Towards a Socio-Ecological Systems View of the Sand River Catchment, South Africa

An Exploratory Resilience Analysis

by

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Acronyms

BBR	Bushbuckridge (region of Mpumalanga Province)
CDF	Community development Forum
CMA	Catchment Management Agency
CMS	Catchment Management Strategies
CPA	common property association
CPF	Community Policing Forum
EGS	ecosystem goods and services
IWRM	Integrated Water Resources Management
KNP	Kruger National Park
NGO	Non-governmental organisation
NRM	natural resource management;
RA	Resilience Alliance
SES	Socio-ecological system
SRC	Sand River Catchment
T.A.	Traditional Authority
WMA	Water Management Area

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Executive Summary

The Save the Sand Programme (a catchment based rehabilitation initiative) together with SANParks (South African National Parks) has been supported to test a socio-ecological approach in the Sand River Catchment. Our purpose is to set up a usable overarching framework for understanding inter-relationships between the main drivers (be they social, economic or biophysical) in the Sand sub-catchment using resilience thinking. This is being undertaken in support of improved natural resources governance and hence livelihood security.

In South Africa, the Sand River Catchment is an example of the increasing conflict that is developing around natural resources and their sustainability. The imperative to generate and share wealth through development, land reform and black empowerment must be balanced with long-term environmental security. Water resources, in particular, are stressed and likely to come under further pressure to meet the demand for increased development. South Africa is in a period of transformation and the arrangements for water resources governance are highly dynamic with redress constituting a key focus.

Several initiatives in southern Africa such as Integrated Water Resources Management, are attempting to adopt a more holistic approach to natural resource management than historically used. In an environment of emerging policy frameworks, juxtaposed characteristics of wealth and poverty, ecosystem health and degradation, new approaches are being sought to build sustainable futures. This view critiques the more narrow approach to natural resource management (often aimed at maximum sustainable yield of stable states and devoid of links to wider issues) which is considered too ill-equipped to meet the challenges of a complex and rapidly changing world.

In this study we test resilience thinking and its associated concepts to explore if the potentially scarce water-based ecosystems services of the Sand River Catchment can be mobilised and sustained in a sustainable and equitable manner. A landmark in linking ecological to social and economic systems took place in 1995 with the publication of "Barriers and Bridges" (Gunderson et al., 1995), and is refined by the Resilience Alliance (http://www.resalliance.org). A key feature of this approach is to try to view the system as an integrated socio-ecological system (SES) in a way that has not been done before to address the above concerns.

Our **purpose** was thus to set up an overarching framework for understanding interrelationships between main drivers (be they social, economic or biophysical) in the Sand Catchment using the resilience approach. By viewing the Catchment as a linked socio-ecological system, we sought to address two objectives, namely:

(a) to examine the state of the Sand River Catchment in terms of degradation and vulnerability/resilience, and;
(b) to assess the usefulness of the SES as an approach in understanding these issues and charting a more sustainable future.

Chapter 1 outlines a proposed framework, developed in 2005 by the team that was used for the analysis. This is not dissimilar to the proposed steps of the Resilience Alliance (2007). In summary it consists of eleven steps.

1. Determine the primary focus and a system boundary
2. Identify the main characteristics and user groups

3. Comprehend the prevailing mental models
4. Undertake an analysis of trends over time and space, with a view to understanding their effect on resilience in later steps
5. Examine governance and its effect on the intended resilience analysis
6. Identifying alternative states
7. Identification of key fast and slow variables in the system
8. Identify sources of leadership, empowerment and learning
9. Identify ecological and social redundancy
10. Panarchy analysis
11. Scenario generation.

Chapter 2 offers an overview of the main conceptual underpinnings, including systems approaches and complexity theory, resilience and panarchy analysis, livelihood approaches, social learning and ecosystem goods and services. A central concept for sustainability is that of *resilience*, which lies at the very heart of sustainability. Resilience is defined as "The capacity of a system to absorb disturbance and re-organise so as to retain essentially the same function, structure and feedbacks – to have the same identity (that is, to remain in the same system regime)". Resilience is not always a positive attribute – there are highly resilient but unfavourable resilient systems (e.g. Apartheid). Given the suite of related terms and concepts, we suggest that a useful starting point is to illustrate how sustainability, resilience, complexity and panarchy are related and to then examine the implications. These links are illustrated through the following question: If <u>sustainability</u> is synonymous to <u>resilience</u> (see Chapter 2), how do we build <u>resilience</u> in a <u>complex system</u>?

Complexity theory arose as a critique of linear causality and reductionist science. Natural and social systems are complex in their interactions and complexity. Socio-ecological systems show a number of key attributes (Box A) which need to be acknowledged (especially in management). They are heterogeneous and in flux (they are dynamic), they have multiple drivers which interact and display feedback loops, and, because of this, the outcomes are (a) not always predictable and (b) they display lags.

Box A
Complex systems

A complex system can be distinguished from a simple one, albeit complicated, by a number of attributes. A complex system shows <u>feedbacks</u> (reinforcing or balancing) in its cause and effect relationships, which, usually because of operation at different <u>scales</u>, cause <u>emergence</u> (i.e. the feedbacks generate surprising new properties not predictable from the original bits and pieces making up the system). Almost all ecosystems, and almost any socio-ecological system can be shown to exhibit this complex behaviour and hence emergence. Ironically, complex systems often have only a few predominant drivers – it is the way these interact (and in particular the feedbacks) which produce the complexity. The drivers invariably vary in strength over space and time, producing different combinations of outcomes. At a certain range (called a *threshold*) in the values of these different drivers, systems can fundamentally change their nature, say from grassland to savanna, or from family to sibling kinship networks. In practice this usually takes place as a series of linked thresholds and system states, called a *regime*, and a regime shift follows. Essentially in a new state the rules-of-the-game – or underlying processes – change.

A resilient system shows many of these attributes (see Table 2.2). Three implications for resource management of accepting complexity are:

(1) models and perspectives based on linear thinking are inadequate (including optimization models);

(2) qualitative analysis is an important complement to quantitative approaches; and

(3) a multiplicity of perspectives is needed to analyse and manage complex systems.

Management processes can be improved by making the flexible and adaptive so as to deal with uncertainty thereby building capacity to adapt to change.

Box B **Resilience and the general adaptive cycle in a nutshell…**
The idea of a **general adaptive cycle** was developed and refined by the Resilience Alliance into a plausible metaphor for understanding the social, economic and biophysical 'systems' as just one interacting social-ecological system. The general adaptive cycle posits four phases (exploitation, conservation, release and reorganization) as universal to systems (socio-political, economic or biophysical). Although largely conceptual, an increasing number of practical examples are emerging. An underlying aim is to encourage **resilience** of desired regimes, and weaken resilience in the case of undesirable regimes. The book "Panarchy" (Gunderson and Holling, 2001) extends the understanding of adaptive cycles into a nested hierarchy at different scales so as to understand cross-scale linkages (say local, regional and international).

The livelihoods framework recognizes five essential capitals: human, natural, financial, social, and physical that must be considered in examining livelihood sustainability. These, together with concepts related to social capital and learning in complex systems, are also discussed. One of these capitals – that of natural capital – is given greater depth through the concept of ecosystem goods and services which are introduced.

Chapter 3 provides an overview of the Sand River Catchment and identifies the main socio-economic, ecological and political characteristics. The Catchment is 2000 km^2 in size and home to some 383 000 people, thus characterized by high densities of people. With the exception of the wetter, western mountainous region, the catchment is semi-arid with an average rainfall of 600 mm. The Sand River rises at an altitude of 1800 m but descends rapidly to an altitude of 500 m in the lowlands. The area comprises principally the former Bantustans of Gazankulu and Lebowa and the legacy of apartheid is still prevalent. Over the years livelihoods for residents have become increasingly vulnerable under apartheid and today most families rely on income from pensions or wage remittances. The effect of poverty that accompanied mass removal of people to the area is reflected in the increasing environmental degradation. The main land-uses include commercial forestry in the upper catchment, rural residential areas combined with subsistence agriculture, some limited irrigated agriculture in the central region, and conservation (mainly exclusive high-income tourism) in the eastern region.

Chapter 4 presents the synthesized systems view at two scales (the catchment and the wetland) and in two eras: apartheid and under transformation. Timelines depict the history to identify major drivers and outcomes, used as the basis for the system dynamics diagrams.

The systems dynamics diagrams highlighted the following:

a. The key drivers in the apartheid era were politico-legal. Associated drivers included forced removals (high population densities), manipulated forms of local resource governance, the demand for cheap labour and a deprived education system.
b. Key feedback loops that emerged were as follows:
    i. Agricultural water abstraction coupled with clearing of land (both for agriculture and people), led to a wide-scale decrease in riverine integrity. As flows declined sedimentation increased, jeopardizing ecosystem services and livelihood security.

In response, people moved onto increasingly marginal areas and sedimentation increased. Over two to three decades, environmental degradation has rendered farming less viable and livelihoods more vulnerable.

  ii. A second feedback loop existed between livelihood security and social capital. The combined effect of livelihood vulnerability, together with the demand for cheap labour for the mining sector led to the temporary migration of males – often absent for most of the year. Female-headed households became the norm and impacts were felt on family stability – or social capital. Again livelihoods became more vulnerable and as they did so, men, and some women, left home in search of work.

c. Despite the policy transformations associated with the democratic changes of 1994, <u>the feedback loops that prevailed during the apartheid era still persist</u>. Lags are evident in the implementation of the National Water Act (and other natural resource/land focused acts) so that currently the feedback loop between use and livelihood security are still negative. If key determinants are not made operational, these are unlikely to change, ultimately impacting on peoples' livelihood security.
d. At a finer scale (the wetland micro-catchment), further feedback loops are evident (namely between the local water table and wetland integrity).
e. Slow variables appear to be sedimentation, education and land tenure security and governance. Tenure and governance are critical drivers of land-use practices. Weakened local-level institutional arrangements, together with the lack of governmental capacity to act and the uncertainties rendered by land reform mean that the <u>natural resource base is becoming increasingly vulnerable impacting on local livelihoods</u>. This is exacerbated by opportunistic entrepreneurial ventures which are taking advantage of these uncertainties.
f. The effects of poor education and high population densities associated with forced removals of the apartheid era persist today (although the driver has been removed).

The collaborative development of systems diagrams and scenarios (Chapter 5) is an important process in reviewing the issue of resilience and degradation – be this socio-economic or environmental. This suggests that a key constraint to sustainability in two scenarios is the lack of feedbacks, the lack of acknowledgement of slow variables[1] and low social capital.

Chapter 6 offers (a) an analysis of the resilience of the current situation and the scenarios, and (b) an assessment of the resilience approach. The assessment of the current situation was that although degraded, no system 'flip' was evident in the ecological system. However, the social system may have transformed in the last two decades with the erosion of parental networks, and the emergence of sibling networks. This appears to represent a fundamentally different system. Apartheid planning was a key driver and the repetitive shocks such as HIV/Aids and crime are evident today. Further work is required in this regard. Key slow variables that require attention are sedimentation, education and land tenure and governance.

Although change is underway in the SRC, the situation is still in a state of transition. A major implication seems to be that the <u>historical feedback loops still persist despite policy changes and that new feedback loops are not in place</u>. The important role of new sources of leadership (e.g. the Catchment Management Agency and inter-sectoral initiatives) has been highlighted through a systems approach. In particular their role in the transformation of (water resources) management will be to ensure that the important feedback loops between policy, practice, reflection, action and learning are in place with attention to slow variables.

[1] Slow variables, if not explicitly acknowledged, have the potential to 'creep up' and have a sudden, surprising and potentially catastrophic effect.

A major benefit of using systems diagrams (not normally incorporated in a resilience analysis) lies in their co-construction and collaboration – a process that facilitates learning and integration. Specialists from different disciplines are encouraged to think outside of their 'comfort zone'. Defining and discussing linkages, feedbacks and cross-scale effects using systems diagrams as a heuristic was an important part of the process. A major value lies is the prominence that it lends to identifying and describing feedback loops. This reveals issues that require immediate attention without suggesting a simplistic, single-factor cause or solution. It is important to stress that systems diagrams are a *heuristic for the co-construction of a common understanding* and should complement, not replace, narratives. This is equally true of scenarios which require joint reflection on possible futures. The exercise also compels a closer examination of claims regarding vulnerability or resilience. The construction of a SES view and of scenarios could serve varied purposes in research and development in many fields, but remains to be tested.

Identifying multiple and cross-scale factors by constructing a panarchy proved largely unsatisfactory. With little practical guidance the exercise was one based on judicious, but unvalidated opinions of where different components lay on the adaptive loop. Given that the 'resilience approach' is still in a strongly exploratory and developmental phase, this is not surprising and offers an exciting challenge for future work.

Ultimately we would suggest that the process of attempting a resilience analysis – and indeed the wider acceptance of the key concepts – has potential to shift the discourse on degradation, vulnerability and livelihoods. The reorientation requires an exploration of scale, multiple linkages and relationships, 'surprise', unintended consequences and attention to drivers and processes. One is not just examining the 'state' of system alone but also the patterns and configurations within a 'whole' system. By acknowledging complexity one works with rather than constrained by system dynamics, being better prepared for emergence and opportunity and emphasising learning and adaptation.

Chapter 1

Introduction, objectives and overall approach

1.1 Background and purpose

Somewhat extraordinarily, practitioners and academics alike still continue to approach natural resources management from a single-domain perspective - this despite evidence in that charting a sustainable future remains an elusive goal (Walker & Salt, 2006). For instance, the biophysical understanding of wetland processes in a certain area may be good, but without taking into account the linkages to the surrounding terrestrial landscape, and to the wider socio-political context, rehabilitation processes are bound to fail (Pollard et al., 2007b). Even more commonly, the linkages between biophysical and socio-economic processes receive insufficient consideration, and whole programmes with a biophysical or social focus may fail without an understanding of the supporting social or ecological processes. In this regard, we developed the following heuristic to apply to the evaluation of any resource management situation

- is the desired result being obtained from the intervention?
- is that effect durable, or does it only work for a while?
- are there significant unintended effects?

Worrying answers to one or more of these questions indicate that we are very likely not thinking holistically, and highlight the need for re-appraisal, if not for a different paradigm.

Several initiatives are currently underway in Southern Africa, such as in the Blyde-Sand catchments and environs, to establish integrated approaches to water and natural resources, their sustainability, equitable use and management. In the water sector generally Integrated Water Resources Management is being widely tested (see Pollard & du Toit, in press), whilst in the land-use planning sector certain versions of bioregional planning reflect a wider socio-economic and conservation objective. These more holistic approaches make direct reference to balancing human and natural systems in an equitable way.

This more holistic perspective arose as a critique to the more narrow view of natural resource management – often referred to as the 'silo' mentality – which is considered to ill-equipped to meet the challenges of a complex and rapidly changing world. In an environment of emerging policy frameworks, juxtaposed characteristics of wealth and poverty, ecosystem health and degradation, new approaches are being sought to build sustainable futures. In this study we test resilience thinking and its associated concepts. We do this to explore if the potentially scarce water-based ecosystems services can be mobilised and sustained in a way that the balance between natural assets and the human communities can be re-adjusted to secure growth and equity without jeopardising future options. A key feature of this approach is to try to view the system as an integrated socio-ecological system (or SES sensu Berkes and Folke, 1998) in a way that has not been done before. We suggest that by adopting a systems view, one is in a better position to achieve this balance.

A landmark in linking ecological to social and economic systems took place in 1995 with the publication of "Barriers and Bridges" (Gunderson et al., 1995). The idea of a general adaptive cycle was developed and refined by the Resilience Alliance (http://www.resalliance.org) into a plausible metaphor which has attracted much attention and is now being increasingly used as a basis for understanding the social, economic and biophysical 'systems' as just one interacting social-ecological system (Berkes and Folke, 1998). The general adaptive cycle posit four phases (exploitation, conservation, release and reorganization) as universal to the overall system and to any conceived sub-systems such as socio-political, economic or biophysical. This understanding is largely conceptual although an increasing number of practical examples are emerging (see for example Berkes et al., 2003). An underlying and fundamental aim is to encourage resilience of desired regimes (in which systems vary but still retain their fundamental identity), and weaken resilience in the case of undesirable regimes (Walker and Salt, 2006).The book "Panarchy" (Gunderson and Holling, 2002) extends the understanding of adaptive cycles into a nested hierarchy at different scales (say local, regional and international), with guidelines to help understand types and actions of inter-scale linkages. The potential relevance of this overall approach to systems in and around the Kruger National Park is discussed in several chapters in a recent book (du Toit et al., 2003). Two of the authors of this report refer to this methodology as a tool for integration (Biggs, 2003), and to conceptualise the re-coupling of disconnected social and biophysical systems around local communities to the west of the Park (Pollard et al., 2003). These concepts are further elaborated in Chapter 2.

The construction of such an SES and its related products (such as scenarios), as attempted in this study, could serve varied purposes in research and development in many fields, and is further discussed in Chapter 5. Concurrently, a much broader-scale SES formulation to encompass the entire Greater Limpopo Transfrontier Conservation Area is being prepared, intended to act as an overarching framework for a programme known as AHEAD (see www.peaceparks.org) which seeks geographical and societal context for the challenges that face veterinary health agencies in the area now that many fences and controls are being removed.

In South Africa, the Sand River Catchment in the far north-east of the country (see Figure 3.1) is an example of the increasing conflict that is developing around natural resources and their sustainability. On the human side, the imperative of generating and sharing wealth through development, land reform and black empowerment are widely stressed. The natural capital of the region, contained in scenic or game-rich areas currently utilised mainly as ecotourism destinations, is situated in and around poor rural communities. Water resources, in particular, are stressed and likely to come under further pressure to meet the demand for increased development. South Africa is in a period of transformation and the arrangements for water resources governance are highly dynamic with redress constituting a key focus.

Our **purpose** was thus to set up a usable overarching framework for understanding interrelationships between main drivers (be they social, economic or biophysical) in the Sand Catchment using the resilience approach. This is offered for use, discussion and refinement, in Integrated Water Resources Management, bioregional initiatives, and any other current or future work which requires such overall understanding of interrelationships.

This work is framed by the widely-held view that the Sand River Catchment is degraded. Thus the stated goal of the project is to develop a picture of the Catchment as a linked socio-ecological system in order to explore the vulnerability of the system, with a particular focus on water security. Underlying this are two key objectives relating to (a) the state of the Sand River Catchment and (b) the usefulness of the SES as an approach. These two areas of focus are formulated as questions. First we ask:

1. How vulnerable is the Sand River Catchment? Specifically, we ask this in terms of water security and hence the implications for the security of peoples' livelihoods. Thus this work hopes to deepen our understanding around the questions 'how degraded is the catchment,' and 'which components are degraded'?
    - Is it mainly the biophysical foundation that is degraded or equally the social and economic systems?
    - Have these (or one) changed states?
    - If state change has occurred can this be reversed/addressed?

- Are there 'windows of opportunity', as some authors assert (Olsson et al., 2004) for addressing this at a political or other levels?

2. A second sub-set of questions is evaluative in nature and asks:
    - Does the SES approach offer a useful framework?
    - If so how do we steer the catchment to a more resilient future?

The work commenced in 2004 and the project ran until 2007 although we had the benefit of presenting our draft findings (Biggs et al., 2008; Pollard et al., 2008b; Rogers et al., 2008) and receiving feedback at a workshop of the Resilience Alliance group held in 2008[2]. The core team consisted of Harry Biggs, Derick du Toit and Sharon Pollard. Two students assisted the project, Ms. R. Biggs and Mr. D. Biggs. Furthermore, various specialists gave numerous inputs – in particular through the specialist workshop held in May 2006 (see Chapter 5).

1.2 Overall approach

Our overall approach was that of used by Allison and Hobbs (2004) who employed the generalised adaptive cycle as proposed by Holling and Gunderson (2002), combined with qualitative system dynamics (Forrester, 1961, cited in Allison and Hobbs, 1994), the latter generating holistic cause-effect networks. This particular approach was selected mainly because of the intuitive appeal of combining systems diagrams with resilience theory after an influential visit by Helen Allison. As much as we wanted to test resilience concepts, we also wanted to elucidate inter-relationships, and the systems diagrams appeared to offer us that complementary ability, in somewhat the same way that Allison and Hobbs (2004) had combined them. The underlying belief was that we should attempt to view the system as a whole; along the lines of what is known as a socio-ecological system (SES). A key corollary is "the rule of hand" which suggests that only a handful of drivers are responsible for most consequences in the system, with many other being entrained or 'dragged along'.

Given that work of this nature is quite new – both globally and in South Africa - the team spent considerable time and effort developing a framework and approach for undertaking the work. Importantly at the time of its development we did not have the benefit of the recently available workbooks (Resilience Alliance, 2007 a, b). This framework (Table 1.1), comprising a series of steps, is offered as guidance for any such future endeavors, together with the aforementioned workbooks of the Resilience Alliance. (The two frameworks, ours and that of the RA were developed separately and interestingly, share many of the same features with the exception of our inclusion of system dynamics diagrams – see comments in Chapter 6). Nonetheless, in reality a number of the steps were consolidated, or in some cases, only attempted as a first iteration, in particular that of the panarchy analysis (see later discussion). This consolidation is described below.

[2] "Dynamics of Institutions in Water Resource Management" January 9-11, 2008 at the Center for the Study of Institutional Diversity, Arizona State University

Table 1.1
The proposed framework for developing an overall integrated, socio-ecological systems view

A series of key steps make up this framework. Each step is illustrated with information from the Sand River Catchment (SRC) as an example.

12. **Determine the primary focus and a system boundary**[3]. The history and current developmental landscape of the SRC suggests that freshwater could be one obvious central focus in a resilience study. Changes in land use characterize the area. For example, the current change from forestry on five state farms to grasslands for ecotourism is important in system function and very influential with regard to regional hydrology.
13. **The main characteristics and user groups** must be identified. In the SRC, the rural poor were a relatively important focus and an understanding of sources of power and conflict and the influence on resource use.
14. **Comprehending the prevailing mental models** in use is crucial. Do scientists and/or managers use flux-tolerant philosophies, or only steady-state, linear resource availability models? How well are these understood by communities? How much grasp is there of the need for, and ways to achieve sustainability? Is the dominant profitability and growth model based on the idea of an infinite resource? How are all of these mental models linked to social values, and what leverage might there be for change? Historically the wider lowveld was dominated by an approach that solved all problems through technological interventions. The large inequities today mean that people are claiming their right to water. An environmental ethic is starting to emerge (see also du Toit et al., 2007) on mental models in the Crocodile River)
15. Undertake an analysis of **trends over time and space**, with a view to understanding their effect on resilience in later steps. The main factors that were considered for the SRC included changes in land-use, demographics, governance and envisaged climate changes. Cross-scale understanding is crucial so that the interacting effects across scales, wherever significant, can be built into the understanding of the system dynamics. Different scales that were considered included households, areas in the landscape of similar land-use, catchments, regional scale climate, and national and international market effects.
16. **Governance and its effect on the intended resilience analysis**. An important consideration for the SRC and the focus on water was of the likely effect at different scales of implementation of new legislation (Water Act; integrated development plans of municipalities; land reform and biodiversity legislation).
17. **Identifying alternative states**, and thresholds, which lead to the system crossing into these other states. Are managers modifying these drivers? The key issue here was to suggest when the system changes state, and in particular where self-reinforcing loops were apparent? In the SRC the biophysical system has not changed states whereas opinion suggests that the social system may have done so.

[3] The system boundary choice is necessarily partly arbitrary. There are three categories of variables eventually chosen: internal (produce outputs and receive inputs i.e. we can make a difference by influencing them.); external (influence our system but we assume we can have no influence back into the system) and so-called "environmental" (ones which we choose to ignore)

18. **Identification of key fast and slow variables in the system**. While examining for alternative states and for the thresholds associated with these, several of the variables become apparent. In general, the biophysical variables operate at slower timescales (decades to centuries e.g. soil degradation; sedimentation). Rates of change are extremely important, as systems can be resilient a slower rate of greater absolute change, compared to a faster rate of lesser absolute change. In the SRC sedimentation, decreased flows and the quality of education are examples of slow variables.
19. **Identify sources of leadership, empowerment and learning**. We speculate that these factors may be more diverse in an African setting and that the diversity may be a key source of resilience. If this is true, a corollary is that we should perhaps be cautious to try and unify or homogenize this social system, as this may undermine resilience. In the SRC for example, a plural legal system – together with the associated sources of leadership) - is evident for managing wetlands (see Pollard & Cousins, 2007).
20. **Identify ecological and social redundancy**. Which other communities or organisms can take over a function (e.g. nitrogen fixation) if one source is obliterated? The key to this investigation was to have some understanding on functional diversity and not just an understanding of composition and structure of components.
21. **Panarchy analysis**. This is the ultimate analytical step, in which the identified major system drivers at the scales of interest (and as influenced by drivers at different scales through so-called "revolt" and "memory") are integrated to tell a full story over time. It should focus on potential crises or positive transitions, and their causes. In the SRC one iteration has been attempted and is reported in Rogers et al., in prep).
22. **Scenario generation** makes up the final futuristic step, in terms of expected responses to stresses and shocks. According to practitioners, it is best done with stakeholders, thereby spreading appreciation of system and enhances the chances of a realistic grasp of various trajectories. Slow variables are usually critical (see Chapter 5).

As stated, these key steps were consolidated so that the overall approach consisted of a number of phases, outlined below. Details of each of these are given in the appropriate chapters that follow.

1. Determination of the primary focus, objectives and system boundary which involved the following key steps.
    a. Description of the system boundaries, and the key focus areas.
    b. Definition of appropriate temporal and spatial scales for description and analysis:
    c. Description of the current state of the catchment and the major socio-economic, ecological and political characteristics.
2. Exploratory analysis and the co-construction of iterations of systems diagrams. This step, which occupied a significant part of the project, also allowed for the analysis of key drivers, the identification of fast and slow variables.
3. Refinement and specialist review

    A specialist workshop was held over a two-day period (May 2006) to (a) review and refine the systems diagrams, (b) to provide inputs on state changes and; (c) to develop future scenarios focusing on sustainability and equity and the impacts of shocks on these.

4. Preliminary panarchy analysis. This aspect of the work will not be reported on here because, although a preliminary iteration has been undertaken (Rogers et al., 2008), this has been a difficult exercise that is as yet, incomplete. In spite of the theory being available, no detailed guidance is given on the analytical application thereof although the recent workbooks do offer some assistance in this regard (Resilience Alliance, 2007b). When we attempted it, it turned out to be a somewhat 'messy' exercise that, unguided by any framework, was largely driven by expert opinion. This meant that people applied and derived panarchy's for different scales in different ways and there was little guidance on how to consolidate these or alternatively, to resolve differences. Nevertheless some found it meaningful as a heuristic, and we were able to present the preliminary attempts at the aforementioned workshop in Arizona.
5. Finally, results were presented and discussed with a number of members of the Resilience Alliance at a workshop in Phoenix, Arizona in January 2008.

1.3 Structure of the report

This following chapters provide a consolidated report of the above phases of the project, as follows. Chapter 2 offers an overview of the main conceptual underpinnings of the work including systems approaches and complexity theory, resilience and panarchy analysis, livelihood approaches, social learning and ecosystem goods and services. Chapter 3 provides an overview of the Sand River Catchment and identifies the main socio-economic, ecological and political characteristics. In Chapter 4 we present the synthesized systems view of the catchment in two eras: apartheid and under transformation. Chapter 5 takes this one step further by examining potential future scenarios. Finally Chapter 6 draws conclusion regarding the usefulness of the systems approach to understanding vulnerability of the catchment and how the approach has both influenced and been taken up in other work.

Chapter 2

Sustainability in socio-ecological systems: An overview of key concepts

2.1 Introduction: Sustainability in socio-ecological systems

The ultimate objective of this work is to contribute to efforts on sustainability, both within the Sand River Catchment, and wider. We break from more conventional approaches to natural resources management by recognizing the catchment as one linked socio-ecological system influenced by - and influencing - systems at other scales. But, it may be asked – why do so? The essence of this has been succinctly captured by Gunderson et al. (1995), who note that resource use brings about an ecosystem response (change) which in turn influences and changes resource use, representing what they call a 'coupled, dynamic system exhibiting adaptive behaviour'. Pollard et al. (2003) broaden this concept by describing various drivers and attributes, captured in the acronym V-STEEP (for values, social, technical, ecological, economic and political), that influence behaviour and the state of the resource use (see also Campbell and Olson, 1991).

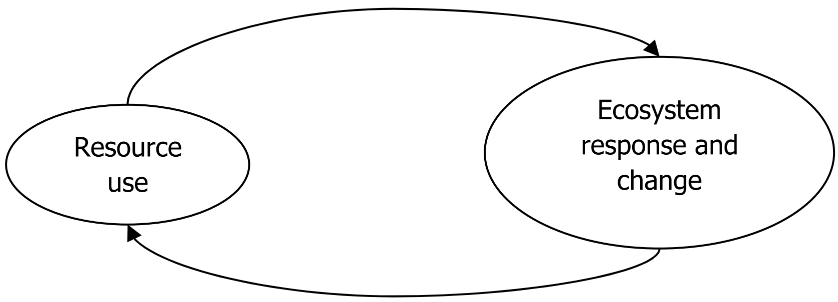

Figure 2.1 Social-economic, political and ecological systems do not exist in a vacuum but are coupled, dynamic systems

A number of concepts underpin the work presented here, the central ones being **complexity, resilience and panarchy.** These are then applied in a context which links biophysical integrity and the capacity to deliver ecosystem goods and services, livelihoods security, (mediated through land-use and water-use practices) and social learning,. The tenet is that livelihoods in the Sand River Catchment (SRC) are partially supported by ecosystem goods and services from within the Catchment and that a decline in ecosystem integrity will impact on livelihoods.

2.2 The importance of complexity, resilience and panarchy for sustainability

> **Resilience Project**
> This was a five year project
> Their overall theories emerged from selecting, expanding and integrating existing theories in institutional research, economics, ecosystem science and adaptive complex system theory This was a precursor to the Resilience Alliance Network.

A central concept for sustainability that was introduced by Holling in 1986, and further developed by the Resilience Network, is that of *resilience*. Indeed this concept lies at the very heart of sustainability. Holling and others suggest that a resilient socio-ecological system can buffer disturbance and adapt to change without flipping states (a concept that is described later). Importantly, ecological, social and economic sustainability is synonymous with resilience[4] (Berkes et al., 2003 p.15). Despite the enormous advances that have been seen through the work of people in the Resilience Alliance, the wealth of terminology and concepts can be somewhat overwhelming and even alienating, making it difficult for the newcomer to see the practical value. Indeed in recognition of this Brian Walker and David Salt entered into a partnership to produce a more digestible – and hence practical - book (Walker and Salt, 2006).

A central, organising concept is that of *resilience*. Indeed it has gained popularity at a political level in the conservation arena in South Africa partly, we suggest, because it is easily understood and communicated, at least in the colloquial sense. Nonetheless, this section will attempt to deepen understanding by unpacking the related and underlying concepts of complexity and sustainability.

We suggest that a useful starting point is to illustrate how sustainability, resilience, complexity and panarchy are related and to then examine the implications (such as adaptive management, for example). These links are illustrated through the following question: If <u>sustainability</u> is synonymous <u>resilience</u> is (see above), how do we build <u>resilience</u> in a <u>complex system</u>? Let us start by examining the issue of complexity and then return to resilience and panarchy. Colloquially, 'complexity' has a loose meaning, which differs somewhat from the more technical or conceptual meaning explained below.

Complexity theory arose as a critique of linear causality and reductionist science. At the heart of this critique was the concern that this thinking has - and continues to - so influence management and governance (see for example Levin, 1999; Gunderson, 2001; Holling, 2001; Folke et al., 2002b; Folke, 2003; Allison and Hobbs, 2004; Walker et al., 2004; Anderies et al., 2006). In challenging this, scholars have pointed out that sustainability remains an elusive vision. Not only has linear conventional thinking failed to chart a sustainable path but in many cases it has actually contributed to the problem (Walters and Salt, 2006).

It is widely recognised that natural and social[5] systems are complex in their own right and that additional complexity is added by their interactions. Berkes et al. (2003) note that this poses particular challenges for disciplinary approaches (the 'silo' approach referred to in Chapter 1). Indeed, some assert that they cannot be understood - let alone managed - through conventional disciplinary approaches (Jasanoff et al., 1997, cited in Berkes et al., 2003). This is because the phenomena that we experience or see are reflections of multiple, diverse and distributed (scalar) causes. These attributes essentially describe complex systems, hence leading us to the assertion that complex systems thinking is thus required.

[4] This does not imply that all resilient systems are favourable. Indeed many longstanding but nefarious political regimes are resilient (over a certain timescale) but are ultimately unsustainable

[5] The primary focus of *social systems* in the sense applied by the Resilience Network is on governance (especially property rights); knowledge, ethics and values; whilst *ecological systems* are self-regulating communities of interacting organisms (including people) (Berkes et al. 2003)

This acknowledgement lies at the heart of new integrative approaches such as sustainability science (see Lubchenco, 1998; Burns et al., 2006), and 'bridging' approaches such as ecological economics (Constanza et al., 1993-) and integrated conservation and development. Indeed the call for integrated approaches in water resources management, such as those embodied in Integrated Water Resources Management reflects such concerns (see for example Munro, 1995; McKay, 1996; Gorgens et al., 1998; GWP, 2002; Penning de Vries et al., 2002; King and Brown, 2006; Pollard and Toit, in press).

Complexity thinking builds on *general systems approaches* pioneered in the 1930s, which examined 'wholeness' and how parts operate together, not from examining the parts themselves (Von Bertalanffy, 1972). General systems theory was enhanced by subsequent developments in the field of complexity studies such as those of Forrester (1992) and Holland (1992). These approaches foster a broader view of overall context and focus on dynamics of cause-and-effect and feedbacks. Two useful references are work by Cilliers (1998) who deals with complexity in detail, and Levin (1999) who examines complexity and the commons. Levin suggests that any system which shows the following three attributes will show complex behaviour: diversity of components; interactions between these components (especially local ones); and any selection process such as that posed through natural selection or a stock market.

A complex system can be distinguished from a simple one, albeit complicated, by a number of attributes including non-linearity, uncertainty, emergence, multiple scales and cross-scale effects, self-organisation and feedback loops (see later discussion on resilience). Acknowledging these means accepting both implications and lessons which are discussed later. A complex system shows <u>feedbacks</u> (reinforcing or balancing) in its cause and effect relationships, which, usually because of operation at different <u>scales</u>, cause <u>emergence</u> (i.e. the feedbacks generate surprising new properties not predictable from the original bits and pieces making up the system). A simplistic but effective example of emergence is the way in which *words* strung together make up a *sentence* with an emergent meaning, not directly evident from the meaning of the individual words. Almost all ecosystems, and almost any socio-ecological system can be shown to exhibit this complex behaviour and hence emergence. Ironically, complex systems often have only a few predominant drivers – it is the way these interact (and in particular the feedbacks) which produce the complexity (In an ecosystem for example, these typically include factors such as rainfall, fire and herbivory). The drivers invariably vary in strength over space and time, producing different combinations of outcomes. At a certain range (called a *threshold*) in the values of these different drivers, systems can fundamentally change their nature, say from grassland to savanna, or from family to sibling kinship networks. In practice this usually takes place as a series of linked thresholds and system states, called a *regime*, and a regime shift follows (see inter alia Scheffer et al., 2001; Carpenter, 2003; Folke et al., 2004). An example of a regime shift is the change in the nature of rivers in the lowveld from bedrock-influenced. higher-flow, and with lower human utilisation to alluvium-dominated, lower flow, and with higher levels of human abstraction. A series of interlinked thresholds is crossed in each of these factors, leading to a different overall state. Essentially in a new state the rules-of-the-game - or underlying processes - change.

Complex patterns stand in contrast to *complicated* patterns which, in a technical sense, have very many parts but these parts are connected in a way which produces a deterministic (always the same, entirely predictable) outcome. Examples of complicated systems are aircraft or electronic circuit boards. These fundamental concepts are reviewed by Walker and Salt (2006) and a series of thresholds and regime shifts are listed on the Resilience Alliance website http://resallaince.org (and see Box 2.2).

Although not as predictable, complex systems show remarkable pattern – it may be mistaken to see these systems as being near "the edge of chaos" (Langton, 1990, see http://en.wikipedia.org/wiki/Edge_of_chaos). They can be managed with an appropriate but not exaggerated sense of confidence. Mistaking a complex system for a complicated one leads to problems of rigidity, with the complex system (if one can imagine it as a living or adaptive entity) tending to "outwit" the complicated human plan. An example we see regularly is that of free-flowing rivers versus canalization. Ultimately, the latter system can 'backfire' (some people call this 'nature showing 'revenge'), as demonstrated by, for instance, the Aral Sea saga and in chronic ecological and societal problems with highly regulated rivers (e.g. the Mississippi River). We are fortunate in South Africa to have progressive water legislation consistent with sustainability science principles which recognise complexity (Burns et al., 2006; Pollard and Toit, In press) though this is only in the very early stages of implementation (see also Bammer, 2005).

Table 2.1: Key attributes of complex systems (synthesised from Holling, 2001; Gunderson and Holling, 2002; Berkes et al., 2003; Walker et al., 2004; Allison and Hobbs, 2006)

Attribute	Example
Socio-ecological systems are **heterogeneous**, **dynamic** and in a state of **flux**. Variability is essential and not a 'management inconvenience or problem'.	Rainfall may vary around an 'average' of 500 mm per year – from 200 mm in a dry year to 800 mm in a wet year. This brings about different effects each year and cumulatively.
Systems have **multiple drivers**, many of which are non-linear in their effects and which operate at different scales. Hence outcomes are usually not entirely predictable. Also some of these drivers may relate to other 'sub-systems' such as a political or global drivers.	For example, a reduction in base flows may reflect increased abstraction, the impacts of a weir and a political decision to expand agriculture, such as biofuels which are seen as a way to improve our foreign exchange
Components of systems are independent and interacting and understanding the linkages is important. In particular **feedback loops** are an important attribute of complex systems.	For example, a reinforcing loop is evident when wetland health improves, causing an increase in the water table which causes a further improvement in wetland health (Pollard and Perret, 2007). In Tanzania, despite socio-political change, persistent feedback loops between monitoring and action have ensured a resilient management system (Tengo and Hammer, 2003).
Multiple drivers and feedback loops often mean uncertainty because we **can't predict exact outcomes**, Moreover they can lead to **unexpected outcomes**	For example, the global drive to reduce dependence on fossil fuels (viewed as a favorable position for sustainability) has increased biofuel initiatives which are impacting on water resources and on food availability. This was not anticipated a decade ago.
Complex systems display **lags**	For example, we are unlikely to see immediate benefits from the policy to determine environmental flows because of the complex socio-economic and political arrangements needed to achieve this
Complex systems are not necessarily complicated, in fact, they often only have a **basic set of drivers and responses**.	For example, fire, rainfall and fire management may be the key drivers of a system.

But what does this mean in practice? The essence of these systems is that their inherent variation in space and time is what determines the system function, and that it is this persistent variation and novelty that facilitates adaptation. Gradually we are getting better at understanding and managing such attributes them. Importantly, we strive to see the system holistically, with all systems as sub-systems of bigger systems, and invariably interacting with other sub-systems and the bigger and smaller systems to which they relate. Berkes et al. (2003) assert that there are three fundamental implications for resource management of accepting complexity:

(i) models and perspectives based on linear thinking are inadequate (including optimization models);

(2) qualitative analysis is an important complement to quantitative approaches; and

(3) a multiplicity of perspectives is needed to analyse and manage complex systems.

A key lesson for management is that management processes can be improved by making the flexible and adaptive so as to deal with uncertainty thereby building capacity to adapt to change.

Box 2.1 Resilience – what's in a word?

Despite the aforementioned definition, attention has turned recently to the need understand the somewhat different emphases that each discipline has brought to bear as the discourse on resilience has evolved. A lengthy review of this is given in Brand and Jax (2007) who argue for a clear descriptive concept since this provides the basis for operationalisation and application of resilience within ecological science (see also Carpenter et al., 2001). They point out that resilience is increasingly interpreted in a broader meaning across disciplines as a way of thinking, a perspective or even paradigm for analyzing social-ecological systems (Folke et al., 2002a; Folke, 2003, 2006; Anderies et al., 2006; Walker et al., 2006). They refer to a tension between the original descriptive concept of resilience first used in ecological science by Holling (1973, cited in Brand and Jax, 2007) and a more recent, vague, and malleable notion of resilience used as an approach or boundary object by different scientific disciplines. Their analysis points to at least 10 different approaches to resilience, although they concede that each holds at its core the notion of sustainability. Each approach emphasizes different aspects of resilience with respect to the specific interest. The ecological aspect is stressed by ecologists, whereas the political and institutional aspects are stressed by sociologists.

Particularly in the last two decades, many initiatives have grappled with and embraced complexity. One such initiative, the Resilience Alliance (http://resalliance.org) has popularised the handling of complexity through the concept of *resilience.* They point out that systems which aim at maximum productivity (even the classic concept "maximum sustainable yield") tend to be vulnerable because of their underlying assumption of equilibrium and linearity (see Carpenter et al., 2002). These systems assume a single central point of "balance" - or optimisation - which should be strived at or managed for, based on intuitively appealing concepts of generally linear cause-effect responses The Resilience Alliance argues that there is little evidence supporting this linearity and equilibrium, and that systems typically show non-linear behaviour and produce surprises consistent with complex behaviour. They thus propose that a better goal (than one that seeks to achieve maximum or optimum stable production) is to embrace variation. This, they suggest, accepts that all systems show cyclical behaviour through a 'front loop' (consistent with *some* of the assumptions of e.g. continuing growth in economic theory) but followed by a 'back loop' which is seldom taken into consideration. They propose that being honest and explicit about the universality of the 'back loop' opens real opportunities to manage sustainably and to stop seeing surprises (like droughts and floods) as unfortunate accidents interfering with continued growth along the 'front loop'. The aim becomes **resilience**, the ability to keep a system within prescribed 'healthy' but varying bounds (or in the case of undesirable system configurations, to overcome this 'undesirable' resilience and transform the system along a trajectory to a more desirable configuration). The Resilience Alliance (or RA) has defined resilience as:

> "The capacity of a system to absorb disturbance and re-organise so as to retain essentially the same function, structure and feedbacks – to have the same identity (that is, to remain in the same system regime)".

The Resilience Alliance also notes that "A resilient system is forgiving of external shocks. As resilience declines the magnitude of a shock from which it cannot recover gets smaller and smaller. Resilience shifts attention from purely growth and efficiency to needed recovery and flexibility. Growth and efficiency alone can often lead ecological systems, businesses and societies into fragile rigidities, exposing them to turbulent transformation. Learning, recovery and flexibility open eyes to novelty and new worlds of opportunity".

Some of the key concepts of resilience have already been discussed as part of complex systems theory. The Resilience Alliance introduced two metaphors to illustrate the concepts of non-linearity, adaptive cycles (including multiple scales and cross-scale effects - "panarchy") and (b) alternate regimes and thresholds. These are the reclining "figure-of-eight" and the "cup-and-ball", each of which is described below.

Non-linearity, adaptive cycles and multiple scales and cross-scale effects
Resilience thinking was first widely publicised through Gunderson et al. (1995) in a book which made a compelling case for a plausible framework. The Generalised Adaptive Cycle has attracted much attention and is now being increasingly used as a basis (currently mainly conceptual) for understanding the social, economic and biophysical 'systems' as one interacting system. It published a now well-known diagram (Figure 2.1).

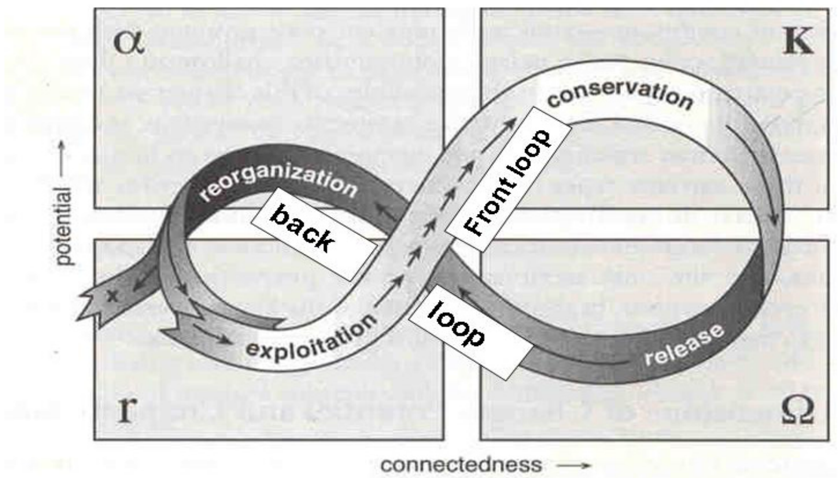

Figure 2.2 The Generalised Adaptive Cycle. (modified from Gunderson at al., 1995) which acts as a generic explanation of how all systems (biophysical, economic, social, and linked social-ecological systems) are believed to evolve. The vertical axis represents "potential" which can be taken to mean, for instance, accumulation of biomass, financial capital or social capacity. The horizontal axis indicates the cross-linkages or connectedness, such as biomass linkage (of say burnable fuel of the same height in a forest) or similar concepts (such as financial linkages in a market; or social connections in a society). The four phases indicated by the Greek letters represent four phases which characterise stages along this growth path

Two of the four phases (exploitation, conservation) describes what was previously referred to as the front loop reminiscent of conventional thinking (e.g. of plant succession); but then the cycle postulates a back loop (consisting of the two phases release and reorganisation). Rather than seeing a process like plant succession as simply sliding up and down a continuum along various positions on the front loop, the implication here is that the changes following disturbance (e.g. flood, avalanche, fire, pestilence) lead to a discrete new opportunity with its own defining characteristics, one in which differing forces can compete and potentially establish new system trajectories.

The adaptive cycle is intrinsically scaled and nested, in that, for instance, patches fit into (say) ecosystems which fit into (say) biomes. This nesting, and the all-important cross-scale linkages, are discussed in a book describing this so-called 'panarchy[6]' or full nested array (Gunderson and Holling, 2002; Holling et al., 2002). Such a panarchy is illustrated in Figure 2.3.

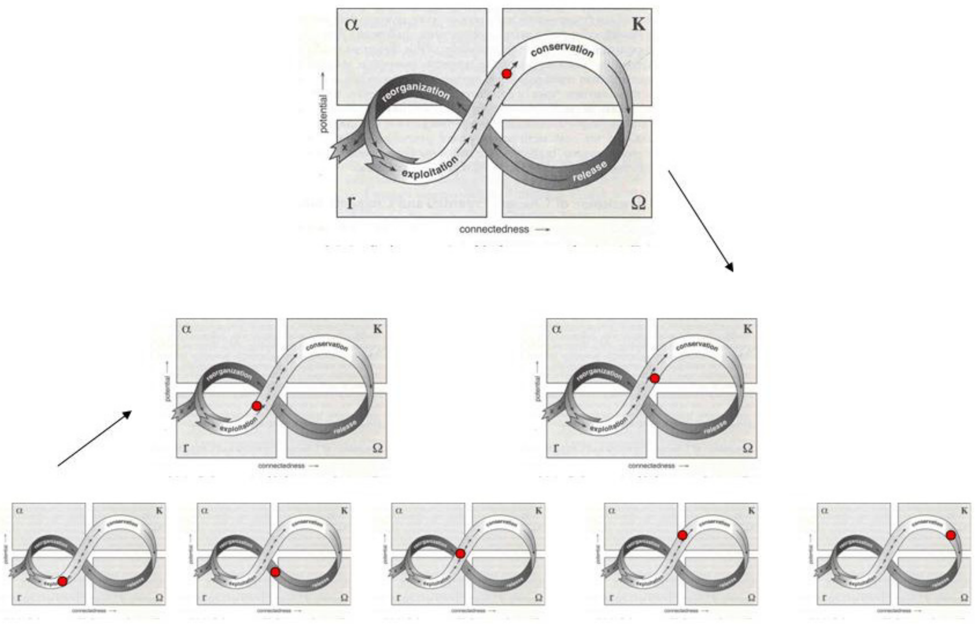

Fig 2.3 A panarchy of hierarchically nested adaptive loops. The lowest level of loops could be considered, for instance, to be village systems, the middle level district systems and the upper a provincial or national system. The red dots indicate that the different systems can be, and usually are, at different phases, and the arrows indicate that effects can materialize at different scales from stimuli from a lower or higher scale, though this is not universal – specific sets of conditions are believed to be necessary for either upward (known as 'revolt' in Resilience vocabulary) or downward (known as 'memory' in Resilience vocabulary) effects. These cross-scale linkages, when they occur, are often extremely important in system function, and can be easily overlooked.

Alternate regimes and thresholds

The "cup-and-ball" metaphor shown in Figure 2.4, indicating basins of attraction in a stability landscape (Walker et al., 2004), is offered to illustrate that a socio-ecological system can exist in one or more system configurations. Some configurations are desirable from a human perspective whilst others may not be. Each configuration comprises a set of sub-system states - and such a configuration (each sub-system retaining its own same structure and function) is termed a system "regime" (see earlier). As biophysical and social attributes of the system change, the positions of the attractors move around, and the various basins of attraction get smaller and larger, or appear and disappear. Alternate regimes are separated by thresholds that are marked by levels of controlling variables (often slowly changing) where there is a change in feedbacks. It is the changed feedbacks that lead to the changes in function and therefore structure.

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[6] Panarchy is a conceptual term first coined by the Belgian political economist de Puydt in 1860, referring to a specific form of governance (-archy) that would encompass (pan-) "all others". In the twentieth century the term was re-coined separately by scholars in international relations to describe the notion of global governance and then by systems theorists to describe non-hierarchal organizing theories (wikipedia.org).

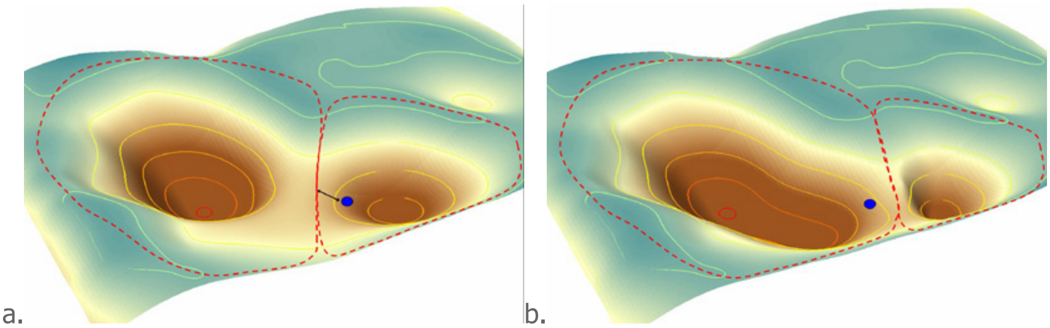

Figure 2.4 A "ball-in-the-basin" representation of resilience (from Walker, 2004). The state of this two dimensional system is the ball and its dynamics cause it to move to the 'attractor' - the bottom of the basin. The system can change regimes either by the state changing, or through changes in the shape of the basin (i.e. through changes in processes and system function), as shown in (b).

'Resilience thinking' holds three key concepts at its core (Walker and Salt, 2006). Firstly, social systems are inextricably linked with ecological systems within which they are embedded. Thus, we exist within socio-ecological systems. Secondly, these socio-ecological systems are complex adaptive systems. Importantly this means that they do not behave in a linear, predictable fashion. Moreover, because systems are linked, changes in one 'sub-system' will cause changes in other sub-systems. Thirdly, these systems have the capacity to absorb disturbance, to undergo change and still retain essentially the same function, structure and feedbacks. That is, such systems have resilience.

An important component of this analysis is to recognize the attributes of a resilient system some of which overlap with those mentioned for complex system shown in Table 2.1. These attributes then offer a framework for assessing whether or not the configuration of a system is in a sustainable state (see also Levin, 1999). According to Walker (pers. comm) and Walker and Salt (2006), the attributes or issues summarized in Table 2.2 are what may confer resilience (see also additions in Chapter 6). We have omitted one attribute – that of modularity – due to inadequate definition in the literature[7] which left the team unclear as to the meaning. It is suggested, although not explained, that it is synonymous with connectedness which we disagree with. Walker (pers. comm.) also spoke of openness and reserves and reservoirs, which are included. He makes the point that this is by no means a comprehensive list but the following list captures what most would agree on. There are likely many more attributes and this is an area requiring further work.

[7] A modular system has loosely coupled sub-systems that are internally tightly connected. Modularity slows the spread of pathogens and 'bad ideas' in systems giving time for preparation and re-organisation, and hence makes the system more resilient (Walker, pers. comm., April 2008)

Table 2.2 Some key attributes of a resilient (favourable) system (adapted from Walker and Salt; 2006; Walker, pers. comm. 2008; and see Resilience Alliance, 2007b)

Attribute	A resilient world would…
Diversity	..promote and sustain diversity in all forms (biological, landscape, social and economic). *Diversity is a major source of future options and important in a system's capacity to respond and adapt to change (but see comment under Complexity and learning)*
Ecological variability	…embrace and work with ecological variability (rather than attempting to control and reduce it).
Acknowledgement of slow variables	…have a policy focus on "slow", controlling variables associated with thresholds. *Slow variables are often controlling variables. They may result in slow creeping changes which can often go undetected, but which are eventually the signals or drivers of deep change.*
Tight feedbacks	…possess tight feedbacks (but not too tight). *It is the changed feedbacks that lead to the changes in function and therefore structure (RA key concepts). Recognising feedbacks facilitates detecting thresholds before we cross them. Globalisation is leading to delayed feedbacks that were once tighter.*
Social capital	….promote trust, well-developed social networks, and leadership (adaptability). *Resilience in SESs is strongly connected to the capacity of people to respond collaboratively and effectively and this relies on trust, networks, leadership and governance (see below).*
Innovation	….place an emphasis on learning, experimentation, locally developed rules, and embracing change. *Our current system seems to focus on getting better at a smaller number of activities rather than fostering novelty and innovation. However innovation is the basis for adaptability.*
Overlap in and polycentric forms of governance	….have institutions that include "redundancy" in their governance structures and a mix of common and private property with over-lapping access rights. *The range of agencies carrying out similar functions is regarded (within reason, and if in concert) as a positive contributor to resilience. This fosters cross-scale awareness and responses.*
Ecosystem services	…..include all the unpriced ecosystem services in development proposals and assessments. *Many of the benefits that society gets from ecosystems are either unrecognized or free (e.g. water purification, pollination). They are often only appreciated when lost due to a regime shift.*
Openness	*Openness applies both to the biophysical and social systems. A closed system does not get the infusion of novelty, organisms and ideas.*
Reserves and reservoirs	*Reserves also applies to both ecosystems and social systems - seedbanks are classic 'reserves' that confer resilience on ecosystems, social memory is a reserve of 'how to do things' that confers resilience in social systems.*

In concluding then, we can discern in complexity and resilience theory is growing dissatisfaction with single-system, or 'silo' approaches to natural resource management, as evident in increasing calls for integration (Allison and Hobbs, 2006). Furthermore, we see increasing concerns in practice that the management of ecosystems a ones which can deliver a constant and maximum yield (such as with fishing quotas) fail to recognise that they are in a state of flux. Complexity and resilience theory has thus arisen partly as a critique of such thinking, noting that variability is an inherent characteristic that confers strength on a system and should be viewed as such rather than dampened through a conceptual and management approach based on averages.

As mentioned much of the work in the complexity arena seeks to identify and understand key (but multiple) drivers and outcomes in a systems - in other words uncovering a requisite level of simplicity but not over-simplifying key processes and functions. Holling (2001) asserts that "there is requisite level of simplicity behind the complexity that, if identified, can lead to an understanding that is rigorously developed but can be communicated lucidly." On the one hand we have to simplify sufficiently to get the cooperation from non-technical groups with different expertise and agendas – from those who providing the financial resources to those who will be affected by the management intervention. At the same time we dare not simplify so far that we fall into the arena of the 'simplistic' – the failure to grasp crucial subtleties of the problem. Most scientists fear the tag of the simplistic, because it is a mark of failure amongst their peers. However the 'requisite simplicity' combines lucidity and rigour, and when identified, provides a platform to move forward.

We set out to view this study's finding through a resilience lens. Walker and Salt (2006) summarise a resilience analysis through a number of key steps:

1. Appreciate that the system under exploration is a socio-ecological system
2. Define the key attributes of the SES
3. Define the slow variables that drive the system
4. Describe feedback loops
5. Analyse if these changing. Are thresholds being crossed? Importantly are there changes in feedback loops?
6. What phase is the adaptive cycle in?

Box 2.2 An example of a regime shift in the Sahel

(Available from Resilience alliance website http://resallaince.org)

This example cites Sinclair, A. R. E., and J. M. Fryxell. 1985. The Sahel of Africa: Ecology of a Disaster. Canadian Journal of Zoology 63: 987-94.

In the southern Sahel, a rapid increase in the populations of people and livestock has resulted in overgrazing. Constant intensive grazing has destroyed the rootstock of palatable perennial shrubs, giving way to short-lived, shallow rooted annuals. Subsequently, the annuals were grazed out, leaving a landscape of bare soil and shallow rooted unpalatable shrubs. Much of the topsoil with its nutrients was blown or washed away, leaving bare rock. Silt, which settled in drainage areas, baked hard after rain. Roots could not penetrate this hard layer and no germination could occur. The grasslands have been replaced by desert. A continuous drought has accompanied this shift in vegetation.

Did the shift in vegetation type trigger the prolonged drought, or did the drought contribute to the shift? Coupled biosphere-atmosphere simulations (Wang and Eltahir, 2000a) have shown that a warming of 2.5^{o}C sea surface temperature is sufficient to trigger a shift from a self-sustaining wet climate equilibrium to a self-sustaining dry climate equilibrium. A 20% reduction in vegetation cover (i.e. 1% per year for the 20 years preceding the drought onset) is enough to maintain this shift, in the form of a multi-decadel drought. The most likely scenario for triggering the Sahel drought includes regional changes in land cover, and changes in the patterns of global and regional sea surface temperature, which was seen around the time of the onset of the drought. The impact of human activities on the landscape was not included in this study.

Fernandez et al. (2002) produced a model for cropping (subsistence and cash) and livestock farming in Western Niger, in the southern Sahel. Here the soils are sandy, low in organic matter and deficient in phosphorus and nitrogen. Productivity is limited by soil fertility, which is related to a combination of fallowing (for non-manured croplands) and herbage intake by livestock. Some key thresholds in the model include:

1. For unmanured cropland, soil fertility can be maintained when 3/8 of the arable land is left fallow.
2. Soil fertility is affected by the ratio of total herbage intake by livestock to total palatable herbage available during the wet season. The threshold for sustainability is set at 1/3 of the mass of palatable herbage at the end of the growing season, to allow for continual growth of annuals during the wet season and to account for the limits of grazing efficiency.
3. Economic sustainability was measured as a minimum threshold for the basic needs of household members.

State 2: During the famines, emergency drought assistance provided food aid for starving people. Some attempts were made to restore the grasslands in bare areas by reducing livestock numbers, but this has had little effect. The bare areas have remained in this state for more than 20 years.

2.3 Livelihoods

A discussion of a complex socio-ecological system would be incomplete without adequate attention to the human and social aspects. In this regard, the challenge is to apply an adequate and reasonable analytical framework that enables an SES analysis to appropriately understand the nature of social dynamics operative within a particular context and over a given timeframe. In this work we have drawn on the widely-used livelihoods framework as a way of integrating the social aspects of a system with the natural and physical components.

The livelihoods framework recognizes five essential capitals: human, natural, financial, social and physical (Chambers and Conway, 1992; Carney et al., 1999; Farrington et al., 1999; Bebbington, 1999; Campbell et al., 2002)). Whilst a detailed analysis of livelihoods approaches is beyond the scope of this report, it is important to note that the emergence of livelihoods approaches has led to new understandings for the discourse on poverty, and the ability of people to move out of poverty. Notably, it recognises that peoples' ability to survive is not simply reliant on financial resources but is predicated on a range of assets. This has also fundamentally reshaped development interventions. Much of the thinking emerged from work by Chambers (1992) who defined livelihoods thus:

> A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation: and which contributes net benefits to other livelihoods at the local and global levels in the long and short term.'

Central to the livelihoods approach is to understand the capabilities and assets (or lack therefore) that are available to people and in particular to the poor. This includes:

1. Human capabilities (such as education, skills, health, psychological orientation);
2. Assets - access to tangible and intangible assets (this includes human, material[8], social, natural and economic capital);
3. Activities - these capabilities and assets define the sorts of activities that make up the livelihoods of the poor and, through strengthening them, form the basis for many actions to reduce poverty.

The interaction between these attributes defines what livelihood strategy a household may pursue. Based on work by Chambers and Conway (1992), a number of fairly similar livelihoods models exist, the primary of these being those of DFID and CARE. The differences have been addressed by Carney et al. (1999). The model used in this report, shown in Figure

[8] access to land, other natural resources, financial capital and credit, tools and inputs into productive activities and others

3, is one adapted from these aforementioned models. This indicates that natural resources are one of the five capitals upon which people rely directly and hence contribute to peoples' livelihoods. The tenet of this study is that the rehabilitation of wetlands (the natural capital) will lead to improved financial and social security (see later discussions).

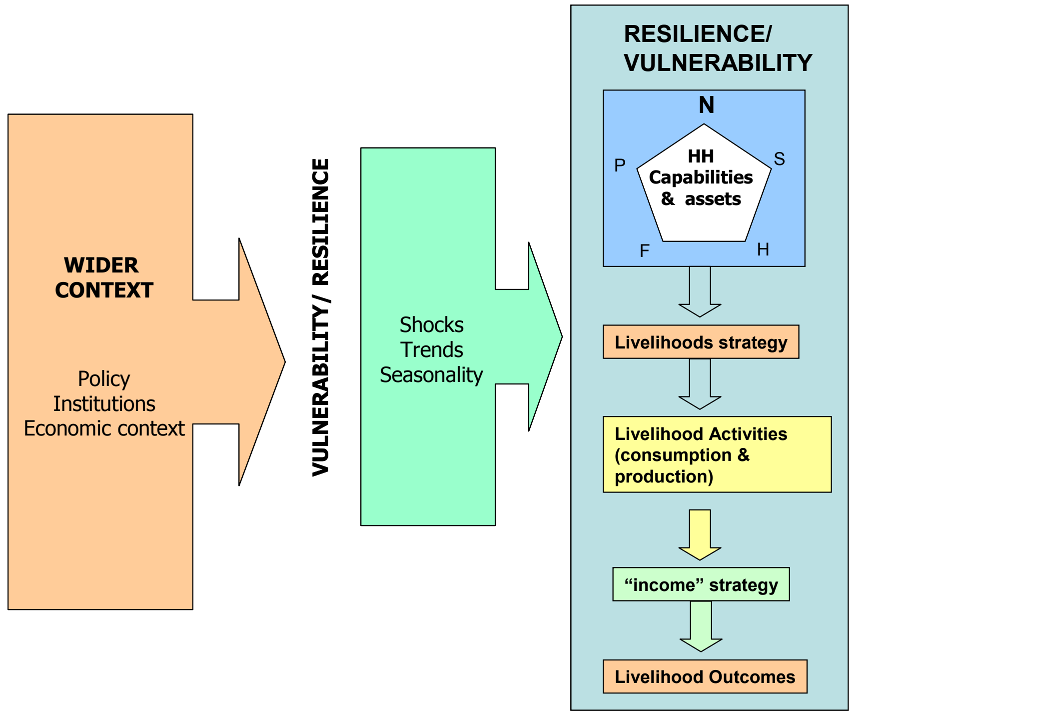

Figure 2. 5 The livelihoods model that frames work reported in this study (Pollard et al. 2007; adapted from (DFID; Drinkwater and Rusinow 1999). The five capitals used by households (HH) include natural (N); social (S); human (H); financial (F) and physical (P)

The human components are expressed by the framework as three of the five capitals, namely: financial, human, and social (Figure 4.5). Most notably, the concept of social capital potentially provides a way of assessing the non-material aspects of a system. The emergence of social capital as an organising concept is relatively new and despite its appeal, authors report that practical application is not without problems (Bebbington, 1999; Stone, 2001; Bossel, 2001). Scheffer et al. (2002) highlight the importance of dynamic interaction of social societies and ecosystems. They too draw on the concept of social capital, expanding specifically on the networking and connectedness aspects of social capital. Two important aspects of social capital for the work presented in this document are those of horizontal social capital and vertical social capital (Scheffer et al., 2002). Horizontal social capital refers to the connectedness and links within groups (like-minded groups or organisations) while vertical social capital refers to links across different groups, organisations, agencies and government actors. Despite the identification of social capital as an important component of socio-ecological systems, these authors do not provide further guidance on how to conduct a rigorous study of the two types of social capital.

In order to ground our discussion of the social aspects conducted later in the report we provide a brief orientation to the concept of social capital and how we have drawn on it in this paper. The French sociologist Pierre Bourdieu (1983) published some of the early work on the different forms of capital. Two of many available definitions, have been selected for the purposes of this report. He defined it thus:

Social capital is the aggregate of the actual or potential resources that are linked to possession of a durable network of more or less institutional relationships of mutual acquaintance and recognition

Stone (2001) provides a more practical definition in her discussions on methods for measuring social capital:

Social Capital consists of networks of social relations that are characterised by norms of trust and reciprocity. It is the 'quality' of social relationships between individuals that affect their capacity to address and resolve problems they face in common.

In an early critique Bourdieu warned of the misappropriation and misapplication of the concept of social capital. Despite this the idea has been used in a multitude of ways and in a variety of contexts. Indeed, Stone (2001) warns: "Where social capital has been measured to date, it has been done so using 'questionable measures', often designed for other purposes, and without sufficient regard to the theoretical underpinnings of the concept to ensure validity or reliability." In accordance with Stone's proposal, we look broadly at the three aspects, namely those of (a) networks, (b) norms of trust and (c) norms of reciprocity in order to arrive at a indication of social capital of the system.

Complexity and learning

In complex systems, learning becomes critical and this is drawing increasing attention in such studies. But what is the role of learning within complex systems? And, more specifically, does learning have a role to play in moving systems towards more resilient, stable and sustainable states? If we regard learning as a socially grounded process (see Von Glaserfeld, 1989.) for example), the question is how is it grounded within social systems and what are its ultimate outcomes in terms of benefits and consequences for the system as a whole?

Complexity theory proposes that socio-ecological systems derive their essential properties, and in fact their existence, from their relationships (Capra, 2007). The character of these relationships is influenced by interactions around events, communication and **learning**. The resilience, and hence sustainability of a system, is not an individual property, but a property of an entire network. One would assume that a vulnerable (unsustainable) system would have weak networks where feedback plays little or no role in organizing or regulating the system. This means that learning (from mistakes for example) cannot - or does not - occur. On the other hand, a system that is able to experience events, reflect on them and so learn is assumed to be responsive and capable of adapting to changes that are inherently part of complex systems.

Assessing the modes and modalities of learning within socio-ecological systems potentially provides a way of understanding just how adaptive and resilient the system is or can be. In a sense, such an exploration would look at the 'internal intelligence' or capability of social system to learn and respond to contextual events and changes.

The tendency to look towards analyzing (formal) education systems as a proxy for the kind of learning expressed above is misleading as they are not always set up to support this kind of reflexivity and responsivity. In other words, formal education may be co-opted by specific socio-political agendas and therefore does not tell us much about leaning in response to complexity (see Forrester, 1992) for example. In Chapter 3 we touch on the nature of evolution in Bushbuckridge and comment on the role of learning in preparing societies for complexity and change.

In order to get an understanding of how 'ecological' learning within complex systems proceeds (i.e. taking into consideration feedback loops) requires attention to how a social system utilizes the principles underlying ecological processes in ways appropriate within a particular context (Wals, 2007). If flexibility and diversity are key features of a resilient and sustainable system that help it cope with 'disturbances' then these two attributes need to be considered when taking opportunities for social learning into consideration. Note however that as Capra (cited in Wals, 2007) points out, diversity offers strategic advantage for a community only if there is a vibrant network of relationships and if there is a free flow of information through the network. When the flows are restricted, suspicion and mistrust are created and diversity becomes and obstacle rather than an advantage. Where networks do not function or where there is fragmentation, diversity can generate prejudice, friction or destructive conflict.

If we accept that learning has a vital role to play in ensuring that feedback loops have an impact on self-regulation and self-organization then it becomes a critical process in the support for, or hindrance of, establishing resilient, sustainable systems. In this regard, learning is taken to be a social process where engagement, communication and dialogue provide the basis for reflecting on and responding to feedback in a way that is open to change and that encourages creative and innovative responses to an ever evolving context. Some case studies on socio-ecological systems and resilience have started to address the issue of learning (see for example Tengo and Hammer, 2003), it is an issue that requires further attention.

2.4 Ecosystem goods and services and societal well-being

A central tenet of this work is that healthy societies are more likely to be associated with healthy ecosystems. Society's productive base is composed of natural, human, social and manufactured capital (Millennium Ecosystem Assessment, 2003). A society's 'natural capital' – its living and non-living resources - is therefore a key determinant of its well-being. Ecosystems are thus an important component of societal well-being through the provision of a wide range of 'goods and services'. Despite the apparent safeguards of technological advances, society is still fully dependent on ecosystems. Ecosystems are the productive engines of the planet that provide us with soils, nutrients, water, food, genetic resources, timber, and non-timber products. They also provide a range of ecosystem services such as water supply and flood control. To do this, the processes and cycles that maintain them are essential. Compromising these goods and services and processes compromises life itself.

Nowhere are these links starker than for the rural areas of developing countries, such as the Sand River Catchment, where an estimated 80% of the people rely *directly* on ecosystems for their livelihoods (Jazairy et al., 1992). For poor rural communities there are few substitutes Millennium Ecosystem Assessment 2003). This does not imply that the wealthy are independent of ecosystems but that they are indirectly reliant on goods and services. In fact, their demand for these, far exceeds that of the poor (e.g. Wackernagel and Rees, 1995). In a society focused on technological advances, these services have been, until recently, largely undervalued or ignored, particularly since they are not traded in the conventional economy (Carpenter et al., 2002). This changed with a publication by Costanza and his colleagues in 1987 and '97 (Costanza et al., 1997), which valued the world's natural resources and associated services at three times as much annually as all human created economic activities[9]. Since then the concept has been refined through local-level studies.

[9] The 1996 value of $ 33 trillion is (i) conservative, and (ii) at a 3 % inflation would be equivalent of $45.6 trillion today

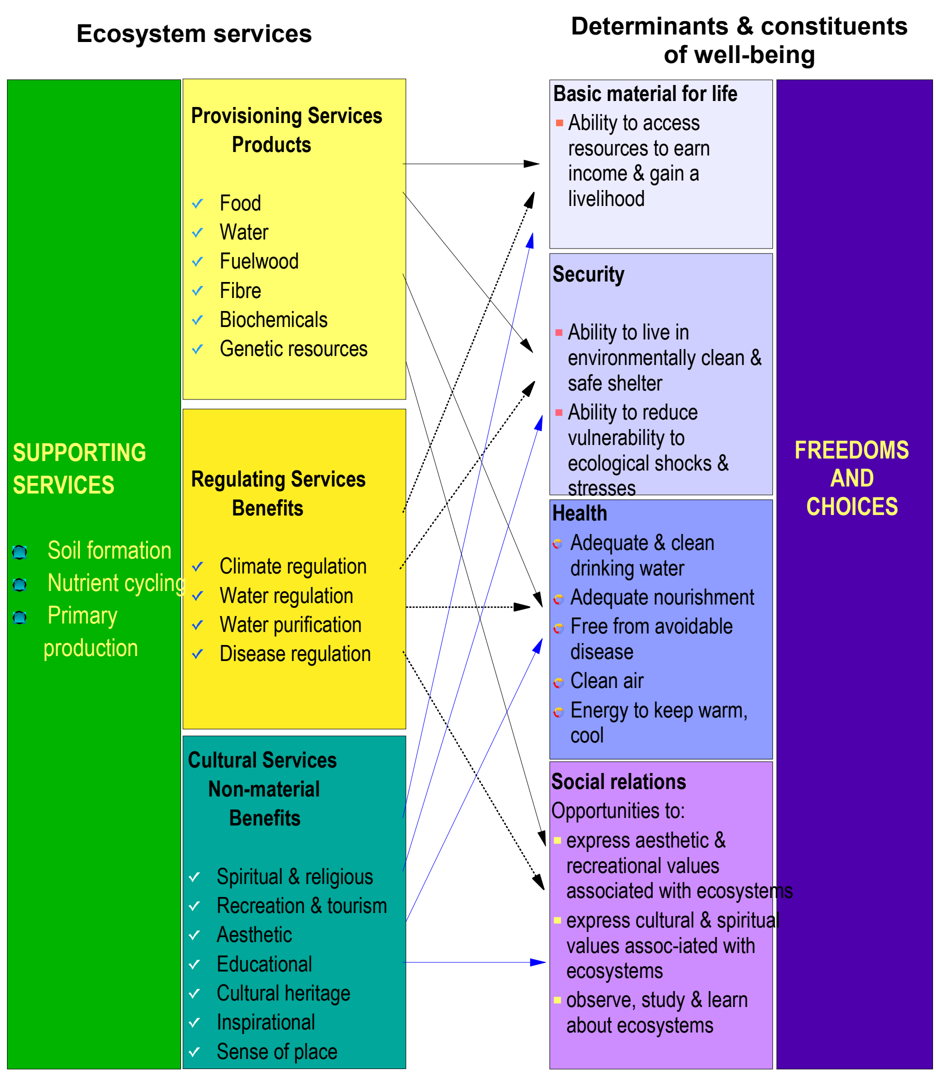

Figure 2.6 The links between ecosystems goods and services and human well-being (Millennium Ecosystem Assessment 2003)

The framework for ecosystem goods and services outlines that these comprise underlying supporting services, and the attendant provisioning, regulating and cultural services. These all contribute in different ways to human well-being (Figure 2.6).

Chapter 3

An overview of the Sand River Catchment

3.1 Introduction

In South Africa, the Sand River Catchment is an example of the increasing conflict that is developing around sustainable natural resource use. On the human side, the imperative for generating and sharing wealth through development, land reform and black empowerment are widely stressed. The natural capital of the region, contained in scenic or game-rich areas currently utilised mainly as ecotourism destinations, is situated in and around poor rural communities. Water resources, in particular, are stressed and likely to come under further pressure to meet the demand for increased development.

If we are to address this in any meaningful way, the socio-ecological systems (SES) framework suggests that ecosystem services, and in our case the potentially scarce water-based ones, can be mobilised and sustained in a way that the balance between natural assets and the human communities (of widely differing wealth status) can be rationally re-adjusted to work positively for many more people, in a way that preserves the natural base, without reducing future options. One of several reasons we believe our particular approach has a good chance of success, is based on the way in which we plan to view the overall system as **integrated** - the core of this submission.

The objective of this chapter is to describe the past and current status of the catchment. This includes of description of the biophysical and social attributes, including – where available - a summary of trends over time. Additionally, an examination of leadership, user groups and the governance regimes of natural resources (both formal and informal) will provide an overview of the dynamic relationship between people and resources over time. Understanding the dynamic spatial and temporal characteristics is an essential component to understanding their effect on resilience in later steps.

As noted in Chapter 1, the initial step in the 'Resilience Approach" is the selection of the system boundary (Allison, 2004). In the case of this project the focus is on water security and the links with livelihoods through ecosystem services provide by water in particular. The rationale for this focus is that preceding work by the Save the Sand Programme[10], under which this project falls, has identified water as the key constraint within the catchment (Pollard et al., 1998a). In keeping with the new policies in South Africa that pertain to water and for the purposes of this assessment, the natural corollary is the selection of the **catchment** as the system boundary.

3.2 A socio-ecological profile of the Sand River Catchment

The Sand River Catchment (SRC) lies in north-eastern South Africa, straddling the provinces of Limpopo and Mpumalanga (Figure 3.1). The SRC is the major tributary of the Sabie River, regarded as the most pristine of the six rivers that flow eastward through South Africa into Mozambique. Unlike the larger Sabie sub-catchment however, the Sand sub-catchment is severely degraded (Pollard et al., 1998). The Sabie-Sand system forms part of the Inkomati Basin, one of 19 legally-constituted Water Management Areas in South Africa. The Inkomati is an international watercourse, with shared rivers between South Africa, Swaziland and

[10] An Integrated Catchment Management initiative designed to restore the productive potential of the Sand River Catchment (see www.award.org.za)

Mozambique. In constructing a socio-ecological systems view of the catchment, the SRC may be conceptualised as consisting of interlinked ecological and social subsystems. The focus of this study is on understanding the dynamics of each of these subsystems, and particularly the interactions between them, in order to construct an integrated view of the whole. Understanding the underlying ecology provides insight into the opportunities and constraints to the use of natural resources in the SRC. Understanding the attributes of the social subsystem, which includes values, demographics, technology and well-being, provides insight into the demand for resources, as well as the way in which resources are used. The direct interaction between people and the environment is expressed through the reliance on ecosystem services and the use of ecosystem goods, by means of various land use practices. This interaction is influenced by various attributes of the social system, and mediated by the governance structures in the society (Figure 3.2).

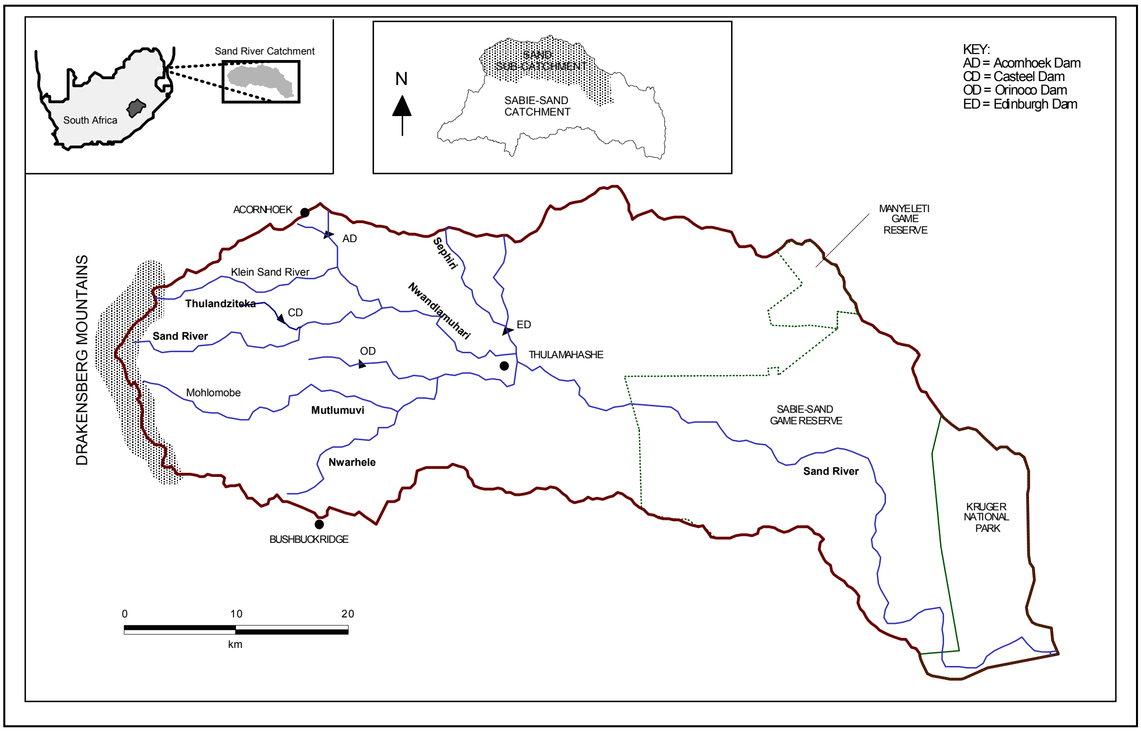

Figure 3.1. Map of South Africa showing the location and of the Sand and Sabie and Catchments. Three major tributaries drain the upper catchment, and join to form the main Sand River.

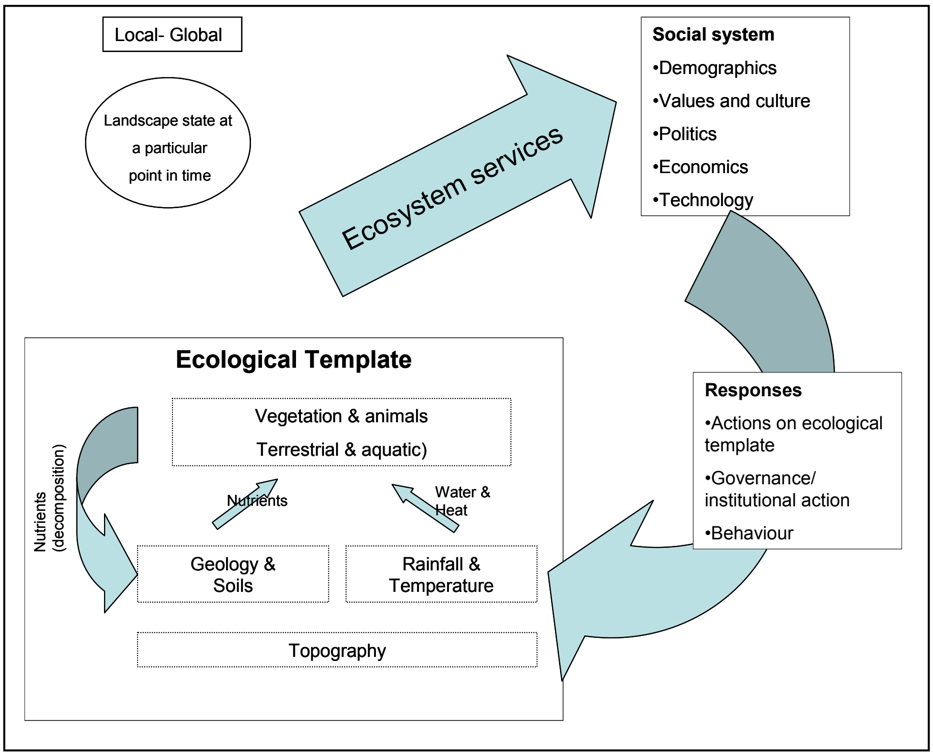

Figure 3.2 In constructing an integrated view of the socio-ecological system, the SRC can be conceptualised as consisting of ecological and social subsystems, and the interactions between them. The major form of interaction between the subsystems is through the flow of ecosystem services to the social subsystem. Attributes of the social system, mediated by governance structures in the society, influence the flow of these services, and the ecological template itself, and is expressed through various land use patterns.

3.2.1 Ecological template

The Sand River originates in the mountainous region of the Drakensberg, where elevations reach 1800 m above sea-level, and mean annual precipitation exceeds 2000 mm a^{-1}. Nearly half the mean annual runoff (MAR) is generated in this region, which constitutes about 25% of the catchment area. From the mountainous western region, the Sand River descends 1000 m within a distance of 10 km into a semi-arid, low-lying region, colloquially known as the *Lowveld.* The Sand River then descends more gradually to reach an altitude below 300 m at the confluence with the Sabie River. The precipitation gradient is follows a similar pattern, declining rapidly to below 1000 mm a^{-1} in the west, and then more gradually to about 550 mm a^{-1} over a total distance of 80 km.

The SRC covers an area of 1910 km^2, with estimates of virgin MAR between 122 Mm^3a^{-1} (Hughes et al., 1996) and 158 Mm^3a^{-1} (Chunnett and Partners, 1990). Streamflow is highly variable (Figure 3.3). It is estimated that afforestation has reduced the Mar to 96 Mm^3a^{-1} and 122 Mm^3a^{-1} respectively. Chunnett et al. (1990) estimated that groundwater contributes only about 5% of the total water resources in the catchment, although this figure has been questioned (see below). No description of the water resources is complete without mention of the water availability especially in ‘closed’ (where requirements exceed availability) catchments such as the Sand. Recent work in the SRC has contested the use of the mean annual runoff as representative of water availability, based on the view that in highly variable semi-arid systems such as the Sand the mean tends to overestimate water resource availability (see Moriarty et al., 2004, Pollard et al., 2004). These authors suggest that the median, and lower quartile in drought periods is more realistic. They also suggest that groundwater contributions may be more significant than previously thought (Table 3.1).

Table 3.1
Summary of the water resources availability within the Sand River catchment (from Moriarty et al., 2004).

Description		Resource
Surface-water availability	Median	75,200,000
	Lower quartile	48,830,000
Ground-water	DWAF est.	8,000,000
	2% recharge	30,902,127
	5% recharge	77,255,319
	10% recharge	154,510,637

Precipitation is a major driver of the ecology in the region. Inter-annual rainfall variability is high and intra-seasonal drought is common. Three quarters of the rainfall in the SRC falls during summer, from October to March. A situation in which the monthly or annual rainfall is less than 75% of the average rainfall occurs as often as every 3.5 years in the northern portion of the catchment (Shackleton et al., 1995). There is evidence of various long-term cyclical rainfall fluctuations superimposed on the normal annual variability typical of the region. A quasi 18-year rainfall oscillation of alternating wet and dry periods of approximately nine years each has been identified in the eastern summer rainfall parts of southern Africa (Tyson, 1986). Periods characterised by higher than average rainfall were 1934-42, 1952-60, and 1971-78; drier periods were experienced from 1943-51 and 1961-1970. The 1979 period onwards has fallen within a dry period, with a 38% decrease in expected annual rainfall in the Lowveld (Mason, 1994).

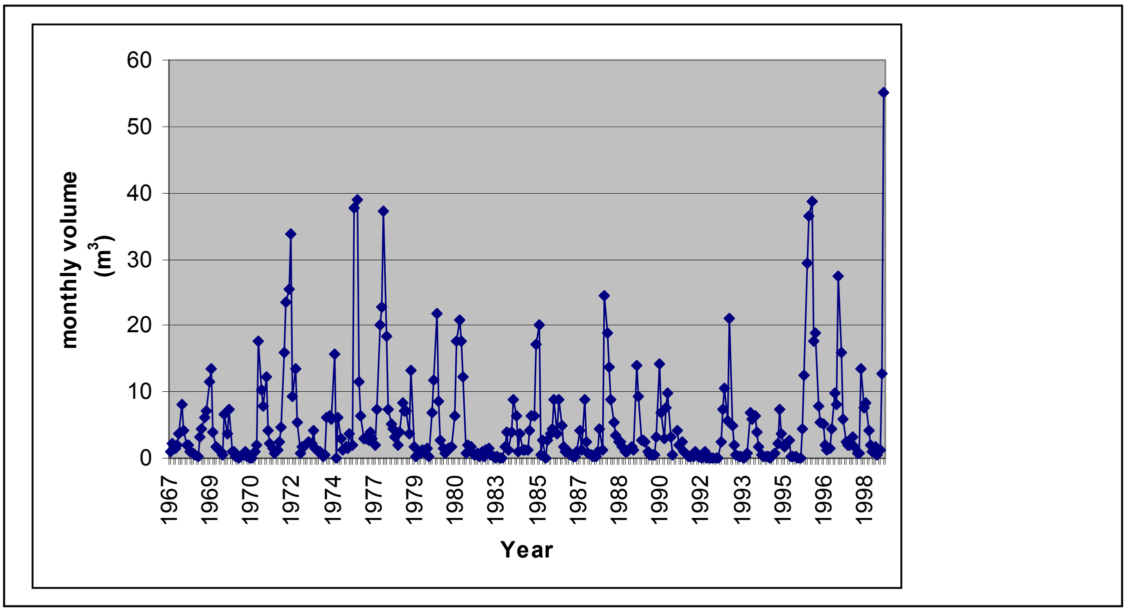

Figure 3.3. Graph depicting streamflow variability. Hydrological data (monthly volumes) depicts the period 1967 – 1998 from hydrological gauge station X3008.

The SRC experiences a warm to hot subtropical climate. Average daily maximum temperatures are approximately 30°C in January and 23°C in July; average minimum temperatures are about 18°C and 8°C respectively (Development Bank of South Africa, 1989).

Maximums in excess of 40°C have been recorded in the low-lying eastern parts. The high summer temperatures result in high evaporation rates, varying from 1850 mm in the west to 2200 mm in the east. In most of the region, this is considerably in excess of rainfall, resulting in a deficit in the water balance. Minimum-maximum water temperatures range between 20°C and 35°C in summer, and 10°C and 15°C in winter (Pollard et al., 1998). Rapid water temperature changes, rather than observed extremes, tend to be more critical for biota. For example, sudden reductions in temperature following hailstorms have resulted in fish kills.

Most of the SRC is underlain by the granitic Basement Complex, with minor intrusions of gabbro. The highly weathered granite produces friable, nutrient-poor soils, while gabbro areas are typified by nutrient-rich black turf soils. The granitic geology has produced a gently undulating topography with a characteristic catenal sequence. Clay particles and bases move downslope, resulting in shallow, sandy, nutrient-poor soils on the ridgetops, and relatively deeper, clayey, nutrient-rich soils in the bottomlands. A seepline generally forms where water meets the relatively impermeable clay layer in the bottomlands and is forced to surface.

The vegetation in the SRC reflects the altitudinal, temperature and rainfall gradients, as well as the soils in the basin. The majority of the SRC lies within the savanna biome. The upper reaches of the Sand River drain sour afro-montane grassland. Woody species composition also reflects smaller-scale catenal sequences. The ridgetops are dominated by broad-leafed Combretum species, the bottomlands by fine-leafed Acacia species, and the seeplines by Terminalia species (Low and Rebelo, 1996).

A number of natural shocks or disturbances have been recorded in the system over the past century. Notably, as mentioned above, drought is a key characteristic of the area. Indeed, an analysis of long-term rainfall trends from the Kruger National Park (KNP) indicate that one-third of all years since 1910 experienced above or below average rainfall (Zambatis, Scientific Services, KNP, pers. comm.)[11]. Disease has also had its influence on the lowveld. Interestingly, the combination of drought and rinderpest at the turn of the last century is implicated in the demise of the dreaded tsetse fly, host to nagana and sleeping sickness which opened up the lowveld for permanent settlement (see Pollard et al., 2003). Malaria was also prevalent in the area and for this reason the KNP was closed for six months of the year until the early 50's when treatment and prophylaxis improved (see Carruthers, 1995). The unprecedented floods of 2000 also had impacts within the catchment although the effects were more significant and devastating in the larger catchments such as the Olifants (Lepelle), the Crocodile and the Sabie and downstream in Mozambique.

Land-use and zoning of the catchment

By the mid-1940's three land-use zones had emerged within the SRC (see Pollard et al., 1998). These partially reflected land-cover, but were mainly driven by political factors which so shaped the profile of the catchment (Figure 3.4). These were:

1. **Zone A**: Commercial forestry in the upper mountainous, western regions of the catchment.
2. **Zone B**: Communal lands of the mid-catchment comprising the former Bantustans of Lebowa and Gazankulu.
3. **Zone C**: Conservation area of the lower, eastern region including the privately-owned Sabie-Sand Game Reserve and small portions of Manyeleti Game Reserve and the KNP.

[11] Despite this, policies by government and practices by residents reflect little adaptive responses to drought other than to evoke standard infrastructural solutions (such as dams), and both continue to respond with surprise when confronted by dry years

These zones were chosen as the basis for catchment planning (see Pollard et al., 1998) and will form the basis for the subsequent discussion and future work of the SES project. A brief overview of their history and socio-economic profile is given below.

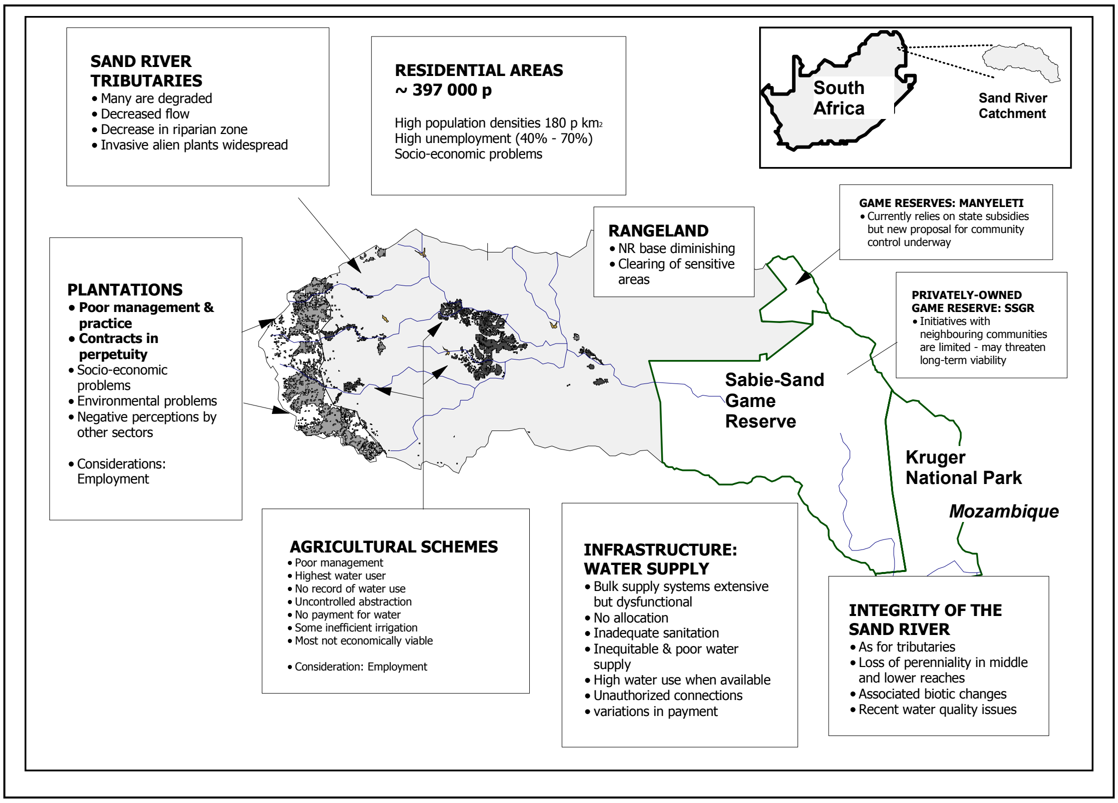

Figure 3.4 The Sand River catchment showing the three zones of commercial forestry, communal lands and conservation areas in the East. The major problems found in each zone are also summarised (from Pollard et al., 1998).

The upper portion of the catchment is state-owned and is under commercial afforestation. The middle portion – comprising the former bantustans of Gazankulu and Lebowa - is under communal tenure. The majority of the population live in the middle portion of the catchment. The lower catchment is under conservation, both state and private. The dominant landuse activities in the communal lands include small-scale cropping, state-owned commercial farming, and grazing. Uncultivated land is used for natural resource harvesting and grazing, where stocking rates are at agricultural carrying capacity (Parsons et al., 1997). The privately-owned conservation area is run as a share-block scheme (e.g. encouraging traversing rights on each others' properties). Interestingly, whilst being economically-dominant, as the downstream stakeholder they are located in the most vulnerable part of the catchment in terms of water security.

Zone A: Commercial forestry areas

The upper SRC comprises the steep mountainous slopes of the eastern escarpment, sometimes known as the Drakensburg. Historically, the natural vegetation comprised a mixture of grassland and cloud forest- an uncommon vegetation type in South Africa. However, the need to provide labour to the Lebowa Bantustan (the administrator at the time) and the desire to develop strategic reserves acted in concert to radically modify the landscape. Today the land use is strongly dominated by plantation forestry which started in the early 1900's (Figure 3.4). Of the 11 900 ha, on three farms (known as Welgevonden, Hebron and Onverwacht) about 50% is under pine. By the time the new government of a unified South Africa took over these former-Bantustan operations in 1994, the area was showing suffering the effects of poor management. It appeared that in an attempt to service the evergreen contracts of two sawmill operators, the Lebowa authorities had afforested highly sensitive areas such as wetlands, riparian fringes and excessively steep slopes. Moreover, established as a labour scheme rather than as a commercial enterprise with double the industry standards for labour, the high wage bill exacerbated the already precarious economic viability. For example, for the 1997/98 financial year, this landuse suffered an R 11.5 M loss (income R3.5m, expenditure R15m; see Appendix 6.3 in Pollard et al., 1998.). It was clear that a change in landuse was necessary if the principles of sustainability were to be addressed.

Nonetheless, under a strategic plan to reduce forestry in the area through the conversion of these state-owned forests to conservation in the form of the new Blyde Canyon National Park, all alien trees were to be removed from the slopes by 2006. A significant catalyst for this conversion was the recognition of the effects of forestry mismanagement on the water resources of the Sand River. Not only was the Mean Annual runoff reduced by an estimated 10% but also large amounts of sediments were introduced to the river through poor placement of roads and the clearing on excessively steep slopes. Moreover, the area was infested with dense stands of alien vegetation which was initially addressed through a partnership with Working for Water in the late 1990's. It is envisaged that the new Park will be zoned in such a way as to allow sustainable use by neighbouring communities and community beneficiation is high on the agenda.

Zone B: The communal areas

Today, as a consequence of forced removals, a large number of people - between 320,000 and 400,000 - reside within the SRC, with densities varying between 176 and 300 people km^{-2} in the communal lands (Pollard et al., 1998; Figure 3.4). This includes a small number of former Mozambican refugees which has declined from an estimated 24000 people at the height of civil strife in that country. A recent analysis of a micro-catchment of the SRC shows that the major increase in population took place over a nine year period between 1961 and 1970. This area showed a 1000% population increase due to forced resettlement (Pollard et al., unpubl. data). The resultant densities, not dissimilar to those in densely-populated areas such as Holland, are a major feature of the landscape. They underscore an important paradox of all former homelands which are termed **rural** but which have a socio-economic profile that has few features that typify a so-called rural area. Most notably, livelihoods are based on migrant remittances and social welfare rather than agriculture. Indeed, natural resources and land are under such pressure that they can only form a supplementary, although critical part of peoples' livelihoods (Shackleton et al., 2001). Moreover, today's youth attach little value to the land and there is an increasing shift toward a consumerist ideal.

Densities and distributions of people have vast implications for development of water services provision and natural resource management in general. Niehaus (2001) provides persistent reference to the ever-growing populations and outstripping of resources that so characterised the forced resettlement of people into Bantustans. Realisation of this amongst the authorities prompted various measures - most vividly the rounds of so-called betterment and the establishment of schemes designed to provide labour (see also Box 3.1). Indeed, the legacy of such strategies means that today's government faces the challenges of rationalising over-staffed and non-viable schemes, designed less for their named purpose (agriculture or forestry) than for the crises of an ever-burgeoning (over-concentrated) population.

Box 3.1.
A brief history of the Lowveld (see Pollard et al. 2004)

From the beginning of white settlement in the 17th century, South African society was segregated and after the Union of South Africa in 1910 a number of laws ensured that whites remained politically and economically dominant. The Native Land Act (1913) and the Natives Trust and Land Act (1936) stipulated that Africans (the majority) had legal tenure only in designated regions – a mere 13% of South Africa (De Wet 1995). So-called 'betterment schemes' that entailed the concentration of the population into villages, and placed restrictions on livestock and agricultural production (purportedly to rationalise agriculture), ensured that African traditional conservation and farming practices were abandoned in what became a struggle for survival. In 1948, the apartheid policies of the National Party government entrenched ethnic segregation through the establishment of homelands (Bantustans), through the Promotion of Bantu Self-Government Act of 1959, and a plethora of other apartheid laws. The homelands became dumping grounds for what the state regarded as 'surplus' Africans and large-scale forced removals occurred, creating overcrowded and impoverished Bantustans in which investment and development was negligible (Fischer 1988, de Wet 1995). In 1972 the central lowveld was divided into piecemeal parcels of land comprising two 'self-governing states'. Gazankulu was established for the Tsonga 'tribe' and Lebowa, adjoining Gazankulu on the western side, for the Pedi people. Traditionally, the driest eastern districts that were used only for seasonal grazing and hunting due to the inhospitable summer climates (Harries 1989, Spenceley 2001). After 1994, these bantustans were abolished and it is this area that is referred to as communal lands. The situation in the communal lands stands in stark contrast to the adjacent private conservation areas (SSW), currently owned mainly by English and Afrikaans speaking whites.

An estimated 55% of the population is women, and they head some 30% of households. The average literacy rate is estimated at 66%, however the functional literacy has been questioned in a recent report (PIRLS 2006). Only 46% of children attend secondary school. Unemployment varies between 40% and 80% although establishing accurate figures is confounded by the difficulty in distinguishing between formal and informal economic activities. An estimated 50% of men are economically active outside of the catchment. For many households, the major sources of income are wage remittances, pensions and social grants. The major employment sectors include commercial activities, tourism, forestry, agriculture, and civil service posts such as local government, teachers and nurses.

So-called 'commercial' agriculture, amounting to 438 ha of permanent tree crops, is limited to three state-administered schemes namely Champagne Citrus, Allandale and Zoeknog which is effectively defunct. In total, these schemes employ between 370 and 430 permanent staff (excluding management of about 12 people) and some 550 seasonal staff (2 to 5 months a year). All run at a loss (Table 3.2). In addition, there are four schemes under irrigated annual crops (Dingleydale, New Forest/Orinoco, Dumfries, the Allandale Small Farmers Schemes) that are operated by numerous small farmers, each cultivating a small area of between 1 to 6 ha. The total area is estimated to be 2145 ha although only some 1612 ha of this is farmed. There are an estimated 1000 farmers involved in these schemes. Dryland cropping on about 1600 ha provides about 4,712 jobs (see Appendix 6.6, Pollard et al., 1998). The direct use values of home consumption from livestock, agriculture and natural resource harvesting are high, accounting for more than 50% of total livelihood streams (Shackleton et al., 2001). A crude estimate of jobs created for the agricultural sector is 6,488 people or about 1.6% of the population. If each person supports an average of six household members, the livelihood benefits accrue to some 39,000 people or 10% of the population.

Table 3.2
Summary of area, number of employees and financial status of state-owned assets in the SRC. Figures are based on data from 1997/98 (see Pollard et al., 1998). p= permanent, s = seasonal

Parameter	Commercial forestry	Champagne	Allandale	Zoeknog
Ha	5400	282	53	104
Labour units	346 perm[12].	180 p 150 s	134 p.	120 p.
Financial status	Net loss = R 11.5 M	Net Loss = R1.95 M/a	Net Loss = 2.96 M/a	Net Loss = R2 M/a
State subsidies (excl. water)	Cover of above loss	R 2.4 M/a	State grant received but amount unknown	No state grants but capital loans from DBSA & NPDC

Women perform an important role in the social and economic life of the area. They are responsible for water and firewood collection, they usually run household gardens and perform minor income generating activities to supplement household incomes. At the same time women are marginalized.

Zone C: State and privately-owned conservation areas

There are three conservation areas within the SRC, totalling 69 486 ha: Manyeleti Game Reserve, the Sabie-Sand Game Reserve (SSGR) and the Kruger National Park (KNP). Both Manyeleti and the SSGR lie on the sensitive interface between communal lands and the KNP, which itself comprises the boundary with Mozambique.

Income from conservation is mainly derived from tourism and to a lesser extent from by-products such the culling of animals and the sale of curios and secondary products such as income generated by tourism in the catchment is also dispersed among other land-uses. These include income derived by the accommodation industry outside the conservation areas, informal traders in agricultural products and secondary products, and small service and trade businesses.

In 1998 it was estimated that on average, the privately owned Sabie-Sand Game Reserve (SSGR) generates more than R6 million in gross income per annum per individual concern. It was suggested however that a major part of this income has little benefit or effect on the remainder of the catchment due to the closed nature of the reserve's operating system. Tourists are mostly flown straight in and out of the reserves and do not have any direct contact with the remainder of the catchment.

As stated, the Sabi-Sand is the downstream user of the Sand River and hence is vulnerable to upstream land and water use. This is most acutely felt in flow reductions particularly during the dry winter months and changes in the sediment regime. Both of these factors have caused a loss of riverine habitat for invertebrates, fish and large fauna such as hippo (see for example Pollard et al., 1996; Weeks et al., 1996).

3.2.2 Socio-political history and current socio-economic profile

The diverse ecological template of the SRC is paralleled by equally diverse cultural and socio-economic heterogeneity, and underlines the fact that human ecology is shaped, in part, by the environment. A striking feature of the catchment is the dense concentration of people in so-called 'rural' areas juxtaposed with sparsely-settled, often affluent areas. This contrast is reflected in the socio-economic differentials that exist and huge disparities in access to services, most notably water. How did this situation arise? Indeed, any consideration of contemporary water issues within the catchment and, in reality in many areas of rural South

[12] Adjusted for SRC

Africa, must be set within the wider historical context. It is well recognised that the country's apartheid policies have shaped the landscape and practices of the catchment that we see today. Whilst this report cannot present a detailed history of racial division in South Africa, human settlement patterns were strongly controlled by dominant political ideologies and a brief mention of some key events is warranted (Box 3.1).

Colonisation in the Lowveld was relatively recent and it was in the mid-1800s that the socio-economic landscape was transformed in favour of whites. Interestingly, much of the Lowveld was regarded as worthless and inhospitable for permanent settlement at this time due to erratic rainfall and high temperatures, poor soils, and endemic and sometimes fatal livestock and human diseases (Carruthers, 1995). However, with the reduction in malaria and demise of the tsetse fly (due to rinderpest in 1896 and drought between 1897 and 1913) this perception changed and the Lowveld opened up for denser settlement (Pollard et al., 2003). It was also at this time that nascent conservation areas were established in the drier eastern regions, and the Kruger National Park was proclaimed in 1926. In the communal lands, agriculture was the mainstay until the mid-1930s, but political and economic polices acted in concert to produce a rural economy that, by the 1940s, was dependent on migrant remittances and state pensions for cash injections (Bundy, 1998, May 2000, see Pollard et al., 2003).

3.2.2.1 Legislation, water and natural resource governance

In the communal lands, many of the practices associated with accessing a variety of ecosystems are grounded in generations of traditional/local-level use. Nonetheless, these have been controlled and modified by the major political ideologies of apartheid in order to achieve political hegemony. In some cases, customary protocols and 'rules' of access were established and implemented by traditional leadership and governance structures that were nominated by the state (Shackleton et al., 1995). Contestations to these systems and to individuals in leadership roles, viewed as puppets of the state, particularly in the 80's, together with high densities of people placing increasing pressure on ecosystems have meant that effective governance systems over most natural resources is eroding (Pollard et al., 2003; Pollard & Cousins 2007). This is not entirely the case for **water supply** which now falls within the remit of local government, and the governance of the water resources now falls under the newly-established Inkomati Catchment Management Agency. In theory, local-level participation will be secured through catchment forums but these are still in the process of being established. However, the governance of other natural resources such as woodlands and wetlands is weak (Pollard et al., 2008a).

The democratic reforms instituted after the elections in 1994 brought considerable legal reform to South Africa. Apart from the Constitution (1996) that makes clear the rights of access to "adequate food and water", a collection of new laws have been developed to support sustainable resource use. However this situation is very recent and consequently little of this legislation has had time to evolve into actual practice (see Chapter 4). The delay in implementing the legislation is aggravated by the vast differences between old and new approaches.

While 'command and control' approaches to resource management where largely part of the previous system they continue to be carried over into what is currently regarded as an 'enabling' legal environment. The effects of these new legal frameworks have yet to be felt. This is further elaborated in Chapter 4, in the post-apartheid systems dynamics diagrams.

In terms of water, South Africa has received global attention regarding the policy reforms that accompanied the democratic transitions in South Africa in 1994. Indeed, these have had direct bearing governance and leadership roles within the SRC. A number of key policy instruments were directed to the management of water resources (the National Water Act 1998, NWA) and to water services deliver (Water Services Act, 1997, WSA). Through the NWA, a number of key changes were introduced. Firstly, riparian and private rights were abolished and water became a national asset under the custodianship of the Minister. Secondly, catchments were constituted as the units for water resource management and 19 water management areas were designated. Thirdly, statutory protection of the right to water was afforded to the environment and to people through the concept of the '**Reserve'**. Fourthly, the active participation of stakeholders was required. These changes required re-thinking practices towards the integration of land and water, with the support of all stakeholders. A complex array of legal instruments has been derived along with strategic plans and planning instruments (The Constitution "A rights approach", The National Water Policy, The National Water Act (1998) for resource management, The Water Services Act (1997) for water supply, The National Water Resource Strategy (2001)). Each place a governance onus on various spheres of government and on civil society.

3.2.3 Summary of current land and water use

The present-day land uses are summarised in Table 3.3. This indicates that land under communal tenure, where the majority of the residents live, accounts for 56% of the catchment. Table 3.4 indicates that the SRC is stressed in terms of water security. Without considering groundwater, which is under-exploited and the inter-basin transfer, there is very little surplus water available for 'new allocations.

Table 3.3.
Land-use/land-cover categories for the SRC, based on a re-classification of raw data from the 1996 TM image of the sub-catchment. The approximate totals for each zone are: Zone A = 12 000 ha; Zone B = 107 000 ha; Zone C = 70 000 ha.

LAND-USE		TOTAL(ha)	Sub-totals per land use (ha)
Water bodies		926	
Forestry[13]	• Planted • Unplanted • Indigenous vegetation	5 339 656 5 931	11 926
Residential	• Sparse with garden plots • Dense	15 391 2 750	18 141
Dryland agriculture	• Annual • Permanent	7 600 142	7742
Irrigated agriculture	• Permanent • Annual	438 2 145	2538
Rangelands[14]		80 193	80 193
Conservation bushland		69 486	69 486
TOTAL		**191 002**	

[13] Only a portion of the total forestry area, restricted to the western portion of the SRC, is planted. The additional land incorporated under this category reflects the temporarily unplanted land as well as the indigenous vegetated areas.
[14] "Rangelands" is a generic category in that it refers to vegetated land under communal tenure. It falls principally within the middle portion of the SRC. The main activities in this land-type are livestock grazing and the harvesting of natural resources. Rangelands are comprised of a combination of the woodland and bushland.

Table 3.4
Summary of the water resources availability and demands within the Sand River catchment (from Moriarty et al., 2004). The surface water availability does not include the inter-basin transfer from the Marite River. ER = Ecological Reserve; BHNR = Basic Human Needs Reserve.

Description		**Resource**	**Demand/ Entitlement**
Surface-water availability	Median	75,200,000	
	Lower quartile	48,830,000	
Ground-water	DWAF est.	8,000,000	
	2%recharge	30,902,127	
	5%recharge	77,255,319	
	10%recharge	154,510,637	
ER	IFR 50% probability of exceedance		38,620,800
	25 l $p.c.d^{-1}$		2,466,907
Domestic	100 l $p.c.d^{-1}$		9,867,629
Agriculture	(DWAF est.)		12,170,000
Forestry	(AWARD est.)		6,755,706
Total			**62,489,335**

3.2.4 The formal education system

An overview of the education and the nature of learning within a system might provide an insight into the ability of such system to be flexible, adaptive to change and resilient. The 'success or failure' of an education system is not what is of primary importance in this assessment but rather the 'type' of education that is taking place. In this section we will give a brief description of the type of education that has emerged over time in order to discuss the possible impact that this might have on the resilience of the system.

In Figure 3.5 we provide a timeline of the evolution of the education system that applied to Bushbuckridge (and South Africa in general; see also Figure 4.1).

1600s

1658 First schools for slaves

- Colonial period

Formal schooling initiated

- Roots in mission and colonial formal education

1950s

President Verwoerd introduced ‘ Bantu Education’

- Education removed from missionary control and brought under control of the State (committed to White supremacy)
- Apartheid era legislation of the ‘50s
- Legislation affecting Black population: Bantu Education Act (1953), The Extension of University Act (1959), Education legislation linked to broader goals of political economic and social domination of black people

1960s

Expansion of primary, secondary and tertiary education for Blacks. Further disaggregation of education system for Coloured, Indians and Black sectors

Coloured Persons Education Act 1963

Indian Education Act 1965

National Education Act 1967

1970s

- Education policies aimed at developing education system within context of Bantustan policy
- Education fragmented into 19 different education ‘departments’ along race and ethnic lines
- Unequal spending on education for children administered under White, Indian, Coloured and Black education departments
- Poor quality education for ‘non-whites’ emerged under this regime
- Growth of resistance to political and economic oppression in education system

1980s

- Massive resistance to education over goals, control and quality of education
- Attempts to reform education system failed
- 1986 Minister of Education (FW de Klerk) announces 10 year plan to upgrade black education
- 1989 Minister admits plan has failed: slow national economy cannot release funds for transformation and to keep pace with growing numbers of scholars
- Resources decrease yet number of enrolments increase
- Age restrictions imposed on entry into secondary schools for Blacks
- Growth of private provision of education and Black children who could afford were enrolled where Whites schools would not admit black children
- Majority of Black children failed - could not be reabsorbed by system. High fees prevent them from attending private schools

Per capita subsidies for formal education (1986)

- Whites: R2365
- Blacks (DET): R572
- KZN (Homeland): R262

1994

- New Constitution: education as a basic social right
- New education policies, repealing apartheid legislation and new information systems, structures and personnel
- 1994: 50% of poor have no formal education, 7% have completed a secondary and higher education
- 1995 White Paper on Education and Training

1996

- The South African Schools Act (1996)
- South African Qualifications Act (1996)
- Ownership of farm schools to State
- New National Qualifications Framework launched. Aimed at skilling society
- Outcomes based education for schools aimed at providing appropriate education for all South Africans
- National norm of 1:40 teacher to pupil ratio applied to primary schools
- 1997: 1:44 pupils to teacher ration in Limpopo Province

Figure 3.5 Education time line for the SRC (South Africa in genera) provides an overview of the major issues over the decades (Kallaway, 1984)

When taking formal education in South Africa as a whole we obtain a picture of a system that has been co-opted for the purposes of supporting racial discrimination and promoting white supremacy for its major part. It is only after 1994 that we see the transformation of the system towards equity and social justice. This legacy has left Bushbuckridge (and South Africa as a whole) with a largely under-skilled population with low levels of literacy. This in itself has implications for individuals and communities to be self-motivated, organised and in a position to respond to a rapidly evolving context. All these factors taken together lead us to suggest that such a system is weak at learning and therefore slow at responding and embracing change. Even if we look at the best aspects of formal education during the colonial and apartheid era we would have to arrive at the conclusion that the education system, which was largely based on 'objective, content knowledge', poorly prepares civil society for the kind of learning that characterises ecological or systems thinking (Capra, 2007). Capra maintains that education for sustainability, and hence resilience, "is less about transmitting the content of ecology to citizens, and more about utilizing the principles underlying ecological processes in helping communities and their members respond to the challenges of sustainability in ways appropriate to their situations". This kind of learning is not in evidence in the formal sector in Bushbuckridge.

Systems theory suggests that living, open systems generally remain in a stable state, but on occasion they will encounter a point of instability where there is either breakdown or the spontaneous emergence of new forms of order. 'Emergence' has been recognised as the dynamic origin of development, learning and evolution (Capra, 2007). How does an education embrace 'emergence'? Capra maintains that it is facilitated by creating a culture of learning by encouraging continual questions, and rewarding innovation. Facilitating emergence means supporting a network of communications with feedback loops where learning is valued as much as 'success'. In reflecting on this we conclude that the formal education system has contributed and continues to contribute very little to the kind of learning that is required for generating resilient sustainable systems.

3.2.5 Assessments of Social Capital for the SRC

As stated in Chapter 2 a discussion of socio-ecological systems would be incomplete without adequate attention to social aspects. In this section we focus on social capital as a proxy for assessing the status of the non-material aspects of a system. We have based the assessment, 2001 and captured it against the framework (Table 3.5) devised by Stone (2001).

Table 3.5
Social capital in the SRC using networks, norms of trust and norms of reciprocity (Stone, 2001) as a suggestive approximation (data for the SRC extracted from Shackleton et al. (1995 unless otherwise indicated)

Social capital: Types and aspects (according to Stone, 2001)	Issues from the SRC that form part of social capital	Example or supporting narrative from research literature
1. Networks		
Family within household: • Presence of parents • Child support and care • Child well-being • Parent-child relations • Parent-parent relations • Culture and rituals	• Absence of parents • Single parent households • No parent households • Care by grandparents • Marital strife • Domestic stability and harmony • Values and norms in families	1. Absent men can usually not provide adequate financial support for these roles to be fulfilled 2. The separation of men and women has negative implications for the stability of the family unit and for marriage (Pollard et al., 1998; Niehaus, 2001)
Beyond family: • Kinships • Networks of extended family • Kinships • Intergenerational social support	• Pensions to support families from the State • Remittances from working kin • Time and cash investments	1. Tshunelani village: support for burial societies is high through financial and time investments

Friends and neighbours • Neighbourhood networks • Social disengagement • Activities in public spaces • Distance to friends? • How many? • Characteristics of network activity	• Interaction in neighbourhood • Social activities • Support networks in villages • Sharing amongst friends and community • Communication between friends and support groups	1. Pubs and shebeens are common meeting place for males, youth and those that work. Sports such as soccer bring young males together. Church activities, domestic chores (water collection), sewing and handiwork connect women 2. Day care is provided by neighbours for children who lack parental supervision during the day. 3. There are patterns of sharing between households (Tshunelani). Co-operation is evident in the degree to which neighbours share food and other resources. Links become visible at times of extreme crisis (death and drought)
Non-group civic relations • Civic participation (political and non-political) • Volunteer work, support and help	• Petitions around infrastructure malfunction (especially water) • Strikes • Demonstrations • Protests • Council meetings	1. Strikes in Gazankulu to remove Chief Minister during apartheid era 2. Border disputes in 2001 resulted in mass demonstrations 3. Traditional leadership has come under criticism. Chiefs may be unpopular and seen as powerless to effect change. Their power was historically enshrined in their ability to allocate land but this is severely limited by the state.
Associations/group based relations • Membership • Involvement in formally constituted groups	• Burial societies • Religious groups • Cultural associations	1. Mashongolo traditional dancing bring Tsonga speakers together 2. Stokvels are a way of investing money locally 3. Soccer clubs amongst young males 4. Large church membership. Church networks in villages to members and neighbours
Work-based associations • Work environment • Professional and association/unions • Employment networks	• Unions • Cooperatives	1. Although workers in neighbouring farms and town often belong to unions (no studies on effectiveness of this membership exist)
Institutions • Links of individuals and families to government, police, social welfare etc	• Police relations • Welfare issues and links • Community Development Fora participation • Water Committees • School Governing Boards are active form of adult networks • Few have access to networks outside of local area - exchanges between members	1. Water committees established to solve local water relate problems 2. Community members often frustrated with outcomes of participation in community forums (AWARD, 2004) 3. Services and provisioning by local government and police documented in Niehaus (2001) 4. Police relations vary – often poor levels of trust (Niehaus, 2001)
2. Norms of Trust		
Trust of familiars • In established relationships and social networks	• Strong sibling networks (Niehaus in du Toit, 2006)	1. Siblings and elders trusted to care for the young. Niehaus maintains system has flipped from parental to sibling networks due to economic and health matters
Generalised or social trust • Extends to strangers on the basis of expectations and shared norms	• Farmers in Criagieburn report mistrust amongst each other and community • (AWARD, 2006) • Crime and theft	1. Weak, accusations of witchcraft when things go wrong, fear of theft of goods (crops, household goods; Niehaus, 2001, AWARD, 2006)
Civic or institutional trust • Basic trust in formal institutions of	• Narrative of allocation and political issues • Elections and need for services delivery	2. Money loans and actual exchanges in community 3. Suspicion of local government in business ventures (see BBR

government • Fairness of rules, official procedures, dispute resolution and resources allocation	• Confidence in councillors and local government	brickworks, tourist ventures in upper catchment as example) (AWARD, 2007) 4. Concerns around access to water (AWARD, 2006)
3. Norms of reciprocity		
Family-based reciprocity • Flexible • Long term • Obligations • Robustness	• Culture of reciprocity within family unit	1. Reports of families feeding extended to members without income 2. Sibling support - "it is our custom to give food to one another. We never want to see our relatives die of starvation" (Shackleton et al., 1995)
Non-familial reciprocity • Less regular • Shorter term • Less robust • Less flexible	• Borrowing and sharing is reported to be a daily occurrence amongst poorer households. • Reciprocity at other levels unclear/unreported • Disrespect for traditions of care suggested	1. Materialism around commodities and cash economy might negatively affect support and care in community 2. Labour is offered and exchanged as required in Tshunelani - "… such relationships and reciprocal sharing become a meter of survival" (Shackleton et al., 1995)

In Table 3.5 we draw together suggestive evidence of the state of social capital in the SRC. Whilst no study was specifically conducted to obtain empirical measurements of social capital we believe that previous studies give an indication of the nature of three aspects of social capital namely, networks, norms of trust and norms of reciprocity (after Stone, 2001). We will consider each of these briefly.

1. Networks

Networks seem to be the strongest at the family, sibling and kinship level with network functioning weakening outside of this realm. Networks seem to be a valuable source of interaction in times of crisis (death and drought). Networks at the community level do not appear to function beyond these times suggesting generally low social capital at the community and catchment level. Networks and connectedness surrounding political events and unrest appear to support levels of self-organisation that reduce vulnerability and increase resilience.

2. Norms of trust

Norms of trust appear to be highest within the family and decreasing within other spheres of society. Previous research (Niehaus, 2001) suggests that witchcraft and accusations of malevolence frequently prevail leading to a climate of mistrust and suspicion at the community level. The additional aspect of petty crime - within the villages and wetland fields (AWARD, 2007) - promotes mistrust. Reports of communities no longer trusting leaders (traditional and democratically elected) suggests lowering levels of trust at this level (AWARD, 2007).

3. Norms of reciprocity

Reciprocity at the level of the family is reported especially in terms of crisis. Reciprocity beyond the family is unreported but anecdotal evidence suggest that growing consumerism and materialism conflicts with the culture of care and support where the youth tend to look after themselves and immediate family members in preference to supporting non-family members.

Although it is difficult to get an exact picture of the status of social capital for the system based on the research literature consulted, it suggests that there is moderate to high social capital within the poorer communities. If we take social capital as a proxy for resilience we suggest that there is moderate to high resilience within the poorer levels of society and that resilience decreases with affluence and at community and institutional levels. Also, social capital appears to be higher within the family unit, decreasing away from the family. Niehaus (pers.comm. 2006) maintains that there has been a system flip with sibling networks playing a more important role that parental support in the SRC. This issue is discussed in Chapter 6.

3.3 Ecosystem services in the SRC

Human society interacts with the ecological template by making use of various ecosystem services. The use of ecosystem services may be mediated by governance structures, and results in a pattern of land use. Land use in the SRC is closely related to water demand. The major land uses in the SRC were shown in Figure 3.4. A preliminary analysis of the ecosystems services delivered in the SRC is summarised in Table 3.6.

Table 3.6
Summary of the three zones that comprise the SRC highlighting ecosystem services, drivers of the land-use in question, the livelihood impacts and management (see also Pollard et al., 2007b)

Zone A Forestry	Zone B Rangelands	Zone C Conservation
Ecosystem services		
▪ Construction timber: total area, value (R), total offtake ▪ Carbon sequestration ▪ Water regulation – flow regime affected by clearing practices ▪ Water production – 50% of MAR ▪ Biodiversity – high 'natural' biodiversity ▪ Recreation – hiking trails	▪ Green water – provides water for grass and tree production ▪ Fuelwood ▪ Construction timber ▪ Grazing ▪ Medicinal plants ▪ Fibre ▪ Small amount of foods e.g. honey, marulas, marogo ▪ Genetic resources – relatively high biodiversity	▪ Recreational services e.g. ecotourism ▪ Other cultural services e.g. spiritual, existence value of wildlife, aesthetic ▪ Cultural identity of South Africa – Big 5 ▪ Educational ▪ Biodiversity, genetic resources ▪ Grazing for wildlife ▪ Minor fuelwood harvesting – for local use by lodges, Kruger swapped to gas & sells only alien wood; Kruger used to harvest from Mozambique – reflection of changed values
Disservices		
▪ Reduction of surface runoff ▪ Erosion through roads ▪ Soil acidification	▪ Degradation: maybe loss of carbon, excessive fuelwood harvesting, overgrazing	▪ Diseases? To livestock ▪ Dangerous animals e.g. elephant, leopard – threat to livestock & human life
Drivers		
▪ Subsidised & Driven by labour incentives (perverse) ▪ Not economically sustainable ▪ Environmental concerns	▪ Rainfall ▪ Tenure and rights of access and use	▪ At first only preservationist – closed to public, aimed to restock animals ▪ Sabi-Sand established for Elite spots hunting ▪ Manyeleti proclaimed for black people ▪ Shift in mindset – commercialisation of conservation. Sabi-Sand only turned commercial in 1980s. ▪ What is the current dependence of Sabi-Sand & Kruger on international tourists? What vulnerabilities does this introduce?
Livelihoods		
▪ Water ▪ Fuelwood from indigenous forest between plantation patches ▪ Medicinal plants ▪ Employment	▪ Water ▪ Value of livestock ▪ Non-timber products	▪ Employment ▪ Revenue to catchment – and distribution (mostly revenue is being exported)
Management of area		
▪ Indigenous veg managed by different dept to forestry areas ▪ Within indigenous veg – alien plant problem – impacts	▪ Alien invasives – not much of a problem due to working for water ▪ "joint management" between traditional & legislative systems – but unclear responsibilities e.g. control of livestock numbers and harvesting	▪ Red Line – restricts movement of cattle ▪ Exclusivity of conservation – alienation of local community

Chapter 4

A systems view of the Sand River Catchment

4.1 Introduction and overall approach

The initial step in the 'resilience approach' is the selection of the system boundary (Allison and Hobbs, 2004). In the case of this project the focus was on water security and the links with livelihoods provided through ecosystem services, and water in particular. The rationale for this focus is that preceding work by the Save the Sand Programme identified water as the key constraint within the catchment (Pollard et al., 1998b). In keeping with the new policies in South Africa, the natural corollary is the selection of the catchment as the system boundary (i.e. the Sand River Catchment – SRC), whilst recognising that several wider systems feed out of or into this (e.g. labour and remittance transfers). Thematically, water security and livelihood vulnerability were examined at two scales:

a) at the catchment scale in order to elaborate major attributes and drivers of the system in relation to catchment water security and water resources governance; and
b) from a local-scale perspective, riverine and wetland function (including the upland processes feeding into these) as related to ecosystem services and hence the livelihoods of people were also examined. This scale was considered to be important in exploring issues of legal pluralism that are evident at a local scale as well as the impacts of multiple statutory policies related to natural resources governance and management.

Regarding timespans, we defined a hundred years until the present as the operative timespan from which we examined data, and a generation ahead (25 years) as the desired timespan of our intended scenarios. Initially, five eras were recognised by the team, but the focus was on the two most recent eras. The key dates demarcating eras's were:

a. Pre-1860: Transmigrants – seasonal grazing land
b. 1860: Influx of settlers and refugees
c. 1912: Rinderpest – allowed permanent settlement; inception and growth of disenfranchisement for black people and the entry of entrenched racism and apartheid planning; Land Acts start racial segregation
d. 1948: Racial segregation is formalised and institutionalised; autocratic and separatist policies further entrenched under Nationalist Party government
e. 1994: Democratic transition (release of Mandela, new policies).

In constructing a socio-ecological systems view, the catchment may be conceptualised as consisting of interlinked ecological and social sub-systems. The focus of this study was on understanding the dynamics of each of these sub-systems, and particularly the interactions between them, in order to construct an integrated view of the whole. Understanding the underlying ecology provides insight into the opportunities and constraints to the use of natural resources in the SRC. Understanding the attributes of the social sub-system, which includes values, demographics, technology and well-being, provides insight into the demand for resources, as well as the way in which resources are used and managed. The direct interaction between people and the environment is expressed through the reliance on ecosystem services, and the use of ecosystem goods, by means of various land-use practices. This interaction is influenced by various attributes of the social system, and mediated by the governance structures in the society.

System dynamics diagrams are explicit cause-and-effect interactions which seek to portray the most influential basic drivers and their consequences. Formulation of these diagrams is done with a view to simplicity, but without trivialization (see Holling (2001) on requisite simplicity). Minor or entrained variables or consequences can be depicted on "unpacked" versions of parts of the diagram, which are often very useful for persons who want to understand how an issue of concern to them fits into the overall picture. Most importantly, sequences of arrows in such a diagram can form a circle (or feedback). When they do, it is crucial to determine whether the net result is a "counterbalancing loop" (so-called 'negative feedback, where an effect is ameliorated) or a "reinforcing loop" (so-called "positive feedback" where the effect of interest is exacerbated). Understanding reinforcing loops is the main way of determining the direction of trajectories, and invariably lead to thresholds being crossed and the system passing into another state, a key insight required in this approach.

Most data used were drawn from existing datasets and analyses, and these sources are recorded elsewhere (Pollard et al., 2005a). A limited number of fresh data analyses were undertaken to check particular issues: for instance whether sedimentation had increased in the middle catchment over the last two decades; the influence of the growing ecotourism industry in the eastern part of the Catchment.

The history of events in the respective zones (A, B and C; see Figure 3.3) was depicted as timelines, in which an attempt was made to identify major drivers and outcomes. These formed the basis for development of the system dynamics diagrams.

For each zone we examined trends over time and space, main users groups, governance and leadership and the prevailing mental models. To this was added an examination of key fast and slow variables in the system. This was followed by a description and analysis of the feedback loops that characterised each time period for each zone and for both the catchment and the wetland. With high densities of people and associated socio-economic and environmental issues, we focused on Zone B in this report without discounting the linkages with the other zones (see Chapter 3 and Figure 3.3). An important aspect was to consider if these attributes are changing and if thresholds are being crossed. This was undertaken based on specialist inputs at a two-day workshop. Also undertaken at the specialist workshop was an analysis of the phase of the adaptive cycle (see Rogers et al., 2008) and scenario generation (see Biggs et al., 2008).

4.2 Timelines and key drivers

As stated, the history of events in the respective zones (A, B and C) of the Sand River Catchment was depicted as thoughtfully as possible in timelines, in which an attempt was made to identify major drivers and outcomes. These, together with other information such as the system dynamics diagrams, were intended to inform the rest of the steps below, as building blocks. The timeline in Zone B is shown in Figure 4.1 as illustrative of the outcome of the methodology (see also Figure 3.5 for an education time line). Using the timelines and the information in the systems dynamics diagrams, it was concluded that the strongest drivers, taken over the last hundred years as a whole, were politico-legal, and drew a primary adaptive loop based on this (Table 4. 1). Though not nested within this cycle, we concluded that the second strongest driver of our system, in quasi-twenty-year cycles, was droughts.

TIMELINE OF MAJOR EVENTS IN ZONE B: 1900 -

1864 to mid 1950 migration of Northern Sotho and Tsonga speaking refugees into lowveld

1880 – Kruger's govt. surveys and sells large tracts of land to speculators and mining

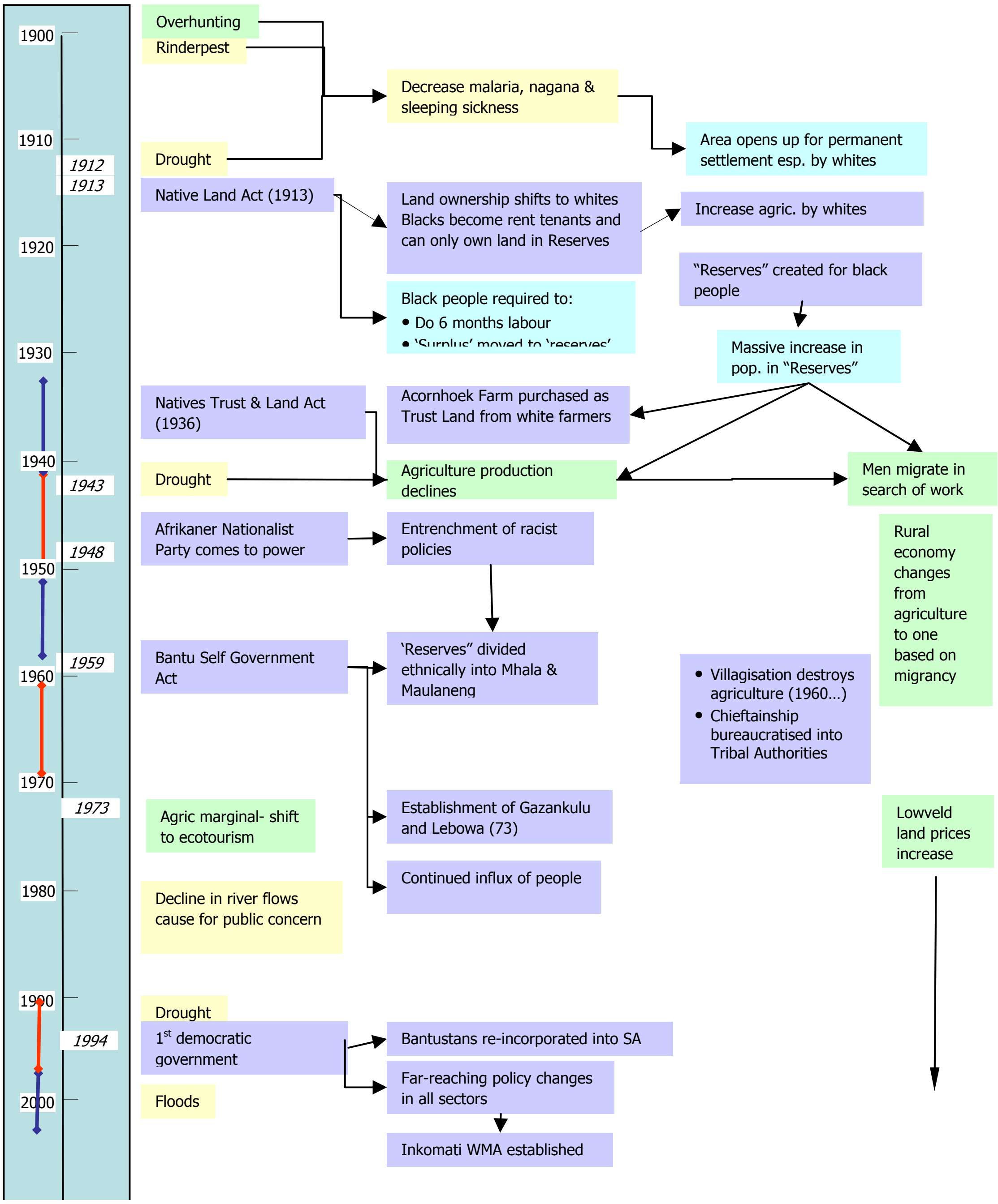

Figure 4.1. Timeline for Zone B, Bushbuckridge showing key events and outcomes. Primary drivers are shown on the left. Similar timelines were also drawn for Zones A and C. WMA = Water Management Area.

Table 4.1
Interpretation of political drivers over the last 100 years as these match the adaptive cycle phases. This table should be read in conjunction with Figure 2.2.

Time periods	Loop	Comment
Circa 1890 - 1913	Ω?	***omega phase of release*** ("things fall apart") with the prevailing livelihoods collapsing with the advent of the immigration of hunters and entrepreneurs.
1914 – 1935	"	**Alpha phase** of new ideas being tested, namely labour recruitment plans, Native land Act, Black Reserves. Conditions favourable for permanent white settlement. The 1913 Land Act symbolised the formal initiation of the separate development philosophy which came to be the dominant one (of one competing idea over another).
1936 – 1947	R	***r phase*** which is the beginning of the 'conservation' phase, ideas being consolidated.
1948 – c 1988	K	***K phase consolidation*** of power of the whites under the apartheid regime.
1988 –present	Ω	***omega phase – 'crisis' and re-organisation***

4.3 Account of two time periods based on a systems view

A substantial amount of time was devoted to developing and narrating system dynamics diagrams. Our initial strategy was to derive a systems view of (i) each 'sub-system' (ecological, economic and social), (ii) for each time era and, (iii) for each of zones A, B and C. Since many of these proved to be overlapping, they were later consolidated into fewer key diagrams, depicting as complete a set of inter-relationships as possible in the overall socio-ecological system. We illustrate the two key examples of this in Figures 4.1 and 4.2 for Zone B during the apartheid years and from the early 1990's to present (time of transformation), respectively. These are discussed at two scales: the catchment scale and at the scale of the wetlands within the catchment in order to illustrate new learnings that such an approach derived at two scales for two different purposes (in this case projects).

Note that systems diagrams are designed to represent a hypothetical increase in the variable in question so that the direction of influence is clear. For instance in examining a relationship between control, abstraction and water security, one would read as "the impact of an *increase* in the control would result in a *decrease* in abstraction (represented by a minus)"; but "an *increase* in abstraction would lead to an *increase* in water security". This represents how it "should" be However, in many cases the *de facto* situation is different (e.g. control isn't happening) and we have chosen to represent this reality.

4.3.1 Catchment-scale

The apartheid era

Although a detailed description of the political history of South Africa is beyond the scope of this paper, it is important to understand how the 20th century history has shaped the governance arrangements of natural resources in communal areas and what we see – or appear to see – today. Democratisation in 1994 set the stage for change and yet, with the legacy of apartheid planning still pervasive, South Africa continues to be a deeply divided country (see May, 2000; May and Rogerson, 2000). Bushbuckridge, part of which falls into the SRC, is regarded as the poorest area in the northern province (Gyekye and Akinboade, 2001). It is widely appreciated that with the institutionalisation of racial segregation after 1948, many of the imposed divides that separated people on the basis of race were then officially entrenched through statutory means. As pointed out in Chapter 3 the management of natural resources was effected through chiefs, with state support, who instituted fines against transgressors (Figure 4.2, referred to as 'regulation').

Prior to 1994, water resources were managed nationally, with very little stakeholder involvement (except from that of powerful sectors such as commercial agriculture). With little evidence of holistic thinking, water demand was dealt with on a sectoral basis with little consideration of downstream consequences or those for other users, or for long-term issues of sustainability. In many cases water use was highly inefficient and although water quantity and quality problems were being experienced, the 'hydraulic mission' was all pervasive, with infrastructural development and dams being seen as viable solutions. With policies that regarded all water that reached the sea as 'wasted', issues of sustainability and environmental flows were not high on the agenda. Equally the lack of equity mirrored overall apartheid policies. As people were forced into Bantustans the need for water supply was dealt with on a fairly ad hoc basis. Still today, despite the extensive 'spaghetti-like' bulk supply infrastructure in the SRC, the legacy of un-coordinated planning means that access to basic water supply is highly problematic (Pollard et al., 1998a, 2004; Moriarty et al., 2004)

The creation of Bantustans on land with low agricultural potential combined with the high densities of people, rendered an agricultural-based livelihood virtually impossible (Figure 4.2). Consequently in the SRC - as in other Bantustans - the need for jobs was recognised by certain officials as part of the creation of a viable 'self governing' and even autonomous self-governing territory. As part of the push, agricultural schemes and forestry were developed – not so much as viable enterprises but rather for job provision (Pollard et al., 1998). The migration of men to the cities in search of work together with the states' strategy to create labour pools for the mines, resulted in female-headed households with men absent for large parts of the year (May, 2000; Niehaus, 2001; Collinson et al., in press-b; see also Fischer 1988, 1996, De Wet 1995, Thornton 1997, Perez de Mendiguren and Mabelane 2001). Leadership was also manipulated so that legitimate village headmen (indunas) and chiefs were replaced by individuals seen to be sympathetic to the state. Populist uprising contested these individuals who were regarded as lackeys of the apartheid system. Although schools were established, the quality of education was poor with expenditure on each black child being 10% of that spent on a white child (see Chapter 3).

As is well-recognised today, in Bantustans such as those represented in Zone B of the SRC, livelihood security for black people was severely jeopardised, whilst that of white people flourished. Overall water security declined. In the 1980's concerns were raised about declining flows and associated water quality problems, and the first proposal for environmental flows was made from the national Department of Water Affairs- albeit simplistic.

A number of feedback loops were evident in Zone B and we suggest these were similarly experienced in many other Bantustans (Figure 4.2). Firstly, agricultural (including forestry) water abstraction[15] coupled with clearing of land (both for agriculture and people), led to a wide-scale decrease in riverine integrity. As flows declined sedimentation increased – with effects being evident at both a catchment and local scale (van Niekerk and Heritage, 1993). This in turn jeopardized ecosystem services, water security and hence livelihood security. The influx of people together with increasingly vulnerable livelihoods saw people moving onto increasingly marginal areas (e.g. steep slopes, wetlands, riparian zones) and sedimentation increased. Over the scale of two to three decades, environmental degradation rendered farming even less viable and livelihoods more vulnerable.

A second feedback loop existed between livelihood security and social capital. As explained, the combined effect of livelihood vulnerability, together with the demand for cheap labour for the expanding mining sector, led to the temporary migration of males who were often absent for most of the year, although this has now stabilized (Collinson et al., in press-a). Female-headed households became the norm and, as the migrant labourers established second families in their places of work, impacts were felt on family stability - or social capital – in the rural bantustans such as Bushbuckridge. Again livelihoods became more vulnerable and as they did so men, and some women, left home in search of work.

The post-apartheid era

A number of key changes occurred with the transition to democracy in 1994 (Figure 4.3). A major overhaul of policies had implications for the way all natural resources - including water - were to be managed. Both land and water reform were regarded as highly sensitive issues that needed addressing. Water reform proceeded with vigour and dynamic debate under the leadership of Minister Asmal, and new National Water Act was promulgated in 1998. Amongst the many and fundamental changes that this act brought, a key aspect was the change in governance over water resources. The Act demarcated 19 Water Management Areas (mega-catchments), each to be managed by Catchment Management Agencies with representative, elected board members (Box 4.1). The SRC falls within area under the Inkomati CMA which is the first of the 19 CMA's to be established (2006).

Box 4.1
Water resources sustainability

Based on the framework of Integrated Water Resources Management, three key principles underscore the management of water in South Africa today: sustainability, equity and efficiency. All CMA's are directed to bring about such transformation through their catchment management strategies (Pollard et al., 2007a). In particular, sustainability is defined through the setting of environmental flows, known in South Africa as the Reserve. The Reserve for the Sand River (or a prototype thereof) was developed in 1996 (DWAF 1996) and offers a benchmark against which both water quality and quantity can be measured. Furthermore concerns regarding the integrity of the riverine system prompted a number of other initiatives such as agreements for the removal of commercial forestry in the upper catchment. Operating rules are also in place to regulate water use by commercial agriculture although implementation is still a challenge. To address the inequities in access to basic water supply, devolution of responsibilities to the local level is seen as key and infrastructure is being developed so as to improve water services.

Land reform has been more protracted and contentious. In communal areas in particular progress has been slow and to date has not been implemented (this is discussed below). Although reform has been seen in other policies related to natural resources management, implementation is challenging and regulation largely absent.

[15] Although a loop would be in existence between livelihood security and water abstraction, this was probably not as strong. The agricultural schemes were all developed at around the same time and abstraction remained fairly constant thereafter. A weaker loop did however exist with forestry. As it attempted to service contacts in perpetuity so it expanded into sensitive areas impacting on both base flows and sedimentation.

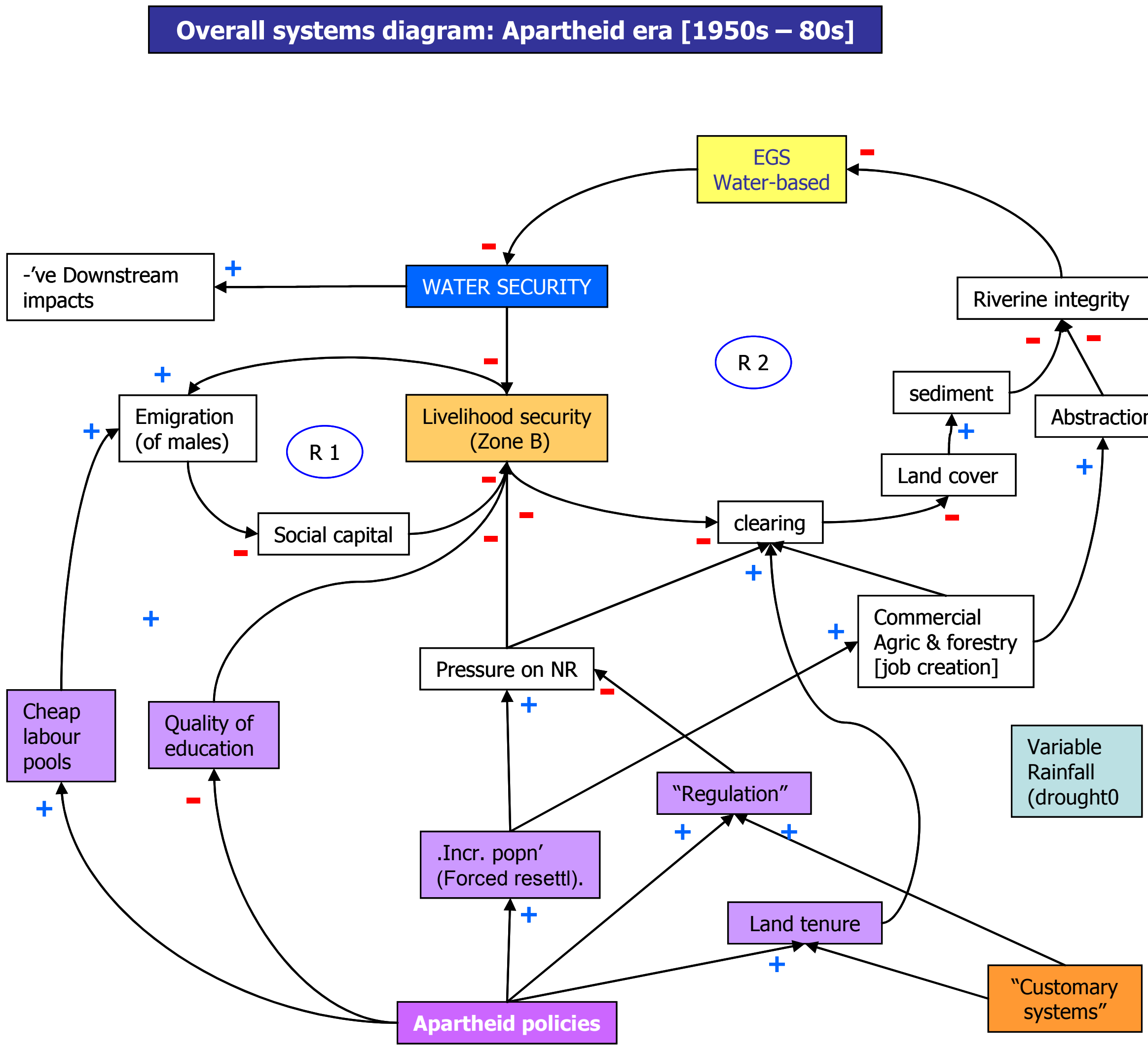

Figure 4.2 Systems diagram for the Catchment (Zone B) for the apartheid era between 1948 and the mid-80's. Two reinforcing feedback loops are evident. EGS = ecosystem goods and services

Note:

1. Whilst apartheid policies drove labour requirements, education, forced resettlement, land tenure/access and the regulation of natural resources ('regulation' in the diagram), the last two were also influenced by customary systems. Thus legal pluralism was evident even throughout this era (see Pollard and Cousins 2008).

2. A tension existed between the pressure on natural resources emanating from the increased populations (+) and the controls applied mainly by the traditional authorities (-), the latter being stronger in most cases although most indunas would not apply regulations in cases of extreme pressure or poverty. Also note that [land tenure']was influenced by state policies (demarcation of homelands for black people) as well as at a more localised scale by both state policies (the 'permission to occupy or PTO) and customary systems (membership of a community affords rights to land). Again, this illustrate legal pluralism that was operative

3. Quality of education refers to education in the broader sense. This is discussed in Chapter 2

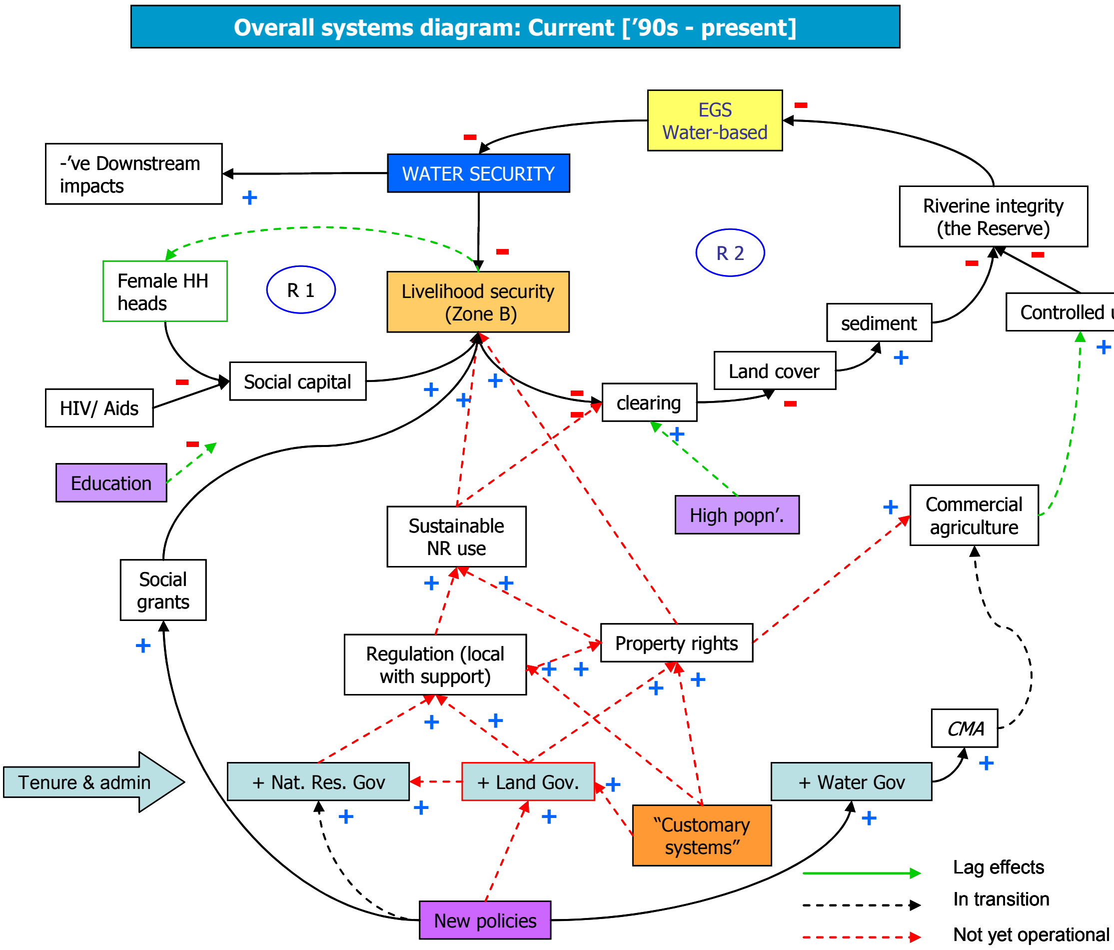

Figure 4.3 Systems diagram for the Catchment (Zone B) for the present period of transition. Two feedback loops are shown. EGS = ecosystem goods and services. NRM = natural resource management; CMA = Catchment Management Agency; HH = household

Notes:
1. A range of statutes and policies are aimed at tenure reform (blue), with intended positive consequences (+) for land management and sustainable natural resource use. However these are (a) not yet operational and (b) overlapping, in that they emanate from different statutes dealing with restitution, tenure on communal land, water tenure, and community-based organizations (e.g. common property associations, Land Administration Committees, Traditional Councils, Catchments Forums). All of these structures have implications for NRM but what these responsibilities are and how this will be harmonized is unclear. Since the positive consequences are not yet in place the same reinforcing loops have persisted.

2. Water reform is in the early stages of being operationalised. Commercial agriculture has been included in the diagram to highlight as the major user of water, its impact on abstraction will persist until the CMA is effective. At the same time there is increasing pressure for commercial agriculture and so the potential demand of this user may grow. This is a tension the CMA will face given the water deficit in the catchment

3. The Reserve (see Chapter 4) provides a detailed benchmark against which [riverine integrity] can be assessed

4. The lag effects of Apartheid drivers are clearly evident in many areas, for example (a) the high population densities (despite the policy having fallen away), (b) poor education and (c) fractured households, still effectively female headed, due to the historic migration of males

4.3.2 Wetlands: Experiences from the Craigieburn wetlands

The apartheid era

Wetlands comprise an important resource for local communities[16] in that they offer land for small-scale agriculture that is more fertile and wetter for longer periods of the year than the adjacent hillslopes. As was discussed above for most land and natural resources, the protection and use of wetlands was effected through chiefs and indunas (with limited state support). Some grey areas did exist however since although wetland plots were 'allocated' by the induna (Pollard et al., 2005b)[17], it was illegal to farm there according to the Conservation of Agricultural Resources Act (1983). In 1994 – as part of the popular challenge to apartheid – this tribal control, which had afforded some degree of protection, albeit autocratic, collapsed (Shackleton et al., 1995).

Once a more localised lens is applied to water security through an examination of the key drivers behind wetland integrity, two additional feedback loops are evident (Figure 4.4; compare to Figures 4.2 and 4.3). These include the links between (i) wetland and riverine integrity and (ii) the links between land clearing and localized water tables. The key drivers behind wetland integrity are landuse (both hillslope and within-wetland use) and riverine integrity. Clearing of land results in land desiccation and a reduction in the localised water table (see Pollard et al., 2005; Pollard and Perret, 2007). Excessive clearing also leads to sediment deposition within the main river channel and the increase in the slope resulting in the formation of major erosional headcuts which in turn lead to wetland desiccation. This is also associated with a loss of fertility which results in decreased plant production- including that of crops – thereby impacting negatively on peoples' livelihoods and exacerbating livelihood insecurity (Pollard & Perret, 2008; Pollard et al., 2008a).

The post-apartheid era

The weakened institutional arrangements that have persisted since 1994 have been exacerbated by the inability of government to implement the wide array of new laws and policies, which are little understood at a local-level in any event. Moreover roles and responsibilities for natural resources management in communal areas are inadequately addressed leading to overlapping and conflicting roles in some cases and gaps in others (Pollard and Toit, 2005; Cousins et al., 2007; see Table 4.2). Now in many cases people view the resource as a public asset that can be commandeered for personal gain, often through threat (see for example Pollard et al., 2003; Dovie et al., 2004).

Thus the systems dynamics diagram shown in Figure 4.5 suggest that even with major policy reforms (the drivers), constraints to implementation render the overall result to be fairly similar, if not weaker, to that of the apartheid era shown in Figure 4.4. Indeed the confusion regarding responsibilities, together with the almost total lack of localised controls over natural resources mean that the resource base is increasingly threatened. This is likely to increasingly weaken already vulnerable livelihoods.

Today people continue to use communal land for grazing, cropping and the harvesting of natural resources (wood (trees), reeds, medicinal plants and fruit). Research suggests however that for many resources – in particular wood and medicinal plants – the current rates of use are not sustainable. The lack of regulation by the village headmen and the lack of support from state bodies mean that neither the 'customary' nor statutory institutional arrangements are adhered to.

[16] AWARD has worked with Craigieburn village on a wetlands and livelihoods project for a number of years which has provided much of the information for this component.

[17] This is also part of work in progress: 'Developing community based governance of wetlands in Craigieburn Village', IDRC RPE Programme.

This situation is exacerbated by the highly contested land tenure reform programme. Two new pieces of legislation that have a direct and profound relevance for common property resources in communal areas are introduced: (a) the Traditional Leadership and Governance Framework Amendment Act (DPLG 2003; TLGFA), and (b) the Communal Land Rights Act (DLA 2004; CLRA). These statutes have been and remain highly contested (see Pollard and Cousins, 2007 for a discussion of this). Perhaps the most fundamental concern is that of how 'communities' will be defined and therefore at what scale representation, participation and the derived community rules will be developed. This requirement for setting fixed boundaries stands in direct contrast to the nature of customary tenure systems which are dynamic and flexible. Secondly, traditional leadership has been less than happy with what they regard as an erosion of their powers. In addition, many of the critiques relate to capacity. While strengthening land administration through a system of registration of rights could be positive, if there is insufficient capacity and administrative support for registration to be accessible and simple the system will then be meaningless. At worst it creates more ambiguity and weakens rights and tenure security.

Table 4.2

Summary of role-players involved in natural resource governance in the Craigieburn wetlands. T.A. = Traditional Authority; CDF = Community Development Forum; CPF = Community Policing Forum;

	Community membership	**T.A. /Induna**	**CDF/CPF**	**NGO**	**STATE**
Authority					
All		X			X
Monitor		X		X	
Responsibilities					
Abide by	X				
Monitor	X	X	X		X
Report	X	X	X	X	X
Act on transgressions		X			X
Administer		X			X
Act as recourse		X			X
Adjudicate		X			X
Rights					
Access	X				
Decision-making (rules and sanctions)		X			X
Usufruct		X			X

Thus today, it is suggested that weakened local-level institutional arrangements together with the lack of governmental capacity to act, and the uncertainties rendered by land reform (which has not yet started), mean that the natural resource base is becoming increasingly vulnerable (Figure 4.5). This will undoubtedly impact on local livelihoods. Exacerbating this are the dynamics introduced by new opportunistic entrepreneurial ventures which appear to be taking advantage of these uncertainties. Further vulnerabilities have been introduced by the HIV/Aids pandemic. South Africa's literacy rate scored the lowest of all countries tracked in a recent study (PIRLS, 2006) and site-specific data are also suggestive of very low educational standards (Nyathi, 2006). On a positive note, the new government has instituted a system of pensions and social grants for the disabled and for those with children under 12 years of age which is operational. Also the establishment of the CMA for water resources management is largely on track.

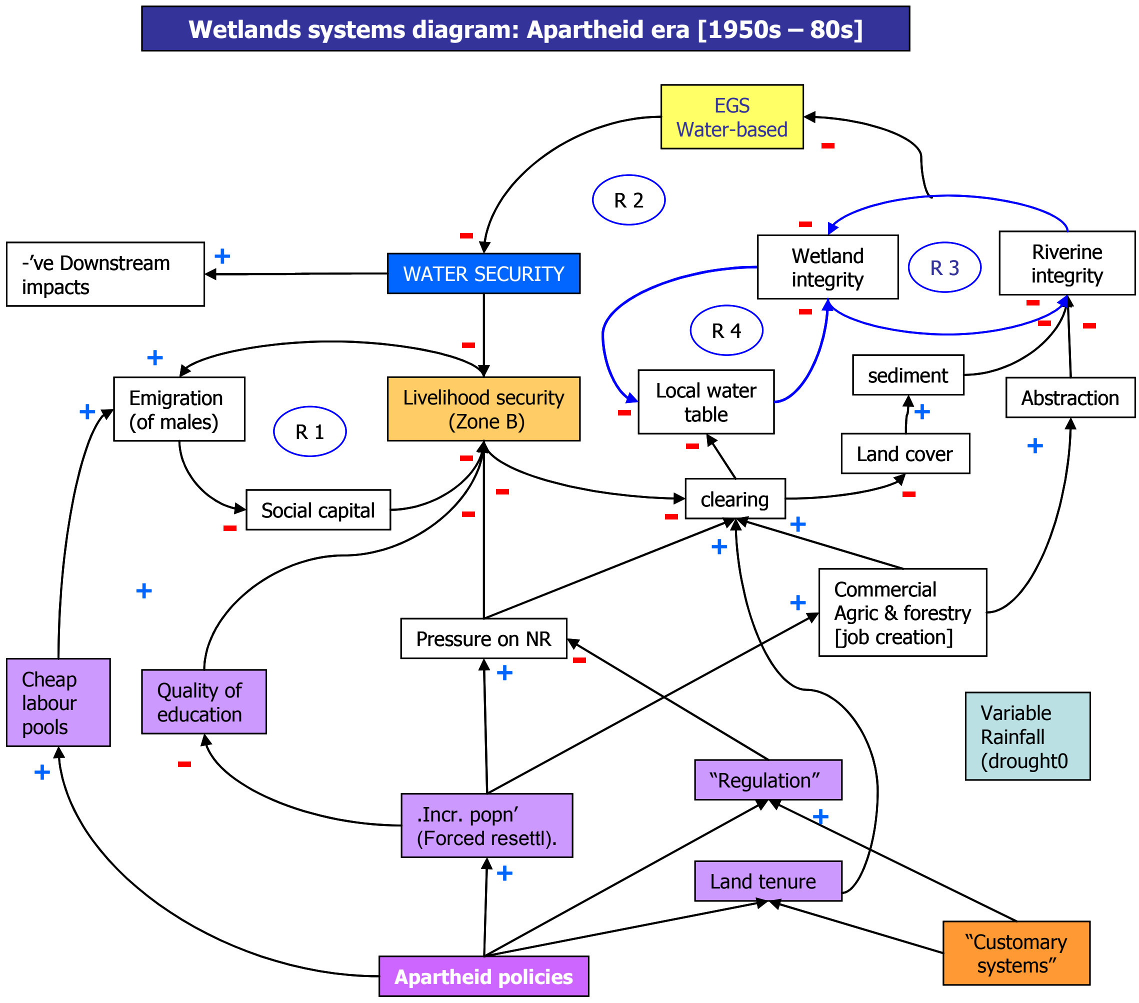

Figure 4.4 Systems diagram for the Craigieburn wetland (Zone B) during the apartheid era. Four feedback loops are shown. EGS = ecosystem goods and services.

Note:

1. The addition of two reinforcing loops is evident when examined at the scale of the wetland. This feedback has caused a system 'flip' in many parts of the wetlands where erosion and loss of wetlands has led to wide scale micro-catchment desiccation.

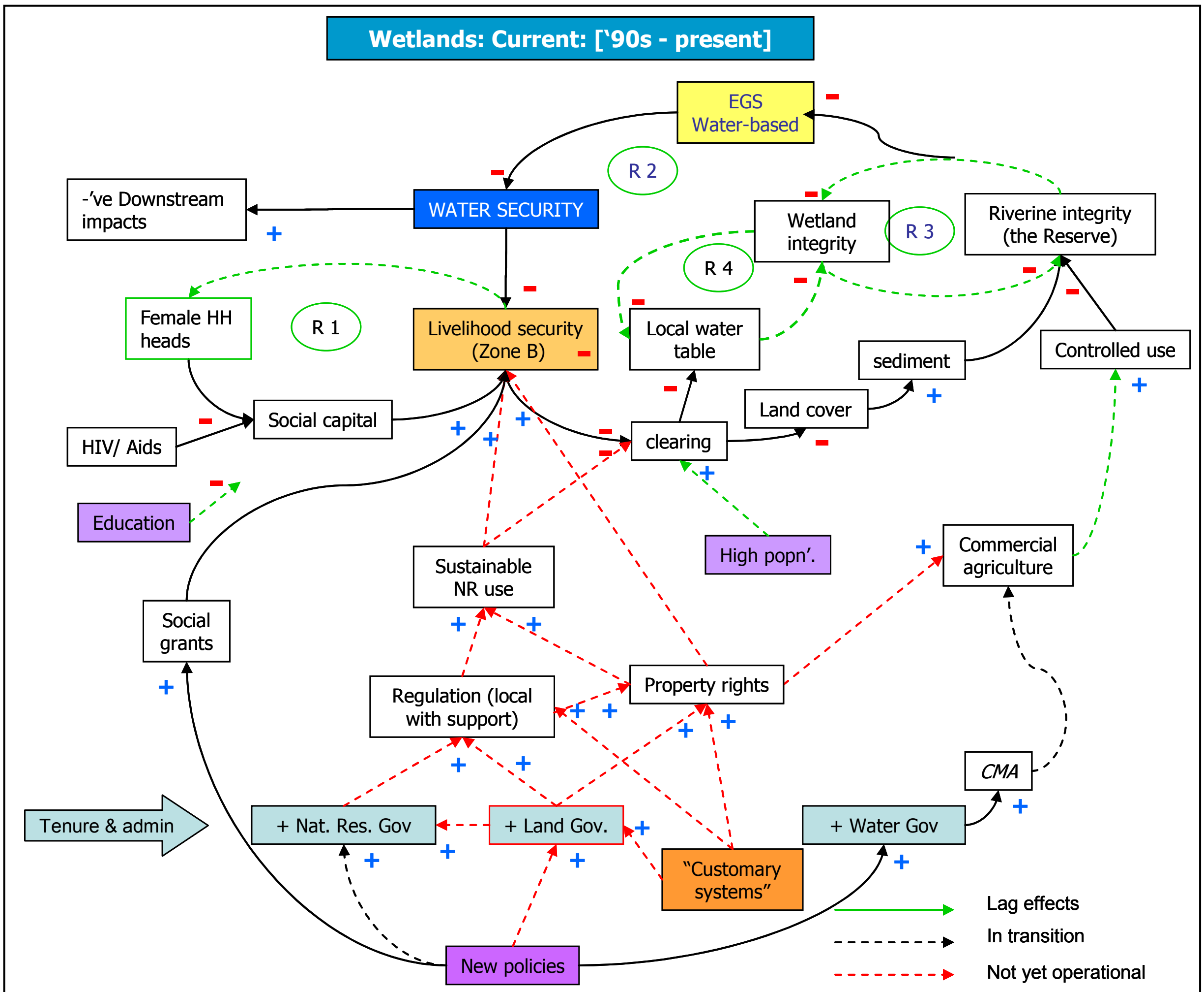

Figure 4.5 Systems diagram for the Craigieburn wetland for the present period of transition. Three feedback loops are shown. Note that the links between new policies and natural resources tenure (land and water) which theoretically mediates practice, are weak (see for example where *external economic interests* link presently). EGS = ecosystem goods and services. NRM = natural resource management; CPA = common property association.

Note:

1. The two reinforcing loops, evident when examined at the scale of the wetland, persist despite new policies which overturned the Apartheid drivers However, this is a time of transition and such lags are to be expected. More importantly is the elucidation of the intended effects of new policies on these loops.

2. As with Figure 4.3, the lag effects of Apartheid drivers are clearly evident in many areas, for example (a) the high population densities (despite the policy having fallen away), (b) poor education and (c) fractured households, still effectively female headed, due to the historic migration of

3. The Reserve (see Chapter 4) provides a detailed benchmark against which [riverine integrity] can be assessed

4.4 Discussion

The question of state changes

Historically, a number of feedback loops that led to unsustainable practices and a loss of ecosystem services were evident. At a catchment scale agricultural abstraction coupled with clearing of land has jeopardized ecosystem services and hence livelihood security through sedimentation and associated consequences. With few changes in peoples overall livelihood security, people continue to farm marginal. Nonetheless, the opinion of specialists is that despite widespread degradation, a system change has not yet been experienced (du Toit, 2006). At a local-scale however, the loss of fine sediments in wetlands through erosion has lead to a system 'flip' (i.e. into a true alternate state). This however is relatively local in effect on livelihoods, influencing the respective micro-catchments. Other alleged biophysical system flips (such as degraded vegetation) appear to not yet be near threshold, testifying to a resilient system. However, unlike the ecological resilience, that of social capital appears to have undergone a state change. It appeared from expert consultation that a threshold was passed more than a decade ago in which the extended patriarchal family, and even the nuclear family, unit had been replaced by a flexible and dispersed social support network (Prof. Niehaus, Department of Anthropology, University of London, pers. comm.), the implications of which for resilience require further thought.

At the more localised wetland scale, whilst the overall drivers may appear to be different (Figure 4.5), the outcomes for water security, wetland integrity and livelihood security are similar to the past if not becoming progressively worse. The removal of the 'local controls' (see Figure 4.4) have meant that institutional arrangements over land and landuse have slowly weakened. There appears to be little incentive to change when the reality of poverty forces people to act now to accrue immediate – if small – benefits, forfeiting long-term but less tangible ones (du Toit and Pollard internal report).

Moreover, increasing evidence of market forces as an external driver is being seen. Indeed, cross-scale linkages are an important analytical aspect of systems dynamics. External economic drivers have had, and continue to have, influential catchment-wide and local impacts. During apartheid, the creation of cheap labour pools to service the lucrative mining sector coupled with increasingly precarious local livelihoods prompted and sustained the temporary migration of men, leaving women to sustain their families. Locally this has had impacts on the availability of ecosystem services and hence on livelihoods. More locally the growing need for cash has acted as an important driver for some of the landuse practices that are evident, especially on fragile systems such as wetlands. Today, the national and international demand for medicinal plants has led to an increase in local harvesting at rates that are considered to be unsustainable (Shackleton, 2004). Additionally economic interests, prompted by the development of the biofuels industry, have resulted in various proposals to develop irrigated sugarcane production. Economic opportunism is merely serviced by the lack of clarity that prevails and new dynamics are emerging as the weakened governance structures fail to respond. Usufruct rights are a new issue for local communities and contestations are likely heighten as different institutions become aware of the associated economic benefits.

The lack of harmonisation of policies both at, and between, provincial and local levels is evident in the unintegrated plans. Local municipalities in the SRC have developed their five-year plans (the IDPs or Integrated Development Plans) with little cognizance of water resource constraints and consequently have oversubscribed the Sand River by some 200%. Nonetheless, this is a time of transition and the new sources of leadership such as the

Catchment Management Agency, and an increasing number of inter-sectoral initiatives, mark a definite increase in the kind of societal learning required for resilient resource management (see Biggs et al., 2007). Moreover government is increasingly aware of its own lack of capacity and encouraging of stakeholder participation, opening up opportunities for meaningful local-level governance (Pollard and Cousins, 2007). This is particularly true within the water-sector where are range of actors are actively involved in water resources issues (often referred to as 'redundancy' in resilience analysis).

In general it is clear that although change is underway in the SRC, the situation is still in a state of transition. A major implication seems to be that <u>the feedback loops that prevailed during the apartheid era still persist despite policy changes</u>. For instance, lags are evident in the implementation of the National Water Act so that currently the feedback loop between abstraction and water security is still a negative one. Slow variables appear to be sedimentation, education and land tenure security and governance. Tenure and governance are critical because they are the drivers behind land-use practices. As noted, weakened local-level institutional arrangements together with the lack of governmental capacity to act, and the uncertainties rendered by land reform, mean that the natural resource base is becoming increasingly vulnerable and directly impacting on livelihoods. This is exacerbated by new opportunistic entrepreneurial ventures which are taking advantage of these uncertainties. Moreover, if key determinants are not made operational these are unlikely to change. We suggest for example that if issues of local-level natural resource governance are not addressed the negative feedback loops (reinforcing loops) will continue - ultimately impacting on peoples' livelihood security. Currently this is unlikely to be addressed through the changes suggested by land tenure reform policies (see Cousins et al., 2007). Nonetheless, in the case of water it is likely that with the newly established CMA changes will be evident at a catchment-wide scale with water security – and hence livelihoods – improving. A further discussion on the resilience of the system is given in Chapter 6.

Chapter 5

Three scenarios of livelihood trends and water-based ecosystems services

5.1 Introduction

As mentioned, the broader investigation set out to describe the system in social-ecological terms (Berkes et al., 2003) and examine its resilience (Walker and Salt, 2006) in this way testing the applicability of these concepts to the challenges presented in this economically poor and degraded area (Chapter 3). As part of this process, and using information generated for the SES description, scenarios were generated, primarily to support an integrated understanding of ecosystem services and livelihoods issues in the region.

There are several ways to approach scenarios, for instance by building likely alternative futures from existing realities and trends, or envisioning drivers which may be seen to support certain desired on undesired future states. Scenarios invariably involve integration between socio-political, economic and biophysical views, usually done at a particular geographical scale. The work of finer-scale scenarios is often made easier by nesting these within coarser-scale scenarios. Broader scenarios used for this purpose are available "off-the-shelf" (i.e. having been, often periodically, pre-constructed) from a variety of sources, such as Shell Global Scenarios (http://www.shell.com/scenarios) which are mainly used for business purposes, especially concerning energy. Several other sources are available, such as the Global Scenarios Group (http://www.gsg.org) which develops integrated global and regional scenarios. A review of major South African political scenarios is dealt with in Segal (2007). The use of scenarios which incorporate looking at future supplies of ecosystem services is a recent development epitomised by the Millennium Ecosystem Assessment's scenario initiative (http://www.millenniumassessment.org/en/Scenarios.aspx), and is illustrated in separate papers such as Gallopin (2002), Peterson et al. (2003).

Alternatively, multiple methodologies exist for generating scenarios (e.g. Wollenberg et al., 2000; Peterson et al., 2001; Segal, 2007). Some texts (e.g. Institute of Natural Resources, (2005) recommend a structured sequence of steps such as identifying a central question; then identifying drivers (especially unpredictable drivers with major potential impacts); then contrasting outcomes of combinations of these drivers (often the two most important). The latter outcomes are often represented as a 2X2 table (low-low, low-high, high-low and high-high values of driver levels). Typically, for each of these quadrants, a systems diagram (akin to those in Chapter 4) is drawn showing the influences between the remaining drivers - ones not embedded in the axes. These "way-that-world-works" diagrams form the basis of scenarios (usually then four). There are also shorter, more intuitive and direct ways of generating scenarios (e.g. Evans et al., 2006). Each scenario is allowed to be somewhat contrived yet just plausible – this has the advantage of illustrating, sharply, the effects of the particular driver set, and hence stimulates thoughts about responses to that particular set. A narrative often accompanies each scenario so as to capture the essence of these dynamics and present them in an engaging way to the target audience. "Softer" qualitative storylines are sometimes mixed with "harder" quantitative modelling (Peterson et al., 2001; Gallopin, 2002; Carpenter et al., 2005).

This chapter describes the scenario-generation process and the scenarios, and culminates in a discussion on what we learnt and how useful the scenarios were or might still be.

5.2 Methods

The scenario development process was based on the profile for the Sand River Catchment (SRC) outlined in Chapter 3. A two-day 'expert' workshop was held to review and critique the SES description, and to help construct scenarios based on this information (see du Toit, 2005). The workshop, held in May 2006, involved 15 specialists. The team included individuals from a broad spectrum of fields of knowledge, with experience of the study site, experience with scenario development, familiarity with systems, and an interest in trans-disciplinarity (sensu Max-Neef, 2005). The team included a number of biophysical scientists, social anthropologists, and persons with some understanding of the economy of the region. Detailed documents were circulated to participants to facilitate preparation for the scenario development exercise. The first day was spent reviewing the SES formulation and systems dynamics understanding, with the scenario generation activity taking place the following day.

The approach adopted was that of extracting oft-repeated expert proposals of drivers from the first day of the workshop. Key ideas that emerged were of the apparent ongoing externally-driven economic development; the nature of undesirable political changes in which there is progressive weakening of such external subsidization, unaccompanied by any meaningful local substitution; and a suggestion that meaningful local diversification of land-use has actually started taking place. It was agreed that these ideas would form the basis for three scenarios which would be called respectively: "affluent society", "desperate measures" and "resilient adaptor". The last represented an idealized adaptive, resilient system. The group also agreed to emphasise responses to at least the following major co-factors over and above the ones directly reflecting water and human livelihoods:

- HIV/AIDS
- governance bottlenecks (lack of capacity and lack of implementation)
- education
- Tourism
- global environmental change (especially increased temperature)
- consumerism, coupled with apathy to environmental, resource and social issues

Each of these had been also prominent in the previous day's discussions. All scenarios were constructed for a 25 year timespan - describing situations for the year 2030. The group worked through the three scenarios mainly in plenary, and dealt with two major headings as guidelines – drivers and outcomes.

5.3 Scenarios for Bushbuckridge

The three scenarios are presented in comparative tabular form, and then as a short narrative. Although drivers and outcomes cannot be neatly separated because of circuitousness in cause and effect, Table 5.1 attempts to deal with what the group considered to be the main drivers under each scenario. We have emphasised certain driver factors in bold - this is our emphasis for quick reference. Table 5.2 depicts the chief outcomes – note these should not be seen as separate to drivers. Again we have emphasised the most salient issues.

It is important to note that the team found each of the three scenarios plausible in their own right, but with varying commitment to specific aspects. However, unlike the case with the other two, no clear pathway to "resilient adaptor" could be tracked. This is because the starting point – a significant decrease in population – seemed untenable in reality and had elements of social engineering that were uncomfortably reminiscent of the forced removals of the apartheid era. The group felt that it would only develop in response to either (a) bad experiences (suffering, hopelessness, and fear of worse outcomes) during the unfolding of "desperate measures" or (b) corrections to environmental degradation and social excesses as "affluent society" developed. Table 5.3 deals with the relevance of scenario outcomes to water governance, under five selected headings.

Table 5.1
Particular characteristics within major driver groupings of the scenarios.

Drivers groupings	Scenario 1 Affluent Society	Scenario 2 Desperate Measures	Scenario 3 Resilient Adaptor
Economic	**International growth**; Strong local economic programmes Increased disposable income	**Global economic failure**; production sector and nature-based tourism decline; Overall, national economy still fares reasonably	Open economy supports **innovation;** shifting investment patterns. Mixed regional economy; no dominant. Self-employment common. Knowledge-based and services economy, including tourism
Political	[Not mentioned; implicitly stable]	Rise of **nepotistic, autocratic** system	Government policy effective
Population, distribution and activities	**Strong urbanization** leading to outmigration from rural areas; falling population growth in such areas.	[not explicit; seen as result rather than driver]	**More diverse social and biophysical landscape. High skills** and low resource dependency. Lower rural population; some slums in peri-urban areas
HIV/AIDS	Vaccine promised but not deployed except experimentally	Ongoing HIV infections; no vaccine forthcoming	[Described as an outcome – more favourable than other scenarios]
Land tenure	Communal Land Reform Act (CLRA) leads to **widespread privatization of land**; amalgamation of smaller units of land	**Land tenure disparity** – biphasic CLRA widely operative but appropriated by individuals. Landless class develops	More **coherent institutions around land management** arise partly from CLRA
Ecological and ecosystem services	More focus on economic use of water; less on environmental concerns; society mentally "disconnected" from natural resources	Widespread degradation; water shortages	More use of rainwater; agriculture shifts partly towards horticulture. Tapped water and sanitation are adequate
Values and Attitudes;	"Rampant consumerism"	Non-compliance; no accountability	Widespread attitude of 'what can we do to remedy situation?'
Institutions	**Removal of labour law restrictions** "command-and-control" of water; less co-management	**Institutional decay**	**institutions generally strong;** Payment for Ecological Services; Arrangements favour increase in cut-and-carry agriculture; Diversity of entrepreneurship forms
Energy	[Not mentioned: assumed that production adequate]	Wood use; LPG; paraffin	More solar and bio-energy
Funding as a social security net	[implicitly adequate]	**Grants available but with political obligations**	[implicitly better; higher social capital and networking]
Education	**Improved quality**	[Not discussed – implicitly poor]	**Patchily and increasingly better**
Technology	Technical innovations for water quality	Some innovation for survival	Innovation flourishes

Table 5.2
Outcomes characteristic of each scenario, classified into groupings of similar genre.

Outcome	Affluent Society	Desperate Measures	Resilient Adaptor
Resource use	More **exclusive**	**Conflicts** over water, land and fuelwood.	**Varied** and tends to be localized.
Zone trends (as described in Chapter 3)	**More intensive use of eco-tourism zone**; forestry zone becomes a park	Some **land invasions** into parts of previous private and game farms; Patchy well-managed "pockets of hope"	**Stronger flows of money and labour** between upland, midlands (Bushbuckridge) and lowveld zones
Sustainability	Some production means **degrade resource** base because of overemphasis on profit	**Cross several degradation thresholds**	**Livelihood security improves**; incr. social capital and less migration
Institutions	Social grants disappear; **principles of human and environmental rights are tested legally**	Previously designed framework increasingly seen as meaningless. Institutions weaken considerably. **Rise of fundamentalism**	**Innovative networks and community forms;** Pro-poor tourism arrangements. Support services grow in a **decentralised** manner
HIV/AIDS	More travel and thus **more exposure to HIV**	Social breakdown **worsens rates**	**Fewer cases, better dealt with**
Tenure	Increase in structured **private tenure**	[No specific mention, presumably stuck in transitional arrangements]	**Varied**. Something for everyone.
Economy	**Increase in land prices**; Eco-tourism increase, especially SA component ; Rand strengthens→ less competitive markets	**Fair.** Lower tourism → lower income for conservation agencies. Use local produce and cheap options External diaspora subsidise region.	More opportunities in tourism and information about these. **Extra wealth from upgraded rather than more jobs**. Services locally sourced. Appropriate cultural tourism. **Diverse economy.**
Water condition and supply arrangements	**More inter-basin transfers** Quality suffers at first, later improves	No change in yield but peaking as storm rather than base flow. **More sediment deposition. Loss of wetlands**; lower potential of remaining wetlands	**Mostly secure and equitable** Quality improved. Ecological buffering prevent sediment and pollution; Rehab of wetlands and indigenous forests
Human capacity	Improves as result of better education	[Presumably stagnant]	Skills diversity grows
Social security	[Presumed good]	Landless class develops. Poor are increasingly vulnerable. Increase in crime. **Welfare net collapses**	**Improves**

Table 5.3
Relevance of scenarios to the likely state of water governance in 2030.

Relevance area	Affluent Society	Desperate Measures	Resilient Adaptor
Attributes: mood and landscape	Direct economic targets assertively pursued; landscape of large homogenous production blocks; Constitution and **National Water Act repeatedly challenged legally** with a view to "trade-offs"	Democratic groups have little influence; **'strongman' tactics** used to exercise territoriality over resources; some local pockets of "orderly and well-functioning systems"	**Ethic of participation**; linked vertical and organically-evolving spread of governance arrangements across levels; **Landscape moderately fine-grained heterogeneous**; move away from direct dependence on resources, made possible by urbanisation
Robustness	Impetus of well-organised economic system guarantees **production according to mechanistic norms; impending 'overshoot' of certain ecological thresholds** leads to a partial "caring response" by society; high financial and infrastructural capital acts as buffer	**Poverty "lock-in"** (Gunderson & Holling, 2001). Combination of 'strongman' action and displays of (token?) democracy allows some resource access in patronizing manner – which develops its own robustness as an institution.	Experimentation and diversification 'live and let live' attitude promotes **search for sustainability and is usually shock-tolerant**
Effect on ecosystem services	Resources seen as primarily for **utilitarian** purposes; **ecosystem limits often challenged** by a behaviour of 'let's see if it's exceeded' right up to or over legal limits	**Degradation and clear exceedances of thresholds**; Seasonal 'crunch periods' and pollution episodes deleterious.	**Improved ecosystem services** as a result of 'lighter footprint'. Water-based ecosystem services generally accessible and adequate. Thresholds seldom crossed.
Effect on other capitals	**Economy grows** over this time period; human capacity development and trust good	Low social capital; **poor human capacity** development; fair **state of national economy** assists system	**High social capital**; good rural-urban link; **economy moderately productive** but more smoothly sustainable
Effect on principles of National Water Act	Under pressure, acts as constraining backdrop. Leads to question **"is all this protection necessary?"** asked repeatedly	**'Cannot afford environmental flows'**; weak and failed attempts at substitution; ongoing poor compliance; no motive to improve	Generally widely 'bought into' by society, **compliance of environmental flows fair-good**. Some misunderstandings and mishaps but these are effectively dealt with

5.4 Discussion

The systems diagrams (Chapter 4) offered an important basis for the development of scenarios. They helped elucidate drivers, linkages and feedback loops thereby presenting a systems view of the present situation in the Catchment for discussion. Scenario development then built on this process by charting various future options and examining which drivers and outcomes either persisted or changed. Importantly participants appreciated that multiple drivers operating at different scales are likely to influence the state of the system.

The key drivers in the scenario of "affluent society" are economic growth (particularly that of international influences), urbanization, privatisation of land tenure, reduced labour law restrictions, improved education and technological innovation. Ultimately this results in a situation of exclusivity of resource use, increased land prices, some degradation due to the developmental agenda overriding that of sustainability accompanied by litigation (testing of environmental and social rights), technological interventions as solutions and some social security improvements although HIV exposure increases. Ultimately the outcome is a highly utilitarian perspective of resource use with ecological limits being reached or exceeded and challenges to the legal environment which act as a constraining backdrop to uncontrolled development. The economy grows (or appears to over the timespan) and production returns to a highly mechanistic, maximum yield approach.

The key drivers in the scenario of "desperate measures" are global economic failure (although nationally the economy fares reasonably), the rise of a nepotistic, autocratic system with institutional decay, and some local-scale innovation for survival. The outcomes are increased conflicts, widespread degradation, and increase in HIV/Aids, the development of a landless class although the economy does not collapse. The capital inflows from the diaspora become important. Ultimately poverty and degradation worsen.

Clearly as a engineered scenario, many of the attributes of a resilient system characterized the 'resilient adaptor" scenario: innovation, diversity, coherent governance, willingness to act and improved education. However given that current resource use is considered unsustainable (see Chapter 3) a major challenge that emerged was that of achieving a 'lighter' ecological footprint. The only apparent paths for doing so appeared to be through economic diversification or a population reduction.

Whilst these descriptive are important to illustrate key drivers and outcomes, a further step to considering options for sustainability was undertaken in the resilience assessment of the first two scenarios. This is reported on in Chapter 6.

Use of the scenarios

As with systems dynamic diagrams, one of the most beneficial aspects of scenario-based planning is in the co-construction of the scenarios with stakeholders. It is through this process that participants share information and develop mutual respect and understanding for the challenges that lie ahead (Wollenerg et al., 2000; Evans et al., 2006, Segal, 2007). We feel it most likely that stakeholders are likely to benefit from an engagement in which they re-develop these scenarios for their own particular use, either using these as starting points, or re-building them in different ways. Overall, it is possible that wider awareness and popularisation of such initiatives may in fact help stakeholders at various levels deal better with the future challenges and opportunities, and make choices that are more likely to be sustainable.

An important part of the process of generating and discussing scenarios was that they helped consolidate information in the minds of different experts. In fact they resulted in a series of pictures which different persons helped create, and at least partly 'bought into', even if these were associated with different likelihoods of realisation. Experts agreed that a mix of these outcomes was possible and probably likely, and most importantly, the exercise helped to focus on possible futures in a way that had not done as critically before. It is likely that each of the participants takes away a mental picture with them that they use in describing or thinking about such futures in the area.

Apart from this immediate benefit for workshop participants, do the scenarios have a use? It is suggested that they could be packaged in various ways that would make them useful for a number of initiatives of fairly immediate concern in our sphere:

(a) Wetland rehabilitation and governance work with which we are currently busy in the area.
(b) Bioregional initiatives such as Kruger-to-Canyons, the planned rollout of the North-eastern Escarpment Bioregion, and the southern African component of the Greater Limpopo Trans-Frontier Conservation Area. To date, these stakeholders have not been engaged, although a related initiative working across South Africa, Zimbabwe and Mozambique (AHEAD) is using scenario techniques, and sharing experiences with us.
(c) In Integrated Water Resources Management for each of the 19 Water Management Areas in South Africa.
(d) For municipalities and regional planners.

Two issues that arose quite contrary to expectation, require mention. Firstly, some of the aforementioned initiatives have shown little interest in using scenarios. This may be because of perceived low value to them. Secondly, a surprise arose in the Sand Catchment just before this report went to print, involving the potential resurgence of forestry in Zone A (see Chapters 3 and 4). Whatever its outcome proves to be, this challenge to conservation and water security interests was in no way even suggested by any of the scenarios, probably indicating that our driver analysis was not comprehensive.

5.5 Conclusion

Scenarios have become practical and acceptable tools for helping navigate uncertain futures. According to the Millennium Ecosystem Assessment (Carpenter et al., 2005, chapter 2) scenarios are "plausible, challenging and relevant stories about how the future might unfold, which can be told in both words and numbers". They stress that they are not what are normally understood as forecasts, predictions or recommendations, which are usually based on an idea that the future will follow a particular determinable course. It is helpful to clarify the purpose (Wollenerg et. al, 2000) of using scenarios at the outset, as this guides the way in which they are approached and generated. Some commonly stated purposes include improved management, conflict resolution, awareness raising, and policy advice. The importance of the scenarios is that they allow debates in these different arenas to be open and to continue in an ongoing adaptive manner

In particular, the collaborative development of scenarios is an important process in developing and reviewing the issue of resilience and degradation – be this socio-economic or environmental. Using the systems dynamics diagrams in scenario development had the advantages of not only refining these but also consolidating them into a planning process. As mentioned, it is in their co-construction that real meaning, learning and progress is made In this case the exercise strengthened the conceptual grounds for claims regarding vulnerability or resilience, but we have yet to take forward the process into planning forums. Their value, for example in the realm of strategic planning in the water sector (i.e. Catchment Management Strategy development) has yet to be tested.

Chapter 6

Analysis of resilience and sustainability and an assessment of the resilience approach

6.1 Analysis of resilience and sustainability in various scenarios

In this, the final chapter we return to the analytical questions that have guided the study, namely an improved understanding of vulnerability and options for addressing this and an assessment of the resilience approach in deepening this understanding.

Thus, a final step in the resilience analysis was to assess the resilience or vulnerability of the Sand River Catchment. This analysis was conducted during the specialist workshop (du Toit, 2006) and further refined by the authors using Walker's and other key characters of a resilient state (see Table 2.2; and see Resilience Alliance 2007b). A detailed analysis, undertaken for the current situation described in Chapter 4, is discussed below. As a further step to considering options for a sustainable future, an assessment of two of the scenarios was also undertaken and is summarized in Table 6.1. The purpose of conducting the scenario assessments was to provide an opportunity to deliberate on the prospects and possibilities for the system to move towards a more, or less, resilient state.

Resilience of the current situation

With respect to the biophysical system, the collaborative assessment of the current situation was that although degraded, no system 'flip' was evident (see Chapters 4 and 5). Nonetheless, scale is an important issue here and at a finer scale than that of the catchment, the loss of clay 'plugs' at the bottom of wetlands on the granitic substrate in Bushbuckridge appears to have led to a system 'flip' i.e. into a true alternate state. This has had a relatively local effect on livelihoods within the micro-catchment. Other alleged biophysical system flips (such as degraded vegetation) appear to not yet be near threshold, testifying to a resilient system. However, the social system may well have seen a transformation with a threshold being passed more than a decade ago. The extended patriarchal family and even the nuclear family unit appear to have been replaced by a flexible and more dispersed sibling social network. This conclusion does require further research however, and the implications of this require further attention. It was also suggested that the situation of weaker social networks are further compounded by repetitive shocks such as HIV/Aids and crime.

A more detailed analysis of the current situation depicted in Chapter 4, according to the characters of a resilient system, is given below.

- *Diversity* (language culture, biodiversity): This is considered to be moderate. Biophysical diversity has remained static. Socially there has been some diversification in terms of the increased job opportunities of different types of work than those previously available.

- Ecological variability: Although considered to be moderate, in the aquatic system this appears to be decreasing since the flow regime is displaying increasingly less variability (see below on the *Acknowledgement of variability*)

- *Acknowledgement of slow variables*: In terms of policy there is a strong recognition of slow variables (the effects of sedimentation, 'education' and land tenure/governance) but in practice is weak. Sedimentation in river systems in the lowveld has been posited as a slow variable, and it indeed appears from some additional work that the Sand River is becoming sandier in the long run (M. Rountree, pers comm.). Implications of this and of diminishing flow regimes in the Sand River signify degradation but not necessarily catastrophic thresholds. Social capital, especially the educational component (in its broadest sense), is considered to be a slow variable. Only a sustained and marked improvement in the nature and quality (see social learning in Chapter 2) will confer additional resilience. Importantly, land tenure security was identified as a potential slow variable.

- *Tight feedbacks*: Currently there are very few new feedbacks in the system and this appears to be worsening. In Chapter 4 we argued that despite new policies, there is currently little evidence of the necessary feedbacks to 'close the loop' (implementation, learning, reflection and action).

- *Social capital*. Currently social capital, and in particular networks and trust (see Chapter 2), are relatively poor and weakening. Lack of respect for elders and HIV/Aids are cited as key factors in the weakening of networks. Contemporary research (Prof Niehaus, Department of Anthropology; see du Toit, 2006) suggests that they may well have been a state change or 'flip' in the social system. He points out that a social system based on sibling networks, as is increasingly evident, is fundamentally different to one based on parental networks. However, it was also noted that the immense capacity of people to adapt makes identifying thresholds very difficult. Social grants have provided a safety net for people, but grants are not lifting people out of poverty, merely buffering them. Also some innovation is noted in the informal sector trade.

- *Innovation*. This is generally lacking although there are pockets of highly innovative action. In terms of the latter, examples include withdrawal of afforestation, diversifying options in the tourism industry and the negotiation around environmental flows. However these are largely driven by drivers external to the catchment. Some innovation within the SRC includes expansion of the informal sector, some of which have negative impacts (e.g. escalation in sand mining).

- *Polycentric and overlapping governance* is moderate and tending to weaken after and initial growth. Since the early 1990s, water resources issues have been driven by a number of government, conservation, and water user agencies, and a number of NGOs. It appears that although the structures are still in place, the interest appears to be waning. Additionally, the initial drive for strong participatory processes has become fragmented. Further, although policies promote integration this is not evident in practice (integrated planning and harmonization of efforts see Pollard and Toit (2005)). Moreover this requires fairly high levels of competency but government departments are experiencing skills drain. The current suite of well-intended resource-related policy reforms are not yet operating in concert, and many, even in isolation, are not yet proving tenable. Depending on how this situation develops and is managed, resilience or vulnerability is equally likely.

- *Ecosystem services* (with a focus on water). These are moderate and fairly static although increasingly vulnerable to new development 'at any cost'.

- *Openness*. The system is now more open than it was a decade ago. This is evident in inflows of money and ideas on the positive side. However, on a more negative note, there is a continuing inflow of HIV/Aids infected persons, crime and rampant consumerism (over-expenditure at both a household and intuitional level).

- *Reserves and reservoirs*. This is regarded as moderate in terms of stocks with reasonable biodiversity and human capital, but less so in terms of skills and economic power.

In addition to these our analysis has suggested a number of other important considerations for a resilient future.

Recognition of cross-scale issues

It is becoming increasingly important to acknowledge and pay attention to the importance of cross-scale factors. Economic growth elsewhere in South Africa had already offset several potentially weaker features of the local system (e.g. water infrastructure), thereby contributing to improved water security and the local livelihoods (this is not necessarily synonymous with improved resilience). National imperatives of governance are also extremely important. The establishment of three tiers of government has seen the devolution of responsibilities to local municipalities. However, the emerging local picture in Bushbuckridge is one of extremely weak governance[18].

Recognition of variability

Linear thinking still predominates in much of management, especially in agricultural production, thereby enhancing vulnerability. One form of this is the so-called "hydraulic mission" (an old-style engineering approach to water resources management) that is evident in regional planning instruments for water supply. In the water resources management arena however, variability is explicitly acknowledged but remains to be fully operationalised.

The nature of learning

The presence of a responsive and adaptive society is strongly influenced by processes and modes of learning. Whether these are formal (as in formal education system) or informal- through various ways of communicating and responding - is of less importance than the character of the learning process. For example, we perceive an increasing number of inter-sectoral initiatives that mark a definite increase in the kind of societal learning required for sustainable resource management (e.g. catchment management agencies as guided by the catchment management strategies (Pollard and Toit, in press). Where learning is based on reflexive, adaptive, social processes there is more likelihood of sustainability emerging within a particular context. The challenge remains to support and nurture this learning, sometimes against the grain of established formal education systems.

As mentioned in Chapter 4, although change is underway in the SRC, the situation is still in a state of transition. A major implication seems to be that the historical feedback loops still persist despite policy changes and that new feedback loops are not in place. If key determinants are not made operational these are unlikely to change ultimately impacting on sustainability and peoples' livelihood security.

[18] Another important cross-scale interaction of interest is that of medicinal herbs which are being stripped to unacceptable levels. This is due to the combined effect of weakening local-level governance in the face of rising sub-continental demand. This suggests reduced resilience

Resilience of scenarios

As a further step to considering options for a sustainable future, a rapid assessment of two of the scenarios[19] was also undertaken and is summarized in Table 6.1.

Table 6.1
Summary of resilience analysis for the three scenarios created for this study. An assessment of the current situation in the Sand River Catchment is provided for comparison

Attribute	Current state: SRC	Scenario 1 Affluent Society	Scenario 2: Desperate Measures	Scenario 3: Resilient Adaptor
Diversity	Moderate	Low	Moderate	High
Ecological variability	Moderate – decreasing	Low	Moderate	High
Acknowledgement of slow variables	Moderate Policy – high Practice – low	Moderate	Low	High
Tight feedbacks	Low	Low	Low	High
Social capital	Low – decreasing	Low	Low	High
Innovation	Low with pockets of high	Moderate	Moderate	High
Overlap in governance	Moderate	Moderate	Low	High
Ecosystem services	Moderate	Moderate	Low	High
Openness Positive	High	High	Moderate	Moderate
Openness Negative	High	High	Moderate	Moderate
Reserves and reservoirs	Moderate	High	Moderate	Moderate

A fundamental constraint to sustainability in both the 'desperate measures' and 'affluent society' scenario is the lack of feedbacks, the lack of acknowledgement of slow variables (which is moderate in the 'affluent' scenario) and low social capital. Slow variables, if not explicitly acknowledged, have the potential to 'creep up' and have a sudden, surprising and potentially catastrophic effect. For example, the incremental increase in crime or food prices may suddenly cause disinvestment and/or political instability with taxing knock-on effects. Equally, the slow increase in sedimentation in rivers may reach a point where the rivers braids, dispersing flows over a wider area and affecting abstraction offtake points. In terms of social capital, the lack of trust and learning for example, will only serve to ferment political instability and will make development initiatives extremely difficult. It is interesting to note that tight feedbacks have been acknowledged in some studies as being fundamental to a resilient natural resource management system (see for example Biggs and Rogers, 2003; Tengo and Hammer, 2003).

It is interesting to reflect on the fact that the original South African workshop group who generated these scenarios insisted that a 'sustainable future' for the SRC could end up as a combination of aspects from the three basic scenarios. Although 'resilient adaptor' is a more 'favourable' scenario for sustainability in water governance, in reality one expects some elements of all three scenarios to emerge - and the hope becomes that sufficient qualities from 'resilient adaptor' emerge. The importance of the scenarios is that they allow this debate to be open and to continue in an ongoing adaptive manner.

[19] This was only necessary for the first two scenarios as the third "Resilient Adaptor" is taken to be an idealized resilient state against which other scenarios can be compared.

6.2 Assessment of the usefulness of the resilience approach in understanding sustainability

A second aspect of this work was to assess how useful a resilience approach had been in furthering our understanding of degradation – and options for responding – in the Sand River Catchment and wider. Over the three years of the study the approach has clearly influenced the team's thinking in that it is now an integral part of our discourse in most of the spheres of work and hence the way we engage others. A key aspect of this has been catalysed by adopting a systems approach that acknowledges complexity.

Without the benefit of the more recent work of the Resilience Alliance (2007 a,b), we developed a framework to guide our analysis. As mentioned in Chapter 1, the two frameworks, ours and that of the RA were developed separately but interestingly, share many of the same features, with the exception of our inclusion of system dynamics diagrams. These were used to develop conceptual models of socio-ecological systems (akin maybe to the RA Step 2) and as a heuristic for group discussions on relationships and change. Indeed, the overriding benefit of a systems approach is that of the process. It is in their co-construction and collaboration that learning and integration occurs. Importantly, specialists from different disciplines and stakeholders are encouraged to think about issues outside of their field of interest or 'comfort zone' (see also Ostrom, 2007). For example in a recent review of community-based management governance of water resources, it was noted that almost all work focusing on wetlands and livelihoods either failed to mention governance as an important aspect - if the focus was natural resources, or failed to mention the limits of the natural resource base - if the focus was more 'social' in nature (Pollard and Cousins, 2008). This failure to appreciate important linkages of socio-ecological systems must surely reverberate at both the project and policy levels.

Defining and discussing linkages and cross-scale effects using systems diagrams as a heuristic was an important part of the process. These are not generally incorporated as part of a resilience analysis (Resilience Alliance, 2007b) although we would recommend their inclusion. Indeed, the linkages drawn between resilience analysis and systems dynamics by Allison (pers. comm.) were critical. For example, claims of cause-and-effect can be made and become 'truths' which, when examined more closely, are actually mediated through other variables or factors. An example of such a 'truth claim' may be the links between wetland practices and knowledge – 'if awareness is raised, people will 'know' and change their behaviour'. Examination of the systems diagrams revealed that this is overly simplistic. Another claim is that 'it is the village headman who governs natural resources'. Our preceding discussions have shown that again this is far more complex in reality and is in a state of transition. Equally, team members only really started to appreciate the issues of legal pluralism when systems diagrams for local-level governance were examined and explored through important prompts (for example, why do you say there a linkage between those two factors?, how?, when? and so on).

A major value in the development of a systems view is the prominence that it lends to identifying and describing feedback loops. In the Sand River Catchment the transformation of water resources management - catalysed by policy changes - does not currently display feedback loops so that the important steps of practice, reflection and action are not in place (see Figure 4.3). This is even more evident in the related fields of land and natural resources management. This reveals, rather starkly, issues that require immediate attention without suggesting a simplistic, single-factor cause or solution.

We suggest that of the numerous 'holistic' methods, resilience theory most clearly and explicitly raises the profile of cross-scale linkages. Moreover it offers a fresh vantage (through heuristics such as the adaptive cycles "figure-of-eight") on a complex topic. An important, and at times difficult concept for those that have been involved in this process was not only elaborating that multiple drivers are operative in complex systems but internalizing that consequently outcomes cannot be predicted. Moreover, the varying effects at different scales introduce surprise and unintended consequences which may be counterintuitive. However this, together with the process of making linkages explicit, also meant that it was evident that various options ('solutions') are available in complex systems. Systems diagrams certainly support a collaborative effort in identifying multiple drivers. An important outcome for example, for our work on governance in wetlands has been the identification of certain factors, or "pre-conditions" without which, we believe, sustainable practices are highly unlikely. Clearly, such a conclusion has major impacts for livelihood security and future work.

However, identifying multiple and cross-scale factors proved more difficult. It must be noted that our attempts to construct a panarchy (see Rogers et al., 2008) in order to understand the multiple, cross-scale linkages were largely unsatisfactory. Despite the large body of theoretical work, with little practical guidance[20], the exercise was primarily one based on judicious, but unvalidated, opinions of where different components lay on the loop (see Figure 2.2). Whilst some authors have retrospectively placed a system on the loop (see various case studies in Berkes et al., 2003), as we did (Chapter 4), describing the scaled and nested effect was more challenging, the result is a limited analysis that remains to be further developed. Given that the 'resilience approach' is still in a strongly exploratory and developmental phase this is not surprising and offers an exciting challenge for future work.

Reflections also revealed that a certain amount of discomfort was experienced in 'compartmentalising' attributes in systems diagrams such as those shown above. At times one specialist felt that this was merely replacing one simplistic approach with another. Whilst these concerns cannot be ignored, it is important to stress that systems diagrams are a *heuristic for the co-construction of a common understanding*. They cannot replace - but should rather complement – narratives. It has an important function of encouraging specialists to appreciate social, economic, ecological and political aspects that comprise a system. The value of diagrams lies in their relationship to emergence. They are not about simplification but rather 'complexity reduction' where the principles are drawn to the fore rather than trying to reduce the system to simplistic cause-effect relations.

The use of scenarios was not new terrain for the team and some reflections on their value were offered in Chapter 5. However their use within the field of resilience analysis was untried. Tensions therefore existed regarding the 'right' way to develop scenarios (namely that they lie somewhat on the edge of probability) and the desire to develop ones that were plausible. The need to understand the role of the scenario in this context is critical. Scenarios do not act as instruments of prediction but rather they can articulate a spectrum of possibilities based on current understanding of patterns and processes. This issue is not about 'getting it right' or about having one better scenario than another, but rather about understanding and deliberating the issues intrinsic to a particular future state and how the collective can respond to inevitable change (or alternatively put, embracing emergence). This was evident in both the team meeting and at a complexity conference in Arizona (see Chapter 1). On reflection the team expressed dissatisfaction with the lack of application of the scenario process to further planning – without this, the process was regarded as incomplete. The value in scenario development is in taking them into a strategic planning environment – either collaborative planning or development of a vision, for example.

The collaborative *development* of scenarios is an important process in articulating and reviewing the issue of resilience and degradation – be this socio-economic or environmental, or both. Using the systems dynamics diagrams in scenario development had the advantages

[20] We acknowledge the workbook (Resilience Alliance 2007) but still found difficulty regarding decisions on where to place the system and how to examine the composite effect

of not only refining these but also consolidating them into a planning process. As mentioned, it is in their co-construction that real meaning, learning and progress is made In this case the exercise strengthened the conceptual grounds for claims regarding vulnerability or resilience, but we have yet to take forward the process into planning forums. There value, for example in the realm of strategic planning in the water sector (i.e. Catchment Management Strategy development) has yet to be tested.

The resilience analysis given above (Section 6.1), provides a diverse perspective of status of the catchment as it is (current state), and as it is likely to be in 25 years time. These help us deliberate the future and more broadly about the unknown and the uncertain, thereby providing a mechanism for practitioners to consider their likely responses to threats and unforeseen changes. The articulation of the scenarios also provides grounding for ideas thus serving as points of engagement in multidisciplinary environments. Without such scenarios the practicalities of engagement and dialogue become difficult. The major value of the scenarios is therefore to act as a point of departure for engagement, comparison and reflexive learning. In a sense the scenarios provide a platform for broadening thinking of how to handle and respond to possible futures.

6.3 Conclusion

In conclusion, this is a time of transition for natural resources governance in South Africa. The important role of new sources of leadership such as those evident in the Catchment Management Agency, and an increasing number of inter-sectoral initiatives, has been highlighted through a systems approach. In particular, their role in the transformation of (water resources) management will be to ensure that the important feedback loops between policy, practice, reflection, action and learning are in place. The resilience analysis has also pointed to key slow variables and other aspects of resilience, such as governance, innovation and social capital that require attention in the catchment.

Ultimately we would suggest that the process of attempting a resilience analysis – and indeed the wider acceptance of the key concepts – has enormous potential to shift the discourse on degradation, vulnerability and livelihoods. The reorientation requires an exploration of scale, multiple linkages and relationships, 'surprise', unintended consequences and attention to drivers and processes. One is not just examining the 'state' of system alone but also the patterns and configurations within a 'whole' system. By acknowledging complexity one works with rather than constrained by system dynamics, being better prepared for emergence and opportunity and emphasising learning and adaptation.

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