Public Works 30 Sept 1859.
[2] Dept of Mines formed 1 May 1874.
[3] Water Conservation Branch formed 11 May 1887 with four staff from Lyne Royal Commission (1884-1887). It was attached to the Public Watering Places and Reserves section under Secretary for Mines.
[4] Dept of Agriculture formed 10 Feb 1890.
[5] For a few month in 2003 water was administered by the Dept of Sustainable Natural Resources.
[6] Represents amalgamation of Dept of Mineral Resources, NSW Agriculture, NSW Fisheries and State Forests of NSW.

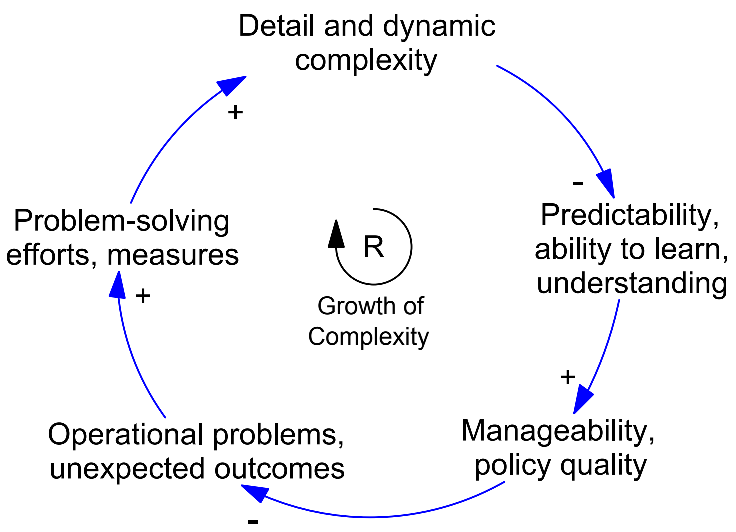

Figure 11.10: Decision-driven complexity in a managed system. Positive feedback effects produce the generic behaviour underlying the process of increasing the complexity of a system. In these systems learning from experience is difficult. See text for discussion.

11.3.5 Generic pattern

Tainter (1988) has argued that increasing levels of complexity in social systems can ultimately lead to their collapse. His basic thesis is that societies invest in higher levels of complexity as a 'fundamental problem-solving tool'. This works initially, but with declining marginal returns as complexity increases. Although he based his initial studies on an examination of ancient societies, his findings are clearly relevant to policy learning in modern organisational management (Tainter 1995, Sterman 2000).

Figure 11.10 represents, in a simple causal-loop diagram, the dynamics of the growth of complexity in a policy-making setting. The loop labelled *Growth of Complexity* (R) is a reinforcing loop that captures this generic behaviour. In a managed system, more complexity decreases the predictability of system behaviour, and thus reduces the ability of managers to learn from experience and to generate understanding. The increasingly complex system becomes harder and harder to manage, and the adequacy of policies declines. Under these conditions the number of operational problems and unexpected outcomes increases. Then, with more problems to handle, managers must increase their problem-solving efforts, which typically results in more complexity.

11.4 Summary

The AEH study of irrigation development presented in Part III has produced two dynamic hypotheses that can help to explain the failure of a community to learn from experience. These hypotheses relate to two important impediments to learning from experience:

- The generic bistable system (Figure 11.5)
- Decision-driven complexity in a managed system (Figure 11.10)

In establishing the MIA, the NSW Government was undertaking an enormous development project that involved an entirely new agricultural enterprise for the state. It entailed much more than water-delivery. The steady growth of system complexity, and the extent to which government actions caused that growth to accelerate, was a major barrier to policy makers' ability to learn from experience and from the past.

The scheme demanded that planners become involved in the multi-disciplinary development of an extensive and complicated human-environment system. Compared with previous operations in south-eastern Australia, irrigation at the level of the MIA created an extremely complex system, involving many sub-systems with a large number of state variables and feedback loops. Each sub-system (bio-physical, economic, social, scientific, technological, political) itself exhibited a high degree of dynamic complexity. For example, land selection and classification had to take account of social, economic, bio-physical and agricultural factors. Planning for this scale of development called for good integration of the sub-systems. The engineers understood the technology of dam and infrastructure construction and, as Lloyd (1988) has correctly noted, these aspects of the MIA were first class. But in their dominant role as planners and managers engineers were particularly poor in experience with those sub-systems involving human-environment relationships. In these critical areas where integration was vital, the engineers, not surprisingly, performed poorly, and the resulting policies were inadequate, leaving the scheme and its people highly vulnerable.

For several reasons MIA policy makers did not learn from past about the matters essential for the scheme. They did not learn from past policy failures, either their own, or the earlier failures in Mildura and in India, because they did not see the full system *qua* system. Because they did not see the many state variables and their causal connections, they had no whole-system policy that addressed the core issue: long-term sustainable agriculture. In New South Wales policy makers failed for the same reason as the policy makers in India had failed before them: each group was focused on isolated sub-systems. In particular, engineering considerations drove almost all of the initial planning phase of the MIA, and the government fiscal policies drove its on-going operation. It was not until the late 1960s that Davidson (1969) presented the first critical, and controversial, analysis of the bio-physical and economic limits to irrigation development in Australia.

In the course of this study I have observed that, while the balancing effects of negative feedback tend to dominate bio-physical systems, the dynamics of human systems tend to be dominated by the run-away effects of positive feedback. Therefore, in the absence of deliberate measures to control growth, overshoot-and-collapse must be inevitable in many human-activity systems.

The causal-loop diagrams developed in this chapter represent dynamical hypotheses that should have generic validity. In an AEH investigation that is part of a wider dynamical study, these diagrams would be tested, and possibly revised, as they are integrated into the wider socio-bio-physical picture. In such a study, diagrams like these would provide the first steps towards a working dynamical model of the whole system. They would also alert policy makers to the range of issues that they ought to be considering in comparable human-environment systems. As the number of AEH investigations increases, my claim that these diagrams represent generic patterns of human behaviour will be subject to increasing scrutiny.

CHAPTER 12 APPLIED ENVIRONMENTAL HISTORY

The aim of this chapter is to produce a set of operational guidelines that can be used in AEH studies. The starting point is the experience generated in the exploratory AEH study of irrigation development presented in Part III. The guidelines presented in §12.2 represent a first step towards the AEH approach.

The AEH approach has been developed to provide historians with a means to contribute better to the study of the dynamics of human-environment systems. The aims of Applied Environmental History, outlined in Chapter 5, are:

- to help establish an area of common conceptual ground between NRM practitioners, policy makers, historians and dynamicists.
- to provide a framework that can help NRM practitioners and policy makers to take account of the historical and dynamical issues that characterise human-environment relationships.
- to help NRM practitioners and policy makers improve their capacity to learn from the past.

12.1 Evaluation of the AEH Principles

The five AEH principles that were developed in Chapter 5 provide a broad definition of the approach. The following discussion deals with the effectiveness of each principle in helping to shape the exploratory study presented in Part III.

P1 AEH must integrate the humanities and the sciences

Scientists have had a long time to develop an understanding of the bio-physical nature and context of salinity, for it has been associated with irrigated agriculture since antiquity. Although it is clear that serious effects of salinisation cannot be reversed easily, communities continue to build irrigation infrastructure where problems are likely to occur. Wherever poor irrigation practices prevail, agriculture is at risk from salinisation. Thus, human behaviour can turn a bio-physical phenomenon into a socio-bio-physical problem. An explanation for this behaviour is not found by focusing on the bio-physical sub-system; it requires an understanding of the problem set in the wider human-environment system.

Principle 1 calls for approaches developed in the humanities to investigate the broad social, cultural, economic, political and institutional context of salinity. I used the techniques of history, which were familiar to me. But Principle 1 also calls for approaches from the sciences, and this took me into new ground. First, I had to acquire specific subject knowledge of soils, groundwater and agricultural crops, that allowed me to understand accounts of salinity in historical sources and contemporary accounts. Next, I needed to learn some principles and techniques of system dynamics in order to understand feedback effects. I also had to become familiar with key ideas from cognitive science in order to understand the role of cognitive adaptation in situations involving learning from experience. Finally and more fundamentally, I had to become familiar with the general methods of science.

P2 AEH must begin with the techniques of good historiography

The knowledge that India was an important source of colonial knowledge, and that the Australian colonies had strong links with British authorities in India, prompted my initial search for evidence of understanding about salinity in records relating to nineteenth century India. Indian irrigation was occasionally the subject of discussion at meetings of the Royal Society of NSW in the 1880s and 1890s. The records of the Society enabled an encouraging line of investigation, which sent me looking for data on groundwater and soils. I focused on these broader topics because I suspected that *salinity* was a technical term not used in the nineteenth century. I looked for events that showed growth of knowledge about groundwater and soils.

I looked for significant players, or groups of players, and how they perceived the problem of salinity. The records of the Royal Society of NSW revealed two interesting individuals: the Irish engineer, Hugh McKinney, who had ten years experience working in India; and the Scottish chemist, William Dixon, who appeared *not* to have worked in India, but demonstrated an unusually deep understanding of salinity. The statements made by both men suggested that a closer study of their respective backgrounds would be rewarding.

Published histories of the MIA include several accounts that have relied on, and uncritically reproduced, the official line promoted by the WCIC (*Irrigation Record*, 15 March 1913). Cowper (1968) developed new insights via an investigation of a significant body of primary sources. In particular, his careful and detailed study of newspapers, parliamentary debates, and minutes of meetings of the Farmers and Settlers Association allowed readers to see the MIA development through the eyes of a social historian. Cowper's initial research was done for a Masters thesis in 1968, but was not available to the wider community until 1987, when he self-published a small book. This book adds a valuable new perspective to accounts of the MIA that already existed from the work of geographers, generalist historians, economists and scientists.

The eras with which I was mainly concerned (i.e., 1820s to World War II) put my research outside the range of oral history. The only interviews conducted were with descendants of Hugh McKinney, and with Richard Cowper. Cowper's experience as a minister in the Methodist

Church in the MIA from the 1960s brought him in direct contact with community of farmers who had come there as Soldier Settlers. This experience enhanced his awareness of the issues and problems of an important historical nature in the MIA.

My approach to the sources used in Part III is described in Appendix B. Although the sources were of different quality and accessibility, this will always be a problem in empirical studies that deal with historical data. Principle 2 guided me through the historical sources with a critical eye.

P3 AEH studies must incorporate good scientific methods

Applying the methods of good science entailed (a) studying a number of cases that illustrated salinity; (b) setting out my guiding questions, and (c) articulating my theories and hypotheses.

(a) Three cases of irrigation development at different times and in different places were examined: India (1820s-1870s), Mildura (1890s) and the MIA (1900-1930s). Each case could be examined through the records of one or more public inquiries. In India the report of the *Reh* Committee (1879) proved to be a valuable primary source. I consulted a copy in the India Office Library, London. For the Mildura development the Royal Commission on the Mildura Settlement (1896) was my major source. There were three parliamentary inquiries related to the MIA during 1903-1906, and two Royal Commissions in 1914-1915. Through the 1910s and 1920s there were many public inquiries into the problems associated with irrigation in the three MDB states. Settlers, and soldier settlers in particular, in New South Wales, Victoria and South Australia were facing similar problems. They were struggling to make a living on farming blocks that were designed without adequate attention to local soil and groundwater conditions. In each case it was possible to look for evidence that the community paid attention to soils and groundwater, and to the problem of salinity. Similar patterns of behaviour were apparent in each place. It was also possible to see a growing complexity over time in the communities' approach to irrigation development.

(b) The study was organised around a sequence of three specific questions addressing the ability of planners and policy makers in the MIA to learn from the past. The questions, as set out in the Preface to Part III, were: (1) *Could* they have learnt from the past? (2) *Should* they have learnt from the past? (3) *Did* they learn from the past? In addition, they built up an historical context from which it was possible to discuss possible reasons for the failure to learn (Chapter 11).

(c) The theories and hypotheses formed on the basis of the irrigation study were presented in Chapter 11 in the form of models — specifically, causal-loop diagrams (CLDs). Unlike stock-and-flow models, CLDs cannot be used safely to infer dynamical behaviour. However, they can be used to guide a study of the pressures and constraints, both endogenous and exogenous, operating in a human-environment system. It may be a relatively straightforward task to trace the logic around someone else's CLDs. However, I found that creating a convincing set required considerable reflection and experience, in addition to careful application of the CLD rules (described in Chapter 3). As in all good dynamical studies, it was not my intention to model the whole system, but to explain selected behaviour.

In the discussion of Indian irrigation, the construction of CLDs helped to identify significant effects of government water-pricing policy, and of canal irrigation on the type of crops that were cultivated. In the discussion of irrigation in the MIA, CLDs were used to identify significant feedback effects as a result of policies and decisions affecting land resumption and development in 1910, the selection of settlers for the MIA (social policy), and the land valuations operating in the MIA (economic policy).

Finally, the study suggests two patterns of generic behaviour in irrigation development, whereby learning from experience was difficult. These were expressed as tentative dynamical hypotheses. The first hypothesis is that the system is bistable, in that a particular worldview becomes locked in, under the influence of positive feedback (Figure 11.3). The second hypothesis is that there is an increase in decision-driven complexity in the managed system (Figure 11.10).

Principle 3 prompted me to examine the development of irrigation by looking at the dynamics of the system. Consequently, I gained insights about a human-environment system that the techniques of traditional historiography alone would not have revealed.

P4 AEH studies must establish a broad system context

Salinity becomes a NRM problem as a result of complex connections and interactions between sub-systems of the human-environment system. Establishing a broad system context requires (a) an analysis of events to identify state variables, (b) the use of spatial and temporal scales adequate to reveal changes in key variables, and (c) diachronic and synchronic studies.

(a) Key events in the history of the MIA were identified over the period 1902-1926. They could be grouped as events connected with climate, the political system, public works for irrigation infrastructure, the economic and social aspects of irrigation development, and policy processes or decisions. Because climate or natural events, political events, and the progress of major public works readily attracted attention, they were reported in the newspapers. They also appeared in official records. Changes associated with economic and social aspects often developed slowly over long timescales, because they were usually the result of a steady accumulation of effects.

These 'slow events' had to be found by building up the picture of the MIA over time. Government policy processes or decisions were best discovered in enactments of legislation (or other regulations) and in annual reports to parliament, and in the context of public inquiries, legal 'test' cases, and political manifestos. After analysing events, it was possible to assemble an initial list of state variables, and to begin sketching out rough causal-loop diagrams. (See Figure 12.1.)

(b) The three cases in the study collectively cover a period of more than 100 years: India (1820s-1870s), Mildura (1886-1890s) and the MIA (1900-1930s). Each one produced evidence of changes in key variables over different temporal and spatial scales. Change was most obvious in those variables that describe the bio-physical and agricultural sub-systems. In India the first phase of intensive irrigation development began in 1836. By the 1860s communities were aware of adverse effects in many districts along the Western and Eastern Jumna Canals. In Mildura, where the settlement was established on salt-affected Mallee soils, the temporal and spatial scales were reduced. Within five years of settlement the first drainage and salinity problems appeared, and were serious enough to prompt a Royal Commission by 1896. All these events had occurred in only ten years. In the MIA, where the soils were naturally less saline than at Mildura, rates of change were more like those in India. While the community first became aware of a rising watertable within two years, evidence of saline groundwater appeared only 20 or more years later, after periods of severe flooding in 1931 and 1956. The worst effects of salinity appeared much later, after rice-growing was introduced in the Riverina; it was particularly evident in the early 1980s at Benerembah and Coleambally, in areas adjacent to the MIA.

(c) The diachronic element of the exploratory AEH investigation involved the study of irrigation development, with a focus on salinity, from the 1820s in India into the mid-twentieth century in south-eastern Australia. Effects of policies accumulate over time. The synchronic element of the investigation involved the study of state variables related to the land resumption and development program, the selection of settlers, and the land valuations — all in the MIA. These aspects of the MIA were considered at about the same time, the first decade of operation. (See Figure 12.1.)

Principle 4 helped me to maintain the essential tension between looking too broadly at the situation and focusing too narrowly on the issues.

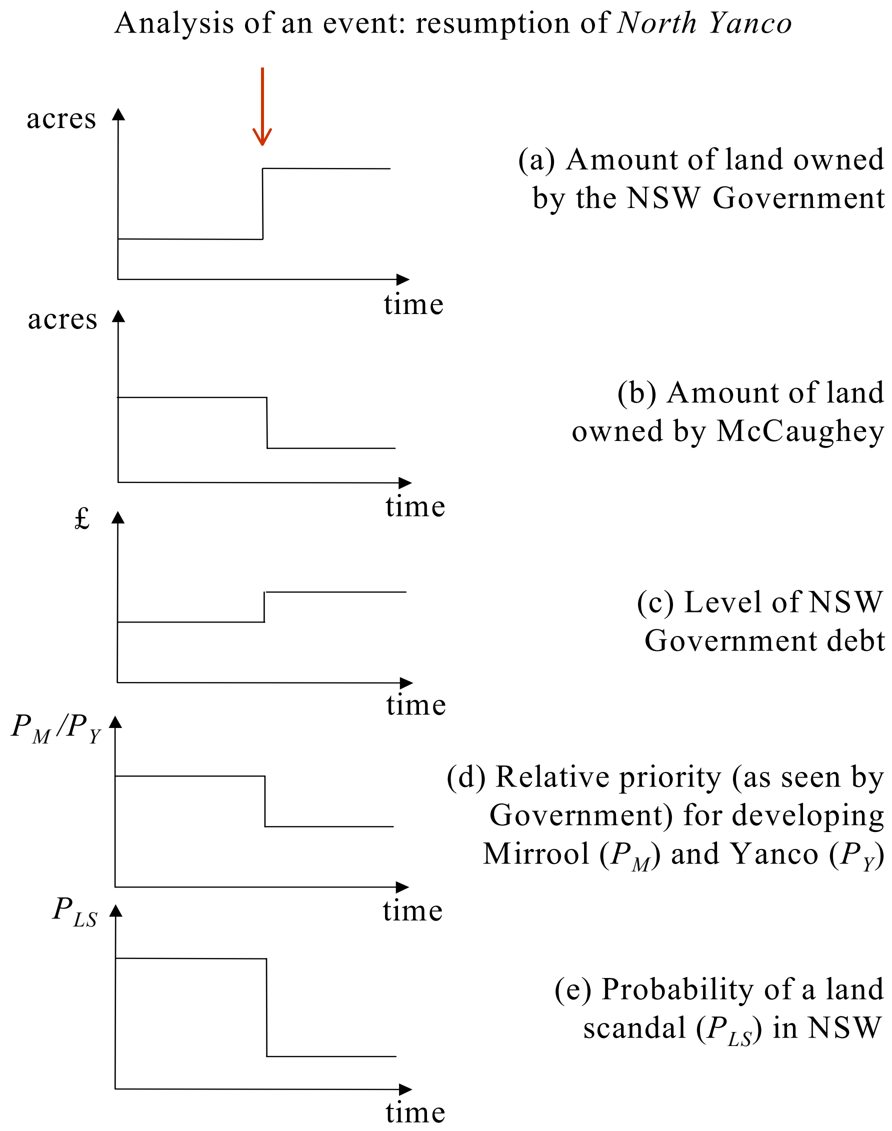

Figure 12.1: Identification of possible state variables. The technique described in P4 is illustrated here using schematic time series that relate to a significant event in the history of the MIA. The individual graphs show the behaviour of different state variables (on the vertical axis) plotted against time (on the horizontal axis). The vertical arrow marks the government resumption of *North Yanco* in 1910. This event had at least five consequences which can be expressed as changes in state variables: (a) the amount of land owned by the government increased; (b) the amount of land owned by McCaughey decreased; (c) the level of government debt increased; (d) the relative priority that the government gave to developing Mirrool, rather than Yanco, decreased; and (e) the probability of a land scandal in NSW decreased.

This diagram also provides an example of the type of data generated in a synchronic study as described in P4 and G3. (Compare Figure 5.1.)

P5 AEH studies must take account of the influence of key players in the NRM history

It was particularly useful to identify over time the policy makers (formal and *de facto*), their backgrounds and worldviews. This information helped reveal the worldviews that shaped policy through the period of the AEH study.

A notable feature of the periods covered in Chapter 9 and 10 is the proliferation of public inquiries (including many with the powers of Royal Commissions). Many players introduced themselves at these inquiries by presenting a precis of their professional background; their words are a major source of the profiles in Appendix C.

The case of William Dixon illustrates how important it can be to understand the background of key players. The level of knowledge of salinity that Dixon displayed in the 1880s and 1890s caught my attention as being unusual. Source materials gave no explanation for his depth of understanding. Dixon had published 12 papers in the *Journal of the Royal Society of New South Wales* between 1877 and 1893, but they gave no indication that he had previously worked in India or in irrigation. It was only when I read a small obituary to him published by the Royal Institute in London (*JPRI* 1917-18) that the story became clear. Dixon had received scientific training under Thomas Anderson, Professor of Chemistry, University of Glasgow, and was Anderson's principal assistant between 1862 and 1865. During these years Anderson was making some of the first independent analyses of *reh* samples for the Indian Government (Baden-Powell 1868). Dixon undoubtedly was involved with these analyses, and this involvement would explain the high level of understanding about salinity that he displayed later in New South Wales.

Similarly, the background of Hugh McKinney prompted further investigation because McKinney appeared to be dismissive of the dangers of salt. I wanted to discover whether he had, in fact, any first-hand experience of working in salt-affected areas of India. Even though he had published much during his working life, to reconstruct the details of his ten-year career in India I had to draw on India Office Records in London, and on the knowledge of his descendants in New South Wales. This research resulted in the biographical paper included in Appendix E.

There was another individual whose actions and decisions particularly attracted my attention: the Mildura settler, James Henshilwood. Nevertheless, I did not pursue investigations into his background because I believed that he was unlikely to have influenced events in the MIA.

To augment the biographical data from readily available sources, I took several steps. I placed requests in a metropolitan daily newspaper (*RSVP* column in *The Sydney Morning Herald*);

explored the membership of professional associations; and tapped into published family histories. All these were useful at some level, and people were most helpful. Because finding this kind of data takes time and may be serendipitous, it requires patience; it should take place in the background of the other AEH activities. My efforts were amply rewarded.

Principle 5 ensured that I did not loose sight of the essential human dimension of NRM.

12.2 Guidelines for an AEH Study

The following guidelines address the steps that need to be taken in any AEH study. They are not in strict sequential order, and the AEH practitioner will need to cycle several times through the list. As the guidelines are tested in future applications, and benefit from being applied in different NRM contexts, they can be improved and revised as needed. While the NRM context of different AEH studies will demand different subject knowledge, the methods and insights drawn from system dynamics and cognitive science remain essential for all studies of human-environment systems.

G1	**Identify the NRM problem** The starting point for an AEH study is evidence of contemporary policy failure. From this point the policy can be tracked back into the policy-making system using historical sources.
G2	**Formulate a structured set of questions to keep the AEH study focused on dynamics** The guiding questions will evolve as the study progresses, and as the AEH practitioner cycles through the historical sources and reflects on the behaviour of the system over time. The questions will be those that focus on generic system problems, such as policy resistance.
G3	**Carry out a diachronic and synchronic historical study of the NRM problem and its broad context** The sources of policy failure in the system may be drivers of the wrong behaviour or commitment to, or focus on, the wrong state variables. Identification of these variables will connect the policy failure to a chain of decisions and actions that eventually resulted in poor outcomes. Describe this history in terms of the influence of (a) major events, trends and actions; (b)

	ideas in contemporary culture and society; (c) technological and scientific innovations; and (d) individuals (see G4, G5 and G6). Draw multiple time lines. Look for adherence to existing policies in the face of evidence of policy failure. The AEH practitioner will become aware of alternative ways of setting the problem.
G4	**Look for patterns of success and failure in the policy-making process** The historical data can reveal persistent patterns of success or failure of the measures that policy makers have taken to deal with an NRM issue or problem. More than one case must be observed before a pattern becomes visible, and before the behaviour can be demonstrated as generic. Use graphs showing the behaviour over time of different variables to indicate change.
G5	**Identify and study the key players** It should be possible to infer important drivers and variables of the system by looking for the key players and groups of players, and studying their actions, interests and concerns. Describe the personal histories of these individuals: their backgrounds, motivations, incentives and inhibitions to learning, and their worldviews. Studying the personal histories of key players will also reveal those who had the roles (either formal or *de facto*) of policy makers. Such studies will help build a picture of the policy-making context and contemporary culture. The histories of individuals and evidence of their worldviews can help explain conflicting and/or shifting objectives in the policy-making system, and the pressures and constraints on behaviour. It is useful to identify: - the models and policies that players used to define the issue or problem as they saw it; - the state variables and sub-systems on which they were focused; - their use of historical data; - their response to error or failure; - the amount of time they allowed to understand the issue or problem. The role of G5 is: - to draw attention to the important human dimension of the NRM system; - to emphasise the role of individuals' worldviews on the policy-making process; - to make explicit the sub-processes of experiential learning, and the need to understand them in the policy-making domain.

G6	**Identify and analyse key events in the history of the NRM issue** The historical sources will reveal key events which are connected with one or more sub-system comprising the human-environment system. Enactments of legislation (or other regulations) are events which can indicate a particular focus of the policy community. High-profile events, such as public inquiries, cases brought before judicial courts, and political debates are indicators of associated events that later come to pass in the policy-making domain. Significant natural events can also signal change in policy, but because these may occur slowly, they may be more difficult to recognise (see G7). Significant historical events signal some kind of change. Isolating these events is one way to identify significant variables. A change in a variable will have a characteristic time. Some change will be fast, but even slow changes can be regarded as events if looked as over sufficiently long timescales. In NRM change is often slow both to occur and then to be recognised (see Figure 12.1).
G7	**Set the boundary of the system by identifying possible state variables** It is necessary to identify the state variables and sub-systems that most effectively characterise the dynamical system underlying the NRM problem. It is useful to begin with as wide a list of likely variables as possible. This is the role of the processes outlined in G6. As the study progresses and key variables are isolated, the list may shrink. Variables need to be classified as endogenous, exogenous or irrelevant. It will become clear which connections are critical and which are peripheral or weak. Then it may be possible to re-classify exogenous and irrelevant variables when, on closer analysis, a variable that first appeared irrelevant turns out to be important.
G8	**Look for causal links between state variables** Links that show cause and effect between state variables indicate the structure of the dynamical system. In order to refine the list of variables relevant to NRM, it will usually be necessary to cycle through G6-G8 a number of times. The endogenous variables will be those that are eventually represented in causal loop diagrams. The exogenous variables will have only inward or outward links that cross the system boundary. The role of G6-G8 is: - to draw attention to the wide range of state variables operating in the system; - to investigate changes in variables over appropriate temporal and spatial scales;

	- to emphasise feedback effects in system behaviour.
G9	**Assemble causal-loop diagrams (CLDs)** CLDs can be assembled once the possible causal links have been identified. Each CLD represents a dynamic hypothesis (i.e., a possible feedback structure of some part of the system), and can provide a useful specification of the structure for future modelling efforts. CLDs can make clear the competing forces on variables, as well as highlighting feedback effects where there are delays. Because CLDs do not describe the detailed behaviour of the variables, they cannot be used to infer the *dynamics* of a system. But they can provide a useful preliminary step in defining a modelling problem, for which a stock-and-flow (or corresponding) dynamical model will be needed.

12.3 Next Steps

The issues and problems that NRM policy makers in New South Wales encountered in the development of irrigation at the beginning of the twentieth century were not unique to that time and place. The sustainable use of Earth's natural resources still presents many of the problems discussed in the study in Part III. Today's NRM policy makers still focus on the wrong variables, or on particular variables and sub-systems to the exclusion of other critical parts of the system. They are confounded by dynamic complexity, influenced by entrenched worldviews, and insufficiently aware of the history of NRM issues.

As well as having general application for all whole-system studies, the AEH approach can be applied to NRM problems and issues that share common features. Most obviously, the approach lends itself to NRM problems where natural cycles operate and their impacts occur over stretched temporal and spatial scales. These problems will be characterised by high levels of complexity. Getting to the heart of these problems demands investigation and knowledge of the connections and interactions between the sub-systems that constitute them. It requires detailed historical and dynamical understanding of their bio-physical environment and social context. This includes such factors as government policies, party politics, social learning and economics. Such NRM problems are also characterised by high level of risk and uncertainty.

There are many current NRM debates taking place, in Australia and elsewhere around the world, where the AEH approach has relevance and potential application. Further studies will start to reveal the profile of problems most suited to the AEH approach. Four areas are reviewed briefly below:

- **Fisheries and Property Rights Instruments**

In the last two decades the individual transferable quota (ITQ) has been an increasingly important institutional instrument for fisheries management, and one that has created intense controversy (Connor 2004, Connor and Dovers 2004). The ITQ is an example of a property rights instrument, that is a policy instrument designed to operate as a market mechanism, or economic instrument, by linking economic human motivation with markets to allocate resources via clearly defined rights. Such instruments have their origins in neo-liberal political philosophy and neo-classical economic theory. In defined fisheries, an ITQ is a tradeable right to a proportion of the total allowable catch. The latter is based on current scientific estimates of fish stocks. Individual or corporate fishers can then lease or trade their rights.

Controversy in fisheries management, and interest in new policy approaches, particularly ITQ, has increased since the collapse of previously viable fisheries, brought on by unsustainable resource exploitation (notably Georges Bank in the North Atlantic in the 1990s (Kurlansky 1997)). ITQs must take account of both socio-economic and environmental factors with a view to sustainable practices, and debate over ITQs and sustainability issues has become polarised between economists and biologists-managers. Connor (2004) has concluded that fisheries management in the era of sustainability and ITQs are both more complex than either side in the debate would allow. He has argued that because the economics of fisheries vary from one species and one area to another, the design of ITQs is still evolving, and their efficacy is contested. They may be unsuitable in contexts of mixed species, in widely dispersed or migratory stocks, or small or low-value stocks. Further empirical studies are need that take account of the social and cultural contexts of ITQs, and to understand the potential effects of institutional change in fisheries management.

- **National Water Initiative**

In 2003 the Council of Australian Governments reaffirmed its commitment to implementing the 1994 *Water Reform Framework* and agreed to develop a *National Water Initiative* (Australia DPMC 2004). The *Initiative* is focused on key issues of water use and management: improving the security of water-access entitlements; ensuring ecosystem health; expanding water markets and trading; and encouraging water conservation in cities. Two inter-governmental agreements have been developed: one for the *National Water Initiative* and one for the Murray-Darling Basin.

Because Australia is the driest inhabited continent, and experiences extreme climate variability, it depends heavily on irrigated agriculture. Therefore, water is the natural resource that remains most problematic for both NRM policy makers and resource users. Connell et al (2004) have argued that neither the *National Water Initiative*, nor related documents and policy discussion, have demonstrated an appreciation of the complexity and difficulty of implementing the terms of the *Initiative*. The proposal to introduce property rights instruments (PRIs) in water resource management follows comparable arguments presented for fisheries management. PRIs are designed to improve efficiency in resource allocation and economic use. But, as Connell et al (2004) argued, they fail to take account of a range of other factors, and thus underestimate the magnitude and complexity of implementation.

In discussions of the *National Water Initiative* one group of high-profile scientists, The Wentworth Group, has proposed measures for improved environmental management, referred to as 'decentralised regionalism'. Lane et al (2004) have argued that the views of the Wentworth Group are idealised and therefore naïve, because they ignore the complexities of the human-environment system. The long history of past attempts at establishing regionalism in Australia demonstrates the difficulties of pursuing environmental management at a regional scale. Despite previous efforts, the mismatch between ecological, jurisdictional, economic and social factors have still to be resolved. There remains the problem of dealing with systems that operate across different scales and with dynamic complexity. It makes water policy a potential area for an AEH study.

- **Native and Plantation Forests**

Australia's Federal and State Governments have developed separate policies for the two main wood production systems — the native forests sector and the more recently established plantation sector. The reasons for this separation are found in the long history and dynamics of the forestry industry (Clark 2004). A key feature of the situation is that native and plantation products have become competitors in the market. Furthermore, until very recently, State Governments have been the major providers of the wood derived from both production systems. Despite the new and pragmatic choices available to policy makers in the 1990s, government did not develop a holistic forest policy that facilitated the substitution of wood from plantations for native forest wood. As a result, potential economic and environmental benefits to the community have been lost.

An AEH study of Australia's forest industry would help to generate an understanding of how this situation arose. Such a study would demonstrate that native-forest chip-exporting has been extraordinarily profitable for a long time (Clark 2002). It would trace the chip-export industry's emerging relationship with other key players: other industry groups, industry lobby associations, forestry unions, research bodies, politicians in rural and marginal electorates, foresters, and the government public agencies that supply wood.

As in many long unresolved public policy problems, the debate has become clouded by the lack of shared terminology. In particular, different players use the term ‘forest’ differently, but tacitly, to include or exclude plantation resources. They have used their marketing and lobbying skills to promote perceptions of selected information that suits their agendas. This has been the case in debates about the potential of the plantation sector to meet demand, and to be a viable substitute for native forest resources. Clark (2002) found that despite Australia’s long history of forest policy failure, opportunities are now arising where governments are receptive to new public policy approaches. In these situations, responsible ministers, who are already knowledgeable in their subject area, could benefit from a holistic approach which penetrates through to the nature of the problem, and yields key strategies that can actually address the problem.

- **Coastal Management**

Coastal land in Australia has been cleared and developed at a steady pace since European settlement. The majority of Australians live in this zone, and in more recent decades, there has been strong urban growth along the eastern Australian coast. In many places human-induced changes to coastal environments have revealed the presence of acid sulfate soils which contain iron sulfides. These soils are found in estuarine floodplains and coastal lowlands, including mangrove tidal flats, salt marshes and tea-tree swamps. In their natural, undisturbed state acid sulphate soils are generally found in areas with high watertables, and do not present a threat to estuarine ecosystems. However, as a result of development and land management practices, exposure of the sulfides to oxygen by drainage or excavation generates large quantities of sulfuric acid and other substances. Under these changed conditions estuarine and coastal ecosystems can be adversely affected (Australia 2001b).

The NSW Government now recognises that the control of acid sulfate soils is an extremely important NRM issue. Areas containing these soils have the potential to cause immense damage to environments that support many of the State’s major income-producing industries, such as fishing, aquaculture, dairying, grazing, sugarcane production and tourism. Management of coastal resources needs to incorporate a full understanding of the problems associated with acid sulfate soils and their distribution (NSW DLWC 2004). Acid sulfate soils are seen as a problem potentially more serious than saline soils. For these reasons coastal management is an NRM area with the characteristics and problems, arising from the complex dynamics of human-environment relationships, that make it well suited to study using the AEH approach.

These four vignettes demonstrate the relevance of the AEH approach to different contemporary NRM issues in Australia. No doubt others exist elsewhere where the approach would also be useful.

12.4 The Art and Craft of an AEH Study

The AEH approach is designed to help historians to study the feedback dynamics of human-environment systems. Since established historiographic techniques are unlikely to reveal useful insights into system behaviour, an AEH study should result in a more complete (i.e., whole-system) interpretation of a particular NRM issue or problem. In this respect, the AEH approach is one answer to the problem inherent in establishing a clear and coherent framework for large-scale interdisciplinary projects.

The approach embodied in Applied Environmental History can be characterised as follows:

- It addresses the issues and subjects of interest to environmental history, but extends the current ambit of that field to embrace the special needs of NRM policy makers.
- It places NRM policy issues in an appropriate long time scale.
- It extends the narrow focus of public history, as practised in Australia (*Public History Review* 1992), to include applied history, as it is understood in the USA.
- It combines the techniques of history with those of system dynamics, so that, in addition to its existing set of methods and approaches, history embraces dynamical concepts that can help scholars and managers to understand and explain change.
- It has policy *process* as a core concept and a focus on system structure, to build a process-sensitive approach to NRM issues.
- It shifts the focus and reliance away from methods involving analogy and trends (superficial understanding of an issue) towards sound system-based analysis.
- It uses more than the primary and secondary records of traditional history, and is aware of the techniques used by social sciences to deal with policy-relevant topics.
- It addresses the issue of what needs to change in NRM policy, rather than merely describes where policy has come from.
- It shifts the focus of policy history away from a preoccupation with prediction, towards an understanding of past changes and their relationship to current predicaments, and hence to a 'useable orientation towards the future' (Stearns 1982).

An AEH study will be one that addresses a situation in NRM where there has been policy failure associated with decision-driven complexity. The situation will likely be one where there has been a demonstrated difficulty in learning from the past. An AEH study will pay particular attention to feedback effects, and to the pressures and constraints on the policy makers and other key players.

The AEH approach provides a way to inject a fully professional, historical perspective into the NRM policy environment. It can provide the NRM policy community with a structured view on the past, as well as the skills and techniques that are necessary to learn from experiences beyond the range of personal experience, and beyond the scope of single-disciplinary literature. AEH can equip historians with the additional skills that are necessary to contribute to learning from the past in NRM situations which are part of systems with high levels of dynamic complexity. AEH can enhance the core competencies of historians so that they will acquire an understanding of feedback dynamics. These skills can also help them to communicate with dynamicists working in NRM contexts.

The issue of the sustainable use of Earth's natural resources has set the requirements of the AEH approach. Facilitated by a trained applied environmental historian, the AEH approach is intended to enhance the capabilities of NRM policy makers to learn from the past. Ideally, it should help them to design better policies that contribute to the sustainable use of the natural resource base.

ABBREVIATIONS

AEH	Applied Environmental History
AGPS	Australian Government Publishing Service
AR + year	Annual Report (year)
AWRC	Australian Water Resources Council
CPP	Commonwealth Parliamentary Papers
CSIR	Commonwealth Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organization
DEH	Department of Environment and Heritage
DLWC	NSW Department of Land and Water Conservation
DMC	Development and Migration Commission (Commonwealth)
DPMC	Department of Prime Minister and Cabinet
GHD	Gutteridge, Haskins and Davey
ICID	International Commission on Irrigation and Drainage
IGI	*The Imperial Gazetteer of India*
ISRIC	International Soil Reference and Information Centre
IUCN	International Union for Conservation of Nature
JPRI	*Journal and Proceedings of the Royal Institute*
MDB	Murray-Darling Basin
MDBC	Murray-Darling Basin Commission
MDBMC	Murray-Darling Basin Ministerial Council
MIA	Murrumbidgee Irrigation Areas
MIT	Murrumbidgee Irrigation Trust
NRM	Natural resource management
NSW	New South Wales
NSW PP	New South Wales Parliamentary Papers
NSW VP	Votes and Proceedings of the New South Wales Legislative Assembly
NWP	North-Western Provinces (of India)
Parlt Debates	Parliamentary Debates
PP	Parliamentary Papers
PSCI	Parliamentary Select Committee of Inquiry
PSCPW	Parliamentary Standing Committee on Public Works
SA	South Australia
SCSC	(Commonwealth) Standing Committee on Soil Conservation
SEC	(Australian) State of Environment Committee
Vic	Victoria

Vic PP	Victorian Parliamentary Papers
Vic VP	Votes and Proceedings of the Victorian Legislative Assembly
WA	Western Australia
WCD	World Commission on Dams
WCED	World Commission on Environment and Development
WCIC	Water Conservation and Irrigation Commission

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