Wetland Health and Importance Research Programme

7

Assessment of the Environmental Condition, Ecosystem Service Provision and Sustainability of Use of Two Wetlands in the Kamiesberg Uplands

Authors: D Kotze, H Malan, W Ellery, I Samuels & L Saul
Series Editor: H Malan

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WETLAND HEALTH AND IMPORTANCE RESEARCH PROGRAMME

7 ASSESSMENT OF THE ENVIRONMENTAL CONDITION, ECOSYSTEM SERVICE PROVISION AND SUSTAINABILITY OF USE OF TWO WETLANDS IN THE KAMIESBERG UPLANDS

Report to the
Water Research Commission
by

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Front Cover: Bakleivlei near Leliefontein, Kamiesberg, Namaqualand, South Africa
Photograph: N Job
Inset: Matjieshut, Kamiesberg, Namaqualand, South Africa
Photograph: I Samuels

PREFACE

This report is one of the outputs of the Wetland Health and Importance (WHI) research programme which was funded by the Water Research Commission. The WHI represents Phase II of the National Wetlands Research Programme and was formerly known as "Wetland Health and *Integrity*". Phase I, under the leadership of Professor Ellery, resulted in the "WET-Management" series of publications. Phase II, the WHI programme, was broadly aimed at assessing wetland environmental condition and socio-economic importance.

The full list of reports from this research programme is given below. All the reports, except one, are published as WRC reports with H. Malan as series editor. The findings of the study on the effect of wetland environmental condition, rehabilitation and creation on disease vectors were published as a review article in the journal Water SA (see under "miscellaneous").

An Excel database was created to house the biological sampling data from the Western Cape and is recorded on a CD provided at the back of Day and Malan (2010). The data were collected from mainly pans and seep wetlands over the period of 2007 to the end of 2008. Descriptions of each of the wetland sites are provided, as well as water quality data, plant and invertebrate species lists where collected.

An overview of the series

Tools and metrics for assessment of wetland environmental condition and socio-economic importance: handbook to the WHI research programme by E. Day and H. Malan. 2010. (This includes "*A critique of currently-available SA wetland assessment tools and recommendations for their future development*" by H. Malan as an appendix to the document).

Assessing wetland environmental condition using biota

Aquatic invertebrates as indicators of human impacts in South African wetlands by M. Bird. 2010.

The assessment of temporary wetlands during dry conditions by J. Day, E. Day, V. Ross-Gillespie and A. Ketley. 2010.

Development of a tool for assessment of the environmental condition of wetlands using macrophytes by F. Corry. 2010.

Broad-scale assessment of impacts and ecosystem services

A method for assessing cumulative impacts on wetland functions at the catchment or landscape scale by W. Ellery, S. Grenfell, M. Grenfell, C. Jaganath, H. Malan and D. Kotze. 2010.

Socio-economic and sustainability studies

Wetland valuation. Vol I: Wetland ecosystem services and their valuation: a review of current understanding and practice by Turpie, K. Lannas, N. Scovronick and A. Louw. 2010.

Wetland valuation. Vol II: Wetland valuation case studies by J. Turpie (Editor). 2010.

Wetland valuation. Vol III: A tool for the assessment of the livelihood value of wetlands by J. Turpie. 2010.

Wetland valuation. Vol IV: A protocol for the quantification and valuation of wetland ecosystem services by J. Turpie and M. Kleynhans. 2010.

WET-SustainableUse: A system for assessing the sustainability of wetland use by D. Kotze. 2010.

Assessment of the environmental condition, ecosystem service provision and sustainability of use of two wetlands in the Kamiesberg uplands by D. Kotze, H. Malan, W. Ellery, I. Samuels and L. Saul. 2010.

Miscellaneous

Wetlands and invertebrate disease hosts: are we asking for trouble? By H. Malan, C. Appleton, J. Day and J. Dini (Published in Water SA 35: (5) 2009 pp 753-768).

EXECUTIVE SUMMARY

INTRODUCTION AND RATIONALE

This study has involved investigation of the geomorphology, vegetation and utilisation by humans, of two wetlands (Langvlei and the Ramkamp) which are situated just outside of Leliefontein in the Kamiesberg area of the Northern Cape. This was accompanied by a literature review of the historical settlement patterns and land-use in the area. The information collected was used to establish the environmental condition of the wetlands, the ecosystem services they are likely to deliver and how sustainable the use of those systems is likely to be. Sustainability was assessed both from a sociological, and an ecological, point of view. It is hoped that the results of these studies will help inform various conservation initiatives that are being undertaken in the area. These wetlands serve as an invaluable resource and it is essential that they be managed in order to optimise both the preservation of biodiversity, and to support the people who depend on these systems for their livelihoods.

This study represents a joint initiative between two research groups, namely:

- The WRC-funded Wetland Health and Importance Research group, undertaken by members of the Freshwater Research Unit (FRU), University of Cape Town (Heather Malan); the Centre for Environmental and Agricultural Development (CEAD), University of KwaZulu-Natal (Donovan Kotze); and Rhodes University (Fred Ellery).
- The Agricultural Research Council (ARC): Range and Forage Unit who are undertaking on-going research in the Kamiesberg area (Igshaan Samuels and Lee Saul (the latter now with CapeNature)).

The specific objectives of this collaborative project were to:

1. Test the applicability of “WET-Health” on Langvlei and Ramkamp in order to assess the environmental condition (health) of these wetlands;
2. Test the applicability of “WET-EcoServices” on Langvlei and Ramkamp in order to assess the ecological functions supplied by the two wetlands; and
3. Develop and test the tool “WET-SustainableUse” during the course of the project in order to evaluate the sustainability of wetland use in the area.

MAJOR FINDINGS

The main findings of the study are summarised in the rest of this section.

Historical and social context

- There is a long history of use of the wetlands in the Kamiesberg area. Even for the present generation they represent an important resource to a community that is relatively poor.

Geology, geomorphology and soils

- The geomorphological data for Langvlei suggests that erosion is an important process that lowers the elevation of bedrock and leads to reworking of sediments in the valley, creating a low-gradient valley that supports wetland habitats.

Vegetation of the area

- It appears that past human use (cultivation and heavy grazing pressure) have contributed to a change in extensive parts of the wetland from a mixed renosterbos/ sedge and grass vegetation to becoming dominated by renosterbos, currently the most abundant plant species in the Kamiesberg wetlands.
- A preliminary framework for assessing the condition of wetlands in the Kamiesberg wetlands using specific indicators of condition is proposed (Table E2).

Assessment of environmental condition

- The health scores for the three different components (hydrology, geomorphology and vegetation) assessed using the tool "WET-Health" are summarised in the table below. The Present State categories and the Trajectory of Change symbols are given. Present State categories can range from A (pristine) to F (severely impacted). A downwards-pointing arrow indicates that the wetland is considered to be on a negative trajectory, horizontal arrow that the condition is considered to be stable.

Table E1: Summary of the Present State categories and the Trajectory of Change symbols obtained for the wetlands using WET-Health

	Langvlei				Ramkamp
	HGM 1	HGM 2	HGM 3	Entire wetland	
Hydrology	E→	B↓	A→	**B↓**	**A →**
Geo-morphology	B→	A↓	B→	**B↓**	**A →**
Vegetation	D→	D→	C→	**C/D →**	**C →**

Table E2: Indicators of condition for the vegetation of Namaqualand Granite renosterveld and Thresholds of Potential Concern (TPCs) given for: (1) grazing value for livestock and (2) value for biodiversity (adapted from Milton, 2007)

Indicator	**Measurable variable**	**Threshold value**		**Rationale**
		Grazing	**Biodiv -ersity**	
Renosterbos abundance	% canopy cover	>20%	>30%	Renosterbos has very low value as livestock forage and for biodiversity value, its single-species dominance is not desired because it reduces the species richness of native plants
Carpobrotus edulis Natural sandy areas present: Limited natural sandy areas:	% canopy cover	 >15% >5%	 >15% >5%	*C. edulis* has a low value as livestock forage. It is well adapted to colonizing bare sandy areas, which may be natural (e.g. in the case of some riverbeds) or as a result of human disturbance.
Alien weeds	% canopy cover	>15%	>5%	Any aliens compete with indigenous plants. For grazing, some may be of forage value
Indigenous perennial grass seasonal wetness: temporary wetness:	% canopy cover	 <40% <20%	 <10% <10%	Perennial grasses provide one of the principle sources of forage in the wetlands, and would have been naturally abundant in un-degraded wetlands, particularly in temporarily wet areas. In seasonally wet areas sedges, rushes and red-hot pokers are often dominant
Abundance of perennial grasses relative to annual grasses	Canopy cover: annuals/ perennials	>0.3	>0.3	Annuals are much less valuable than perennials for livestock, particularly in terms of providing dry-season forage. Naturally, perennials would have been much more abundant than annuals. Also, several of the annual grasses are aliens.

- The WET-Health assessment indicates that for the Langvlei wetland the condition is deteriorating with regard to hydrology and geomorphology. The environmental condition of Ramkamp is considered to be stable.

Assessment of ecosystem services provided by the wetlands

- The following ecosystem services (as assessed using WET-EcoServices) were found to be important for Langvlei: streamflow regulation, sediment trapping, phosphate assimilation, erosion control, biodiversity maintenance, provision of harvestable resources and provision of cultivated foods.
- The following ecosystem services were found to be important for Ramkamp: streamflow regulation, sediment trapping, phosphate assimilation, nitrate assimilation, erosion control, biodiversity maintenance and provision of harvestable resources.
- The overall the delivery of ecosystem services has been most affected in Langvlei hydrogeomorphic unit (HGM) 1, next most affected in HGM 2, followed by HGM 3 and least affected in Ramkamp. In all of the HGM units, the ecosystem service most affected by a change in the ecological state is *biodiversity maintenance*. This highlights that a key area of rehabilitation would be to try to shift the vegetation to a state that is less dominated by renosterbos and supports a greater abundance of grasses and sedges.

Assessment of the social sustainability of wetland use

- Information relevant to social sustainability was gathered based on the guiding questions given in WET-SustainableUse relating to tenure, governance and control. Using this information a systems diagram (Figure E1) was developed for the Kamiesberg wetlands illustrating the human-wetland interactions at a range of spatial scales.
- The primary direct impacts on the Kamiesberg wetlands result from the direct use of the wetland by local households for cultivation, livestock grazing and harvesting of matjiesriet.
- There are important long-established customary practices that continue to promote sustainable use and these practices are re-enforced by “peer-pressure” rather than by a formal authority enforcing rules that dictate particular practices. One important customary practice is the movement of livestock from the higher lying areas in summer to lower lying areas in winter.
- In the past, fencing of cultivated lands was not permitted. After about mid-December, when all of the crops would have been harvested, the crop residues would be available to graze. However, some people are now starting to fence off their croplands and thus the commonage has become more “privatised”.

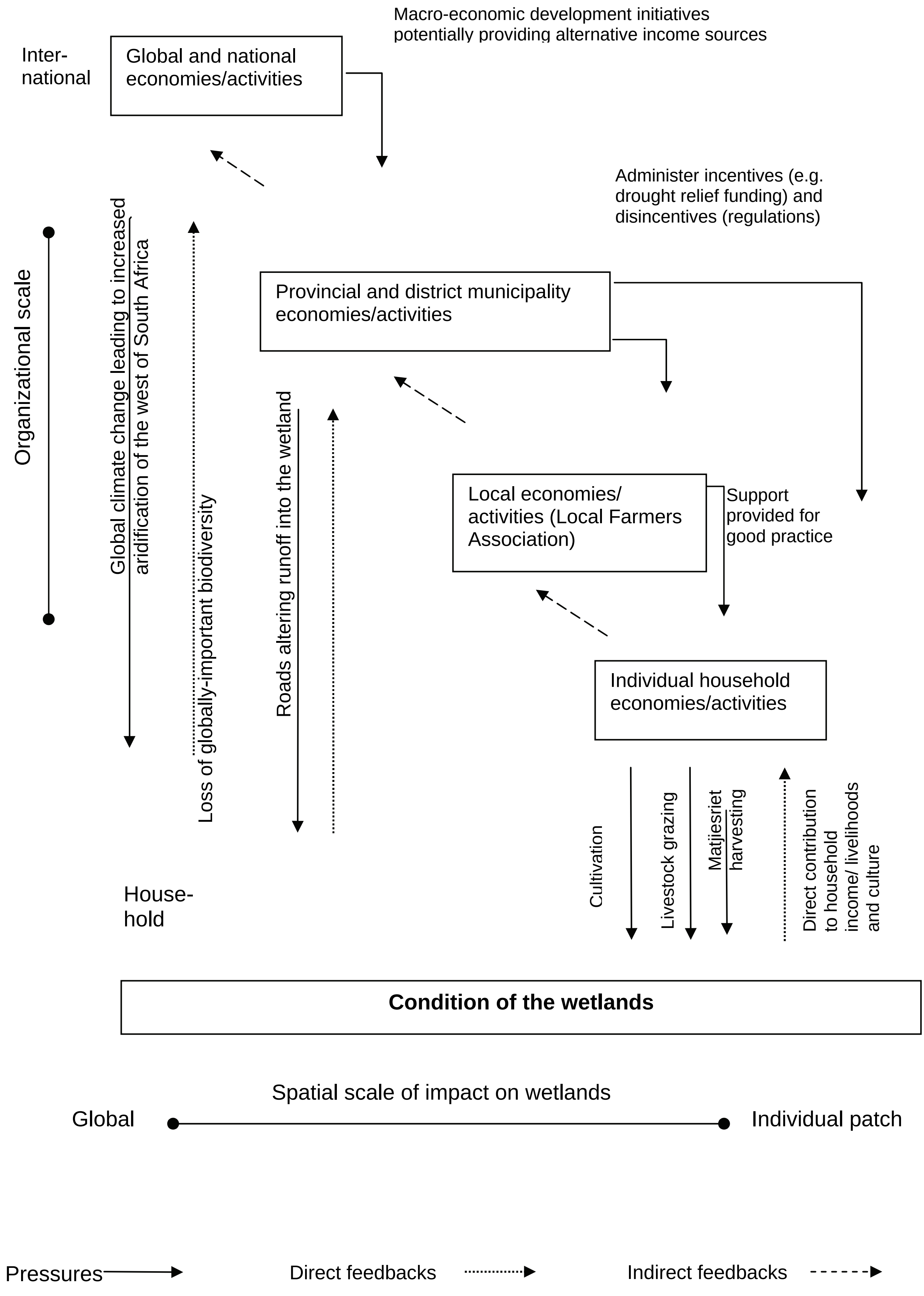

Figure E1: Human-wetland interactions and interrelationships at different spatial scales

Assessment of the ecological sustainability of wetland use

- The overall extent of cultivation in the wetlands has declined, and at the time of the assessment, none of the Ramkamp wetland was cultivated, whilst only approximately 9% of the Langvlei wetland was cultivated.

The impact of cultivation

- The impact of cultivation was assessed using various indicators (applicable to Langvlei only, as there is presently no cultivation in Ramkamp).
- The *level of desiccation* resulting from drains associated with the currently cultivated areas is considered to be moderate.
- The *extent of erosion* caused by the cultivation practices is considered to be moderately low at the scale of the individual cultivated plots. Given that cultivation is confined to a relatively small area (<10%) of the wetland, in terms of the overall geomorphology of the system its effect is relatively small. However, this is likely to increase in the future as a result of advancing erosion in some of the drainage channels used to divert water away from the cultivated lands.
- The impact of cultivation on *soil organic matter* (SOM) accumulation is considered to be fairly high owing particularly to the high level of tillage and the very limited returning of crop residues to the soil.
- Several factors (including diminished SOM levels) contribute negatively to the impact of cultivation on *nutrient retention* and consequently the impact of cultivation on nutrient retention is considered to be fairly high.

The impact of grazing

- When considered from the perspective of vegetation structure and sediment retention, livestock grazing was assessed as having a moderately low impact.
- It is likely that sustained heavy grazing pressure (in addition to other factors) has contributed to the decline in the abundance of indigenous perennial grasses, which affects the condition directly, as well as indirectly by reducing the fuel load potentially able to support periodic fires.

The impact of harvesting of wetland plants

The very selective approach of harvesting *Pseudoschoenus inanus* (matjiesriet), by pulling individual culms, is very efficient in terms of usage of harvestable material. Furthermore, the impacts in terms of disturbance to fauna are likely to be low.

Resilience of the socio-ecological system

- From a geomorphological point of view, the wetlands are fairly resilient, with the location of areas of natural erosion and deposition shifting over time. Their vulnerability to erosion is not particularly high. However, specifically where flow is concentrated in straight diversion channels, erosion is a significant threat.
- The ability of vegetation to recover in previously cultivated areas depends on the extent to which the wetland has been disturbed. The smaller the extent of "good condition areas" adjacent to the recovering patch, the more limited the supply of propagules for colonisation and the less complete the recovery is likely to be.
- The vegetation evolved under fairly high grazing pressure from indigenous herbivores (which have now largely been removed) and it is therefore "pre-adapted" to grazing by domestic livestock. Nonetheless, it appears to be vulnerable to very high levels of grazing.
- Several features contribute positively to the resilience of the social system associated with the Kamiesberg wetlands, namely: the community has a long history of living in the area and dealing with the shocks and disturbances commonly associated with the natural local environment; there are well developed customary practices; and social capital is reasonably abundant.
- However, local governance mechanisms are insufficiently strong to deal with some cases of individuals attempting to monopolize or misuse the natural system. Strengthened partnerships are required with government departments mandated to regulate the use of land and natural resources.

Key management implications arising out of the findings of the study

- Any special attention given to the sustainable management of the wetlands would be well justified given that several important ecosystem services are being supplied by the wetlands.
- The component of environmental condition having the greatest requirement for rehabilitation is the vegetation. In particular, measures are required to increase the abundance of perennial grasses, e.g. through re-seeding. Inclusion of a period of more lenient grazing may be required to assist in the rehabilitation of the vegetation.
- The hydrology and geomorphology of the wetlands are largely intact, and these components are moderately resilient to human use. However, a few drainage channels pose an erosion hazard and threaten to dry out localised portions of Langvlei wetland, and are likely to be worthy of rehabilitation in collaboration with the wetland users.

- The current use of the wetlands for grazing, sedge harvesting and limited cultivation is generally sustainable, although some specific practices highlighted in Section 4 (e.g. reduced tillage) would further enhance the sustainability of use.
- A wealth of local, traditional knowledge exists (for instance, that surrounding the harvesting of wetland sedges) that should be nurtured in support of sustainable use.
- Moderately strong social capital already exists in the area which can be built upon and strengthened to effectively deal with factors, such as the monopolisation of resources by a few private individuals which threatens the long term sustainable use of the natural resources in the area.

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ACKNOWLEDGEMENTS

The authors would like to thank the people of Leliefontein and surrounds who willingly gave of their time to answer our many questions concerning the agriculture, history, social and cultural practices in the area. Thanks also to Nancy Job and Liz Day for their insight and knowledge of the area and to Nancy for providing maps and GIS coverages..

ABBREVIATIONS

amsl – above mean sea level

ARC – Agricultural Research Council

CEAD – Centre for Environmental and Agricultural Development

CPA – Common Property Associations

DEAT – Department of Environmental Affairs and Tourism

DWAF – Department of Water Affairs and Forestry

DWEA – Department of Water and Environmental Affairs

GIS – geographical information system

ha – hectares

HGM – hydrogeomorphic

km – kilometer

MAR – mean annual precipitation

NDA – National Department of Agriculture

PET – Potential evapotranspiration

PGS – Present Geomorphic State

PHS – Present Hydrological State

PVS – Present Vegetation State

SANBI – South African National Biodiversity Institute

SOM – soil organic matter

SPP – Surplus People Project

Spp. – species

TPC – Threshold of Potential Concern

TRANCRAA – The Transformation of Certain Rural Areas Act, Act 94 of 1998

WHI – Wetland Health and Importance (Research Programme)

WRC – Water Research Commission

ybp – years before present

1. INTRODUCTION

1.1 Introduction

Wetlands are vulnerable and threatened ecosystems in South Africa and it is commonly acknowledged that more than 50% have already been lost in this country. At the same time, the pivotal role that these systems play in providing ecosystem services and supporting sustainable livelihoods is slowly being acknowledged. Wetlands in arid or semi-arid areas such as the Northern Cape are especially important resources because they supply grazing and crops (amongst other benefits) during the long dry season. At the same time, they are increasingly under threat due to over-exploitation. In this study the environmental condition of two Kamiesberg wetlands was assessed using "WET-Health", an approach developed by Macfarlane *et al.* (2008). Two tools, "WET-EcoServices" (Kotze *et al., 2*008) and "WET-SustainableUse" (Kotze, 2010) were then applied to the wetlands in order, firstly, to evaluate the benefits the wetlands supply and secondly, to assess the sustainability of wetland use.

This study represents a joint initiative between two research groups, namely:

- The Water Research Commission (WRC) funded Wetland Health and Importance Research group, undertaken by members of the Freshwater Research Unit (FRU), University of Cape Town (Heather Malan); the Centre for Environmental and Agricultural Development (CEAD), University of KwaZulu-Natal (Donovan Kotze); and Rhodes University (Fred Ellery); and
- The Agricultural Research Council (ARC): Range and Forage Unit who are undertaking on-going research in the Kamiesberg area (Igshaan Samuels and Lee Saul – the latter now with CapeNature).

At the same time, a study was being carried out to map and inform the Kamiesberg Municipality of the wetlands in their area (N Job, 2007, pers. comm., Freshwater Consulting Group, Cape Town). A brief summary of the aims of the WRC and ARC research projects is given below, followed by the overall objectives of this study.

1.2 The Wetland Health and Importance Research Programme

A national research programme was initiated in 2003 by the WRC in collaboration with other major role players such as the (then)[1] Department of Environmental Affairs and Tourism (DEAT), the (then) Department of Water Affairs and Forestry (DWAF) and the (then) National Department of Agriculture (NDA) and the South African National Biodiversity Institute (SANBI), in order to optimise wetland conservation. The Wetland Health and Importance (WHI) Research Programme represents the second phase of this national programme. It was initiated in 2006 and is due for completion in 2009. Whilst the scope of the WHI is wide, most of the research activities are concerned with the *assessment* of some or other aspect of wetlands. These aspects may be ecological, social, economic or concerned with the functions provided by these systems.

The main aims of the Wetland Health and Importance Research Programme are to:

1. Develop tools for assessing wetland environmental condition.
2. Develop tools for assessing wetland socio-economic importance.
3. Develop a protocol to assess the loss of wetland function through degradation.
4. Implement a communication programme to advise on the use of assessment techniques developed in the programme.

1.3 The ARC Kamiesberg wetland projects

The research, conducted on the wetlands in Leliefontein by the Agricultural Research Council (ARC): Range and Forage Unit, is part of two projects that the ARC is undertaking in the area. The first project is entitled: “Informing the development of an integrated land-use management plan for the commons of the Namaqualand uplands”. The objective of this project is to develop and pilot a land-use management plan for the Uplands region in a way that enhances the co-existence of biodiversity and rural livelihoods. However, before such a plan can be developed, it is necessary to understand the ecological processes and dynamics of disturbed and undisturbed systems. Wetlands in the Kamiesberg have been identified as special habitats and key resources areas for various livelihood activities, although, most of the wetlands in the region are heavily transformed in terms of land-use.

The second project that the ARC is conducting is funded by BIOTA (Biodiversity Transect Analysis in Africa). This project is entitled “Restoration of degraded systems” and is part

[1]Note that the Forestry division of DWAF has since been incorporated into the Department of Agriculture, Fisheries and Forests, and Water And Environmental Affairs have been linked into a single Department of Water and Environmental Affairs (DWEA)

of BIOTA-Workpackage South-E2. The data on vegetation dynamics and plant functional types and their response to disturbance, obtained from the joint initiative reported here, will be used to advise on the restoration of systems impacted by unsustainable land-use practices. In the Kamiesberg region of Namaqualand, the focus will be primarily on the restoration of impacted wetland systems. Use will be made of local knowledge and experiences of land-users in the Kamiesberg to develop restoration technologies.

1.4 Objectives of this study

The specific objectives of this collaborative project were to:

1. Test the applicability of "WET-Health" on Langvlei and Ramkamp in order to assess the environmental condition (health) of these wetlands.
2. Test the applicability of "WET-EcoServices" on Langvlei and Ramkamp in order to assess the ecological functions supplied by the two wetlands.
3. Develop and test the tool "WET-Sustainable Use" during the course of the project in order to evaluate the sustainability of wetland use in the area.
4. Using the results from the above, to advise on management of the Kamiesberg wetlands.

1.5 Who might find the study useful?

The following people might find the study useful:

- Those intending to apply the tools WET-Health (Macfarlane *et al., 2*008), WET-EcoServices (Kotze *et al., 2*008) and WET-SustainableUse (Kotze, 2010), and who wish to view the outcome of the application of these tools to real sites;
- Wetland managers generally, and particularly those managing wetlands in the Kamiesberg area, who wish to make more informed management decisions;
- Those developing spatial plans and environmental policy for the Kamiesberg area; and
- Those wishing to build their understanding of wetland functioning and use.

1.6 The methods used to undertake the study

The two wetlands, Langvlei and the Ramkamp, investigated in this study, were selected based on the fact that they were accessible, included relatively intact portions of wetland and were subject to the typical uses made of wetlands in the Kamiesberg. In order to give context to the study, background information was gathered based on the literature, field investigation and interviews with local people, on the following:

- the social and historical background to the Kamiesberg area;
- the geology, geomorphology and soils of the area; and

- the vegetation of the area and its response to human disturbance.

The study was based primarily on the application of three assessment tools (which are described in more detail in Chapters 3 to 5) to the two sites:

- WET-Health (Macfarlane *et al., 2*008), for assessing the environmental condition of the wetland, including three components: hydrology, geomorphology and vegetation,
- WET-EcoServices (Kotze *et al., 2*008), for assessing the ecosystem services delivered by a wetland, including supporting, regulating and provisioning services,
- WET-Sustainability (Kotze 2010), for assessing the sustainability of use of a wetland for cultivation, grazing and/or harvesting of plants for craft and construction.

All three of the tools rely strongly on indicators of wetland processes (e.g. disturbance of the soil is taken as an indicator of loss of soil organic matter). These indicators were described in a three-day field visit in October 2007 and another in February 2008. In addition to field observations, interviews were conducted with local people who use the wetlands. The ARC had already been working in the Kamiesberg area for several years, developing good relations and trust with local people, and this provided a very useful entry point for the study.

2. SITE DESCRIPTION

2.1 Historical and social context of the Kamiesberg area
by ARC: Range and forage unit

2.1.1 Early history

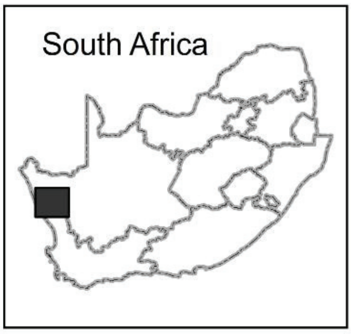
Prior to the arrival of the European settlers, Namaqualand was inhabited by San hunter-gatherers and a Nama speaking branch of the nomadic Khoikhoi (Webley, 1984). The Khoikhoi pastoralists kept small stock and cattle, and engaged in transhumance to take advantage of seasonal differences in grazing and water resources (Hoffman *et al., 2*000). In the area of the present day Leliefontein reserve, Namaqua herders would move their stock approximately 100 km from the Kamiesberg to the "Onderveld", which had a milder climate for lambing and better grazing in winter (Webley, 1984).

The arrival of European settlers in 1652 resulted in many Khoikhoi being robbed of their herds, losing their grazing lands and the subsequent disruption of their traditional transhumance as these early colonists moved into the interior (Webley, 1984; Boonzaaier *et al., 1*996). Many Khoikhoi were driven to slavery and serfdom, and by the 1800s little remained of their pastoralist lifestyle as many took advantage of the increased demand for wage labour in the urban and mining centres (Boonzaaier *et al., 1*996).

2.1.2 Establishment of the Leliefontein reserve

Displaced people of the Khoikhoi found refuge at various mission stations in the Leliefontein district of the Kamiesberg (Figure 2.1). The establishment of mission stations in the early 1800s was encouraged as a means to stabilise indigenous communities by promoting the cultivation of crops. However, some farmers continued to move with their herds in semi-nomadic patterns in the commons surrounding the mission station. Grazing in the immediate vicinity of the station soon became depleted, and smaller permanent settlements and mobile stock posts were formed at some distance from the core village (Boonzaaier *et al., 1*996).

These stock posts were to become an integral part of stock farming in the communal reserves. In 1840, the official boundaries of the Leliefontein communal reserve were laid down and a "ticket of occupation" was issued to the Namaquas, providing certainty and security with regard to their occupation of this land (Surplus People Project [SPP] 1995).



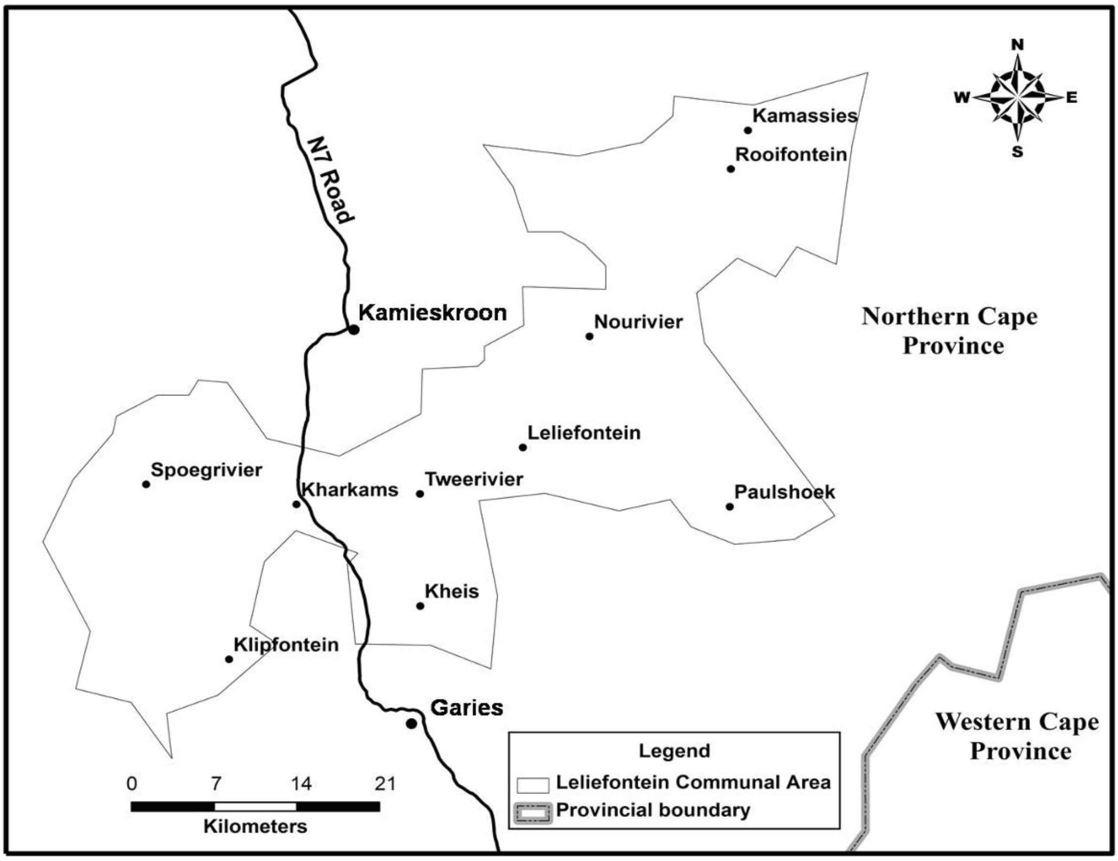


Figure 2.1: Map to show the general location of Leliefontein.

However, the state never recognised their claim of ownership, and only awarded them occupational status. The existing boundaries of the reserve are still disputed as many inhabitants claim that dispossession continued even after formal recognition from the Cape Colony (SPP 1995, May 1997).

2.1.3 The apartheid era

By the 1950s schools and shops became commonplace within the reserve, and people's lifestyles became more sedentary in nature as they settled in core areas. As a result, it became increasingly difficult for families to stay with their herds without help from hired herdsman, who could live with the livestock at stock posts scattered throughout the commonage. Furthermore, many reserve residents were providing wage labour to the mines as a supplement to farming, resulting in a flow of workers out of the communal villages. Upholding links with the reserve and farming was seen as a security net when retrenchments occurred on the mines (Boonzaaier, 1987).

The Rural Coloured Areas Act of 1963 separated residential and agricultural areas, forcing families to leave their stock posts and settle within villages (Archer *et al., 1*989). The official aim of this scheme was to act as a solution to overgrazing and erosion and to develop more profitable farming practices (Boonzaaier, 1987; Archer *et al., 1*989). In 1984, the Leliefontein reserve was subdivided into 47 economic units, ranging between 1500 and 6175 ha (Archer *et al., 1*989). Thirty units were rented to individuals, while only 17 were set aside for communal use. The economic units discriminated against poorer farmers who could not afford to apply for units, restricting many to the smaller communal units.

As a result, many opposed the privatization of the land. Four communal farmers contested the issue in court and the case ended in a Supreme Court victory in their favour (Archer *et al., 1*989). By the late 1980s, land in the Leliefontein reserve had returned to communal tenure (Archer *et al., 1*989; SPP, 1995) and the system of economic units had been abolished.

2.1.4 The post-apartheid era

After the first democratic elections in 1994, the old Land Acts were abolished and a policy of restitution and land reform was adopted resulting in the purchase of additional grazing lands. Today the Leliefontein reserve covers an area of 279 000 ha (SPP, 1995; Hoffman *et al., 2*000). The Transformation of Certain Rural Areas Act, Act 94 of 1998 (TRANCRAA) was the first comprehensive legislation to reform communal land tenure in South Africa (Wisborg and Rohde, 2003). TRANCRAA aims to transfer land ownership of 23 "coloured rural areas", or so-called Act 9 areas, that are used in common by the community. The transitional phase of TRANCRAA was implemented in six rural areas of Namaqualand from January 2001 to January 2003. From November 2002 to January

2003, referenda over land ownership were held and people voted for either Common Property Associations (CPA) in terms of the CPA Act, Act 28 of 1996; municipalities or trust ownership and individual title. Recently the Minister of Agriculture and Land Affairs made the decision to transfer the land to the Kamiesberg Municipality as chosen by the majority of people who participated in the poll.

2.2 Geology, geomorphology and soils of the Kamiesberg area

by W Ellery

2.2.1 Regional geology and topography

A description of the geological history of the area is given in Appendix 1. The regional geomorphology is a product of specific geological processes co-incident with two uplift events that took place 20 million and 5 million years before present (ybp) respectively, which jointly led to continental uplift of approximately 350 m in this area (McCarthy and Rubidge, 2005). Creation of relief by uplift caused incision of streams into bedrock that carved valleys. North of the Olifants River at Klawer, the land rises imperceptibly through gently undulating land such as that between Garies and Kamieskroon and the lowlands to the west provide an indication of how much the land rises. In this area, including Leliefontein, the topography is rugged, mainly comprising weathering granite and meta-sediment that lie at an altitude between 800 m and 1500 m above mean sea level (amsl).

The Langvlei wetland lies at an altitude of approximately 1150 mamsl in a valley oriented roughly from north to south. It is surrounded by steeply sloping metamorphosed granitic rock that rises several hundred metres above the valley floor and slope steeply into it. In contrast, the Ramkamp wetland exists in a nearby valley at an altitude approximately 200 m higher such that the surrounding granitic hills rise from the valley floor to a much lower height relative to the wetland surface.

2.2.2 Geomorphology of the Langvlei wetland

The Langvlei Wetland (Figure 2.2, also Figures 3.4 and 3.5) is situated on sedimentary fill that occurs between gently sloping valley-fill sequences between extensive areas of steeply sloping granitic rock, which rises steeply from the more gently sloping valley-fill and wetland deposits. Given the steep nature of the terrain outside of the valley floor and margins, and the shallow and skeletal nature of soils, runoff entering the valleys must be fast-flowing and discharges reasonably high for a given rainfall event size. This water transports with it sediment that is gradually accumulating as valley-fill, typically on moderately to gently sloping terrain. The wetlands are situated on the floor of valleys where slopes are very gentle at typically less than 5%.

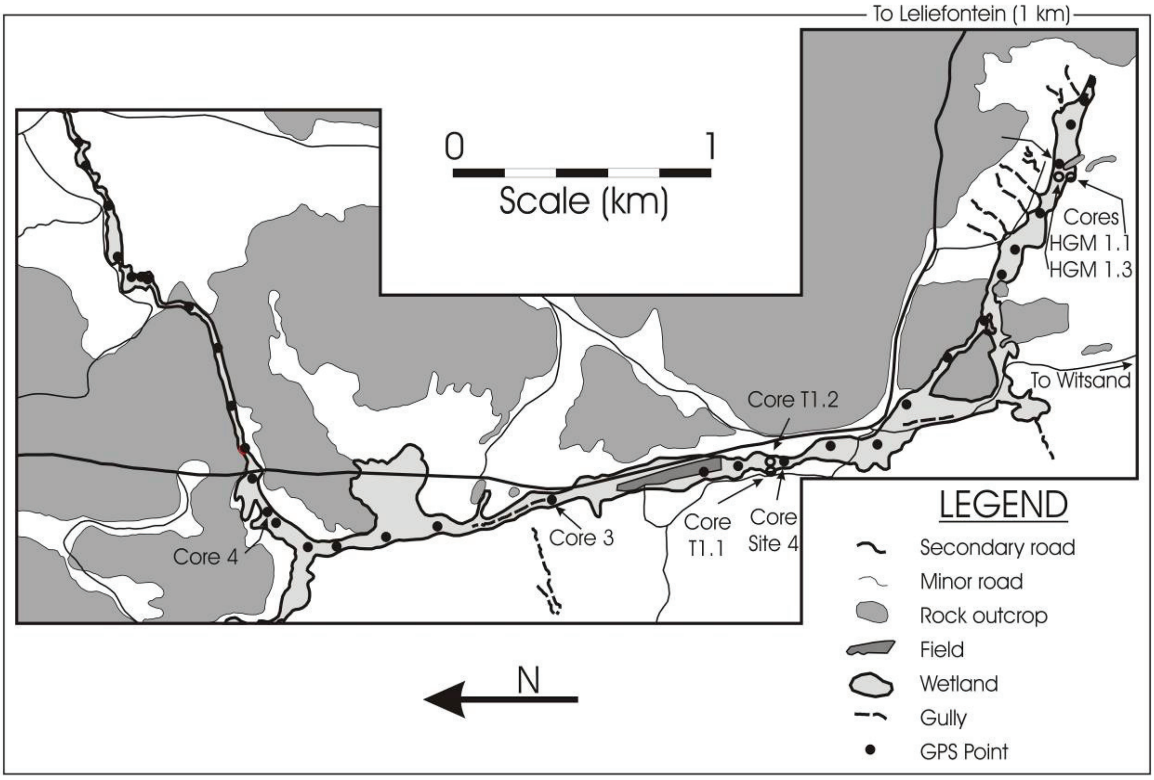


Figure 2.2: Map of the Langvlei wetland showing the extent of rock outcrop in the catchment, roads, agriculture at the time of the survey and erosion features in the wetland and its catchment. The GPS points at which elevation was measured and the approximate locations of core samples are also shown.

A number of erosional gullies exist in the catchment, particularly in the south-east where the head of the catchment rises steeply to the higher lying ground where Leliefontein is situated and the mountainous terrain is particularly striking. In situations like this where runoff intensities are high and unconsolidated valley-fill sedimentary sequences very steep, the land surface is very vulnerable and natural processes of erosion may be initiated or aggravated by small impacts of human activities. It is tempting to say that this erosion has been caused by the construction of the road to Leliefontein, since most gullies in this area are oriented from the valley floor towards the road, but the construction of the road is only one factor (albeit an important one) amongst several possible contributing factors. Land-use practices on the land in which the gullies are present also cannot be ruled out as an agent stimulating change.

The Langvlei wetland is approximately 6 km long and tends to be very narrow with a mean width of approximately 150 m. Parts of the wetland are channelled, parts of it are cultivated, and there are areas in the wetland where erosion gullies are present. The longitudinal slope of the wetland (Figure 2.3) shows that the valley has a logarithmic longitudinal profile, typical of streams, in which there is a gradual and systematic increase in mean discharge downstream along the valley. Despite having what seems a fairly classic logarithmic longitudinal profile, the slope along the valley floor does not change systematically, as shown by irregular changes in slope along the thalweg of the valley. As such, the stream (wetland) is fluvially segmented by geological controls that exert a strong influence on the valley floor, as illustrated by the occasional confinement of the valley between bedrock outcrops and even the presence of rock outcrop in the wetland itself. This is a feature of the wetland in its upper reaches (between hydrogeomorphic units (HGM) 1 and 2) and its lower reaches (within HGM 3) downstream of the point where the secondary road crosses the wetland. The lowermost half of the wetland has a slope of approximately 1%, which for a wetland of this size (30 ha) is high, suggesting preferential sedimentation at the head of the wetland.

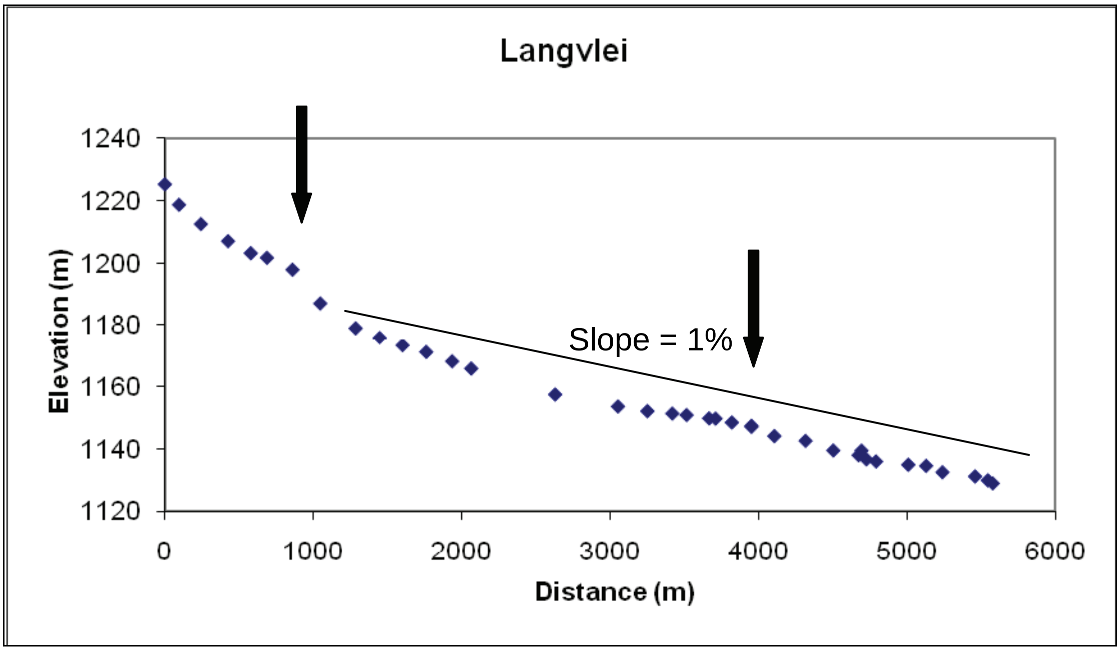


Figure 2.3: The longitudinal slope of the Langvlei wetland determined using differential GPS with a remote base station (accuracy is approximately 1 m in the z-field). The arrows indicate changes in slope caused by the presence of geological controls.

The lower portion of the wetland with the relatively uniform slope of 1% (from approximately 1.3 km downstream) seems to have formed part of a larger catchment such that the uppermost 1.3 km of the wetland as shown in the longitudinal section (Figure 2.3) was a minor tributary of a much larger trunk stream that extended further southwards and flowed northwards along a much larger Langvlei Wetland. Based on this and on the drainage patterns in the area of Witsand (to the south of the area shown in Figure 2.2) it is likely that a large portion of the trunk valley in which Langvlei is situated has been captured by the southward flowing Kysrivier. Based on drainage patterns on the southern side of the Langvlei, where streams at the head of the Kysrivier join it at an extremely high angle (often at a reverse angle), this suggests that stream piracy has taken place such that the head of the Langvlei (due southwards towards Witsand) has been captured by the head of the Kysrivier. It is likely that this will continue to erode headward such that the section of the upper portion of Langvlei wetland will be redirected towards the south rather than towards the north.

2.2.3 Description of the sediments in Langvlei

The sedimentary fill of the Langvlei wetland is mainly sandy to loamy. The finest sediment in the valley fill is typically fine to medium sand in the upper part of the profile, generally coarsening downwards such that gravel (of various grades) is present in the vicinity of the contact of sedimentary fill with bedrock (Figures 2.4 and 2.5). The gravel material was typically quartz, and it was generally angular to slightly rounded, suggesting that it had been transported down the valley, but that it had not travelled a great distance. This is hardly surprising since this wetland was close to the headwaters of its micro-catchment.

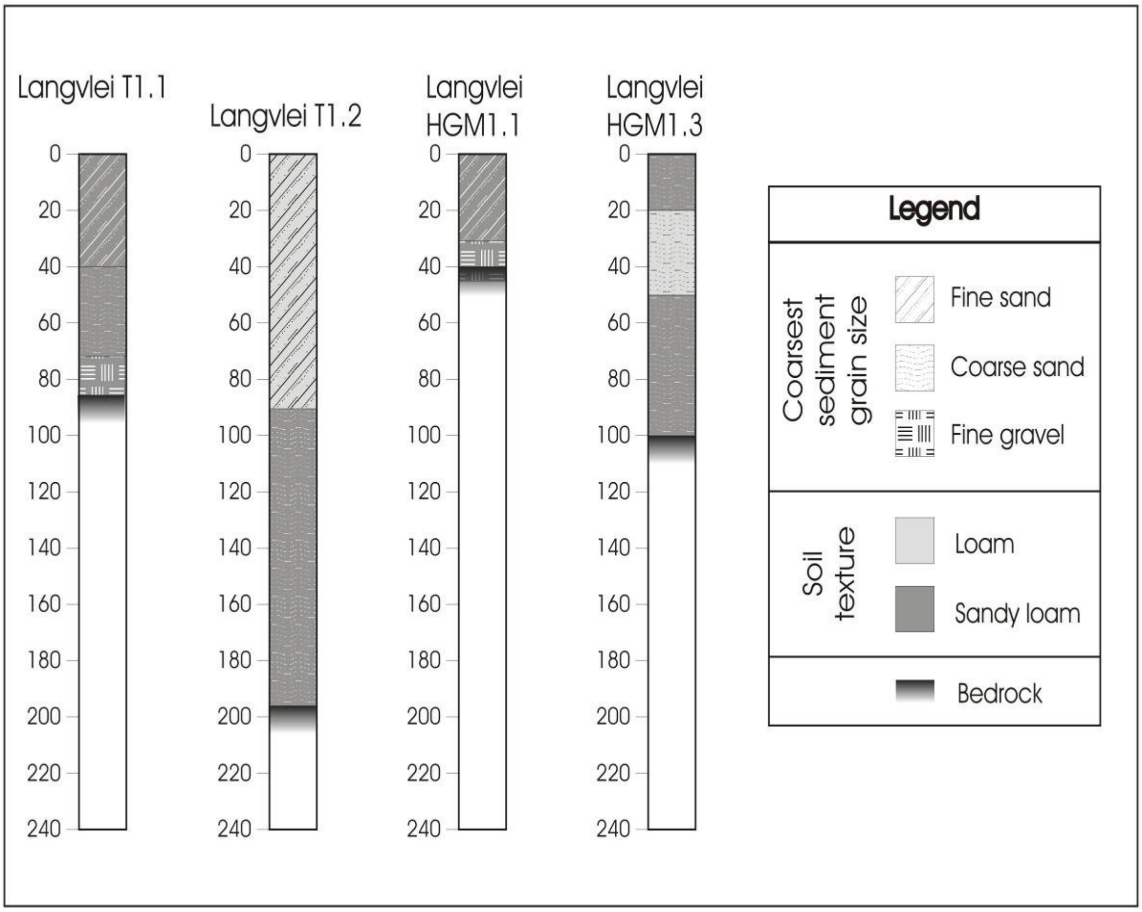


Figure 2.4: Sedimentary cores taken in the Langvlei wetland in November 2007 showing the texture of the sediment as well as an indication of the coarsest grade of material present. The location from which the cores were extracted is shown in Figure 2.2.

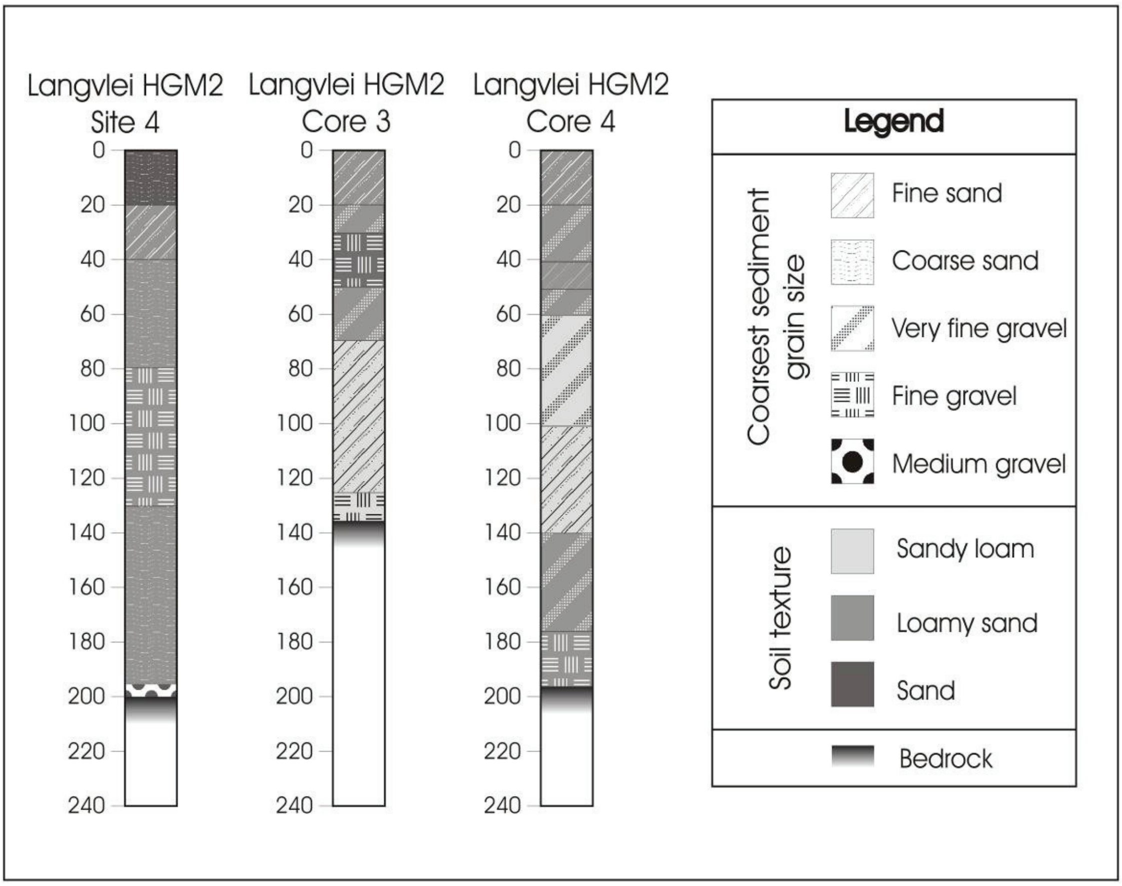


Figure 2.5: Sedimentary cores taken in the Langvlei wetland in January 2008 showing the texture of the sediment as well as an indication of the coarsest grade of material present.

2.2.4 Survey of an erosional gully in Langvlei wetland

An erosional gully in HGM 2 of Langvlei (to the north of Core 3 as shown in Figure 2.2) was investigated by measuring the elevation of the gully floor, gully depth, gully width and characteristics of the bed of the gully floor (Figure 2.6). The gully floor had a longitudinal slope of 0.9%, which was slightly lower than the slope on the valley floor (slope of 1%). For this reason, the gully is deepest closest to its head (just below the erosional nick point) and becomes progressively shallower downstream. The mean depth of the gully over the portion surveyed was 0.70 m (from 0.6 m to 0.9 m depth) and the average width of the gully was 2.25 m (from 1 m to 5 m wide). Ultimately, the bed of the gully and the bed of the valley floor coincide, in this case over a distance of approximately 700 m to 800 m from the erosional nick point. Where the bed of the gully and the land surface meet, a small cone of sandy sediment has been deposited to create a feature of positive relief on the floor of the wetland. Over time, as headward erosion takes place, the toe of the gully is likely to fill such that this gully propagates and gradually fills in an upstream direction. The depth and length of the gully is determined by the available discharge (which we can assume to be relatively constant over the relevant geomorphological timescales – in this case many decades to a few centuries) and by depth to bedrock.

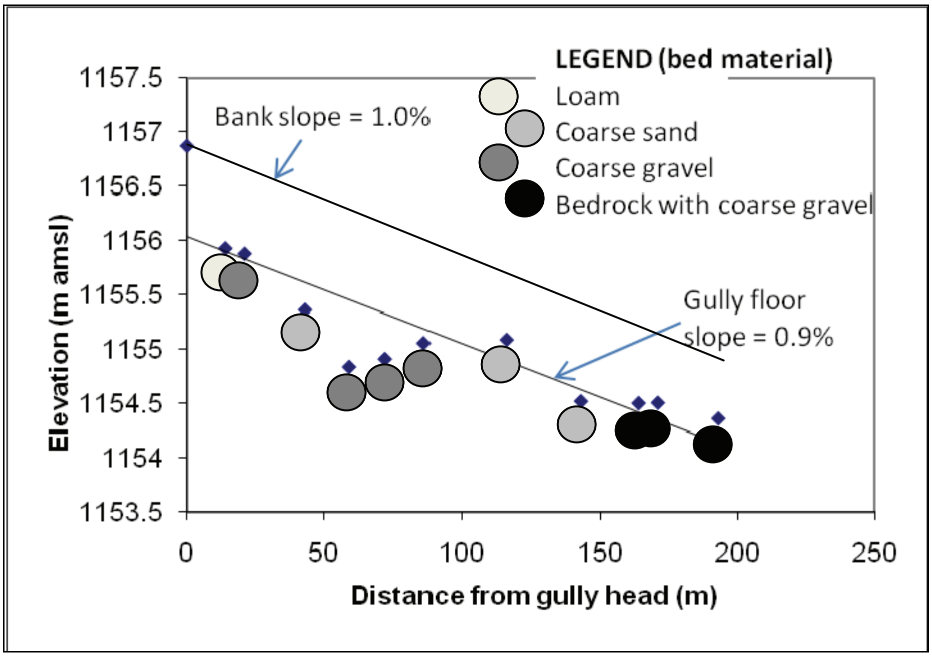


Figure 2.6: The longitudinal slope of the gully in the Langvlei wetland determined using differential GPS with a remote base station (accuracy is approximately 1 m in the z-field). The grain size characteristics of the floor of the gully are indicated as shaded circles below the elevation of the bed of the gully.

The grade of material on the floor of the gully (Figure 2.7) illustrates that there is localised movement of relatively coarse material along the gully floor, and that this material accumulates on or close to bedrock – occasionally on sandy material that has accumulated on bedrock. This is consistent with cores, which typically show a lag of gravel material of varying grade on bedrock beneath sedimentary fill in the valley. Occasionally on the gully floor, there is a gravel layer on sand (not on bedrock), which indicates that either partial filling has taken place locally on the gully floor prior to the deposition of this gravel, or that erosion did not proceed to bedrock due to the presence of a resistant lithology downstream – in this case the bedrock outcrop between 150 m and 200 m from the erosional nick point acts as a local base level that limits the depth of erosion further upstream.

Figure 2.7: A view of the bed of the gully showing typical clast size of material lying on the bed of the gully and the presence of bedrock.

This study illustrates the sorts of processes that shape the valley. The cores in Langvlei wetland contain sedimentary fill that coarsens downwards such that there is typically a drape of moderately rounded pebbles on bedrock, above which there is sand that becomes loamier towards the top. The data suggest that erosion is an important process that lowers the elevation of bedrock and leads to reworking of fill in the valley, creating a low-gradient valley that supports wetland habitats. Further, it seems that valley deepening and widening occurs through gully erosion such that the bedrock floor of the valley is near-flat across the valley, and that sedimentary fill results from infilling of reworked sediments. Over geomorphological timescales relevant to shaping the entire valley, there will be lowering of the land surface as sediment is very slowly exported from the wetland down the valley and bedrock is gradually planed and lowered by these processes, maintaining a valley of this slope and with this thickness of sedimentary fill. It seems likely that variation in the local depth to bedrock is determined by the distance downstream to a local resistant lithology.

2.2.5 Geomorphology of the Ramkamp wetland

As in the case of the Langvlei wetland, the Ramkamp wetland (Figure 2.8) is situated on sedimentary fill that occurs between gently sloping valley-fill sequences between areas of higher-lying granitic rock, which rises abruptly from the more gently sloping valley-fill and wetland deposits. In the case of Ramkamp wetland, which is at a higher mean altitude (approximately 1350 mamsl) than Langvlei wetland (approximately 1150 mamsl), the adjacent rocky slopes are not as high above the valley floor. In addition to having a smaller catchment, the less rugged topography contributes to lower discharges in the Ramkamp wetland than the Langvlei wetland. The Ramkamp wetland at just over 2 km long is much smaller than the Langvlei Wetland, and it is also narrower with a mean width of less than 100 m.

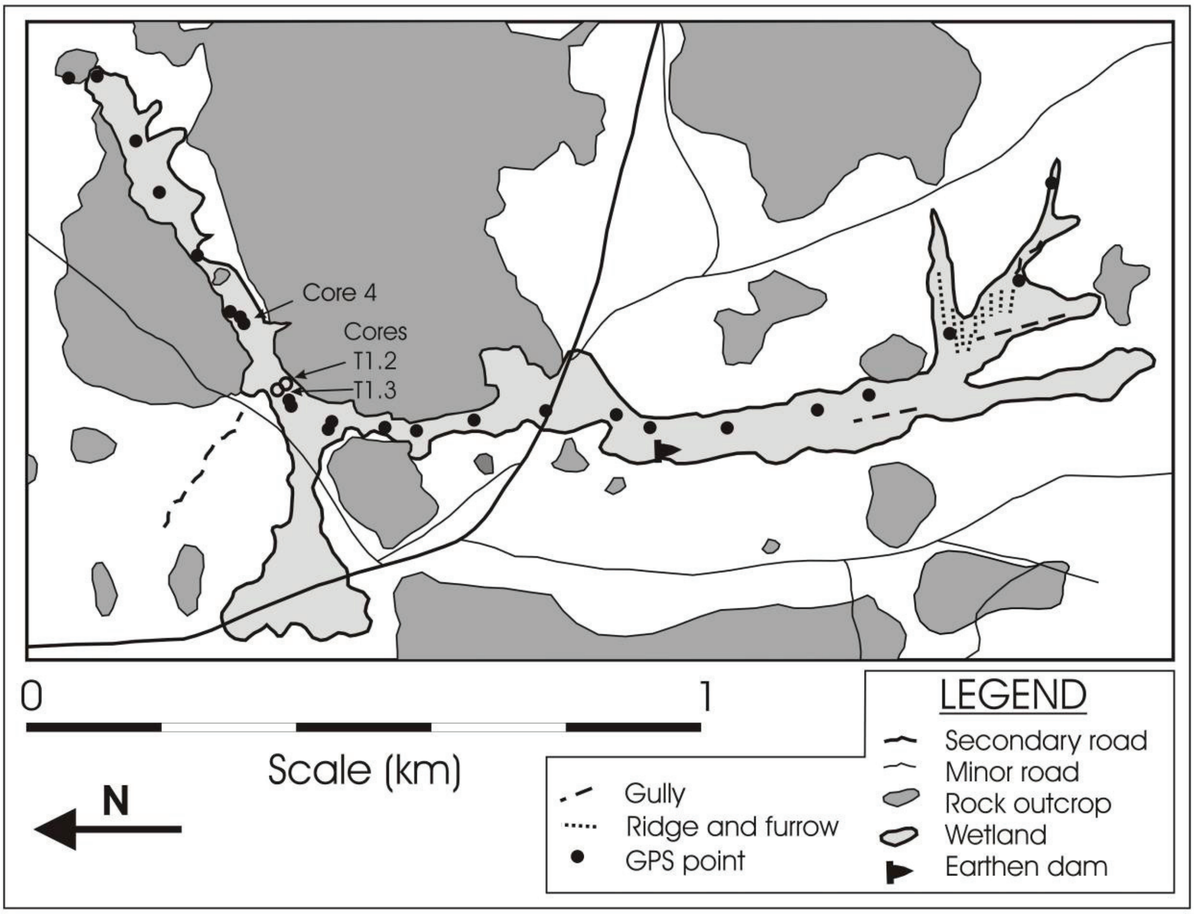


Figure 2.8: Map of the Ramkamp wetland showing the extent of rock outcrop in the catchment, roads, and erosion features in the wetland and its catchment. The GPS points at which elevation was measured and the approximate locations of core samples are also shown.

The longitudinal slope of the Ramkamp wetland (Figure 2.9) shows that the valley has a fairly uniform longitudinal profile with a slope of approximately 2.6%. Despite being fairly uniform the slope along the valley floor does have some irregularities suggesting that the stream (wetland) is fluvially segmented by geological controls that influence the geomorphological evolution of the valley floor, as illustrated particularly by the confinement of the valley between bedrock outcrops in the lowermost third of the wetland. For a wetland of this size, this is a high slope suggesting that sedimentation is taking place preferentially at the head of the valley, which is being held in place by vegetation along the wetland floor.

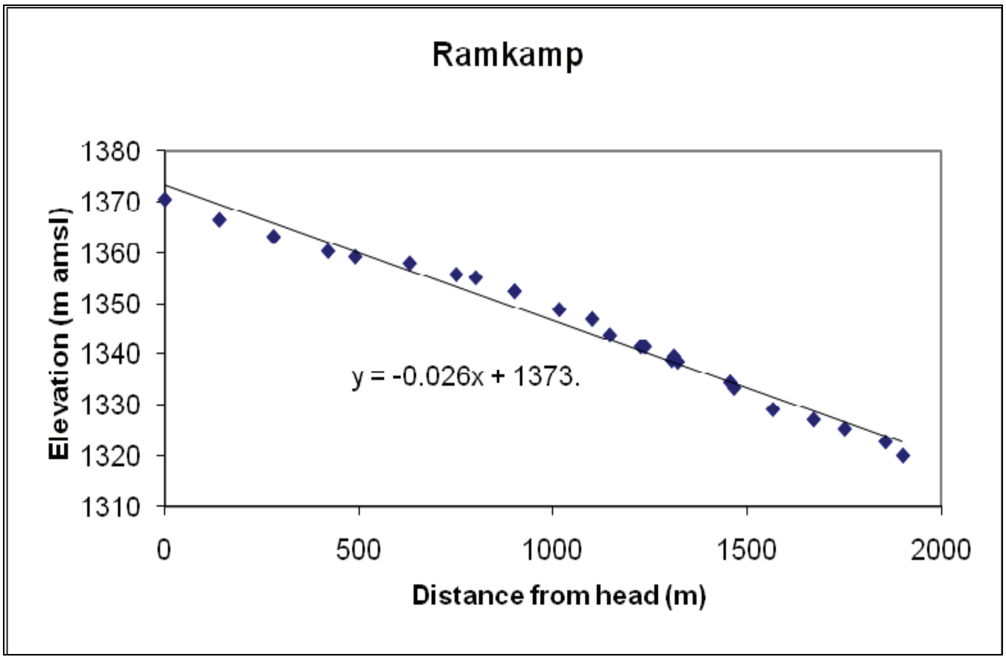


Figure 2.9: The longitudinal slope of the Ramkamp wetland determined using differential GPS with a remote base station (accuracy is approximately 1 m in the z-field).

2.2.6 Description of the sediments in the Ramkamp

The cores taken from the Ramkamp wetland (Figure 2.10) are similar to those of the Langvlei wetland in that they generally coarsen downwards and are characterised by a lag of relatively coarse sediment (sand or gravel) overlying bedrock. Furthermore, a number of small gullies in the Ramkamp wetland are characterised by similar features as the gully described in the Langvlei wetland, suggesting that the sorts of processes shaping the Langvlei wetland and valley are shaping the Ramkamp wetland and valley as well.

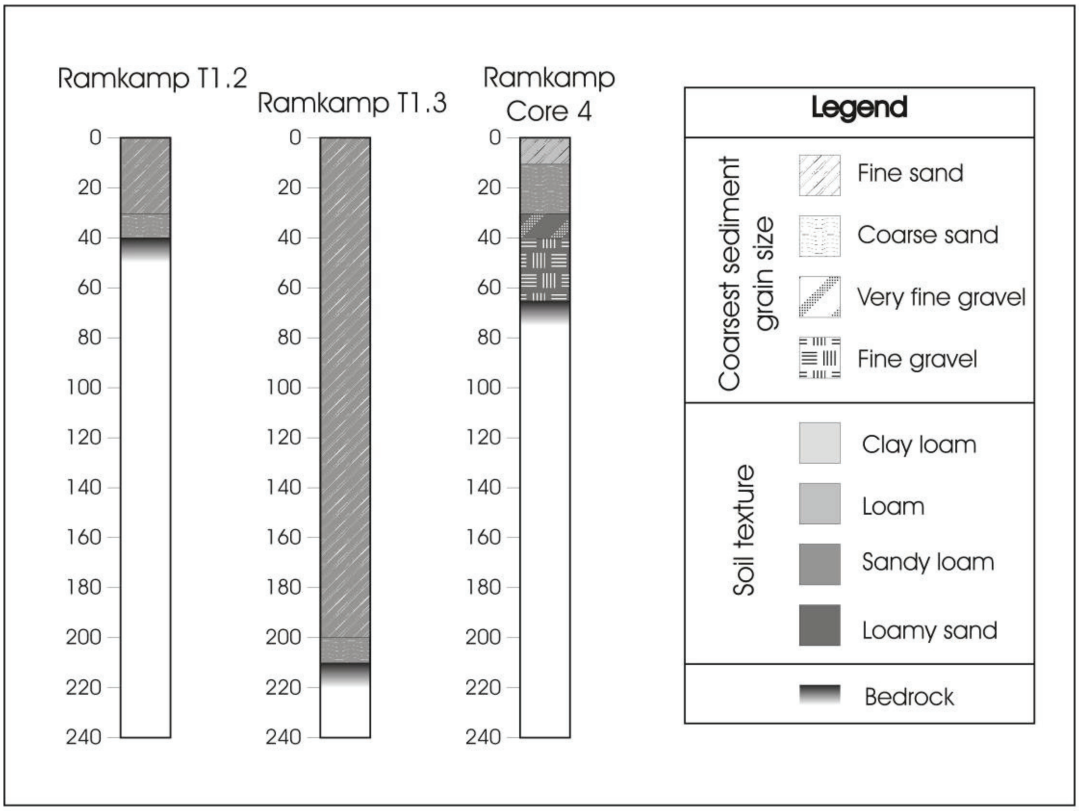


Figure 2.10: Sedimentary cores taken in the Ramkamp wetland showing the texture of the sediment as well as providing an indication of the coarsest grade of material present.

2.3 Vegetation of the Kamiesberg area

by D Kotze and ARC: Range and forage unit

2.3.1 Climate and regional vegetation types

The Leliefontein reserve extends across the Kamiesberg, from low-lying strandveld in the west to the inland border of the Bushmanland plateau. The Kamiesberg is 980 m to 1400 mamsl and consists of gneiss hills and mountains with underlying bedrock of quartzite, which is surrounded by base-rich shallow sandy plains (Cowling *et al., 1*999). Granites and gneisses decay to form rich soils. In the south the Karoo Sequence shales and sandstones give rise to more skeletal soils (Low and Rebelo, 1996). The region falls within the Namaqualand complex of the Great Escarpment, whose combined geomorphologic diversity and changes in soils and climate has a profound effect on plant species diversity.

The reserve experiences unpredictable rainfall with the western areas receiving mostly winter rainfall (May-August) and the eastern areas summer rainfall. The area is generally characterised by a moderate climate (compared to the surrounding lowlands), with the maximum temperatures rarely exceeding 37°C in summer, although the temperature is known to drop below freezing in winter (Hoffman et al., 1997). The vegetation of the region falls within the Succulent Karoo biome (Low and Rebelo, 1996) and is defined as shrubland. The upland area is characterised by *Pteronia glomerata* with pockets of Mountain fynbos which merge into renosterveld vegetation on the high lying rocky areas (Hilton-Taylor, 1994; Petersen, 2004). These fynbos affinities can be recognised by the presence of typical elements from the Proteaceae, Ericaceae, Restionaceae as well as geophytes. The vegetation ranges between 0.5 m and 1 m high and is slightly higher on rocky areas than on plains.

The vegetation type in which both wetlands are located is Namaqualand Granite renosterveld, which is confined to the higher altitude parts of the Kamiesberg area but is also found elsewhere in Namaqualand, mainly on the western escarpment from Skilpad (Namaqua National Park) north to Steinkopf (Rebelo *et al., 2*006; Helme and Desmet, 2007). This vegetation type is characteristically covered with dense, 1-1.5 m tall shrubs dominated by renosterbos (*Elytropappus rhinocerotis*) and other, mainly asteraceous (*Euryops, Arctotis*) shrubs (Rebelo *et al., 2*006).

Namaqualand Granite renosterveld is typically found on the flat, deeper soils of the plateaux, and has thus been heavily transformed by agriculture, primarily by ploughing for cereals and the planting of grazing (Helme and Desmet, 2007). Other vegetation types such as Kamiesberg Granite fynbos are found on the steeper rockier slopes of Kamiesberg, but these have been less heavily transformed. Thus, Kamiesberg Granite renosterveld has undoubtedly been the most heavily impacted vegetation type in the Kamiesberg, and is the one of greatest conservation concerns (Helme and Desmet, 2007). Furthermore, within this heavily impacted vegetation type, the wetlands are probably the most impacted component, given that their high moisture levels make them very attractive for agricultural production in a low rainfall area.

In the Kamiesberg, although still a dominant plant outside of the wetland areas, renosterbos (*Elythropappus rhinocerotis*) grows in association with other shrub species such as gombos (*Oedera genistifolia)* and ysterhout (*Dodonaea angustifolia)*, as described by Helme and Desmet (2007). However, within the wetland areas, renosterbos is the only shrub species present. Two factors that potentially explain this are (1) renosterbos is better able to tolerate the waterlogged conditions encountered in the wetland, and (2) it is better able to invade the wetland following human disturbance.

2.3.2 Current understanding of the historical influence of human use on renosterveld

Because of its high level of transformation there is a lack of baseline data on the condition of renosterveld (Milton, 2007). Furthermore, there is considerable variation in renosterveld composition across a gradient of rainfall quantity and seasonality, further complicating the assessment of renosterveld condition (Milton, 2007). These same problems apply to wetlands occurring within renosterveld. The wetlands of the Kamiesberg and the Namaqualand Granite renosterveld are largely undescribed, and therefore when assessing the condition of wetlands in the Kamiesberg, there are no benchmarks against which to draw comparisons. However, work has been undertaken on renosterbos vegetation in general, and this is considered to have relevance to the wetlands under study.

Renosterveld is confined mainly to fertile shale and granite soils, with rainfall ranging from 250 mm to 600 mm (Krug *et al., 2*004). Renosterveld generally occurs in the transition between fynbos and Succulent Karoo, and consists predominantly of perennial grasses, asteraceous evergreen shrubs, geophytes belonging mainly to Iridaceae, Liliaceae and Orchidaceae (Low and Rebelo, 1996; Rebelo *et al., 2*006). Krug *et al.* (2004) suspect that renosterveld may have always been a shrubland, and that in the past the grassland formed the matrix and the shrubs the patches in the matrix. However, over the last 2000 years it seems that the balance between grass and shrub has shifted under changing human influence as elaborated below.

In the time before (approximately) 2000ybp, renosterveld supported several large herbivore species. The fact that these included mixed feeders (e.g. eland, *Taurotragus oryx*; red hartebeest, *Alclaphus buselaphus* and elephant, *Loxodonta africana*), grazers (e.g. mountain zebra, *Equus zebra zebra*), and browsers (e.g. black rhinoceros, *Diceros bicornis*), indicates that at this time the vegetation included a significant grass and shrub component. Humans inhabiting the renosterveld were the Khoikhoi, and until about 2000ybp were mainly hunter-gatherers, and may have used burning on a relatively small scale to encourage the growth of geophytes, which formed an important component of their diet (Deacon, 1992, cited by Krug *et al., 2*004). Thus, at about 2000ybp, grazing by indigenous ungulates and fire were the two most important processes shaping renosterveld. Unlike fynbos, which is a predominantly fire-driven ecosystem, little adaptation of seeds to dispersal after fire is found in renosterveld species. Instead, the two main seed dispersal vectors in renosterveld are wind (asteraceous shrubs) and animals, mainly through the internal dispersal of seeds (for grasses and geophytes). Another indicator that renosterveld evolved under strong grazing pressure is that species diversity is significantly higher in grazed than in un-grazed renosterveld plots, and there is no significant difference between the less intensively grazed and the more intensively grazed plots, indicating a robustness of renosterveld to grazing (Krug *et al., 2*004). To summarise, although fire played a role in opening up shrubby areas, grazing played a larger role than fire in maintaining high species diversity.

Around 2000ybp, the Khoikhoi acquired sheep and, a little later, cattle, and began using fire on a larger spatial scale, with relatively short rotation times to favour their livestock. Based on archaeological evidence, it appears that sheep were the first to arrive followed by cattle, and over time the ratio of sheep to cattle declined from about 10:1 to 4:1 (Hoffman, 1997). Early settlers record herds of around 10000 to 20000 cattle and sheep (Thom, 1952; Thom, 1954, cited by Krug *et al., 2*004). Areas were intensively grazed by these large herds for a relatively short period and then burnt as the livestock moved onto another area, returning again after 1-4 years (Thom, 1952; Thom, 1954, cited by Krug *et al., 2*004). At the same time, large indigenous ungulates such as black rhino remained utilizing the renosterbos. Overall, this burning and grazing regime led to an increase in the grass component of the vegetation (Krug *et al., 2*004).

In the 17th century, with the arrival of European settlers, came dramatic changes. Almost all of the large indigenous herbivores were eliminated within about 150 years. It is likely that the absence of these herbivores (and probably also a reduced fire frequency) led to the shrublands becoming more closed. In contrast to the nomadic Khoikhoi, permanent settlements with croplands and livestock were established, at first in localised areas, but over the next three centuries or so, increasing in extent. The introduction of extensive artificial watering points reduced the dependency of livestock on natural water sources, thereby increasing the extent and intensity of utilisation.

Because of its accessibility and arable quality, renosterveld was one of the first vegetation types to be transformed following colonisation of the Cape (Milton, 2007), and currently the majority of renosterbos has been converted to agricultural lands. Another important impact associated with European settlement is the introduction of alien species (both grasses and shrubs) that have extensively invaded renosterbos.

Although a considerable extent of renosterveld has been transformed to cultivated lands, it is encouraging to note that this vegetation type shows some level of recovery following abandonment of cultivated renosterveld lands. Walton (2006), by examining old lands that had been abandoned at different times, showed that the longer the time since abandonment, the closer the species composition resembled that of comparable uncultivated areas (through successional recovery). Nonetheless, the oldest abandoned land (about 30 years old) although closest to the uncultivated fields, had not yet fully recovered (Walton, 2006).

2.3.3 The response of renosterbos to disturbance

Renosterbos is the most abundant plant species in the Kamiesberg wetlands (Table 2.1). Thus, in order to be able to assess the environmental condition of the Kamiesberg wetlands and recommend specific actions for improvement/maintenance of this condition, a basic understanding is required of how renosterbos responds to different forms of disturbance. Section 2.3.2 highlighted the potential importance of grazing and fire on the dynamics of renosterveld. Following the approach of Milton (2007), a conceptual model has been developed to assist both in synthesising current understanding and predicting the outcomes of different management options relating to fire and grazing (Figure 2.11). The model is a representation of the interactive effect of grazing and fire on the dynamics of renosterbos, perennial grass and sedge (graminoid) abundance in renosterveld wetlands.

A mixed vegetation situation can degrade to a renosterbos dominated situation under different disturbance regimes (Figure 2.11). Although the three regimes of protection from fire, very heavy grazing pressure and spring burning are extremely different, they all disadvantage the grass component, which would be to the competitive advantage of renosterbos.

Once the system has degraded to a renosterbos-dominated state it can be returned to a mixed vegetation state through autumn burning and lenient grazing provided that there is adequate perennial graminoids remaining or a good supply of graminoid propagules from nearby. Autumn is the flowering time of the renosterbos, and thus burning at this time would kill the bushes before they had set seed. It is, however, likely to be after seed-set for most of the grasses, and thus would favour grass recruitment (Milton, 2007). However, if there was a lack of a graminoid seed source then a system strongly dominated by renosterbos is likely to simply continue replacing itself, even if burning occurs at the most favourable time of the year for graminoids. This suggests that the introduction of propagules of perennial graminoids would assist in this transition from a highly degraded system to a mixed system. This may potentially be undertaken by harvesting ripe seed heads of graminoids in areas where mixed vegetation remains. The best methods of minimizing seed predation and encouraging good establishment of these seeds would need to be established.

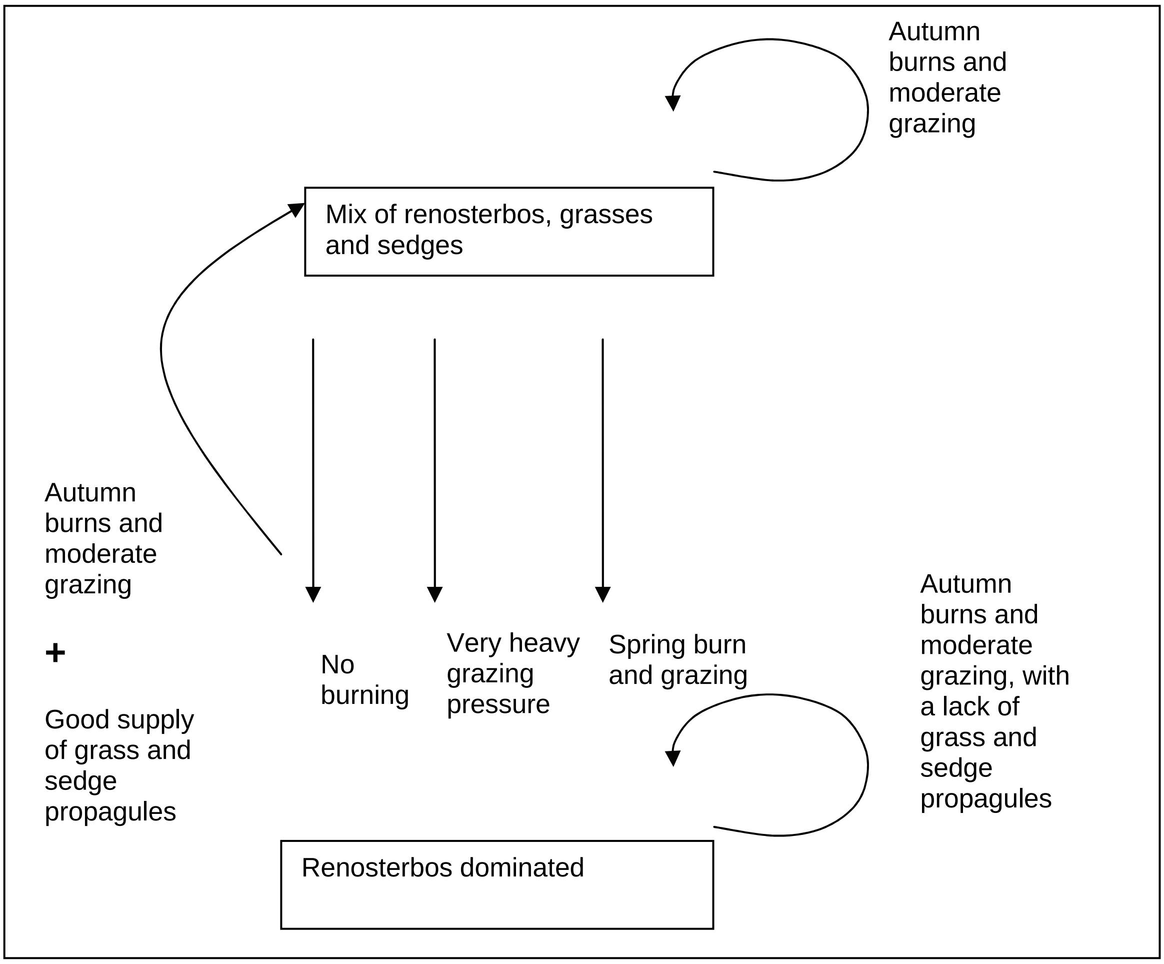


Figure 2.11: Conceptual model to show how cultivation, grazing and fire may interact to change plant composition in the Granite Namaqualand renosterveld wetlands of the Kamiesberg (adapted from Milton, 2007; and Cowling *et al., 1*986).

"Managers at Voëlvlei Nature Reserve have pointed out how difficult it is to burn renosterbos during their control burns, stressing that it needs to be very dry and very hot to catch fire. However, once ignited, renosterbos seems to burn very well because of its high oil content" (Shiponeni, 2003).

It is not always possible and desirable to burn under such conditions and thus managers would generally require a reasonable fuel load from the grass component, and grazing should therefore not be too heavy, so as to allow the accumulation of fuel.

A key aspect of the response of renosterbos to disturbance is its seeding ecology. Renosterbos sheds its seed when it is still immature, during May and June. In germination experiments, Levyns (1926; 1929) showed that if newly shed seeds are sown, the germination is very low under optimum conditions. However, after a year, the germination percentage is greatly improved and this is maintained until the end of the fourth year, after which time there is a steady decline, until by the seventh year the germination percentage is very low. Based on the experimental work of Levyns (1926; 1929) it can be assumed that few viable seeds will persist for more than about 10 years. Levyns (1956) notes further that shade strongly inhibits the growth of renosterbos seedlings, such that even the moderate shade provided by old renosterbos bushes is sufficient to prevent growth.

Thus when managing for the recovery of degraded renosterveld, the critical period is probably the first 10 years, when it would be particularly important to graze leniently and accumulate fuel load for frequent burns. Following this 10 year period, a less frequent burning regime would probably be adequate to prevent the sedges and grasses being out-competed by the renosterbos and the area could probably also be grazed more intensely.

The fact that renosterbos is well adapted to establishing on old lands within wetlands, and then persisting in these areas, was apparent in the Kamiesberg wetlands. Attempts at removing it by local farmers (in order to encourage more palatable forage species) have not been successful (Figures 2.12 and 2.13).

Figure 2.12: Renosterbos seedlings that have recently established on cultivated lands.

Figure 2.13: Young renosterbos bushes, which have regenerated since their clearing, three years before this photograph was taken.

2.3.4 A description of the vegetation of the wetlands

2.3.4.1 The approach used for describing the vegetation

The extent and abundance of species was estimated using 2 m by 2 m plots (45 plots located in the Langvlei and 25 located in the Ramkamp wetland). In each plot, a visual estimate was made of the aerial cover of vascular plant species present in the plot. The plots were described in the summer of 2007/8. Given this timing, it was recognised that the sampling accounted poorly for the spring and autumn aspect forbs and rare plants generally. However, the samples are considered to provide a reasonable basis for describing the more abundant species in the wetlands. Resources did not permit a wet-season visit, and it is strongly recommended that this be undertaken in order to account for the poorly represented taxa and for the rarer plants generally.

In nine of the plots in the Ramkamp wetland and 13 of the plots in the Langvlei wetland, a rapid assessment of the long-term water regime was undertaken. Each of these plots was augered to bedrock with a Dutch screw auger and the depth to water table (if encountered) was measured. Resources did not allow the water table to be monitored over the seasons. Thus, the hydrological zones were inferred from soil morphology (e.g. depth and intensity of mottling and chroma of the soil matrix) according to the method of Kotze *et al.* (1996).

2.3.4.2 Results of the vegetation description

The abundances of the more commonly occurring plants are given in Table 2.1. Although renosterbos was the most frequently occurring species in both wetlands, it is nearly twice as frequent in the Langvlei wetland as in the Ramkamp wetland (Table 2.1). Its abundance is also much higher in the Langvlei wetland, compared with the Ramkamp; with average aerial cover nearly four times as high.

Carpobrotus edulis, a succulent creeping species that is well known as a pioneer in bare sandy areas, is five times more frequent and has a much higher local abundance in Langvlei than in Ramkamp. Annual grasses, which are adapted to colonising disturbed soils, show a similar trend, and are much more widespread in the Langvlei than in the Ramkamp wetland.

In contrast, all four of the most commonly occurring indigenous perennial grasses occur at least three times more frequently in the Ramkamp wetland than in the Langvlei wetland. Two of the sedges, *Carex divisor* and *Cyperus marginatus*, show a much higher frequency of occurrence in the Ramkamp compared to the Langvlei wetland. *Ficinia nodosa*, on the other hand, shows a somewhat lower frequency in the Ramkamp wetland. The frequency for *Mariscus thunbergii* was the same for both wetlands. *Kniphofia uvaria* was absent from Langvlei.

Table 2.1: The most common plants in the Ramkamp and Langvlei wetlands given according to: (1) frequency of occurrence in 2 m by 2 m plots, (2) average aerial cover in the plots where the species occurs (i.e. local abundance) and (3) the characteristic level of wetness under which the plants were generally found

Vegetation functional group	**Species**	**Ramkamp**		**Langvlei**		**Characteristic level of wetness**
		Frequency (%) (n=25)	**Cover (%)**	**Frequency (%) (n=45)**	**Cover (%)**	
Shrubs	*Elytropappus rhinocerotis*	40	10	78	37	_Temporary_ to seasonal
Veldvye	*Carpobrotus edulis*	4	2	20	17	_Temporary_ to seasonal
Annual grasses (species not identifiable)		4	15	29	13	_Temporary_ to seasonal
Perennial indigenous grasses	*Ehrharta calycina*	12	4	4	12	_Temporary_ to seasonal
	Pennisetum macrurum	20	17	2	15	Temporary to _seasonal_
	Pentaschistis spp.	28	16	4	7	_Temporary_ to seasonal
	Tribolium hispidum	28	7	0	0	_Temporary_ to seasonal
Sedges	*Carex divisor*	16	57	2	2	Seasonal
	Cyperus marginatus	36	12	4	38	Temporary to _seasonal_
	Ficinia nodosa	32	32	56	26	Temporary to seasonal
	Mariscus thunbergei	20	17	20	17	Temporary to _seasonal_
"Red hot pokers"	*Kniphophia uvaria*	12	28	0	0	Seasonal to semi-permanent

Note: The frequency and local abundance of annual grasses is likely to have been underestimated given that by the time the survey was undertaken (in the dry season) the annual grasses had senesced several months previously and in some situations had been incorporated into the litter.

The species vary according to the particular level of wetness under which they commonly occur, with species such as *Kniphofia uvaria* confined to the wettest areas, *Ehrharta calycina* confined to the drier areas and species such as *Ficinia nodosa* occurring across a wide range of wetness (Table 2.1). The rushes *Juncus punctorius* and *J. lomatophyllus* were found to be locally abundant but only in a single location in the wettest portion of the Langvlei wetland.

Possible factors accounting for the greater abundance of renosterbos and pioneer species such as *C. edulis* and annual grasses in the Langvlei wetland compared with the Ramkamp wetland are as follows:

- A greater level of cultivation in the Langvlei than in the Ramkamp wetland, with currently, no cultivation occurring in the latter. The topo-cadastral maps for the area (third edition, 2003) show that at that time, the extent of cultivation as a proportion of the overall wetland area in Langvlei, was approximately double that of the Ramkamp wetland. It is postulated that the greater extent of cultivation results in fewer refuge areas in which propagules of perennial graminoids, which are able to compete with the renosterbos, can be produced.
- A lower intensity of use by livestock in the Ramkamp wetland, given that approximately half of the wetland consists of the ram camp, which has a lower stocking rate than the commonage generally (although due to variation in stocking rates and seasonal use of the ram camp this is difficult to establish). A superficial examination of some wetlands in the adjacent commercial farms, which have tended to be utilised at lower stocking rates than on the commonage, also showed a higher abundance of perennial grasses than in the commonage, but this requires further investigation.
- The naturally lower level of wetness in the Langvlei wetland (predominantly temporarily wet) in comparison with the Ramkamp wetland (more seasonally wet areas). It is postulated that while renosterbos is able to easily colonise temporarily wet areas, the competitive ability of the plant may be lowered in the prolonged anaerobic conditions associated with seasonally waterlogged conditions.
- More frequent fires in the Ramkamp wetland, which is burnt approximately every second year or third year, in early autumn. Young renosterbos plants are particularly susceptible to fire, but become less susceptible once they mature after approximately three years (Cowling *et al., 1*986).
- *Ficinia nodosa* is adapted to colonizing open sandy areas where water is available (Gordon-Gray, 1995). This presumably makes it well adapted to colonizing abandoned cultivated lands in the wetland, and would potentially explain why it is

more widespread in the Langvlei wetland than in the Ramkamp wetland. Furthermore, it is a robust tall-growing perennial that forms dense cover, and once established, is likely to exclude competition from other species. According to Wells *et al.* (1986) *Mariscus thunbergeii* is listed as an agricultural weed, which suggests that this species may be adapted to colonizing disturbed areas such as old croplands.

It is interesting to note that *Pseudoschoenus imanus* (matjiesriet) is absent from both the Langvlei and the Ramkamp wetlands but is present very close by in the Witsand wetland (Section 5.3.3). This may possibly be due to specific site factors, or alternatively it may have been eradicated as a result of antecedent cultivation practices in Langvlei and Ramkamp wetlands.

2.3.5 A proposed framework for assessing the condition of the vegetation in the Kamiesberg wetlands

Milton (2007) developed a rapid assessment method for renosterveld, with thresholds set separately for two primary land-use objectives, namely; grazing and biodiversity conservation. The above does not specifically cover wetlands occurring within the renosterveld, but it does provide a very useful starting point from which to develop a system tailored for wetlands. Based on the review of relevant literature (Section 2.3.1-2.3.3), the findings of the vegetation description (Section 2.3.4) and with reference to du Toit (1997; undated), a preliminary framework for assessing the condition of wetlands in the Kamiesberg wetlands is proposed (Table 2.2). It is recommended that this framework be applied in an adaptive management context (Box 1) where, through application, the understanding of the ecosystem will be enhanced and the thresholds refined in the light of the new understanding.

At present, the wider applicability of Table 2.2 beyond the Leliefontein area is unknown, and it is recommended that it be trialled in more wetlands as part of a refinement process. It is likely that different thresholds would need to be set to account for different vegetation types.

Table 2.2: Indicators of condition for the vegetation of Namaqualand Granite renosterveld and Thresholds of Potential Concern (TPCs) given for: (1) grazing value for livestock and (2) value for biodiversity (adapted from Milton, 2007)

Indicator	**Measurable variable**	**Threshold value**		**Rationale**
		Grazing	**Biodi.**	
Renosterbos abundance	% canopy cover	>20%	>30%	Renosterbos has very low value as livestock forage and for biodiversity value, its single-species dominance is not desired because it reduces the species richness of native plants, as elaborated upon in Sections 2.3.2 and 2.3.3.
Carpobrotus edulis Natural sandy areas present: Limited natural sandy areas:	% canopy cover	>15% >5%	>15% >5%	*C. edulis* has a low value as livestock forage. It is well adapted to colonizing bare sandy areas, which may be natural (e.g. in the case of some riverbeds) or as a result of human disturbance.
Alien weeds	% canopy cover	>15%	>5%	Any alien plants compete with indigenous plants. For grazing, some may be of forage value.
Indigenous perennial grass seasonal wetness: temporary wetness:	% canopy cover	<20% <40%	<10% <10%	Perennial grasses provide one of the principle sources of forage in the wetlands, and would have been naturally abundant in un-degraded wetlands, particularly in temporarily wet areas. In seasonally wet areas sedges, rushes and red-hot pokers are often dominant.
Abundance of perennial grasses relative to annual grasses	Canopy cover: annuals/ perennials	>0.3	>0.3	Annuals are much less valuable than perennials for livestock, particularly in terms of providing dry-season forage. Naturally, perennials would have been much more abundant than annuals. Also, several of the annual grasses are aliens.

Box 1: Adaptive management (from Kotze and Breen, 2008)

In response to failures in the command-and-control approach to ecosystem management, which tended to try to maintain the stability of inherently dynamic systems, an adaptive approach is now being widely advocated (Rogers and Bestbier, 1997). Adaptive management is a structured process of ongoing “learning by doing” (also described as “management by experiment”) where management actions are treated as potential learning-opportunities (Walters, 1997; Rogers and Biggs, 1999; Mackenzie *et al., 2*003). This is achieved through monitoring the outcomes of management actions, reflecting on these outcomes and then adjusting future actions accordingly (i.e. a reflexive approach). Successive cycles of action, monitoring and reflection thus lead to a progressive improvement in management competency.

Adaptive management allows for flexibility in response not only to the dynamics of ecosystems but also to uncertainties and changes in the interests of stakeholders, the political climate and in resources available to management (The Ramsar Convention on Wetlands, 2004). Environmental issues are value-laden, and an understanding of the issues is shaped by the different, often conflicting, interests of society. Thus, a critical approach is required, where, during each reflection, issues and assumptions are questioned, which allows one to remain responsive to different contexts (Taylor, 2007).

3. ASSESSMENT OF ENVIRONMENTAL CONDITION

by H Malan

3.1 Background to Wet-Health

WET-Health (Macfarlane *et al., 2*008) is an assessment tool that forms part of the "WET-Management" series developed under Phase I of the National Wetlands Research Programme. The tool is designed to evaluate the environmental condition ("ecological health") of a wetland, by examining the deviation of various parameters from the natural condition caused by human-induced impacts. WET-Health considers three components, namely: hydrology, geomorphology and vegetation. For each component, the extent and intensity of impacts are estimated, and combined to determine the overall magnitude of that impact. The three individual components (hydrology, geomorphology, vegetation), are assessed separately to produce three scores on a scale of 0 (reference condition and thus un-impacted) to 10 (critically altered) and the wetland is placed into one of six categories from A to F (where A represents natural, and F represents impacts at a critical level). Potential causes of change in wetland integrity are evaluated and by considering the threats (and in some cases the vulnerability), an assessment is also made of the likely Trajectory of Change of the wetland. The combination of these aspects gives a picture of the environmental condition or "health" of the system. Thus, the term "state" refers to its present state and "health" to a combination of present state and likely Trajectory of Change (Macfarlane *et al., 2*008).

3.2 Application to the Langvlei and Ramkamp Wetlands

The assessment of environmental condition was based on two site visits, one in early November 2007 and another in February 2008. At the time of the November visit, the area was still fairly wet compared to the usual condition for that time of the year (I Samuels, 2007, pers. comm., ARC, University of the Western Cape, Cape Town). This is a consequence of the unusually high rainfall and snowfall that the area had received for the previous two winters. During the winter of 2007, the rainfall had been so severe that extensive damage had occurred to roads in the area. These factors were taken into account when interpreting the WET-Health scores.

3.2.1 The HGM types in the wetlands

3.2.1.1 Langvlei

The Langvlei wetland forms part of the drainage system for the Buffels River catchment. The wetland was divided into three hydrogeomorphic (HGM) units which were typed and mapped. Although 1:50 000 topographical maps and aerial photographs (most recent 2003) are available, there are no orthophotos for this part of the country (Chief Directorate, 2007, pers. comm., Surveys and Mapping, Mowbray, Cape Town). Furthermore, Google Earth images of the area were found to be at too low a resolution to be useful for examination of wetland features. From examination of the aerial photographs and examination of soil cores in the field it was deduced that in the reference condition the HGM units would have been represented by the descriptions given below, although as will be seen later, significant modification, particularly to HGM 1 and 2, has now occurred.

HGM 1 (at the most southerly portion of the wetland, on the farm "Klutersvlei") was typed as *valley-bottom without channel*.

Downstream of HGM 1 there is a channel which is confined between rocky (granite) outcrops (see Map, Figure 3.5). This was not assessed, as WET-Health is not suitable for assessing the environmental condition of rivers. The river then passes into an open valley and again becomes wetland.

HGM 2 (the middle portion of the wetland) was also typed as *valley-bottom without channel*.

HGM 3 the most northerly, and downstream portion of the wetland, was typed as *valley-bottom with channel.* The upstream boundary of this HGM unit was delimited by the theoretical start of the channelled portion of the wetland in the natural condition. The downstream boundary of the wetland was delimited by the confluence with a significant tributary stream.

Several seeps are also associated with Langvlei wetland. However, these are relatively small and were not included in the assessment.

3.2.1.2 The Ramkamp

The Ramkamp wetland lies immediately south of the village of Leliefontein (Figure 2.1). Its name arises from the local practice of keeping rams confined in this area (Section 2.1). The wetland is comprised of a single hydrogeomorphic (HGM) unit, which was typed as *valley bottom without channel*. A schematic map of the salient features of Ramkamp is shown in Figure 3.6. The wetland is less than 3 km in length and is divided by the main Leliefontein-Garies road into the upstream Baileysvlakte and the lower Ramkamp sections. The Baileysvlakte section arises just below a small peak area (altitude 1443 m amsl). The lower boundary of the wetland is near a crossing with a track leading to Leliefontein. A few meters upstream of this crossing, the wetland becomes a channel due to confinement between rocky outcrops. Two lateral seepage areas were observed feeding into the Ramkamp area; however, these are small and were not included in the assessment.

Figure 3.1: General view of the most upstream portion of Langvlei wetland (HGM 1), looking north, showing land-use in the catchment.

Figure 3.2: General view of the upper portion of the Ramkamp wetland (upstream of Leliefontein-Garies road) Baileysvlakte section. The stock watering dam can be seen.

3.3 Module 1: Hydrological Assessment

An outline of the process that was used to assess the hydrological health of the two wetlands is given in Figure 3.3. “WET-Health” makes use of a scoring system in a series of tables to evaluate the environmental condition. In order to clarify reporting of the process, tables that present important results are given in the text and background results and ancillary tables are presented in Appendix 2.

The Langvlei wetland is situated in catchment F30A, which has a mean annual precipitation (MAP) of 162 mm and a mean annual potential evapotranspiration (PET) of 2469 mm. The Ramkamp is situated in an adjoining catchment (F30B) and has the same MAP and PET as Langvlei. Thus, the ratio between MAP and PET is <0.3 and the vulnerability factor is equal to 1.1 (Table A2.1 Appendix 2). The vulnerability factor is used in WET-Health as a multiplier in calculating the impact intensity of various land-uses that reduce runoff from the catchment. Where the vulnerability factor is >1 (as in this case) it increases the intensity score, since, due to the low rainfall and high evapotranspiration characteristic of the area, these wetlands are considered to be particularly vulnerable to hydrological disturbance.

Step 1: Identify HGM units in the wetland and describe the local climate

Step 1A: Divide the wetland into HGM units

Step 1B: Assess the vulnerability of the HGM unit to altered water inputs, based on local climate

↓

Step 2: <u>Water inputs</u>: For each HGM unit, assess impacts of changes in quantity and pattern of water inputs to the unit from its <u>upstream catchment</u>

Step 2A: Identify, map and assess impact of land-use activities that reduce the **inflow quantity** to the HGM unit

Step 2B: Assess the intensity of impact of factors potentially altering **flow patterns (timing)** to the HGM unit

Step 2 c: Assess the combined magnitude of impact of **altered quantity and pattern** of inputs, accounting for the wetland's vulnerability

↓

Step 3: <u>Water distribution and retention</u>: Assess the degree to which natural water distribution and retention patterns within the HGM unit have been altered as a result of <u>on-site activities</u>

Step 3A: Assess magnitude of impact of **canalisation** and **stream modification**
Step 3B: Assess magnitude of impact of **impeding features**
Step 3 c: Assess magnitude of impact of altered **surface roughness**
Step 3D: Assess the impact of **direct water losses**
Step 3E: Assess the impact of **recent deposition, infilling or excavation**
Step 3F: Determine the combined magnitude of impacts of **on-site activities**

↓

Step 4 Determine the Present Hydrological State of each HGM unit based on integrating the scores from Steps 2 and 3

↓

Step 5: Determine overall Present Hydrological State for the wetland by integrating the assessments from the individual HGM units

↓

Step 6: Assess the anticipated Trajectory of Change of wetland hydrology

↓

Step 7: Describe the overall Hydrological Health of the wetland based on Present Hydrological State and Trajectory of Change

Figure 3.3: An outline of the steps involved in the hydrology module.

The hydrology module first examines the inputs of water to a given wetland from the surrounding catchment and includes a consideration of land-use. This is followed by an examination of the activities or structures (e.g. weirs) which alter distribution and retention of water within the wetland itself.

3.3.1 Step 2: Alteration of hydrology within the catchment

3.3.1.1 Step 2A: Changes in water input quantity

Land-use in the catchment of Langvlei, for all three HGM units, is largely natural with some historically cultivated fields (approximately 25% of the catchment area for each of the three HGM units). There are fairly extensive expanses of bare rock in the form of granite outcrops which are a natural feature (whereas the “hardened surfaces” referred to in Table 3.1 are from roads, paving and other infrastructure and are due to human activities). There appears to be no significant invasion by alien vegetation species (although note the increase of the indigenous renosterbos – Section 2.3). There is also an absence of dams in the catchment. A small area of land (5%) is currently under irrigation within the catchment of HGM 1, but none in the catchments of the other HGM units. Furthermore, the small portion of land that is under irrigation in HGM 1 is irrigated using water from the wetland, and thus this impact is considered later under impacts within the wetland itself. Consequently, the quantity of water reaching the wetland is unlikely to have been significantly reduced from the natural condition. At the same time, there are no inter-basin transfer-schemes or effluent discharges into the system, and thus the amount of water reaching the system is also unlikely to have been increased from the natural condition. Therefore, the combined score for change in water input quantity (increased flows score versus decreased flows score) is zero.

Land-use in the catchment of Ramkamp also includes natural vegetation with some historically cultivated fields (approximately 60% of the catchment area) with no significant invasion by alien plant species. There are no dams in the catchment and no irrigated areas. Consequently, it is considered that the quantity of water reaching the wetland is unlikely to have been significantly reduced from the natural condition. At the same time, there are also no inter-basin transfer-schemes or effluent discharges and thus the amount of water reaching the system is also unlikely to have been increased from the natural condition. The combined score for change in water input quantity (increased flows versus decreased flows) for Ramkamp, as for Langvlei, is therefore zero.

3.3.1.2 Step 2B: Changes in the pattern of water delivery

The next step is to consider the timing and pattern of water inputs into the wetlands compared to the natural condition. Although there are no significant dams, there are areas of cultivated (or formerly cultivated) fields in the catchments of both Langvlei and Ramkamp, which were fallow at the time of the site visit in November. A reduction in vegetation cover is likely to increase the flood-peak magnitude since the infiltration capacity of bare soils is characteristically lower than well-vegetated soil (Macfarlane *et al., 2*008). In the Ramkamp, a significant portion of the catchment (60%) was historically cultivated, although it seems that at present this has been discontinued (section 2.3). Thus, the natural pattern of floods in the wetland is likely to have increased slightly, as shown in Table 3.1.

In the case of Langvlei HGM 1, there is erosion of some of the drainage lines leading down to the upper portion of the wetland. According to a local farmer, the erosion was caused by construction of the new road from Leliefontein, although there are other factors that may be involved (Section 2.2). The road cuts diagonally across the slope, collects flow and discharges the water at a few localised points from which gullies have developed that serve to carry streamflow down to HGM 1. As a result of the erosion, it is thought that the timing of rainfall entering the wetland would have changed compared to the natural condition. The water enters the system within a shorter period of time as surface flow, rather than being sustained over a longer period as interflow, and thus now contributes to the flood-peak. This type of alteration in hydrology is not catered for in the current format of WET-Health. Nevertheless, wetland specialists are encouraged to alter the scores if they consider this justified. In Table 3.1, the score for Langvlei HGM 1, in terms of impact to flood-peak alteration, was increased from +2 to +4, to emphasise that peaks are likely to have increased in volume compared to the natural condition.

The score of +4 for Langvlei HGM 1 indicates that (quoting from WET-Health) flood-peaks have been moderately increased, often resulting in the noticeable reduction of sub-surface water inputs.

The score of +2 for HGM 2 and 3 and the Ramkamp indicates that there has been a discernable but small increase in flood-peaks that may not necessarily have resulted in the discernable reduction of sub-surface water inputs.

Table 3.1: Factors potentially contributing to an alteration in flood-peak magnitude and/or frequency received by each of the HGM units/wetlands (scores allotted according to Table A2.2 Appendix 2)

Level of reduction				
	HGM 1	HGM 2	HGM 3	Ramkamp
(1) Collective volume of dams in the wetland's catchment in relation to mean annual runoff (MAR)*	0	0	0	0
(2) Level of abstraction from the dams	0	0	0	0
(3) Specific allowance for natural floods within the operating rules of the dam	n/a	n/a	n/a	n/a

Level of increase				
	HGM 1	HGM 2	HGM 3	Ramkamp
(4) Extent of hardened surfaces in the catchment	0	0	0	0
(5) Extent of areas of bare soil in the wetland's catchment including that associated with poor veld condition (score from "WET-Health").	(11-40%) = +2	(11-40%) = +2	(11-40%) = +2	(11-40%) = +2

	HGM 1	HGM 2	HGM 3	Ramkamp
Combined score: [Average of (1), (2) and (3)] + (4) + (5) The combined score will be in the range from -10 to +10 depending on whether the increases in peak flow are greater or smaller than the decreases	+ 2	+ 2	+ 2	+ 2
Altered score due to erosion gully leading into wetland	+2	0	0	0
Final score due to altered flood-peak magnitude or frequency	**+4**	**+2**	**+2**	**+ 2**

3.3.1.3 Step 2 c: Combined impact of altered quantity and *timing of water inputs*

The combined impact of altered quantity and timing of water inputs from the catchment is assessed by selecting the appropriate column and row from a look-up table in WET-Health. This table considers hydrogeomorphic type, altered quantity of water inputs and the altered pattern of water inputs, and makes use of the scores already obtained in Steps 2A and 2B. Two different versions of the table are available in WET-Health, depending on whether the wetland is (a) a floodplain or valley bottom, primarily driven by *over-bank flooding,* or (b) other hydrogeomorphic settings, including floodplains and channelled valley bottoms driven primarily by *lateral inputs* (e.g. from tributaries). In the case of Langvlei, all three HGM units are considered to be driven primarily by lateral inputs, as is the Ramkamp. This is substantiated by the number of seeps and drainage lines along the length of the two systems. From this table (Table A2.3 Appendix 2) which integrates the scores for the quantity of inputs and alteration of flood-peaks, HGM 1 has an overall score of 1.5, and the other two Langvlei HGM units, and the Ramkamp have an overall score of 0.5. From the guidelines (Table A2.4 Appendix 2), these scores indicate that modifications to hydrological integrity due to changes in the catchment are small for Langvlei HGM 1. In the case of Langvlei HGM 2 and 3, and the Ramkamp, the scores indicate that modifications to hydrological integrity due to changes in the catchment are insignificant.

3.3.2 Step 3: Alteration of hydrology within the wetland itself

The next step is to examine the distribution and retention of water within the wetland itself, rather than in the catchment. In WET-Health, alteration of the distribution and retention of water within the wetland is investigated by checking for the presence of the following features:

- canalisation and stream modification (Step 3A);
- impeding structures, e.g. weirs (Step 3B);
- change in surface roughness in terms of the form and extent of wetland vegetation (Step 3 c);
- direct water losses, e.g. through abstraction within the wetland (Step 3D); and
- infilling/excavation (Step 3E).

Each wetland/HGM unit was mapped and the presence, extent and characteristics of the above features noted. Areas of different land-use (termed disturbance units) were also identified and are shown in Figures 3.4 and 3.5 for Langvlei and Figure 3.6 for Ramkamp. The extent (in terms of percentage of the HGM unit) of each disturbance unit was estimated and is recorded in Table 3.2. During the site visit, soil cores were taken at various locations and the soils examined for indications of water saturation (current or historical) using standard methods (DWAF, 2006). In this manner, the extent of the wetland in the natural condition could be estimated.

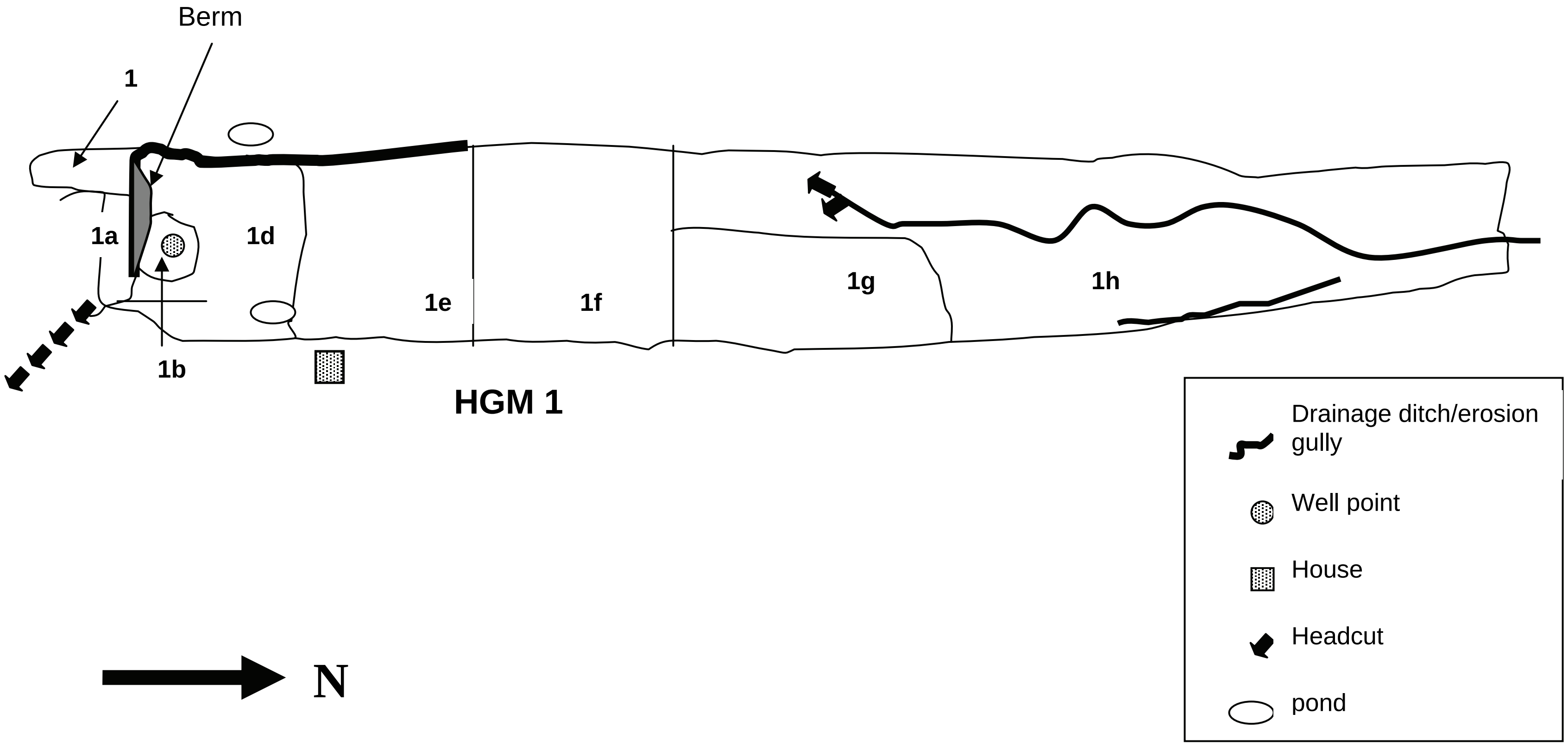


Figure 3.4: Schematic map of the major features and disturbance units of HGM 1 in Langvlei. A description of each disturbance unit is given in Table 3.2.

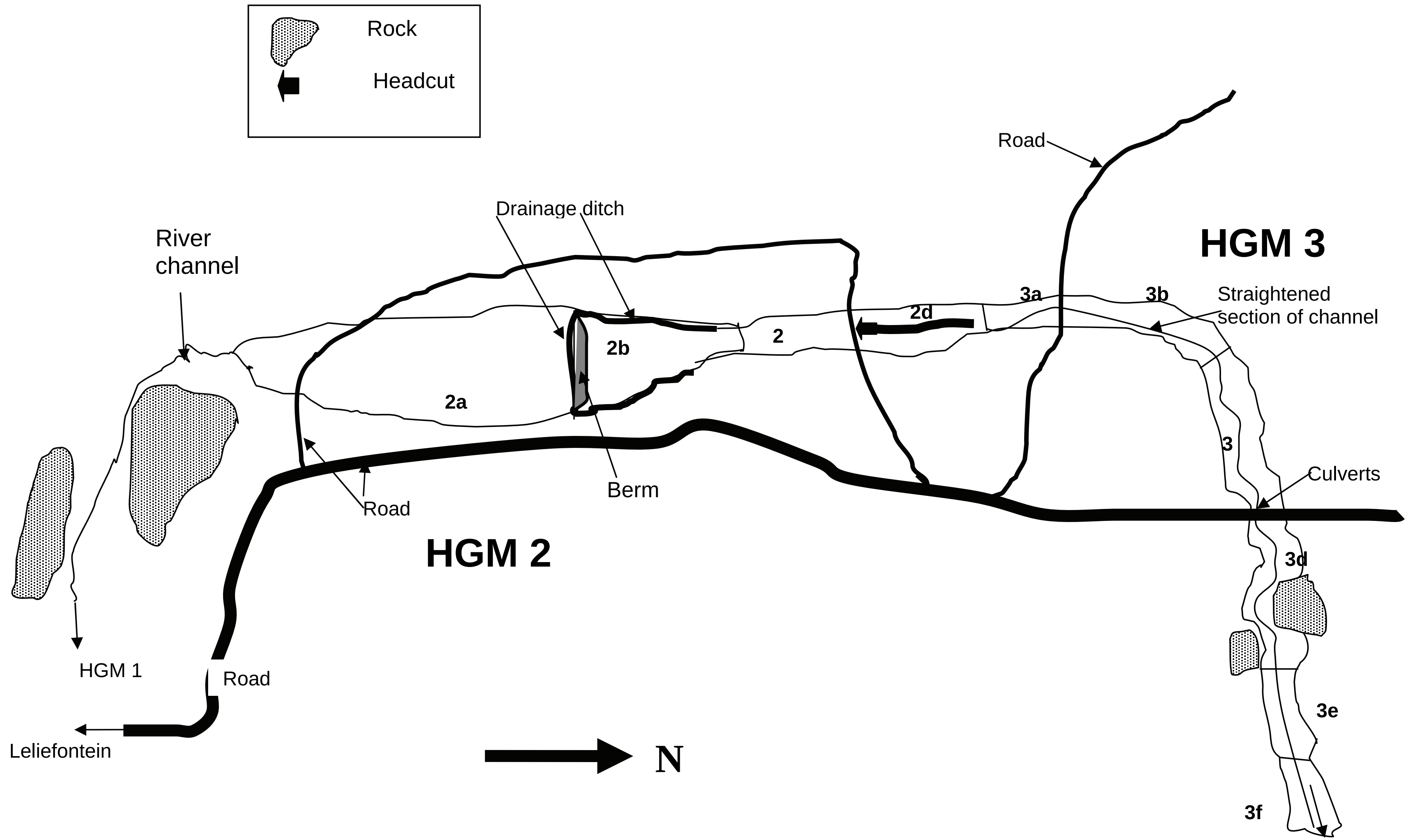


Figure 3.5: Schematic map of the major features and disturbance units of HGM 2 and HGM 3 in Langvlei. A description of each disturbance unit is given in Table 3.2.

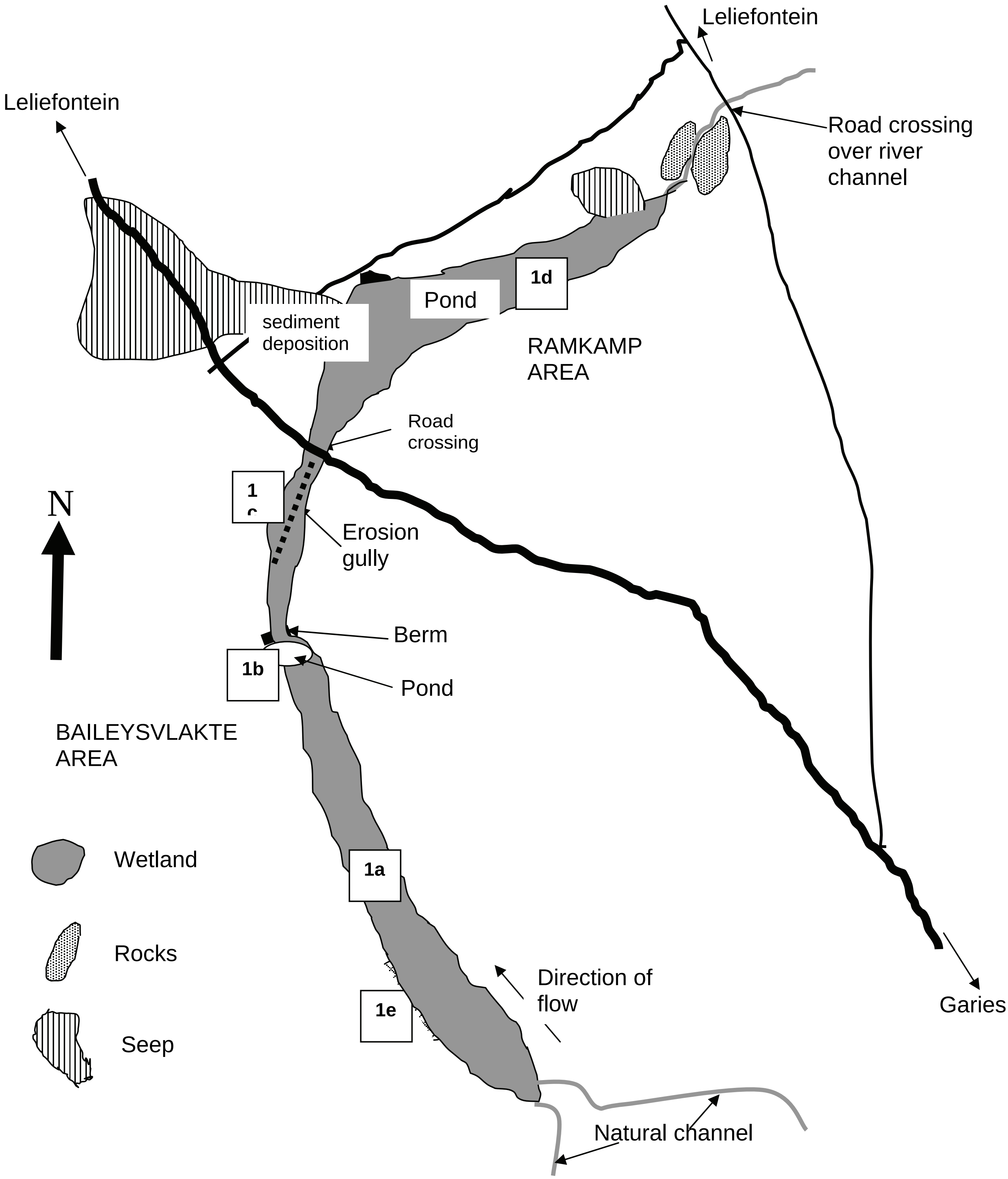


Figure 3.6: A schematic map of the major features of the Ramkamp wetland. A description of each disturbance unit is given in Table 3.2.

Table 3.2: Summary of the different land-uses (disturbance units) in each wetland/HGM unit and the extent affected by drainage or by channel modification (straightening)

Distur-bance unit	Description	Extent (% of HGM unit)	Extent (% disturbance unit) affected by drainage/modification
1a	Recently tilled (soil bare at time of visit in November).	4	None
1b	Area around spring with dense stand of *Juncus* sp.	3	100% affected by diversion berm
1 c	Intact, biodiverse wetland area.	3	None
1d	Pasture/historically cultivated land.	10	100% of area affected by diversion berm and ditch
1e	Fallow land.	15	25% affected by diversion berm
1f	Recently tilled (soil bare at time of visit in November).	15	None
1g	Degraded renosterbos, dried out by erosion gully.	20	100% of area affected
1h	Degraded renosterbos, dried out by erosion gully.	30	Approximately 80% of disturbance unit affected
Percentage of Langvlei HGM 1 (extent) affected by drainage			(3x1)+(10x1) +(15x0.25)+(20x1)+(30x0.8) = **61%**
2a	Relatively undisturbed (apart from livestock). No drains or erosion gullies.	45	None
2b	Cultivated (drainage ditches along each side parallel to the direction of flow and at head of area).	30	100% of area affected
2 c	Historically cultivated area. Extensive sedimentation, but no erosion gullies.	10	None
2d	Historically cultivated area (head-cut with erosion gully along one side).	15	Approximately 50% of disturbance unit affected
Percentage of Langvlei HGM 2 affected by drainage			(30x1) + (15x0.5) = **37.5%**

3a	Relatively unimpacted. Naturally channelled valley bottom.	10	n/a
3b	Channel straightened and deepened.	10	Approximately 50% of disturbance unit affected
3 c	Valley bottom with channel (vegetation recovering from cultivation). Upstream of road.	20	n/a
3d	Relatively unimpacted. Naturally channelled with pools at rocky outcrops. Extensive sedimentation.	10	n/a
3e	Valley bottom with channel (relatively unimpacted).	30	n/a
3f	Valley bottom with channel (relatively unimpacted).	20	n/a
Percentage of Langvlei HGM 3 affected by channel modification			(10x0.5) = **5%**
4a	Natural wetland vegetation, including extensive old historically cultivated areas, now well-recovered.	32	None
4b	Berm and pond area.	2	None
4 c	Canalised area.	10	100
4d	Natural wetland vegetation, including limited old historically cultivated areas, now well-recovered.	48	None
4e	Historically cultivated – recent.	8	None
Percentage of Ramkamp affected by drainage			(10/100x100) = **10%**

3.3.2.1 Step 3A: Impact of canalisation and *stream modification*

Various changes in terms of canalisation and stream modification have occurred along the length of the Langvlei wetland as described below for each individual HGM unit. Note that some of the canalisation was deliberate and some is a consequence of erosion gullies that have formed. The presence of channels of either origin tends to cause drying out of the wetland as water is drained away.

Langvlei HGM 1: This HGM unit has been transformed extensively with only a very small area that is still considered to be relatively natural. A large portion (50%) of the lower part of the wetland has been drained due to the formation of an erosion donga and the digging of drains. Soil cores confirmed that the wetland had formerly been much wetter than at present and this was taken as substantiating evidence that the wetland in the reference condition was unchannelled. The presence of the erosion gullies and ditches results in increased removal of moisture from the system, compared to the unimpacted state.

Langvlei HGM 2: This area was also considered to be valley bottom without channel in the reference condition. The upper part of the HGM unit (area 2a) is still relatively unimpacted, however, livestock (cattle) were grazing in the area during the site visits and there was localised pugging of the ground. Further downstream, a drainage ditch and berm have been constructed perpendicular to the wetland. The drainage ditch also extends either side of the cultivated area (2b). At the bottom of the HGM unit (2d) a head-cut has formed. The location of the drains and gullies in relation to flows into and through the wetland were considered to be intermediate in terms of their impact (i.e. their efficiency in draining water).

Langvlei HGM 3: There are presently no artificial drains or ditches in this part of the wetland. The channel that is present is considered to be a natural feature, since in the reference condition this HGM would have been valley bottom with channel, although a small portion of the channel in HGM 3 has been straightened and modified, thus increasing the rate of delivery of water out of this part of the wetland. This impact was scored later (Table 3.4).

Ramkamp: A small portion of the Baileysvlakte section of the wetland has been affected by the development of an erosion gully (shown in Figure 3.6) leading to localised changes in hydrology. It was estimated that the extent of the wetland affected by this gully is approximately 10%.

Table 3.3: Factors affecting the impact of canalisation on the distribution and the retention of water in each HGM unit. Scores for each factor taken from "WET-Health" (Macfarlane *et al., 2*008)

Factors	HGM 1	HGM 2	HGM 3	Ramkamp
(1) Slope of the wetland	(Slope = 5%) Score = 10	(Slope = 1 -1.9%) score = 5	(Slope = 1.3%) Score = 5	(Slope = 4%) Score = 10
(2a) Texture of mineral soil, if present	Sandy loam (score = 8)	Sandy loam (score = 8)	Sandy loam (score = 8)	Sandy loam (score = 8)
(2b) Degree of humification of organic soil, if present	None	None	None	None
(3) Natural level of wetness	2 (Seasonal zone present but permanent zone absent)	2	2	2
Characteristics of the drains/gullies				
(4) Depth of the drains/gullies	(Approx. 1 m) Score = 8	(Approx. 0.51-0.80 m) Score = 5	Not relevant to this HGM unit (no canalization)	(Approx. >1 m) Score = 10
(5) Density of drains (meters of drain per hectare of wetland)	(26-200 m/ha) Score = 2	(101-200 m/ha) Score = 5		(26-200 m/ha) Score = 2
(6) Location of drains/gullies in relation to flows into and through the wetland	(Intermediate impact) Score = 5	(Moderately poorly intercepted, low impact) Score = 2		(Intermediate) Score = 2
(7) Obstructions in the drains/ gullies	Low level of obstruction Score = 8	Low level of obstruction Score = 8		Low level of obstruction Score = 8
Calculate the mean score for factors 1, 2a or 2b, 3, 4 and 5	30/5 = 6	25/5 = 5		30/5 = 6
Multiply the score for factor 6 by the vulnerability factor (1.1 for the study wetlands)	5.5	2.2		2 × 1.1 = 2.2
Mean score for above two scores	5.8	3.6		8.2/2 = 4.1
Intensity of impact for canalization: divide the score for factor 7 by 10 and multiply this by the mean score derived in previous row	(8/10)x5.8 = 4.6	(8/10)x3.6 = 2.9		8/10x4.1 = 3.3
Magnitude of impact of canalization: Extent of impact/100 × intensity of impact calculated in the row above (extent taken from Table 3.2)	(61/100x4.6) = 2.8	(38/100x2.9) = 1.1		(10/100x3.3) = 0.3

Based on characteristics such as the length of drains/erosion gullies and their depth, in addition to consideration of wetland soil type and slope, the effectiveness of the channels in the drying out of each HGM unit was assessed. These results are shown in Table 3.3. The table indicates that the impact scores due to canalisation are low for Langvlei (2.8 for HGM 1, and 1.1 for HGM 2). A score of zero was obtained for HGM 3 since no canalisation has occurred in this region. The impact due to canalisation was very low for Ramkamp (0.3).

In the case of Langvlei HGM 3, although no artificial canals were present, part of the natural channel had been straightened and deepened. In order to score this impact, Table 3.4 below was used. But first, a weighting factor was derived according to the extent to which HGM 3 is naturally dependent on bank overspill for maintaining the wetland's hydrology. WET-Health recommends application of the following weighting factors:

- if entirely dependent on bank overspill, as may be the case for some floodplains: 1
- if fed by a combination of inputs from the main channel and lateral inputs: 0.6; or
- if fed predominantly by lateral inputs: 0.3.

In the case of HGM 3 it was decided that water inflow was both from the main channel and from lateral inputs (supported by the presence of seeps) and thus a HGM weighting factor of 0.6 was applied, as shown in Table 3.4 below. The change in surface roughness due to alteration in vegetation structure in the present state compared to the natural one was deduced using the guidelines in Table A2.5 (Appendix 2). It is important to take this factor into consideration because, as will also be seen further on in this module, dense vegetation (high roughness) impedes water flow and helps to prevent desiccation.

Table 3.4: Characteristics affecting the impact on the distribution and retention of water in the HGM unit through the modification of a stream channel. Scores taken from WET-Health

Extent of HGM 1 affected by stream channel modification	0%
Extent of HGM 2 affected by stream channel modification	0%
Extent of HGM 3 affected by stream channel modification	**5%**
Extent of Ramkamp affected by stream channel modification	0%

Characteristics of stream channel	HGM 1	HGM 2	HGM 3	Ramkamp
(1) Reduction in length of stream	Not applicable to this HGM unit	Not applicable to this HGM unit	(5-25%) Score = **2**	Not applicable to this HGM unit
(2) % increase in cross sectional area of the stream			(25-50%) Score = **5**	
(3) Change in surface roughness in relation to the surface roughness of the channel in its natural state			(Altered by 1 class) Score = **2**	
Intensity of impact: use the maximum score of factors 1 to 3 × HGM weighting factor			(5x0.6) = **3**	
Magnitude of impact of stream channel modification = extent of impact/100 × intensity of impact			(5/100x3) = **0.15**	

The impacts from canalisation (HGM 1, 2 and the Ramkamp) and stream channel modification (HGM 3) were then combined and summarised in Table 3.5.

Table 3.5: Calculation of the combined magnitude of impact of canalisation and modification of stream channel on the distribution and retention of water

Overall magnitude-of-impact score; canalisation and stream channel modification	HGM 1	HGM 2	HGM 3	Ramkamp
Calculate the sum of scores from Tables 3.3 and 3.4	(2.8+0) **= 2.8**	(1.1+0) **= 1**	(0+0.15) **= 0.2**	(0+0.3) **= 0.3**

3.3.2.2 Step 3B: Magnitude of impact of impeding features

Consideration was given to the presence of structures (i.e. weirs, dams or roads) that might impede the flow of water through the wetland. The impact of these structures, both upstream and downstream, is then considered. From the schematic maps (Figures 3.4, 3.5 and 3.6) it can be seen that in the case of HGM 1 there are no structures that might restrict water flow through the wetland. In the case of HGM 2 there are two small tracks crossing the wetland. In the case of HGM 3, there is one small track crossing the wetland in the upper part of the wetland, and a major (gravel) road with two culverts further downstream. A berm has been constructed in the Baileysvlakte portion of the Ramkamp wetland, most likely to create a small stock-watering hole. Furthermore, the Leliefontein-Garies road crossing also represents an impeding structure to the flow of water through the wetland.

From the field visit in November it appeared that whereas the dirt tracks had little influence on flow, the road across Langvlei HGM 3 did influence flow significantly/noticeably. There were pools of standing water upstream of the road crossing which were estimated to be 1% of the total extent of the wetland. Furthermore, it was considered that in the natural condition, no extensively-inundated areas would exist, but now, due to construction of the road, pools of water would be present during at least some part of the year. These pools are not permanent, however, and had dried out by the time of the second site visit in February. Furthermore, to some extent, they may have been due to the excessively high rainfall experienced that year. Nevertheless, due to construction of the road, it is thought that there has been some change to the hydrological character of the system.

In the case of the Ramkamp, despite the presence of the track crossing and the berm, the upstream impacts were considered to be negligible, although slight impacts downstream were visible.

The impacts, both upstream and downstream, for HGM 3 and the Ramkamp are presented in Table 3.6. Overall, the total impacts were very low (a score of 0.14 for HGM 3 and 0.03 for Ramkamp).

Table 3.6: Changes in water distribution and retention patterns as a result of impeding features. Scores from WET-Health

(a) Upstream impact of flooding

Extent (%) of HGM unit affected by flooding **upstream** of the impeding structure	HGM 1	HGM 2	HGM 3	Ramkamp
	0	0	1	0
Descriptor	HGM 1	HGM 2	HGM 3	Ramkamp
1. Representation of different hydrological zones prior to flooding	n/a	n/a	8	n/a
Intensity of impact: score of (1.) x 0.8*	-	-	(8x0.8) Score **= 6.4**	-
Magnitude of impact score: extent of impact /100 × intensity of impact	-	-	(1/100x6.4) Score **= 0.06**	-

(b) Impact on quantity and timing of flows on the downstream portion of the HGM unit

Extent (%) of HGM unit affected **downstream** of the impeding structure	HGM 1	HGM 2	HGM 3	Ramkamp
	0	0	10	2
	HGM 1	HGM 2	HGM 3	Ramkamp
Extent to which dams or roads interrupt low flows to downstream areas	n/a	n/a	(Slight interruption – moderate no. of culverts) 2	(Slight to moderate interruption) 3
Level of abstraction from the dam(s)	-	-	N/A	0
Location of dam(s) relative to affected area's catchment – proportion of catchment flows intercepted	-	-	N/A	0
Collective volume of dam(s) in relation to MAR of the affected area	-	-	N/A	1 (stock-watering hole)
Intensity of impact: mean score of the two highest scoring factors × 0.8*	-	-	((2+0)/2x0.8) Score **= 0.8**	((3+1)/2x0.8) Score **= 1.6**
Magnitude of impact score: extent of impact /100 × intensity of impact	-	-	(10/100x0.8) Score **= 0.08**	(2/100x1.6) Score **= 0.03**

(c) Combined impact

Combined impact: Magnitude of impact for upstream + magnitude of impact for downstream	HGM 1	HGM 2	HGM 3	Ramkamp
	0	**0**	(0.06+0.08) **= 0.14**	(0+0.03) **= 0.03**

* 0.8 is the weighting factor given relative to the impact of drainage channels which are considered to have the greatest potential impact on hydrological integrity (and thus given a value of 1).

3.3.2.3 Step 3 c: Impact of altered surface roughness

The presence of characteristic vegetation in a wetland is vitally important because it slows the passage of water through the area. Consequently, changes in vegetation resulting from impacts to the wetland can have major effects if roughness is decreased.

This effect was assessed for Langvlei and the Ramkamp by considering each of the disturbance units and then describing change in vegetation (if any) compared to the natural condition. Changes in roughness and hence water retention due to alteration in vegetation were scored by using Table A2.5 Appendix 2 (also used previously to assess the impact of canalisation). One of the impacts to the vegetation in these wetlands appears to be an increase in the density of renosterbos (section 2.3), which is especially apparent in the historically cultivated areas. Nevertheless, the roughness of this vegetation is not considered to be any lower than the natural vegetation, and disturbance units such as 1d in Langvlei HGM 1 were recorded as being “unchanged”. The authors of WET-Health, consider *decreased* surface roughness to be more deleterious to wetland condition than increased roughness (the latter resulting in enhanced water retention). Consequently, only a decrease in surface roughness is scored in the WET-Health approach. The results were used as input to Table 3.7 and the impact scores calculated. In the case of Langvlei HGM 3 and the Ramkamp there was no change in surface roughness compared to the natural condition and so these wetland areas are not included in the table.

The overall effect of altered surface roughness for each HGM unit is presented in Table 3.8. The change in surface roughness, whilst highest for HGM 1 (a reflection of the high proportion of agricultural activity in that area), was not considered to be significantly altered as all the scores were less than 1 (on a scale of 0-10).

Table 3.7: Summary of the different land-uses (disturbance units) in each HGM unit and the change in surface roughness

Disturbance unit	Description	Extent (% of HGM unit)	Change in surface roughness and impact score		Area-weighted score
1a	Recently tilled (soil bare at time of visit in November)	**4**	2 classes	5	0.2
1b	Area around spring with dense stand of *Juncus* sp.	3	Unchanged	0	0
1 c	Intact, biodiverse wetland area	3	Unchanged	0	0
1d	Historically cultivated land	10	Unchanged	0	0
1e	Fallow land	15	Unchanged	0	0
1f	Recently tilled (soil bare at time of visit in November)	**15**	2 classes	5	0.75
1g	Fallow land	20	Unchanged	0	0
1h	Dry-land (historically wetland) currently used for grazing	**30**	1 class	2	0.6
Total area (%) of HGM 1 with changed vegetation roughness		**49%**	**Sum of area-weighted scores**		**1.6**
2a	Relatively undisturbed (apart from livestock). No drains or erosion gullies.	45	Unchang-ed	0	0
2b	Cultivated (drainage ditches along each side parallel to the direction of flow and at head of area).	**30**	1 class	2	0.6
2 c	Historically cultivated area. Extensive sedimentation, but no erosion gullies.	10	Unchanged	0	0
2d	Historically cultivated area (head-cut with erosion gully along one side).	15	Unchanged	0	0.6
Total area (%) of HGM 2 with changed vegetation roughness		**30**	**Sum of area-weighted scores**		**0.8**

Table 3.8: Comparison of surface roughness of an HGM unit in its current state compared with its natural state

Extent of HGM unit affected by change in surface roughness	HGM 1	HGM 2	HGM 3	Ramkamp
	49	30	0	0

Descriptor	HGM 1	HGM 2	HGM 3	Ramkamp
Change in surface roughness in relation to the surface roughness of the wetland in its natural state (from Table 3.7)	1.6	0.6	0	0
Intensity of impact: score for the above row X 0.6*	1	0.4	0	0
Magnitude of impact score: extent of impact/100 × intensity of impact	(49/100)x 1 **= 0.5**	(30/100)x 0.4 **= 0.12**	**0**	**0**

***** The weighting factor is given relative to the impact of drainage channels, which are considered to have the greatest potential impact on hydrological integrity out of all the on-site factors considered, and is therefore assigned a weighting factor of 1.

3.3.2.4 Step 3D: Impact of direct water losses

Some activities in a wetland result in the loss of water. Common activities or land-uses that have this effect include the presence of alien plants, commercial afforestation, or the cultivation of water-thirsty crops such as sugarcane within the wetland itself. Direct abstraction of water can also cause a reduction in the amount of water available to the wetland. In the case of the two study wetlands, there are no alien plants, plantations, or sugarcane. There is, however, direct abstraction of water in Langvlei HGM 1. Two small ponds have been excavated and water is pumped for household use, for livestock and for irrigating crops. Approximately 5% of the catchment for this HGM unit is irrigated. It was very difficult to estimate the magnitude of direct abstraction, and this value is given with caution. A magnitude score of 5 (out of a total of 10) was given, indicating that fairly intensive use of the resource is likely to be occurring. This is supported by the fact that this aquatic resource is in an arid area and there are no alternative sources of water. Direct water loss in HGM 1 is unlikely to impact on the downstream HGM units, however, since the presence of seeps further downstream which feed water in laterally from the sides of the valley is likely to ameliorate this effect. Abstraction from HGM 1 was considered to be affecting 20% of the unit, yielding an impact with a total magnitude of 0.8 (Table 3.9).

No direct water use in the other two HGM units was observed and there was no obvious infrastructure for delivering water. Interviews with farmers in HGM 2 and 3 indicated that they do not irrigate their crops, furthermore there are no people living within these areas on a permanent basis. Thus, very limited direct abstraction is likely to be taking place from these two areas and direct water loss was ignored for HGM 2 and 3 in the assessment.

There are no houses in the Ramkamp wetland and no irrigated agriculture. The only possible direct use of water is from the stock-watering hole in the Baileysvlakte region and another smaller one in the Ramkamp area. However, the number of livestock using the watering holes is low; these losses take place in localised portions of the wetland and are therefore considered to have a negligible impact on the wetland's hydrology.

Table 3.9: Evaluation of the effect of alien woody plants, commercial plantations, sugar cane and direct abstraction on water loss

Land-use activity descriptors	**Level of water usage**					**HGM 1**		
	Low High					Intensity of water loss*	Extent (%)	Magnitude **
	0	2	5	8	10			
(1) Alien woody plant type			Shrubs	Trees		N/A		
(2) Plantation tree type				Wattle and pine	Eucalyptus	N/A		
(3) Sugarcane growth		Poor growth	Good growth			N/A		
(4) Direct water abstractions		Low	Moderately low	Moderately high	High	5	20	(20/100x5) = 1
Overall magnitude of increased water loss: (sum of (1), (2), (3) and (4)) × 0.8* **								1x0.8 Score **= 0.8**

*Intensity = Score ✕ Vulnerability factor (from Table 3.1)

**Magnitude = Intensity ✕ Extent (%) / 100

***The weighting factor is given relative to the impact of drainage channels, which are considered to have the greatest potential impact on hydrological integrity out of all the on-site factors considered, and is therefore assigned a weighting factor of 1.

3.3.2.5 Step 3E: Impact of recent deposition / infilling or excavation

Activities such as deposition of soil, infilling or excavation can alter drainage features and thus this feature needs to be examined when assessing the hydrological health of a wetland. There were signs of recent deposition of sediment only in HGM 3 in the area 3d, just downstream of the road crossing. The sand that had accumulated in this area is likely to have been eroded from the road during the flooding that occurred in the winter of 2007. The scores for this impact are presented in Table 3.10. The magnitude of impact of the deposition in HGM 3 is very small (0.1) because the areal extent was small. Furthermore, because the material deposited in the wetland is sand, the same as the wetland substrate, the effect on the vertical drainage properties of the uppermost soil layer and on the horizontal movement of water was considered to be minimal.

In the Ramkamp section of the wetland, at the intersection with a lateral seepage area, there had been recent deposition of sand, also likely to have been washed from the road during the winter rains. This was also localised in extent and at the side of the wetland. Thus, it was not considered to be affecting hydrology of the system. Apart from the above minor impact, there were no signs of significant, recent infilling in the wetland and this potential threat was ignored.

Table 3.10: Magnitude of impact of recent deposition/infilling or excavation

Extent of HGM unit affected by deposition/excavation or excavation	**HGM 1**	None
	HGM 2	None
	HGM 3	5%
	Ramkamp	None
Descriptor	**HGM 3 Score**	
Effect on vertical drainage properties of the uppermost soil layer	2	
Effect on the horizontal movement of water	2	
Intensity of impact: use the highest score for the above two factors	2	
Magnitude of impact score: extent of impact (%) / 100 × intensity of impact × 1*	(5/100x2)x1 Score **= 0.1**	

*The weighting factor is given relative to the impact of drainage channels, which are considered to have the greatest potential impact on hydrological integrity out of all the on-site factors considered, and is therefore assigned a weighting factor of 1.

3.3.2.6 Step 3F: Combined impact of on-site activities

The combined magnitude of the all the impacts assessed in the previous section (i.e. canalisation and stream modification (Step 3A), presence of impeding features (Step 3B), alteration to surface roughness (Step 3 c), direct water losses (Step 3D) and infilling/excavation (Step 3E)) was then calculated. These results are summarised in Table 3.11 and interpreted using the guidelines given in Table A2.4 Appendix 2.

The final assessment is given in the bottom line of Table 3.11 and shows that within-wetland alterations have had little impact on the hydrological functioning of Langvlei HGM 3 and the Ramkamp. There has been a small impact on Langvlei HGM 2 and a large impact on HGM 1.

Table 3.11: Overall magnitude of impacts of on-site activities on water distribution and retention patterns in each HGM unit

Activity	Magnitude of impact			
	HGM 1	HGM 2	HGM 3	Ramkamp
(1) Calculated magnitude of impact of canalisation and stream channel modification (Table 3.5)	2.8	1.1	0.2	0.3
(2) Calculated magnitude of impact of impeding features (Table 3.6)	0	0	0.14	0.03
(3) Calculated magnitude of impact of altered surface roughness (Table 3.8)	0.5	0.12	0	0
(4) Calculated magnitude of impact of direct water losses (Table 3.9)	0.8	0	0	0
(5) Calculated magnitude of impact of recent deposition/excavation (Table 3.10)	0	0	0.1	0
Total score of magnitude of on-site activities in the HGM unit (sum of the above scores)	**4.1**	**1.22**	**0.44**	**0.33**
Impact category (from score in line above) and Table A2.4 Appendix 2	**Large**	**Small**	**None**	**None**

3.3.3 Step 4: Establishing the Present Hydrological State of the HGM Unit

The final step in the assessment of the hydrological health of a wetland is to combine impacts in the catchment which influence water inputs to the system (assessed in Step 2) with the impacts occurring within the wetland itself which affect water distribution and retention (Step 3 – summarised in Table 3.11 above). This is done by making use of a look-up table provided in WET-Health (Table A2.6 Appendix 2) and interpreting the scores according to the guidelines (Table A2.4 Appendix 2). The combined magnitude of impact on hydrology for each HGM unit is summarised in Table 3.12 below. It can be seen that the hydrological modification in HGM 1 is severe (Present State Category = E), whilst that for HGM 2 is slight (Present State Category = B). The magnitude of impact scores for HGM 3 and Ramkamp is 0, and consequently the Present State Category for hydrology is "A" (Table 3.12). This indicates that there are *"no discernible modifications, or the modifications are of such a nature that they have no impact on the hydrological integrity."*

Table 3.12: Summary of catchment and within-wetland hydrological impacts for each HGM unit of Langvlei and for the Ramkamp wetland

	HGM 1	HGM 2	HGM 3	Ramkamp
Catchment impacts	**1.5**	**0.5**	**0.5**	**0.5**
Within-wetland impacts	**4.1**	**1.22**	**0.44**	**0.33**
Overall magnitude of impact scores (from Table A2.6 Appendix 2)	**6**	**1**	**0**	**0**
Health (Present State Category, from Table A2.4)	**E**	**B**	**A**	**A**

3.3.4 Step 5: Determine the Present Hydrological State for the entire wetland

Having determined the hydrological health scores for each HGM unit for Langvlei, the scores were then combined to yield the overall score for the entire wetland. This was done on an area-weighted basis (Table 3.13). Although the hydrological health for HGM 1 was an "E" category, the area of this unit is relatively small (only 20%) and is balanced by the near-natural condition of much of HGM 3. From the table, it can be seen that the overall Present Hydrological State for the Langvlei wetland is a "B" category. In the case of the Ramkamp, this step was omitted as the wetland is composed of only one HGM unit.

Table 3.13: Derivation of the overall impact score for Langvlei

Langvlei HGM unit number	HGM area as a proportion of total wetland area	Overall impact score for HGM (Table 3.12)	Area-weighted impact score
1	0.2	6	1.2
2	0.4	1	0.4
3	0.4	0	0
Total	**1.0**	**Overall weighted mean impact score**	**1.6 (B)**

3.3.5 Step 6: Anticipated Trajectory of Change of wetland hydrology

An assessment of the future trends in and threats to the hydrological health of the Langvlei and Ramkamp wetlands was made based on interviews with the farmers in the area. The following points were noted:

- no rehabilitation measures for the erosion dongas above Langvlei HGM 1 have currently been planned;
- the head-cut in Langvlei HGM 2 is unlikely to be rectified in the near future, as it is not perceived to be a threat by the landowner;
- there seems to be a movement by the younger generation to the cities, away from agriculture, thus the extent of cultivation may well remain the same in future (or be reduced);
- there appears to be a general lack of control over resource use in the area and so it is difficult to anticipate changes in land-use; and
- the likely Trajectory of Change of hydrological health for Langvlei was assessed using Table A2.7 Appendix 2 and is shown in Table 3.14. The overall Hydrological Health of Langvlei was found to be "B" category with a negative trajectory (↓).

In assessing the likely Trajectory of Change for hydrology in the Ramkamp wetland, the following factors were taken into consideration. The erosion gully upstream of the Leliefontein-Garies road is not likely to progress further upstream due to the presence of a rocky outcrop. Furthermore, farming pressure is unlikely to increase in the area. On the other hand, population in the nearby village of Leliefontein is likely to increase and thus greater abstraction of groundwater in the area may lower the water table. It is however difficult to assess this threat without more detailed knowledge of the geo-hydrology of the region. Overall, it is considered that the likely Trajectory of Change of hydrological health for Ramkamp is stable. Thus, the overall Hydrological Health of Ramkamp was found to be "A" category with a stable trajectory (→).

Table 3.14: Evaluation of threats and Trajectory of Change to hydrology within each HGM unit

Wetland/HGM Unit	Threat Description	HGM extent	Change Score	Area-weighted score	Symbol
1	Hydrological condition is likely to remain stable over the next 5 years	0.2	0	0	→
2	Hydrological condition is likely to slowly deteriorate over the next 5 years	0.4	-1	-0.4	↓
3	Hydrological condition is likely to remain stable over the next 5 years	0.4	0	0	→
Overall weighted threat score for entire wetland and Trajectory of Change:				**-0.4**	↓
Ramkamp	Hydrological condition is likely to remain stable over the next 5 years	n/a	0	n/a	→

3.4 Module 2: Geo-morphological assessment[2]

In the previous section of this report, the hydrological health of the Langvlei and Ramkamp wetlands was assessed using WET-Health. In this section, in a similar 7-step manner, the geomorphological health is assessed (Figure 3.7).

3.4.1 Step 1: Map and determine the extent of each HGM unit

This exercise has already been undertaken for the hydrological health assessment. According to WET-Health, different activities in the catchment and wetland itself impact on the geomorphological integrity of these systems with some HGM types being more vulnerable to specific impacts than others. Table A2.8 Appendix 2 shows for each HGM type, what activity needs to be considered. For example, channel shortening is important in dealing with floodplain or channelled valley bottom wetlands, but is not considered in the case of unchannelled valley bottom wetlands.

In the case of the wetlands under consideration, Langvlei HGM 1 and 2 are valley bottom (unchannelled) and HGM 3 is a channelled valley bottom. Ramkamp is comprised of a single HGM unit, which is an unchannelled valley bottom. Furthermore, the wetlands have limited development of organic soils.

[2] In section 2.2 a detailed description of the geomorphology of the wetlands is given. This was undertaken subsequent to the WET-Health assessment and there are slight discrepancies between the two. In particular, a detailed examination of sediment deposition in an erosion gully of Langvlei HGM 2 indicates that much of the eroded sediment appears to be retained in the system. This is not currently accounted for in WET-Health. As a consequence, the geomorphological health of the system is likely to be slightly better in reality than given here.

Step 1: Map and determine the extent of each HGM unit

↓

Step 2: Conduct individual assessments based on diagnostic features

Step 2A: Impact of dams upstream of or within floodplains
Step 2B: Impact of channel straightening
Step 2 c: Impact of artificial wetland infilling
Step 2D: Impact of changes in runoff

↓

Step 3: Conduct individual assessments based on indicators

Step 2A: Impact of erosion or deposition
Step 2B: Impact of loss of organic sediment

↓

Step 4: Determine the Present Geomorphic State of each HGM unit by combining diagnostic (Step 2) and indicator-based (Step 3) analyses

↓

Step 5: Determine overall Present Geomorphic State for the wetland by integrating scores of individual HGM units

↓

Step 6: Assess vulnerability and Trajectory of Change due to erosion

Step 6A: Assess **vulnerability to erosion** of each HGM unit
Step 6B: Describe the increased extent of gullies in relation to any external controls
Step 6 c: Assess the **likely Trajectory of Change** of Geomorphic State

↓

Step 7: Describe overall Geomorphic Health of the wetland based on the Present Geomorphic State and the Trajectory of Change

Figure 3.7: An outline of the steps involved in the Geomorphology Module

Therefore, the impact of the following activities/features needs to be examined:

Diagnostic component:

- stream shortening/straightening (HGM 3 only);
- infilling that leads to narrowing of the wetland (HGM 3 only); and
- changes in runoff characteristics (all wetlands/HGM units).

Indicator-based component:

- the presence of erosional features (all wetlands/HGM units); and
- the presence of depositional features (all wetlands/HGM units).

The assessment of these components is described in the next two sections.

3.4.2 Step 2: Assessment based on diagnostic features

WET-Health first looks at activities in the catchment and in the wetland itself that may impact on geomorphological health. The activities relevant to Langvlei and the Ramkamp are:

- stream shortening/straightening;
- infilling that leads to narrowing of the wetland; and
- changes in runoff characteristics.

3.4.2.1 Step 2A: Impacts of dams upstream of and*/or on floodplains*

This is not applicable to the study wetlands since there are no dams, and no floodplain systems.

3.4.2.2 Step 2B: Impacts of channel straightening

This activity is applicable only to Langvlei HGM 3 since this is the only one that is a valley bottom wetland with channel. A score of "2" for the reduction in stream length per unit valley length was determined in the Hydrology module (Table 3.4). The length of the straightened section of channel in HGM 3 is approximately 50 m and it is located 3.2 km downstream from the start of the wetland. The entire wetland is approximately 5.2 km in length and the substrate in the wetland is sandy. Using the above considerations, the magnitude of channel straightening on geomorphological health is calculated in Table 3.15.

Table 3.15: Extent, intensity and magnitude of impacts of channel straightening on the geomorphological health of Langvlei HGM 3

Extent of impact of channel straightening.						
Extent: the length of modification plus THE LESSER OF 10 km for sandy stream beds OR 5 km for silty/clayey stream beds OR the distance to the head of the wetland OR to a dam wall (if present), expressed as a percentage of the wetland length						((50+3200) /5200x100) **= 63%**
Intensity of impact of channel straightening						
	0	**2**	**5**	**8**	**10**	**Score**
Reduction in stream length per unit valley length	<5%	6-25%	26-50%	51-75%	>75%	**2**
Magnitude of impact of channel straightening: (extent of impact score/ 100) × intensity of impact score						**1.3**

3.4.2.3 Step 2 c: Impacts of artificial in-filling or narrowing

Infilling is an activity that often accompanies the construction of roads or berms. The construction of such structures frequently results in areas of wetland that are no longer subject to normal erosional and/or depositional processes. As described previously and shown in Figure 3.5, the road to Leliefontein (a gravel road) crosses Langvlei HGM 3. The area around this crossing was examined during the site visit to identify in-filled regions and the extent of the wetland that had been impacted in terms of sediment dynamics, was estimated. It was found that only a small portion of the wetland was affected. The northern bank is confined by a rocky outcrop and, because the wetland is naturally very narrow at this point, only a small area on the southern bank was filled-in. This localised impact was not included in the assessment as it was considered to be insignificant.

3.4.2.4 Step 2D: Impacts of changes in runoff characteristics

Changes to runoff characteristics can alter the ability of water to move and deposit sediments, and thus changes in runoff can lead to erosion, one of the most common factors that damage wetlands in South Africa (Macfarlane *et al., 2*008). Changes in runoff characteristics were assessed by examining the factors described in the Hydrology module. It was found previously that although there was no significant change in the amount of water reaching the two wetlands, there was a likelihood of increased flood-peaks. This was due to the altered condition of the vegetation, a consequence of antecedent cultivation in the catchments. In the case of Langvlei HGM 1, an additional factor is involved, namely erosion of the drainage lines feeding the upper portion of the wetland. Table 3.16, which reports the impact of altered hydrology on sediment transport, calls for an estimate of the proportion of each wetland that is affected by the changed water inputs. In the case of Langvlei, changes in land-use (25% of each catchment is cultivated or historically cultivated) have resulted in altered runoff. It is considered that a fairly high extent of each HGM unit will be affected, especially for HGM 1. In the case of the Ramkamp, most of the historically cultivated areas are located on the Baileysvlakte. It was estimated that the proportion of this wetland that is affected by the changed water inputs is approximately 50%.

Table 3.16: Effect of altered water inputs (increased flows and flood-peaks) on wetland geomorphological integrity

Extent of impact of altered water inputs						**HGM 1**	**HGM 2**	**HGM 3**	**Ram-kamp**
Extent calculated based on length of wetland affected by increased flow as a proportion (%) of the entire wetland length.					**%**	**80**	**50**	**50**	**50**
Intensity of impact of altered water inputs									
		Increased flood-peaks							
		No effect (0-2)	Small increase (2.1-4)	Moderate increase (4.1-7)	Large increase (>7)	**Intensity of impact of altered water inputs for each HGM unit**			
Increased flows (increased flow score	No increase (0-2)	**0 (HGM 2 & 3; Ramkamp)**	**2 (HGM 1)**	4	7*	**HGM 1**	**HGM 2**	**HGM 3**	**Ramkamp**
	Small increase (2.1-4)	2	3	6	8	**2**	**0**	**0**	**0**
	Moderate increase (4.1-7)	4	6	8	9				
	Large increase (>7)	7*	8	9	10	**HGM 1**	**HGM 2**	**HGM 3**	**Ramkamp**
Magnitude of impact score: (extent of impact score/100) × intensity of impact score (from above rows)						(2 × 0.8) **1.6**	**0**	**0**	**0**
						Small	**None**	**None**	**None**

* Unlikely to occur

Despite the extent of the wetland that is affected being fairly high (both for Langvlei and Ramkamp), the magnitude of the impact is small (Langvlei HGM 1) or negligible (Langvlei HGM 2, 3 and the Ramkamp) and unlikely to impact on the geomorphological health of the two systems (Table 3.16).

3.4.3 Step 3: Conduct individual assessments based on indicators

This section focuses on impacts to geomorphology that are visible from aerial photographs and from the site visit.

3.4.3.1 Step 3A: Impacts of erosion and*/or deposition*

As mentioned in the Hydrology module, there are regions of gully erosion in Langvlei HGM 1 (and its catchment) in HGM 2 and in the Baileysvlakte section of the Ramkamp. There is also a small area of sediment deposition in Langvlei HGM 3. These features are taken into account in this section because of they are potentially a threat to geomorphological health.

3.4.3.1.1 Erosional features:

The extent of the impact due to erosional features was calculated as described below and is reported in Table 3.17.

- In the case of Langvlei HGM 1: the length of the erosion gullies (there are two) within this wetland (Figure 3.5) is approximately 50% of the HGM length. The average gully width is 1 m. These values, using Table 3.17 translate to a value of "15%" as the extent of impact of erosional features.
- In the case of Langvlei HGM 2: the percentage of total HGM unit length occupied by gullies is roughly 20%. Average gully width is 2 m. These values, translate to a value of "5%" (Table 3.17) as the extent of impact of erosional features for this HGM unit.
- In the case of HGM 3, there are no erosional features.
- The erosion gully in the Baileysvlakte section of the Ramkamp is less than 20% of the length of the wetland with an average width of 2 m, which translates to an extent value of 5%.

Table 3.17: Estimation of the *extent* of impact of erosional features

		Length of wetland occupied by gully/ies as a percentage of the length of HGM					**HGM 1**	**HGM 2**	**HGM 3**	**Ram-kamp**
		0-20%	21-40%	41-50%	51-80%	>80%				
Average gully width in metres in relation to wetland width*	< 5	5	10	15	20	25				
	5-10	10	15	25	35	45				
	11-20	15	25	40	55	65	**15%**	**5%**	**N/A**	**5%**
	21-50	20	30	50	70	80				
	>50	25	40	60	80	100				

*Sum of gully widths if more than one gully present.

The *magnitude* of the erosional impacts is calculated in Table 3.18 based on the scoring system in Table A2.9 Appendix 2 and on consideration of the following factors:

- The most down-stream erosion gully in Langvlei has one main stem, which is branched at the top. However, all of the side branches are short, none seemed to be very active (as evidenced by a lack of fresh sediment in the gully), and these branches were therefore ignored. The most upstream gully has two active head-cuts.
- On consideration of the extent to which eroded sediment is retained within the HGM unit or wetland, water and carried sediment flows out of Langvlei HGM 1, through a riparian channel to HGM 2. The most upstream portion of HGM 2 has no channel, and is in reasonably good condition with regard to vegetation (section 2.3). Therefore, any sediment eroded from HGM 1 is likely to remain within the wetland. In the case of sediment eroded from the head-cut in HGM 2, this gully is in the most downstream portion of the HGM unit. It is also just upstream of HGM 3, which is a channelled valley bottom system. Thus, sediment eroded from this head-cut is less likely to remain in the wetland. There is however, the road crossing in HGM 3, with only two culverts, which would tend to retain the sediment.

Table 3.18: Intensity and magnitude of impact of erosional features. (Scores according to Table A2.9 Appendix 2). The scores for rows 2 and 3 are unscaled for any natural recovery that may have taken place. Factors used in scaling the intensity of impact of erosional features for natural recovery are presented in rows 7 and 8

Factor	**Unscaled Score**			
	HGM 1	**HGM 2**	**HGM 3**	**Ram-kamp**
Mean depth of gullies	4	0.5	N/A	6
Mean width of gullies	1	2	N/A	4
Number of head-cuts present	2	2	N/A	2
Unscaled intensity of impact score: mean score of above 3 rows	**3.7**	**1.5**	**N/A**	**4**
Scaling factor	**Factor**			
	HGM 1	**HGM 2**	**HGM 3**	**Ram-kamp**
Extent to which sediment from the gully is deposited within the HGM or wetland downstream of the HGM unit (as opposed to being exported)	0.4	0.7	N/A	0.4
Extent to which the bed and sides of the gully have been colonised by vegetation and/or show signs of natural recovery	0.7	0.7	N/A	0.7
Scaling factor score: mean of above 2 rows (value is between 0 and 1)	0.6	0.7	N/A	0.55
Scaled intensity of impact score = unscaled intensity of impact score × scaling factor score	(3.7x0.6) = 2.2	(1.5x0.7) = 1.1	N/A	(4x0.55) = 2.2
Magnitude of impact score for erosional features: (extent of impact score (see Table 3.17)/100) × scaled intensity of impact score	(15/100x 2.2) **= 0.33**	(10/100x 1.1) **= 0.1**	N/A	(5/100x2.2) **= 0.11**

- The erosion gully in the Ramkamp has only one (non-active) head-cut and any sediment eroded from this source is likely to remain entirely within the wetland. Consequently, the magnitude of impact of erosional features is unlikely to be high.

3.4.3.1.2 *<u>Depositional features:</u>*

The extent and magnitude of the unnatural deposition of sediment was assessed and is reported in Tables 3.19 and 3.20. From the site visit, a localised depositional area was found just down stream of the road crossing in Langvlei HGM 3. As mentioned previously, this is most likely a consequence of erosion from the road during the floods in winter 2007. Due to erosion from the head-cut in Langvlei HGM 1 and the unchannelled nature of HGM 2, it might be expected that marked deposition occurs at the most upstream portion of HGM 2. A small alluvial fan is visible in the aerial photograph. A small area of deposition is also present in the lower section of the Ramkamp wetland, which is also likely to originate from the nearby road. The extent of depositional features relative to the size of the relevant wetland/HGM unit was assessed from aerial photographs and from site visits and is recorded in Table 3.19.

Table 3.19: Estimation of the extent of impact of depositional features for known depositional features in the HGM unit

Extent of depositional features in relation to area of HGM unit being considered	0.2-2%	2-10%	11-25%	25-50%	>50%	**HGM 1**	**HGM 2**	**HGM 3**	**Ram-kamp**
Score for “extent” to be used in the estimation of magnitude of impacts	5%	20%	50%	75%	100%	**N/A**	**20**	**5**	**5**

The intensity and magnitude of the impact of the depositional features on the wetland were estimated using Table 3.20. From visual assessments at the site the impact of the various depositional features were not considered to be of major significance.

Table 3.20: Estimation of the extent of impact of depositional features for known depositional features in the HGM unit

Indicator	0	2	5	8	Score			
					HGM 1	HGM 2	HGM 3	Ram-kamp
The position of fan-like deposits within the wetland		Toe	Middle	Upper	N/A	8	5	5
Impact of depositional features on existing wetland features	Not evident	Minor destruction of features	Moderate destruction of features	Large impact on existing features	N/A	0	2	2
Intensity of impact score of depositional features: mean of two rows above					N/A	4	3.5	3.5
Magnitude of impact score of depositional features: (extent of impact score / 100) × intensity of impact score					N/A	(20/100x4) **= 0.8**	(5/100 x3.5) **= 0.2**	(5/100 x3.5) **= 0.2**

3.4.3.2 Step 3B: Impact of loss of organic sediment

There is no organic sediment in this wetland and so this part of the assessment was omitted.

3.4.4 Step 4: Determine Present Geomorphic State of each HGM unit

The Present Geomorphic State (PGS) for each wetland/HGM unit was then calculated by combining all the impacts to geomorphological health (Table 3.21). The scores were translated to PGS category by using Table A2.10 Appendix 2.

Table 3.21: Derivation of overall magnitude-of-impact scores through combining the scores obtained from individual assessments

Impact category	HGM 1	HGM 2	HGM 3	Ramkamp
Magnitude of impact of channel straightening (Table 3.15)	0	0	1.3	0
Magnitude of impact of infilling	0	0	0	0
Magnitude of impact of changes in runoff characteristics (Table 3.16)	1.6	0	0	0
Magnitude of impact for erosional features (Table 3.18)	0.3	0.1	0	0.11
Magnitude of impact for depositional features (Table 3.20)	0	0.8	0.2	0.2
Overall Present Geomorphic State = Sum of three highest scores	**1.9**	**0.9**	**1.5**	**0.31**
PGS category	**B “Largely natural”**	**A “Un-modified”**	**B “Largely natural”**	**A “Un-modified”**

3.4.5 Step 5: Assess the Present Geomorphic State of the wetland

In order to assess the overall Present Geomorphic State of the Langvlei wetland as a whole, the health scores of the three HGM units were combined on an area-weighted basis (Table 3.22). According to this summary, the wetland has an overall geomorphic health of category “B” indicating that the wetland is largely natural.

Table 3.22: Derivation of the overall magnitude of impact score for Langvlei

HGM unit	HGM area as a proportion of total wetland area	Impact score for HGM (Table 3.21)	Area-weighted impact score	Present Geomorphic State Category
1	0.2	1.9	0.4	
2	0.4	0.9	0.4	
3	0.4	1.5	0.6	
Total	**1.0**	**Overall weighted average impact score**	**1.4**	**B**

3.4.6 Step 6: Assess the vulnerability and Trajectory of Change due to erosion

3.4.6.1 Step 6A: Assess vulnerability to erosion for each HGM unit

In this section, the vulnerability of the wetland to erosion from head-cuts is examined. The major factors that are used to do this are slope and discharge. In WET-Health, wetland area is used to approximate discharge. An estimate of the vulnerability of each HGM unit was made using Figure A2.1 Appendix 2. WET-Health suggests a vulnerability score of from 0 (no change likely) to 10 (rapid head-cut advance likely leading to substantial deterioration). A score of 2 or 5 indicates that change may proceed slowly and dissipate within a relatively short distance upstream. As an example, the average slope of the Ramkamp wetland is approximately 3% and the size approximately 25 ha, and therefore from Figure A2.1 Appendix 2, this indicates that the wetland is vulnerable to erosion. The vulnerability scores for each of the Langvlei HGM units and for the Ramkamp have been entered into Table 3.23.

3.4.6.2 Step 6B: Describe the increased extent of gullies in relation to any external controls

The two gullies in Langvlei HGM 1 would be expected to erode longitudinally up through the wetland to the rocky outcrop near the head. The gully in Langvlei HGM 2 is a drainage ditch that was constructed to drain a portion of HGM 2 for cultivation, but is now eroding. It is currently controlled by an irrigation pipe, but this is being undermined by erosion. The gully can be expected to proceed upstream to the riverine section, which is upstream of HGM 2. This riverine section is confined on both banks by rocky out-crops, and thus erosion will be stopped at this point. The head-cut is likely erode along the length of the HGM unit and have a substantial impact by draining the wetland. In the case of the gully in the Ramkamp, further erosion appears to have been arrested by construction of the berm. The above information is captured in Table 3.23.

Table 3.23: Tabulation of the geomorphic vulnerability of each HGM unit of the wetland and the extent of predicted head-cut advancement

Wetland/HGM unit	HGM unit type	Vulnerability score	Extent of predicted head-cut advancement	Comments
HGM 1	VB* - channel	5	To the head of wetland	Vulnerable due to steep slope (Size = 5 ha, slope < 5%)
HGM 2	VB - channel	2	To riverine section upstream of HGM 2	Protected, but on the edge of "vulnerable" (Size = 10 ha, slope < 2%)
HGM 3	VB + channel	No head-cuts present		
Ramkamp	VB - channel	5	No further advance expected	Vulnerable due to steep slope (Size = 25 ha, slope < 3%)

*VB = valley bottom

3.4.7 Step 6 c: Assess the likely Trajectory of Change of the Geomorphic State

The likely Trajectory of Change for the Geomorphic State for each HGM unit as well as for the entire wetland is summarised in Table 3.24. Considerations from the previous section concerning the expected advancement of erosion gullies, in conjunction with other factors that might be expected to influence geomorphic health, were taken into account. A likely change score was assigned based on the guidelines in Table A2.11 Appendix 2. The area-weighted change score was calculated for each HGM unit for Langvlei and these then added together to obtain the change score and hence symbol, for the entire Langvlei wetland. The assessment reveals that, due to the presence of erosion gullies, the Present Geomorphic State for the Langvlei wetland as a whole is likely to deteriorate in the next 5 years. In the case of the Ramkamp, as historically cultivated fields become re-vegetated it is unlikely that the geomorphological health of the system will deteriorate any further. In addition, as discussed under the hydrology model, it is unlikely that the erosion gully will progress further. Therefore, the Trajectory of Change is likely to remain the same over the next 5 years.

Table 3.24: Evaluation of likely Trajectory of Change of geomorphic condition of the entire wetland

HGM unit	Description of relevant sources of change	HGM unit extent (%)	HGM unit change score	Area-weighted change score	Symbol
1	Erosion gullies likely to worsen leading to increased drainage of wetland	0.2	-1	- 0.2	→
2	Erosion gullies likely to worsen leading to increased drainage of wetland	0.4	-1	- 0.4	↓
3	Geo-morphological condition is likely to remain stable over the next 5 years	0.4	0	0	→
Overall weighted change score and symbol				**-0.6**	↓
Ramkamp	Geo-morphological condition is likely to remain stable over the next 5 years	-	-	-	→

3.4.8 Step 7: Describe overall geomorphological health of the wetland

In conclusion, the slightly negative Trajectory of Change score expected for the geomorphic health of Langvlei coupled with the Present Geomorphic State category (Table 3.23) gives the final, overall score for Langvlei as B (↓). This result indicates that, whilst the wetland is currently in a fairly good condition with regard to geomorphology, it is important that rehabilitation efforts be undertaken, particularly in HGM 2. The WET-Health assessment for the geomorphology of the Ramkamp wetland indicates that the Present Geomorphic Health of the Ramkamp is A (→).

3.5 Module 3: Assessment of the vegetation

Vegetation in a wetland is very important for attenuating floodwaters, and for aiding in nutrient cycling. In some wetlands local communities harvest plants (for example matjiesriet in some wetlands of the Kamiesberg – see Chapter 5). Wetland vegetation also provides habitat for fauna (birds, animals) and many wetlands exhibit a high biodiversity with regard to the plant species found in them. For all of the above reasons, it is important to examine the vegetation when assessing the health of a wetland. As is the case for the Hydrology and Geomorphology Modules, WET-Health assesses vegetation health in a step-wise manner as shown in Figure 3.8.

3.5.1 Step 1: Map and determine the extent of each HGM unit

This step is common to all of the WET-Health modules and the results reported previously.

Step 1: Map and determine the extent of each HGM unit

Step 2: Determine the Present Vegetation State of each HGM unit

Step 2A: Familiarization with the general structure and composition of wetland vegetation in the area

Step 2B: Identify and estimate the extent of each disturbance class in the HGM unit

Step 2 c: Assess the intensity and magnitude of impact for each disturbance class

Step 2D: Determine Present Vegetation State for each HGM unit

Step 3: Determine the overall Present Vegetation State for the wetland

Step 4: Assess the anticipated Trajectory of Change to wetland vegetation

Step 4A: Assess the anticipated Trajectory of Change to wetland vegetation within in each HGM unit

Step 4B: Determine the anticipated Trajectory of Change to wetland vegetation in the wetland as a whole

Step 5: Describe the overall vegetation health of the wetland based on Present Vegetation State and Trajectory of Change

Step 6: Record the alien vegetation that is present in the wetland

Figure 3.8: An outline of the steps involved in the Vegetation Module.

3.5.2 Step 2: Determine the Present Vegetation State (PVS) of each HGM unit

3.5.2.1 Step 2A: Familiarisation with the general structure and *composition of wetl*and *vegetation in the area*

The Vegetation Module of WET-Health examines what plant species "should not be there" (for example alien invaders or weedy species) rather than assessing what species should be there in the natural condition (and what are presently missing). This is a pragmatic approach considering the high biodiversity in many wetlands. No obvious plant invader species were seen in the Langvlei or Ramkamp during the course of the two site visits. However, as reported in Section 2.3.2 and onwards, there were challenges to the assessment of the vegetation condition in the Kamiesberg wetlands in that these systems are dominated by renosterbos (*Elytropappus rhinocerotis*). It was also difficult to establish if this species was favoured by cultivation/grazing as no sites could be found that had not at some stage or other been modified through agriculture. It is suspected that the abundance of this species in the wetlands is higher than under natural conditions, and that this may well be a consequence of historic cultivation/grazing. WET-Health makes provision for scoring impacts due to "weedy" species. Thus, the results reported in Section 2.3 were used to inform the broad assessment method used in WET-Health.

3.5.2.2 Step 2B: Identify and *estimate the extent of each disturbance class in the HGM unit*

The Vegetation Module of WET-Health differentiates between different classes of land-use. A description and list of these classes is shown in Table A2.12. The two wetlands were mapped and each wetland/HGM unit divided into disturbance units as is shown in Figure 3.4, 3.5 and 3.6. This allocation was based on current land-use and the history of disturbance. A summary table of the different land-uses was prepared for the Hydrology module for which the change in surface roughness from the natural condition was examined. This table is repeated below with the addition of the disturbance class to which each unit was allocated (Table 3.25). The results are summarised in Table 3.26.

Table 3.25: Summary of the different land-uses in each wetland, their extent and allocation to disturbance classes

Land-use sub-unit		**Description**	**Extent (% of HGM unit)**	**Disturbance Class (from Table 3.12 Appendix)**
Langvlei HGM 1	1a	Recently tilled (soil bare at time of visit in November)	4	Crop lands
	1b	Area around spring with dense stand of *Juncus* sp.	3	Minimal human disturbance
	1 c	Intact, biodiverse wetland area	3	Minimal human disturbance
	1d	Pasture/historically cultivated land	10	Old/abandoned lands
	1e	Fallow land	15	Old/abandoned lands
	1f	Recently tilled (soil bare at time of visit in November)	15	Crop lands
	1g	Fallow land	20	Old/abandoned lands
	1h	Dry-land (historically wetland) currently used for grazing	30	Perennial pasture
Langvlei HGM 2	2a	Relatively undisturbed (apart from livestock). No drains or erosion gullies.	45	Minimal human disturbance
	2b	Cultivated (drainage ditches along each side parallel to the direction of flow and at head of area).	30	Crop lands
	2 c	Historically cultivated area. Extensive sedimentation, but no erosion gullies.	10	Old/abandoned lands
	2d	Historically cultivated area (head-cut with erosion gully along one side).	15	Old/abandoned lands
Langvlei HGM 3	3a	Relatively natural. Naturally channelled valley bottom.	10	Minimal human disturbance
	3b	Channel *straightened and deepened.*	10	Old/abandoned lands
	3 c	Valley bottom with channel (vegetation recovering from cultivation). Upstream of road.	20	Old/abandoned lands
	3d	Relatively natural. Naturally channelled with pools at rocky outcrops. Extensive sedimentation.	10	Minimal human disturbance
	3e	Valley bottom with channel (relatively unimpacted).	30	Minimal human disturbance
	3f	Valley bottom with channel (relatively unimpacted).	20	Minimal human disturbance
Ramkamp	4a	Natural wetland vegetation, including limited old historically-cultivated areas, now well-recovered	32	Minimal human disturbance
	4b	Berm and pond area	2	Shallow flooding by dams
	4 c	Canalised area	10	Eroded areas
	4d	Natural wetland vegetation, including limited old historically-cultivated areas, now well-recovered	48	Minimal human disturbance
	4e	Historically cultivated – recent	8	Old/abandoned lands

Table 3.26: Summary of the extent of different disturbance classes in the two study wetlands

HGM Unit	Disturbance Class	Extent (% of HGM unit)
HGM 1	Crop lands	19
	Old/abandoned lands	45
	Perennial pasture	30
	Minimal human disturbance	6
Total extent		**100%**
HGM 2	Crop lands	30
	Old/abandoned lands	25
	Minimal human disturbance	45
Total extent		**100%**
HGM 3	Old/abandoned lands	30
	Minimal human disturbance	70
Total extent		**100%**
Ramkamp	Old/abandoned lands	8
	Shallow flooding by dams	2
	Eroded areas	10
	Minimal human disturbance	80
Total extent		**100%**

3.5.2.3 Step 2 c: Assess the intensity and *magnitude of impact for each disturbance class*

The next step is to assess the intensity of the impact to vegetation in each of the disturbance classes. WET-Health provides typical intensity-of-impact scores that can be used to inform the vegetation assessment (Table A2.13 Appendix 2). These recommended scores can be modified on a site-specific basis, for example, if extensive infestation of alien/weedy plants has occurred in any disturbance class, the intensity of impact score should be adjusted. As mentioned previously, no infestations of alien plants (other than a few scattered crop plants) were encountered in the wetland.

Table 3.27: Calculation of the HGM magnitude of impact score based on an area-weighted magnitude of impact score for each disturbance class

Disturbance class	Disturbance class extent (%, from Table 3.26)	Intensity of impact score (from Table A2.13 Appendix 2)	Magnitude of impact score*	Factors contributing to impact
Crop lands	19	9	1.7	Actively farmed,
Old/abandoned	45	5	2.3	Erosion gully draining
Perennial pasture	30	5	1.5	Erosion gully draining wetland. A few weeds
Minimal human disturbance	6	2	0.1	Biodiversity may well be reduced due to
HGM 1: Magnitude of impact score**			**5.6 (“D” category)[$]**	
Crop lands	30	9	2.7	Drains also in place.
Old/abandoned lands	25	4	1.0	Grazed. Erosion gully/drain in part of this area.
Minimal human disturbance	45	2	0.9	Grazed.
HGM 2: Magnitude of impact score**			**4.6 (“D” category)**	
Old/abandoned	30	3	0.9	Recovering.
Minimal human disturbance	70	2	1.4	Limited area of deposition of sand.
HGM 3: Magnitude of impact score**			**2.3 (“C” category)**	
Old/abandoned	8	4	0.32	
Shallow flooding by dams	2	4	0.08	
Eroded areas	10	5	0.5	Erosion gully draining
Minimal human disturbance	80	2	1.6	Biodiversity may be reduced due to
Ramkamp: Magnitude of impact score**			**2.5 (“C” category)**	

* Magnitude of impact score is calculated as extent / 100 × intensity of impact.

** Overall magnitude of impact score for the HGM unit = sum of magnitude scores for each disturbance class.

$ Category from Table A2.14 Appendix 2.

3.5.2.4 Step 2D: Determine the Present Vegetation State (PVS) of each HGM unit

The Present Vegetation State was calculated by summing the area-weighted magnitude of impact scores for all the disturbance classes in a given wetland or HGM unit (Table 3.27). Table A2.14 Appendix 2 was used to transform the area-weighted magnitude of impact scores to Present Vegetation State (PVS) categories. As is to be expected from the extensive land transformation in Langvlei HGM 1, the PVS is a low "D" category. The PVS for Langvlei HGM 2 is a high "D" and that for HGM 3 is "C". The Present Vegetation State category for Ramkamp was calculated to be "C".

3.5.3 Step 3: Determine the Present Vegetation State of the entire wetland

In an analogous manner to the previous two modules, overall health for the entire Langvlei wetland for vegetation is calculated using the area-weighted magnitude of impact scores for each HGM unit (Table 3.28). The overall PVS for Langvlei is a "D" category.

Table 3.28: Summary impact score for each HGM and assessment of overall Present Vegetation State of the wetland

HGM Unit	HGM unit extent (%)	HGM unit magnitude of impact score (from Table 3.27)	Area-weighted impact score*	Present Vegetation State category
1	20	5.6	1.12	
2	40	4.6	1.84	
3	40	2.3	0.92	
	100	**Overall weighted impact score****	**3.8**	**C**
			Ramkamp	**C**

*Area weighted impact score = HGM extent /100 × impact score

**Overall area-weighted impact score = sum of individual area-weighted scores for each HGM unit

3.5.4 Step 4: Assess the anticipated Trajectory of Change to wetland vegetation

In considering the future possible state of vegetation in the two study wetlands, the following factors were taken into consideration. There seems to be a rejection of agriculture as a career by the younger generation in the Kamiesberg and the number of people farming is unlikely to increase. On the other hand, there is a danger that ploughing will be done by tractor, rather than by oxen which, as a consequence of the deeper tillage depth, could destroy the seed banks of indigenous plants in the wetlands. Furthermore, in the Geomorphology Module it was noted that some areas are threatened by erosion due to the formation of gullies, which will drain the wetland and lead to encroachment of terrestrial species.

*3.5.4.1 Step 4A: Assess the anticipated Trajectory of Change to wetl*and *vegetation within each HGM unit*

Change scores are first allocated to each disturbance class and are then summed for each HGM/wetland unit (Table 3.29). The change scores assigned were based on the guidelines in Table A2.15 Appendix 2.

Table 3.29: Evaluation of Trajectory of Change of vegetation within each HGM

Disturbance class	Source of change	Disturbance class extent (%)	Change score	Area-weighted change score*
Crop lands	Erosion gully	19	-1	-0.2
Old/abandoned lands	Stable, but unlikely to improve	45	0	0
Perennial pasture	Stable, but unlikely to improve	30	0	0
Minimal human disturbance	Stable. Increased grazing	6	0	0
Change score for HGM 1				**-0.2**
Crop lands	Stable	30	0	0
Old/abandoned lands	Erosion gully	25	-1	-0.25
Minimal human disturbance	Stable	45	0	0
Change score for HGM 2				**-0.3**
Old/abandoned lands	Likely to recover	30	+1	0.3
Minimal human disturbance	Stable	70	0	0
Change score for HGM 3				**0.3**
Old/abandoned lands	Likely to recover	8	+1	0.1
Shallow flooding by dams	Stable	2	0	0
Eroded areas	Stable	10	0	0
Minimal human disturbance	Stable, but unlikely to improve (due to grazing)	80	0	0
				0.1

*Area weighted change score = Disturbance Class extent /100 × change score

**HGM change score = sum of individual area-weighted scores for each disturbance unit

3.5.4.2 Step 4B: Determine the anticipated Trajectory of Change of vegetation for the wetland as a whole

As with the assessment of Present Vegetation State, threats to wetland vegetation are assessed at an HGM unit level and then combined to obtain a score that reflects the anticipated Trajectory of Change for the wetland as a whole (Table 3.30).

Table 3.30: Evaluation of Trajectory of Change of vegetation in the entire wetland

HGM Unit	Description of relevant sources of change	HGM unit extent	HGM change score*	Area-weighted change score**	Symbol
1		0.2	-0.2	-0.04	→
2		0.4	-0.3	-0.1	→
3		0.4	0.3	0.1	→
Langvlei: Overall weighted change score* **				**-0.04**	→
Ramkamp: Overall weighted change score* **				**0.1**	→

*Calculated for each HGM unit

**Area weighted change score = HGM extent /100 × HGM change score

***Overall area-weighted change score = sum of individual area-weighted scores for each HGM unit

3.6 Summary of results for Langvlei and Ramkamp

Table 3.31 below summarises the health scores for the three different components (hydrology, geomorphology and vegetation) obtained for Langvlei and for the Ramkamp.

Table 3.31: Summary of the Present State categories and the Trajectory of Change symbols obtained for the wetlands using WET-Health

	Langvlei				Ramkamp
	HGM 1	HGM 2	HGM 3	Entire wetland	
Hydrology	E→	B↓	A→	**B↓**	**A →**
Geomorphology	B→	A↓	B→	**B↓**	**A →**
Vegetation	D→	D→	C→	**C/D →**	**C →**

4. ASSESSMENT OF ECOSYSTEM SERVICES PROVIDED BY THE TWO WETLANDS

By H Malan

4.1 Background to Wet-EcoServices

An assessment of the ecosystem services provided by the Langvlei and Ramkamp wetlands was carried out using WET-EcoServices. WET-EcoServices (Kotze *et al., 2*008) is a rapid assessment tool that forms part of the "WET-Management" series developed under Phase I of the National Wetlands Research Programme. According to the authors, the overall goal of this tool is to assist decision makers, government officials, planners, consultants and educators in undertaking rapid assessments of wetlands revealing the benefits that they supply. This will then highlight the importance of wetlands and allow for more informed planning and decision-making. Such an assessment is necessary because, although all wetlands are important, the particular ecosystem services that they supply and the extent to which they supply them, varies from wetland to wetland.

The 15 ecosystem benefits shown in Table 4.1 are assessed in WET-EcoServices. As can be seen, they vary from direct benefits (also termed "provisioning services") such as providing harvestable reeds, to indirect services (also termed "regulatory and supporting services") such as improving the quality of water flowing out of the wetland, to the more intangible benefits such as a wetland being of cultural or spiritual importance. Each of the ecosystem benefits is scored from 0 to 4 (where 0 indicates the wetland is not important for that function and 4 indicates that it is very important). These scores are calculated from various readily measurable characteristics of the wetland, which may be available, either from existing sources of information, or measured in the field. For example, when assessing the ability of a wetland to attenuate floods (i.e. by retaining floodwaters within the wetland), the size of the wetland relative to the catchment, the roughness of wetland vegetation, and the steepness of the wetland slope are some of the characteristics that are measured. These characteristics (and others) are then combined to obtain an overall score for the potential importance of the wetland in attenuating downstream flooding.

Table 4.1: Ecosystem services assessed by WET-EcoServices[3] (Kotze *et al., 2*008)

<table>
<tr><td rowspan="16">Ecosystem services supplied by wetlands</td><td rowspan="10">Indirect benefits</td><td rowspan="9">Regulating and supporting benefits</td><td colspan="2">Flood attenuation</td><td>The spreading out and slowing down of floodwaters in the wetland, thereby reducing the severity of floods downstream</td></tr>
<tr><td colspan="2">Streamflow regulation</td><td>Sustaining streamflow during low flow periods</td></tr>
<tr><td rowspan="5">Water quality enhancement benefits</td><td>Sediment trapping</td><td>The trapping and retention in the wetland of sediment carried by runoff waters</td></tr>
<tr><td>Phosphate assimilation</td><td>Removal by the wetland of phosphates carried by runoff waters, thereby enhancing water quality</td></tr>
<tr><td>Nitrate assimilation</td><td>Removal by the wetland of nitrates carried by runoff waters, thereby enhancing water quality</td></tr>
<tr><td>Toxicant assimilation</td><td>Removal by the wetland of toxicants (e.g. metals, biocides and salts) carried by runoff waters, thereby enhancing water quality</td></tr>
<tr><td>Erosion control</td><td>Controlling of erosion at the wetland site, principally through the protection provided by vegetation.</td></tr>
<tr><td colspan="2">Carbon storage</td><td>The trapping of carbon by the wetland, principally as soil organic matter</td></tr>
<tr><td colspan="3">Biodiversity maintenance[4]</td><td>Through the provision of habitat and maintenance of natural process by the wetland, a contribution is made to maintaining biodiversity</td></tr>
<tr><td rowspan="6">Direct benefits</td><td rowspan="3">Provisioning benefits</td><td colspan="2">Provision of water for human use</td><td>The provision of water extracted directly from the wetland for domestic, agriculture or other purposes</td></tr>
<tr><td colspan="2">Provision of harvestable resources</td><td>The provision of natural resources from the wetland, including livestock grazing, craft plants, fish, etc.</td></tr>
<tr><td colspan="2">Provision of cultivated foods</td><td>The provision of areas in the wetland favourable for the cultivation of foods</td></tr>
<tr><td rowspan="3">Cultural benefits</td><td colspan="2">Cultural heritage</td><td>Places of special cultural significance in the wetland, e.g., for baptisms or gathering of culturally significant plants</td></tr>
<tr><td colspan="2">Tourism and recreation</td><td>Sites of value for tourism and recreation in the wetland, often associated with scenic beauty and abundant birdlife</td></tr>
<tr><td colspan="2">Education and research</td><td>Sites of value in the wetland for education or research</td></tr>
</table>

[3] The wetland benefits included in WET-EcoServices are those considered most important for South African wetlands, and which can be readily and rapidly described. This is by no means exhaustive. Other benefits include **groundwater** recharge and discharge and biomass export, which may all be important but are difficult to characterize at a rapid assessment level.

[4] Biodiversity maintenance is not an ecosystem service as such, but encompasses attributes widely acknowledged as having potentially high value to society.

4.2 How the Wet-EcoServices assessment was carried out

WET-EcoServices can be carried out at two different levels, namely as a desktop exercise (Level 1) or at a more detailed resolution, requiring site visits (Level 2). For the Langvlei and Ramkamp wetlands, the latter approach was used. For each of the 15 potential ecosystem services, various characteristics or attributes of the wetland were scored (from 0 to 4) and entered into the data spreadsheet. For the two wetlands under consideration, each characteristic was scored using information gathered from perusal of maps, aerial photos, two site visits, and local knowledge. The assessment was undertaken as a collaborative exercise (I Samuels, L Saul, D Kotze, D Ollis and H Malan) in order to combine expert judgement. The confidence in the score for each characteristic was also recorded. Appendices 3 and 4 show printouts of the score spreadsheet for Langvlei and Ramkamp respectively, including the confidence ratings. From the scores for each characteristic, composite scores were calculated within the spreadsheet for each of the ecosystem services listed in Table 4.1. The composite scores also ranged from 0 (a given ecosystem service is not supplied by the wetland) to 4 (the wetland is very important in supplying that benefit). Table 4.2 shows how the composite scores were interpreted.

Table 4.2: Classes for determining the likely extent to which a benefit is being supplied based on the overall score for that benefit

Score:	<0.5	0.5-1.2	1.3-2.0	2.1-2.8	>2.8
Rating of the extent to which a benefit is likely to be supplied	Low	Moderately low	Intermediate	Moderately high	High

Because different HGM types typically vary in the ecosystem benefits that they deliver, each HGM unit was assessed separately. As discussed in Chapter 3, Langvlei consists of three HGM units and Ramkamp of a single unit. The HGM types are as follows:

Langvlei:

HGM 1 (at the most southerly portion of the wetland, on the farm “Klutersvlei”) was typed as *valley-bottom without channel*;

HGM 2 (the middle portion of the wetland) was also typed as *valley-bottom without channel*;

HGM 3 (the most northerly, and downstream portion of the wetland) was typed as *valley-bottom with channel; and*

Ramkamp was typed as *valley-bottom without channel*.

WET-EcoServices considers both the *effectiveness* of a wetland in performing a certain ecological service and the *opportunity* for the wetland to do this. For instance, due to certain attributes or characteristics (e.g. diffuse patterns of streamflow, high vegetation biomass), a wetland may be potentially very effective at removing nitrate, and yet it may be in a catchment that is almost pristine. Thus the actual extent to which nitrate is assimilated (the opportunity) will be low.

4.3 Results of the assessment

Appendices 3 and 4 show the scores returned for Langvlei and Ramkamp respectively, for each of the individual characteristics. Also shown is the confidence the team felt in assigning those scores. The scores are summarised in Table 4.3 for each ecosystem service. For some of the ecosystem services, namely, flood attenuation, sediment trapping, phosphate, nitrate and toxicant assimilation and erosion control, separate scores are calculated in WET-EcoServices for the effectiveness and for the opportunity. In the case of the ecosystem function “biodiversity maintenance,” noteworthiness and ecosystem integrity (“health”) are calculated separately. WET-EcoServices calculates the average to generate an overall score. Each of the 15 ecosystem services is discussed below in relation to the two wetlands.

4.3.1 Flood attenuation

All three HGM units for Langvlei yielded similar scores for this ecosystem process. The values all fell within the 1.3-2.0 range, indicating (Table 4.2) that these wetlands are intermediate in their importance for preventing flooding. A similar, if slightly higher score was also obtained for the Ramkamp wetland.

In the case of Langvlei HGM 3, (the only naturally channelled wetland), a preliminary prediction was that this HGM unit would not be important for flood attenuation. The rationale for this being that channelled wetlands are not particularly effective in retaining water especially in the late wet season (when the system is already saturated and hence cannot “absorb” additional floodwaters). Nevertheless, the WET-EcoServices assessment indicates that this wetland is of intermediate importance for flood attenuation in general. The characteristic that has resulted in this higher-than-expected score is the fact that the system is very seasonal (and thus has a larger capacity to store floodwaters than a perennial system). Another factor is the relatively large size of the wetland in relation to the catchment and the high frequency that storm flows are spread over the wetland. These factors all made this HGM relatively efficient in retaining floodwaters.

Table 4.3: Summary table of the ecosystem services supplied by each of the HGM units in Langvlei and Ramkamp wetlands (Level 2 WET-EcoServices assessment). The overall scores* are given in bold, and where relevant, the separate scores for effectiveness and opportunity are provided.

Ecosystem service					Scores for each ecosystem service			
					Langvlei			Ram-kamp
					HGM 1	HGM 2	HGM 3	
Ecosystem services supplied by wetlands	Indirect benefits	Regulating and supporting benefits		Flood attenuation	**1.8**	**1.7**	**1.7**	**2.0**
				Effectiveness	2.0	2.2	2.3	2.5
				Opportunity	1.6	1.2	1.2	1.4
				Streamflow regulation	**2.0**	**2.0**	**2.0**	**2.0**
			Water quality enhancement benefits	Sediment trapping	**2.0**	**2.5**	**2.2**	**2.2**
				Effectiveness	1.0	2.1	1.6	1.8
				Opportunity	3.0	3.0	2.7	2.7
				Phosphate assimilation	**2.2**	**2.4**	**1.8**	**2.3**
				Effectiveness	2.0	2.8	1.9	2.9
				Opportunity	2.3	2.0	1.7	1.7
				Nitrate assimilation	**1.8**	**2.0**	**1.7**	**2.1**
				Effectiveness	2.0	2.4	1.8	2.6
				Opportunity	1.5	1.5	1.5	1.5
				Toxicant assimilation	**1.9**	**2.2**	**1.7**	**1.9**
				Effectiveness	1.8	2.4	1.7	2.6
				Opportunity	2.0	2.0	1.7	1.3
				Erosion control	**1.6**	**2.1**	**2.5**	**2.2**
				Effectiveness	1.3	2.0	2.8	2.8
				Opportunity	2.0	2.2	2.2	1.6
				Carbon storage	**0.7**	**1.0**	**1.3**	**1.3**
				Biodiversity maintenance	**2.1**	**2.4**	**2.8**	**2.6**
				Noteworthiness	2.5	2.8	3.0	2.8
				Ecosystem health	1.8	2.1	2.6	2.4
	Direct benefits	*Provisioning benefits*		Water for human use	**2.2**	**1.7**	**1.2**	**1.0**
				Provision of harvestable resources	**3.6**	**3.6**	**2.8**	**2.8**
				Provision of cultivated foods	**3.6**	**3.6**	**2.0**	**1.4**
		Cultural benefits		Cultural heritage	**1.5**	**1.5**	**1.5**	**2.0**
				Tourism and recreation	**1.1**	**1.1**	**1.7**	**1.1**
				Education and research	**1.0**	**1.5**	**1.8**	**2.0**
Total score					**29**	**31**	**29**	**29**
Threats to the wetland benefits					3.0	3.0	1.0	0
Opportunities for enhancing benefits					2.0	2.0	1.0	2

*WET-EcoServices calculates the overall score as the average of the effectiveness and opportunity scores.

4.3.2 Streamflow regulation

Streamflow regulation refers to the supply of water during the dry season to aquatic resources downstream of the wetland. As is the case for flood attenuation, all the wetlands were fairly similar in their scores for delivering this ecosystem service and are of intermediate/moderately high importance for delivering this benefit.

4.3.3 Sediment trapping[5]

It was predicted from considering the HGM type that Langvlei HGM 1, 2 and the Ramkamp wetland, being unchannelled valley bottom systems should be important for trapping of sediment. This is because flow through such systems is diffuse (there is no main channel). Aboveground and subterranean plant mass in such systems and the moderately high surface roughness of the vegetation slows water down, causing sediment to be retained in the wetland.

The scores obtained from the WET-EcoServices assessment indicate that Langvlei HGM 1, 3 and the Ramkamp wetland are intermediate/moderately high in their importance for delivering this ecosystem service and HGM 2 is moderately high (score 2.5). In the case of HGM 1, factors that would lower the ability of the wetland to perform this ecosystem benefit include the fact that although there is erosion from the catchment, little appears to be retained within this HGM unit. Due to the presence of erosion channels, some sediment is transported out of the system. Sediment deposits are visible from aerial photographs though in the upper (unchannelled) portion of HGM 2 and this resulted in a high score for this HGM unit.

The value of 2.2 is slightly lower than might be expected for the Ramkamp wetland which is an unchannelled system with vegetation in a reasonably good condition (WET-Health category for vegetation = C). The reason for this lower-than-expected score is due to the absence of visible sediment deposition in the system. Areas of sediment deposition are difficult to identify however (Macfarlane *et al., 2*008). Consequently after further fieldwork the score for this characteristic may need to be refined and the extent of sediment trapping carried out by the Ramkamp wetland may be found to be greater than previously thought.

[5] The more detailed investigation of the geomorphology (described in Section 2.2) was carried out subsequent to this WET-EcoServices assessment and the retention of sediment within the wetland may have been under-estimated in this rapid appraisal method. Thus ecosystem benefits that rely on sediment retention, namely; sediment trapping, phosphate, toxicant and (to a lesser extent) nitrate assimilation, and erosion control are likely to be underestimated in this assessment.

4.3.4 Phosphate assimilation

Phosphates tend to adsorb to sediments, and thus erosion control, trapping of sediments and phosphate removal are closely coupled. As a consequence, the scores obtained for the wetlands mirrored those obtained for sediment trapping. There is, however, a further consideration, when interpreting the scores obtained from WET-EcoServices. As mentioned previously, for some ecosystem services, including phosphate assimilation, both the effectiveness (potential) of the wetland to perform a function and the opportunity (the actual extent to which this ecosystem benefit is being provided) are considered and are scored separately (Table 4.3).

In the case of the Ramkamp wetland, although the effectiveness of the wetland for removing phosphate is high (2.9), the opportunity for the wetland to do this is low (1.7). This is due to the fact that there is no fertilizer use in the catchment, and low levels of erosion. This results in a moderately high overall score of 2.3. In the case of Langvlei HGM 3, the intermediate score of 1.8 is due to the lower general effectiveness of channelled wetlands in removing phosphate, and thus protecting downstream aquatic ecosystems.

4.3.5 Nitrate assimilation

The scores for amelioration of water quality flowing out of the wetlands due to removal of nitrates are intermediate for all the Langvlei HGM/wetland units. The highest score was obtained for Ramkamp. This was a result of the fairly high effectiveness in removing nitrates owing to the fact that this HGM has the highest level of wetness and the most diffuse flow out of all the wetland areas assessed.

4.3.6 Toxicant assimilation

The importance of the wetlands for removing toxicants (pesticides, metals etc) is intermediate, with Langvlei HGM 2 being moderately high (2.2). HGM 2 scored the highest of all the wetland units, due to the high effectiveness score, a consequence of the fact that it is able to trap sediments well (toxicants are often bound to sediments). There is also a relatively high opportunity for Langvlei HGM 2 to assimilate toxicants, being just downstream of the area of the wetland (HGM 1) where the most intensive cultivation is carried out.

4.3.7 Erosion control

All the wetlands (except for Langvlei HGM 1) scored moderately high in importance for providing erosion control. Langvlei HGM 1 scored as intermediately important in this respect. The lower score for this portion of the wetland was a consequence of the fact that visible erosion is evident, the level of soil disturbance is high, and the extent of vegetation coverage is low.

4.3.8 Carbon storage

None of the wetlands are likely to be particularly important for the storage of carbon. The major reason for this is the absence of peat in these systems. This in turn is likely to be a consequence of the generally arid nature of the area and the absence of permanently saturated areas, which is a requisite for peat formation to occur.

4.3.9 Maintenance of biodiversity

WET-EcoServices considers both the noteworthiness of biodiversity in a wetland as well as the environmental condition ("ecological health") of the system. All the wetlands/HGM units score moderately high, to high, in terms of the noteworthiness of biodiversity. This is a reflection of the importance of the general area for conservation (Helme and Desmet, 2007). The ecological integrity of the wetlands reflects the results obtained from the WET-Health assessment, with Langvlei HGM 1 scoring the lowest (due to the fairly high level of cultivation and other impacts), and Langvlei HGM 3 and the Ramkamp scoring the highest.

4.3.10 Water supply for human use

It is only in Langvlei HGM 1 and 2 that there is direct use of water for human supply (see the WET-Health assessment: hydrology module). As a result, only these two wetlands obtained a high score for this benefit.

4.3.11 Provision of natural resources or cultivated foods

All the wetlands returned high scores for the provision of natural resources. This is a reflection of the aridity of the surrounding area, the importance of the wetlands for providing grazing, and the socio-economic context of the community. In the case of provision of cultivated foods, the scores followed the pattern of general land-use in the area. Thus Langvlei HGM 1 and 2 in which there is cultivation returned the highest scores for this benefit, followed by HGM 3 and the Ramkamp.

4.3.12 Cultural heritage

All the wetlands scored intermediately for this benefit. There are no strong cultural customs linked to the wetlands. However, in the case of the Ramkamp, there are some agricultural practices, for example such as separating rams from the rest of the flock, which are peculiar to this area (I Samuels, 2007, pers. comm., University of the Western Cape, Cape Town).

4.3.13 Tourism and recreation

The wetlands all score moderately low-intermediate in importance for tourism and recreation. This is partly because of the lack of extensive areas of open water. Nevertheless, there is potential for more tourism in the area, particularly during the wild flower season in spring.

4.3.14 Education and research

Langvlei HGM 1 and 2 scored the lowest for this benefit. Langvlei HGM 3 and the Ramkamp wetland scored the highest. This is a reflection of the lower disturbance of vegetation in these areas (and thus higher biodiversity). There are currently several research projects being conducted on various aspects in the general Kamiesberg area.

Although not part of the WET-EcoServices assessment, in this project the overall scores for the different ecosystem services were summed for each wetland. This assumes that each of the 15 benefits is of equal importance – an assumption that is not necessarily true and that requires further research. Despite this limitation, such an approach yielded interesting results. The overall totals are shown in Table 4.3. It can be seen that the scores for the all the wetlands were very similar. Langvlei HGM 2 scored the highest overall score because it has an upper area of fairly unimpacted, un-channelled valley bottom wetland, which scores for water quality amelioration, sediment trapping and biodiversity. The lower half of the wetland is used for cultivation, and thus the wetland scores are also high for this ecosystem service. However, there is no size factor linked to this assessment technique, as it is a rapid method. For a more comprehensive investigation, the proportion of different land-uses within a wetland would also need to be factored into the process.[6]

Table 4.3 also shows the potential threats to maintenance of the ecosystem services being supplied and the opportunity for increasing those benefits. In the case of Langvlei HGM 1 and 2, due to the presence of erosion gullies, which could expand further, the threats to these wetlands are considered to be fairly high. The threats to HGM 3 and Ramkamp are fairly low and this is reflected in the scores. In the case of the Ramkamp, the erosion gully that is present appears to be stabilised and is unlikely to worsen. For both wetlands, there is little threat of urban expansion, despite being close to the town of Leliefontein. The community is aware of the limited carrying capacity of the wetlands. However, it seems as if there is poor regulation of access to the resource, which may result in over utilisation. For a more detailed assessment of the threats to the wetland, see Chapters 3 and 5.

Opportunities for increasing the ecosystem benefits are present as shown by the scores in Table 4.3. These are surprisingly high for Langvlei HGM 1 and 2, reflecting the fact that, with rehabilitation interventions in place, it may be possible to increase the level of some services (e.g. flood attenuation, water quality amelioration) again. The score of 2 obtained for the Ramkamp is due to its potential as a tourist attraction during the wild flower season (July-September). The overall scores are summarised visually in the spider diagrams shown in Figure 4.1.

4.4 Linking the Level of Ecosystem Services and Degree of Impact

In Chapter 3 the effect of human activities on the ecological state of the HGM units in Langvlei and Ramkamp were assessed, and in this chapter, an assessment was undertaken of the ecosystem services delivered by the HGM units. An important question that needs to be addressed now is "*how have the various impacts on the ecological state of the different HGM units impacted upon the effectiveness of the HGM units in delivering specific ecosystem services?* "[7]

From Table 4.3 it can be seen that overall the delivery of ecosystem services has been most affected in Langvlei HGM 1, next most affected in HGM 2, followed by HGM 3, and least affected in Ramkamp. Nonetheless, in all of the HGM units, the ecosystem service

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[6] This approach has been investigated and expanded in another report in the WHI series. See; Ellery *et al.* (2010).

[7] For further ideas on linking wetland environmental condition and levels of provision of ecosystem services also see: Ellery *et al.* (2010).

most affected by a change in the environmental condition of the HGM units is *biodiversity maintenance*. The main factor causing this impact is a change in vegetation from mixed sedge/grass/shrub to vegetation that is shrub (renosterbos)-dominated, which has occurred to a greater extent in Langvlei than in Ramkamp, probably as a result of the more intense use of Langvlei. This highlights that a key area of rehabilitation would be to try to shift the vegetation to a state that is less dominated by shrubs alone. This is likely to be best achieved by a combination of factors, including timing and frequency of burning, lenient use by livestock and strategic planting of grasses and sedges.

4.5 Conclusion

The results obtained for the wetlands under consideration (Langvlei and Ramkamp wetlands) indicate that these wetlands are important in delivering ecosystem services to the community. These are not only the provision of cultivated food and grazing, but also control of erosion and water quality amelioration. This is important considering the aridity of the surrounding area, and the general importance of the Kamiesberg for supplying good quality water to towns in the lowland areas.

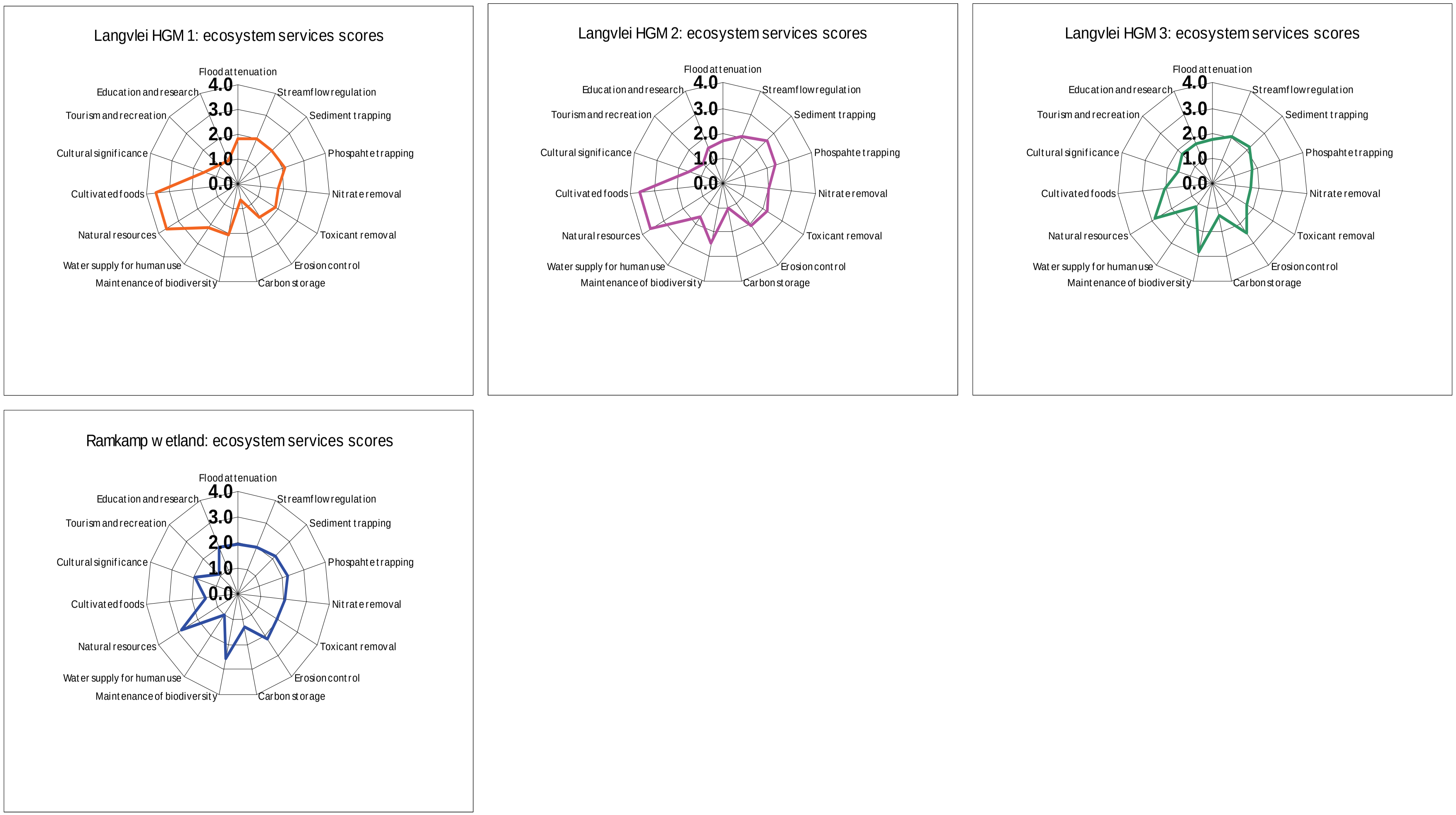


Figure 4.1: Diagram to show the major benefits provided by the Langvlei and Ramkamp wetlands.

5. ASSESSMENT OF THE SUSTAINABILITY OF WETLAND USE

By D Kotze, I Samuels and L Saul

5.1 The framework used for the assessment

The purpose of this chapter is to assess the sustainability of use of the two selected Kamiesberg wetlands, namely the Ramkamp and the Langvlei wetlands. This assessment, for which the fieldwork was undertaken in the summer of 2007/2008, used the assessment protocols given in WET-SustainableUse (Kotze 2010). The assessment also draws extensively from the environmental condition assessment undertaken using WET-Health (Macfarlane *et al., 2*008), which is given in Chapter 3.

In assessing social sustainability, WET-SustainableUse includes consideration of how tenure, governance and other socio-economic factors might influence the sustainability of use. It provides a set of key guiding questions relating to tenure, governance and control (e.g. "Who has access to the wetland resources?"). A framework is also provided to assist with the identification of key factors (operating from a household level to an international level) that may be influencing the use of the wetland, which assists in placing the assessment in a broader socio-economic context.

In assessing ecological sustainability, at the highest level, WET-SustainableUse asks to what extent the use of the wetland has altered: (1) the distribution and retention of water, (2) the retention and accumulation of sediment, (3) the retention and cycling of nutrients and (4) the natural composition of the vegetation in the wetland. WET-SustainableUse assists the user in answering these questions by providing a set of indicators and a structured way of scoring these indicators and deriving an overall score. A series of simple models is used, each comprising a set of metrics that are combined in a simple algorithm to represent how a key process in the wetland (e.g. sediment accumulation) is affected by use. The rationale behind the selection of each of the metrics is also provided, together with the rationale for combining the scores of the different metrics into a single score. WET-SustainableUse also encourages gathering the perspectives of the users on how they see their land-use activities affecting the wetland's condition. Finally, WET-SustainableUse provides guidance to assist in identifying appropriate actions required to improve sustainability in the light of the above assessments.

5.2 Social sustainability

Ecosystem use (and protection) is by definition a social and political process (Brechin *et al., 2*002), and the term 'sustainability' is value-laden because it involves people's 'needs' and people's 'options' (Adey, 2007). Thus, when assessing sustainability, it is not simply a matter of considering technical/biophysical issues (Section 5.3) but social issues must also be considered (Erenstein, 2003; Kotze, 2007). Information relevant to social sustainability was gathered based on the guiding questions given in WET-SustainableUse relating to tenure, governance and control, which are as follows:

- Who owns the wetland?
- Who has access to the wetland resource (e.g. are they accessible broadly to most local households)?
- Are there any rules in place governing use?
- If yes, what are these rules, who has responsibility for enforcing them and what is the level of adherence?
- What are the benefits received?
- How is this access spread across the different users (e.g. concentrated within a few of the wealthier households; spread across households, including some of the poorest)?

The use and protection of ecosystems involves dynamic, scale-related activities playing themselves out in complex ways within and between social and ecological systems. The resultant pressures and feedbacks are therefore difficult to predict and control, and this complexity needs to be acknowledged and addressed (Walker *et al., 2*002; Breen *et al., 2*003). Therefore, the long-term protection and wise use of wetlands lies in developing an holistic view of social-ecological systems as a means of understanding this complexity (Breen *et al., 2*003; Kotze, 2007). Based on the framework provided by WET-SustainableUse, a systems diagram (Figure 5.1) was developed for the Kamiesberg wetlands of the human-wetland interactions at a range of spatial scales.

In the light of the understanding gained from addressing the above key questions and viewing interrelationships at different scales, the resilience of the social structures affecting the wetland ecosystems was discussed, as elaborated upon by authors such as Walker *et al.* (2002) and Anderies *et al.* (2004).

5.2.1 Access to the wetlands, and the organizations and institutions governing this access

From November 2002 to January 2003, referenda over land ownership were held. The Leliefontein community voted in favour of the Kamiesberg municipality taking ownership of the land. However, the Minister of Agriculture and Land Affairs must make the final decision on the transfer of land. Presently, the land is held in trust by the Minister of Agriculture and Land Affairs and managed by the Kamiesberg Municipality (section 2.1.4). Currently, the Kamiesberg wetlands fall within the municipal commonage. However, it is apportioned into sub-units each with differing access arrangements (Table 5.1). Although the arrangements vary greatly from one portion to the next, user access is clearly defined and there are no open-access areas.

Table 5.1: The resource access arrangements found in different sub-units of the two wetlands, Ramkamp and Langvlei

Present Hydrological State **Sub-unit***	**Access arrangement**
Ramkamp – upper	Open for livestock grazing, primarily for the approximately 10 households that have their stockposts nearby to the sub-unit.
Ramkamp – lower	Open for breeding rams of all Leliefontein residents.
Langvlei HGM 1	Two separate portions each used exclusively by an individual household for cultivation and livestock grazing.
Langlvlei HGM 2	Two separate portions, the first is commonage open for livestock grazing, primarily for a few households that have their stock-posts nearby to the sub-unit, the second is used exclusively (in a partnership arrangement) by two individual households for cultivation.
Langvlei HGM 3	Two separate portions, the first is allocated to a women's group (comprising unemployed individuals from several households) as part of a larger area in which the group is cultivating geraniums but is not using the wetland portion in any direct way, and the second is commonage open for livestock grazing, primarily for a few households that have their stockposts nearby to the sub-unit.

* The sub-units are described in Section 3.

Long before fences had been erected, and even before missionaries had arrived in the Kamiesberg area, the practice of keeping the rams separate from the rest of the herd until the desired time for breeding, was well established. This was initially achieved by keeping the rams in a separate herd, but with time, specific fenced ram camps were established. This demonstrates that collective action relating to the management of livestock has a very long established tradition in the Kamiesberg area.

It is also important to highlight that there are other important customary practices that are long established. These practices have over the generations become "the way that things are done". The practices are re-enforced by "peer-pressure" and there is no specific authority making sure that individuals are continuing to follow the particular practice. Two important customary practices of relevance to wetlands are the timing of harvesting of *P. inanus* (described in Section 5.3.3) and the movement of livestock from the higher lying areas in summer to lower lying areas in winter (Box 2).

Box 2: The seasonal movement of livestock in the Kamiesberg.

Traditionally, there has always been movement of livestock between the uplands in the summer and the lowlands in the winter, and this has continued to the present. During winter, there is a general movement from the Leliefontein commons to a portion of Tweerivier commons. The livestock in Tweerivier then shifts to another portion of the Tweerivier commons. The movement generally takes place two weeks after the first rains in Tweerivier, which gives the vegetation time to grow. If it is grazed when the vegetation is too short then the sheep will end up eating soil, which, according to local stock owners, may result in kidney problems. Livestock keepers may also move from the upper Ramkamp area to the lower-lying eastern side of the Leliefontein commons. However, after heavy rains, the roads leading to these areas are almost inaccessible for motorized transport and farmers would therefore rather move to the Tweerivier commons.

Traditionally the breeding rams are also moved with the seasons between an upper ram camp and a lower ram camp. However, the lower camp was "privatised" and is no longer available for the rams. In response to this, the rams are now only kept in the upper camp for most of the year. The loss of this camp is a problem because it has resulted in the rams staying in the upper camp, causing increased mortality and health problems in the cold, as well as placing more pressure on the vegetation in the upper ram camp.

The timing of movement varies according to factors such as location. Those that have their livestock in the highest parts of the uplands, where it is coldest, will generally move before those that have their livestock lower down in the uplands, where it is not so cold. This movement simulates to some extent the natural movement of indigenous ungulates that is likely to have taken place in the area. Besides providing the livestock with the opportunity to move to the warmer lowlands during the coldest months of the year, the movement of livestock out of the uplands during the cold, wet season minimises the opportunities for livestock to damage the winter crops (mainly oats) grown in the uplands. There is, however, one household that keeps their livestock in the uplands through the entire winter, and these livestock, together with a few feral donkeys, cause some damage to these winter crops.

In addition to the customary practices, there are also formal rules governing resource use. In the past (prior to 1994) cultivated lands were leased by individuals from the Leliefontein Management Council (LMC). From 1994 to 2000, croplands were rented out by the Transitional Local Council (TLC). Since 2000, the Kamiesberg Municipality has been administering leasing of croplands to farmers. Previously, an annual grazing fee was paid on a per head basis, which was administered by the LMC, then the TLC, and now by the municipality. If livestock damaged crops then the livestock were impounded, and the owner had to pay a fine. Currently, very few people pay the lease or the grazing fees (because according to livestock owners, they do not get the necessary services from the municipality). In addition, impounding of livestock is not taking place, and thus damage to crops by livestock has increased. In the past, fencing of cultivated lands was not permitted, and after about mid-December, when all of the crops would have been harvested, the crop residues would be available to graze. However, some people are now starting to fence off their croplands, and thus the commonage is becoming more "privatised".

An even more blatant form of privatization of the commonage occurred 17 years ago, when a household acquired the Draaiklip ram camp. This ram camp used to be the lower ram camp, to which the rams belonging to all livestock owners could be moved in winter. As explained in Box 2, this has had negative consequences for livestock generally, and is certainly contrary to the common good. The household, which is probably the most wealthy and resourceful in the area, "bought" the rights to use the camp from the TLC (which is likely to have been an irregularity).

In the past there were committees under the LMC and TLC who managed the rangelands, but these no longer exist. However, there is a well-supported organization, the Agri-Kameelkrans Farmers' Union that provides a mechanism for collective action relating to natural resource use. Currently, the Agri-Kameelkrans Farmers' Union is the most important local organization influencing livestock management. It is the strongest farmers' union in the entire Leliefontein Communal Area, has a constitution, office bearers and holds a bank account. Members pay monthly fees, and if they do not pay then they are excluded.

The shock/crisis of the 2003 drought precipitated the formation of the Agri-Kameelkrans farmers' union. During the drought, livestock owners came to the realization that the only way that they could survive was if they worked collectively. They were led by an individual (who was previously a prison warder) whose education and organizational ability was more advanced than most of the other livestock owners. He has since passed away but the union has persisted. Farmers' unions have lacked longevity in the past, and if members do not see quick and direct benefits, the unions often collapse. Some of the functions carried out by the union include the following:

- provision of a point-of-entry for government programmes (e.g. acting as a channel for distributing drought relief funds);
- assistance to individuals in accessing information (e.g. relating to animal health issues);
- facilitating collective access to animal health vaccines and other items used in animal husbandry;
- applying peer pressure (e.g. "shaming" in public meetings those individuals who have not controlled their livestock properly, leading to the damage of other individual's crops);
- sometimes, providing resources to address problems of common interest (e.g. when the ram camp was accidentally burnt one year and some fence-posts were destroyed, the farmers' union funded the repair of the fence); and
- conducting conservation projects in the area in conjunction with the Agricultural Research Council, Cape Nature and Conservation International.

The influence of the government extension services dealing with agriculture and nature conservation have some interaction with livestock owners, but this interaction appears to have been sporadic. One of the farmers mentioned that "die slim mense" (the clever people) have told them that they should not chop out the renosterbos and had also criticized their cultivation in the wetland. The effect of this interaction on the practices of the farmers does not appear to be great, but requires further investigation.

In summary, although there has been a general weakening of rules and compliance, there are still well-structured systems (particularly customary practices) that operate, and most people follow the seasonal pattern of livestock movement and harvesting times. In addition, strong social capital for collective action still exists, as demonstrated in the sustained positive contribution of the local farmers' union. However, as can be seen from the examples of the "privatised" ram camp and the trend of increasing fencing off of the commonage, contemporary pressures and powerful individuals can over-ride collective decision-making.

5.2.2 An overview of factors potentially influencing use of the wetland

The discussion in Section 5.2.1 focused particularly on how municipal and local-level organizations influence the use of natural resources (and the wetlands). It is important to recognize that the wetlands exist in an even broader social context, and are potentially also influenced by factors operating at provincial, national and global levels. As highlighted in Section 5.2.1, wetlands are potentially affected by activities taking place at a range of different scales. Some of these activities have direct consequences, for example harvesting resources such as reeds from a wetland provides members of a household with a source of income. Others arise indirectly as actions taken in response to political and policy decisions made remotely from any particular wetland, for example economic and structural reform and signing of agreements such as the Ramsar and Biodiversity Conventions. The systems diagram in Figure 5.1 is a representation of the current understanding of how issues relevant to the Kamiesberg wetlands are connected across a range of scales from global to household through direct and indirect interactions and feedbacks.

Global climate change is predicted to most severely affect the arid west of the country (where the Kamiesberg wetlands are located) and cause extensive species loss from the fynbos biome due to this aridification (Rutherford *et al., 2*000).

Although provincial and municipal organizations influence the wetland mainly in an indirect way through more localised entities, there are some direct impacts (e.g. provincial roads which disrupt the runoff of water from the surrounding catchment into the wetland). However, the primary direct impacts on the Kamiesberg wetlands result from use of the wetland by local households. The three main uses are cultivation, livestock grazing and harvesting of matjiesriet (*Pseudoschoenus inanus*). The impacts on the state of the wetland vary greatly amongst the types of use, and this is dealt with in detail in Section 5.3. The use, in turn, contributes to the incomes and livelihoods of the households.

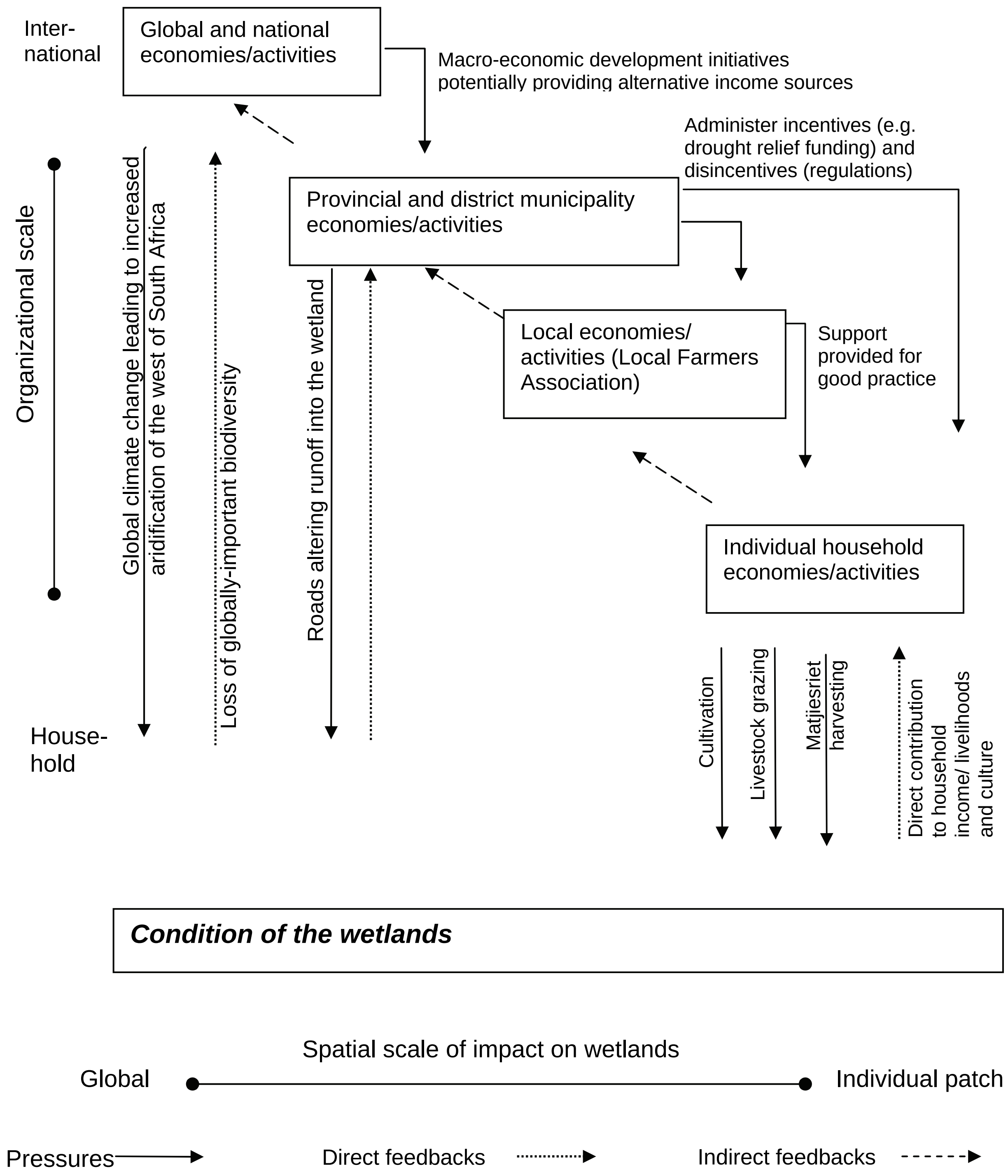


Figure 5.1: Human-wetland interactions and interrelationships at different spatial scales

5.3 Ecological Sustainability

The sustainability of wetland use was assessed from the point of view of impacts to the ecological functioning of these systems. The impacts of three uses were examined, namely: cultivation, grazing and harvesting of vegetation.

5.3.1 Cultivation in the wetland

A distinction needs to be drawn between historical cultivation of the wetland and current cultivation. As elaborated upon further in this section, there are few areas in the wetlands (both Langvlei and Ramkamp) that have not been cultivated at some time in the past. However, the overall extent of cultivation in the wetlands has declined, and at the time of the assessment, none of the Ramkamp wetland was currently cultivated, while only approximately 9% of the Langvlei wetland was cultivated (Section 3). An assessment of the sustainability of cultivation practices in the currently cultivated areas (i.e. Langvlei) is given below.

5.3.1.1 The effect of cultivation on water distribution and *retention in the wetland*

As described in the WET-Health assessment (Chapter 3), the level of desiccation resulting from drains associated with the currently cultivated areas is moderate. Given the relatively low density of drains in Langvlei and the fact that the drained areas are not inherently permanently wet, the effect of the drains in removing water from the drained area is not great. The most important effect of the drains, together with strategically placed berms, is to divert flows, including high flows, around the drained area. The land-use sub-units around which diversion drains and berms have effectively diverted flow are land-use sub-units 1d and 1e (Figure 3.4) and land-use sub-unit 2 (Figure 3.5). It should be added, however, that increased aridification associated with the climate change predicted to occur in the western part of Southern Africa is likely to compound the drying effects of onsite drains in the wetland. The concentration of flows in the diversion drains also has important implications for erosion, as discussed below.

5.3.1.2 The effect of cultivation on erosion control

A summary of the factors influencing erosion is given in Table 5.2. When considered from the perspective of erosion, the fact that tillage occurs primarily outside of the main flooding season is the only factor contributing positively to the sustainability of cultivation practices. Several factors contribute negatively, namely: tillage is complete (i.e. no minimum tillage practices), it occurs annually, it is relatively deep, mainly mechanized, soil cover is poor and the concentration of flow (through diversion drains) is high. Overall, the sustainability of practices from an erosion control perspective is relatively low. The inherent erodibility of the wetland is moderate, and therefore the fact that the cultivation practices are generally not good from an erosion control perspective is of less consequence than if the erodibility of the wetland was high. In addition, the diversion drains reduce the flooding of the field itself, which reduces loss of soil from the field. However, in the case of the upper cultivated area, the berm broke during a major flow event and in the lower cultivated area the diversion channel failed to contain all of the flows. In both cases, there was extensive loss of soil off the land. Furthermore, very importantly, the concentration of flow in the diversion channels has resulted in extensive erosion taking place within the diversion channel (i.e. it moves the erosion problem from the field itself to the land adjacent to the field). This has been particularly severe in land-use unit 2b, which is lower in the wetland than land-use units 1d and 1e and therefore carries higher volumes of flow (Figure 5.2).

Figure 5.2: The eroded diversion channel which is running alongside the cultivated land of land-use sub-unit 2b.

Table 5.2: Factors contributing to intensity of erosion within cultivated plots in a wetland

Metric	Low				High	Score
	0	**2**	**5**	**8**	**10**	
Features of the land-use						
(1) Frequency of tillage	None	Less frequent than every 3 years	Every 2 or 3 years	Annually	Twice annually or more	8
(2) Extent of tillage	None/ No till	Considerably reduced tillage	Moderately reduced tillage	Slightly reduced tillage	Complete tillage	10
(3) Depth (soil) of tillage	<0.05 m	0.05-0.1 m	0.11-0.2 m	0.21-0.4 m	>0.4 m	8
(4) Impact associated with traffic of implements		By hand	Animal traction	Mechanized		6
(5) Timing of tillage in relation to timing of flooding		Outside of the main flooding season	Partly within the main flooding season	Within the main flooding season		3.5
(6) Reduction in soil organic matter, for loamy to sandy soils. If high clay content then omit this factor. See Table 5.3	Low	Moderately low	Intermediate	Moderately high	High	8
(7) Level of soil cover	High	Moderately high	Intermediate	Moderately low	Low	8
(8) Level of reduction of surface roughness	Roughness increased or unchanged[1]	Decrease in roughness is moderate (i.e. by one class)	Decrease in roughness is high (i.e. by two classes)	Decrease in roughness is very high (i.e. by three or more classes)		5
(9) concentration of water flow	Low	Moderately low	Intermediate	Moderately high	High	10
Features of the wetland						
(10) Vulnerability of the site to erosion (given slope and discharge). See WET-Health, Fig. 3.7	Low	Moderately low	Intermediate	Moderately high	High	5
(11) Erosion hazard of the	Low	Moderately low	Intermediate	Moderately high	High	8

soil type						
(12) Soil depth			>1.2 m	0.3-1.2 m	<0.3 m	5
(13) Location in relation to stormflow paths	Outside of stormflow paths		In an intermediate position		Directly within major stormflow path	5
(14) Location in relation to an existing erosional feature	Distant		Nearby		Within or in the immediate advancing path of	5
Overall intensity score: [Average of (1) to (9)]/10 × [Average of the 3 highest scores of (10) to (14)] = 0.74 × 6						**4.4**

[1]A decrease in surface roughness may be mitigated to some extent by retaining bands of permanent vegetation with high surface roughness across the main direction of water flow.

From the effects of wetland cultivation on erosion described above, the sustainability of the cultivation practices is considered to be moderately low at the scale of the individual cultivated plots. However, given that cultivation is confined to a relatively small area (<10%) of the wetland, in terms of the overall geomorphology of the system its effect is relatively small.

5.3.1.3 The effect of cultivation on soil organic matter accumulation

The factors affecting this aspect are summarised in Table 5.3. When considered from the perspective of soil organic matter accumulation, no practices contribute positively. Those that contribute negatively include the annual frequency of tillage, the moderate depth of tillage, moderately low soil cover and high removal of plant material (as a result of grazing of residues by livestock). Although some of the removed organic material is compensated for by cattle manure added to the wetland fields, this is probably much less than is removed. In discussion with the researchers, farmers acknowledged the potential value of mulching. However, the fact that the climate is arid and the predominant agricultural activity is livestock production means that the demand for forage during the dry season is high. Thus, the direct benefits to livestock have taken precedence over potential benefits from conserving crop residues (e.g. for mulching).

Table 5.3: Factors contributing to diminished soil organic matter[8]

Metric	Low 0	2	5	8	High 10	Score
(1) Reduction of plant growth	Low	Moderately low	Intermediate	Moderately high	High	5
(2) Decreased level of wetness (see Table 3.6)	None/low	Moderately low	Intermediate	Moderately high	High	5
(3) Level of erosion (see Table 5.2)	Low	Moderately low	Intermediate	Moderately high	High	5
(4) Frequency of disturbance	None	Less frequent than every 3 years	Every 2 or 3 years	Annually	Twice annually or more	8
(5) Depth (soil) of disturbance	<0.05 m	0.05-0.1 m	0.11-0.2 m	0.21-0.4 m	>0.4 m	8
(6) Level of soil cover	High	Moderately high	Intermediate	Moderately low	Low	8
(7) Removal of whole plants or plant parts, e.g. through burning	Low	Moderately low	Intermediate	Moderately high	High	10
Overall intensity score: {Score for (1) + [Average of the 3 highest of factors (2) to (7)]}/2						**6.8**

5.3.1.4 The effect of cultivation on nutrient retention

The factors influencing this aspect of sustainable use are summarised in Table 5.4. When considered from the perspective of nutrient cycling, no land-use factors are contributing positively. Again, several factors contribute negatively, including reduction in diffuse flows through the wetland and the limited extent of crops with soil-building properties and the moderately high level of soil organic matter depletion reported above. Besides being a source of nutrients itself, soil organic matter generally to plays an important role in enhancing the Cation Exchange Capacity (CEC) of the soil, particularly in sandy soils such as those occurring in Langvlei. The greater the CEC, the greater will be the capacity for retaining nutrients which would then potentially be available for plant

[8] Several factors given in Table 5.3 also appear in some of the other tables because these factors influence more than one of the hydrogeomorphological processes represented in the tables.

uptake, rather than allowing them to "leak" from the system (Mills and Fey, 2003; Sahrawat, 2004).

Table 5.4: Factors contributing to the diminished retention (and therefore "leakage") of nutrients

Metric	Low				High	Score
	0	**2**	**5**	**8**	**10**	
(1) Level of artificial drainage (see Table 3.6)	Low	Moderately low	Intermediate	Moderately high	High	5
(2) Level of erosion (see Table 5.2)	Low	Moderately low	Intermediate	Moderately high	High	5
(3) Level of SOM depletion (see Table 5.3)	Low	Moderately low	Intermediate	Moderately high	High	8
(4) Texture of the soil*	Clay	Clay loam	Loam	Sandy loam	Sand/ loamy sand	8
(5) Synchronization of nutrient availability and plant uptake	High	Moderately high	Intermediate	Moderately low	Low	5
(6) Export of nutrients in harvested or burnt plant material	Low	Moderately low	Intermediate	Moderately high	High	5
(7) Reduction in the level of diffuse low flows through the wetland (Level of drainage)	None/low	Moderately low	Intermediate	Moderately high	High	5
(8) Addition of nutrients	Low	Moderately low	Intermediate	Moderately high	High	5
(9) Extent of soil building crops	High	Moderately high	Intermediate	Moderately low	None	6.5
Overall intensity score: Average of the 7 highest of factors (1) to (9)						**6.1**

*This factor has an important influence over the ultimate effect of SOM depletion on nutrient cycling.

5.3.2 Livestock grazing

5.3.2.1 Effect of livestock grazing on vegetation structure and *sediment retention*

Although livestock grazing was assessed overall, it is recognised that livestock grazing pressure varies from one section of the wetland to the next. In the Ramkamp wetland, for instance, the upper section outside of the ram camp itself is more intensively grazed than the lower section, which is inside the ram camp. In the Langvlei wetland, livestock has recently been excluded entirely from land-use sub-units 3b and 3 c.

When considered from the perspective of vegetation structure, livestock grazing, based on Table 5.5, was assessed as having a moderately low impact. However, it needs to be emphasized that the structural features assessed by WET-SustainableUse are strongly affected by the intensity of grazing in the few months preceding the assessment (i.e. it is affected by short-term effects). Even though the assessment was purposefully carried out in the dry season because this is the time when the grazing pressure is expected to be the greatest, the 2007/8 dry season was preceded by an unusually high rainfall, which resulted in an atypical situation. It appears that because this rainfall is likely to have increased the availability of forage within and surrounding the wetland, the dry season grazing pressure on the wetlands is likely to have been less than in an average-to-dry year.

From Table 5.5 it can be seen that the features of the wetland (e.g. depth of soil) are such that the wetland has an inherently moderate vulnerability to erosion. Given this and the fact that features of use (e.g. low density of paths) indicate overall a moderately low intensity of use, it can be concluded that the contribution of grazing to erosion of the wetlands is moderate to low. It should be added further that the majority of the most abundant plants in the wetland have a low acceptability for foraging livestock (Box 3). Thus, even when utilisation levels are close to their maximum intensity, there will be extensive patches (comprising unpalatable species) that remain little utilised. Nevertheless, at the same time the grazing pressure exerted on the less palatable species may be intense (Box 3).

The modest contribution of livestock grazing to erosion in the wetland, would accord with the observation that most of the gully erosion features visible in the wetland appear to have resulted either from altered flow patterns caused by road runoff or diversion channels around cultivated lands (section 3.2.1) or to be the result of natural geomorphological processes taking place in the wetland (Section 2.2).

Table 5.5: Factors contributing to the intensity of grazing impact on wetland integrity in terms of vegetation structure and sediment retention (The Kamiesberg is considered sourveld, and therefore the vegetation structure scores for sourveld are used.)

Metric Vegetation structure Sourveld: (Sweetveld:) Sediment retention:	Score					Score***
	2	0	2	5	8	
	(3)	(1)	(0)	(3)	(6)	
	0	2	5	8	10	
Features of the land-use						
(1) Aerial cover*	Abundant moribund material	>80% but little moribund material	60-80%	40-60%	<40%	2 5
(2) Effects of grazing on height of vegetation (excluding those vegetation types having a low grazing value)	Uniformly at potential maximum height	Shortly grazed patches within potential maximum height	Approximately equal mix of shortly grazed and maximum height patches	Predominantly shortly grazed with maximum height patches	All uniformly shortly grazed	0 2
(3) Density of paths	<50 m/ha	51-100 m/ha	100-200 m/ha	201-500 m/ha	>500 m/ha	0 2
(4) Extent of poaching**	No poaching	<10 m^2/ha	11-100 m^2/ha	101-1000 m^2/ha	>1000 m^2	0 2
	0	**2**	**5**	**8**	**10**	**Score**
Features of the wetland						
(5) Vulnerability of the site to erosion (given slope and discharge). See WET-Health, Fig. 2.1 Appendix 2.	Low	Moderately low	Intermediate	Moderately high	High	5
(6) Erodibility of the soil type	Low	Moderately low	Intermediate	Moderately high	High	8
(7) Soil depth			>1.2 m	0.3-1.2 m	<0.3 m	5

(8) Location in relation to storm flow paths	Outside of stormflow paths		In an intermediate position		Directly within major stormflow path	5
(9) Location in relation an existing erosional feature	Distant		Nearby		Within or in the immediate advancing path	2
Overall intensity score for vegetation structure: Average of the three highest scores of (1) to (4)						**0.7**
Overall intensity score for sediment retention: Average of the three highest scores of (1) to (4) and the four highest scores of (5) to (9)						**3.6**

*It is recognised that aerial cover is potentially affected by several different factors, including the particular type of vegetation, burning regime, etc.

**This applies primarily to seasonally and permanently wet areas. Poaching (pugging) refers to the disruption of soil structure as a result of the repeated penetration of hooves into the soil (Wilkins and Garwood, 1986).

***The score for vegetation structure is given first followed by the score for sediment retention

Box 3: Some observations of the acceptability of the Kamiesberg wetland plant species to livestock grazing

Renosterbos is well-known to be a forage species avoided by domestic livestock, and in the two wetlands assessed there was no evidence of this species having been utilised. The leaves and culms of *Ficinia nodosa* and *Mariscus thunbergeii* are coarse and hard (and *M. thunbergeii* has scabrid leaves), and are therefore of a relatively low acceptability for foraging animals. In the field, very little evidence was also observed of the vegetative parts of these species having been grazed. It is mainly the flowering heads of these two species that are grazed. In the 2007/8 dry season assessment, only a small proportion of the flowering heads had been grazed. However, it should be noted that there had been an unusually large amount of rain in the 2007/8 dry season, and in average to drier years, the flowering heads would probably be grazed more intensively. Both *F. nodosa* and *M. thunbergeii* are long-lived perennials and are unlikely to be affected even if grazing of flowering heads is severe in some years. This could potentially stimulate increased vegetative growth and possibly contribute to the dispersal of seed, but this requires further investigation. In contrast to *F. nodosa* and *M. thunbergeii*, it was noted that the few *Merxmuellera stricta* clumps that were present had been completely and heavily grazed.

Renosterbos

Ficinia nodosa

Shortly-grazed tussocks of *Merxmuellera stricta*

5.3.2.2 The effect of livestock grazing on vegetation composition

The extent to which the vegetation has deviated from its natural composition was assessed in Table 3.27. In this assessment, several different disturbance units were identified and each was scored based on the level of deviation. The scores given in Table 3.27 have been copied to Table 5.6 below. Several different factors may be responsible for the deviation of vegetation from the natural state, and the question that is addressed below is the extent to which livestock grazing specifically has been responsible for this change.

The impact scores in column 4 highlight that the condition of the vegetation in terms of species composition has been considerably impacted, particularly in HGM 1, although varying according to disturbance class. This is also confirmed by the vegetation composition assessment (section 2.3, Table 2.1) which shows that vegetation in the Langvlei, in particular, and also to some extent the Ramkamp wetland, is degraded. The extent to which livestock grazing is considered to have contributed to the impact scores (Table 5.6, column 5) again varies according to the disturbance class.

In current croplands, the impact on the vegetation composition is very high, but all of this impact can be attributed to the removal of the native vegetation for cultivation, and grazing has played no role in contributing to the impact.

In the case of recently abandoned lands, the primary contribution to the impact is again cultivation, but grazing could also potentially be having a small contribution to the impact as a result of the selection of palatable species under localised heavy grazing pressure, thereby limiting recovery of vegetation condition. At the same time however, instead of restricting the recovery of the vegetation on old lands, grazing could potentially aid recovery by assisting in the dispersal of grass seeds in dung (Shiponeni and Milton, 2006). This may be occurring given the fact that livestock actively select the seed heads of species such as Ficinia nodosa, but this requires further investigation.

Table 5.6: Impact score for the different disturbance classes in the Langvlei and Ramkamp wetlands and an assessment of the potential contribution of livestock grazing to this impact

Disturbance class	Disturbance class extent (%)	Intensity of impact score*	Magnitude of impact score**	The contribution of grazing to the impact on vegetation composition, and multiplier score given in brackets (see Table 5.7)***
Langvlei				
Crop lands (current)	19	9	1.7	None (0)
Recently abandoned lands	45	7	3.2	A small part (0.3)
Old abandoned lands (with some eroded	30	6	1.8	A small part (0.3)
Minimal human disturbance	6	2	0.1	Some (0.6)
HGM 1: Magnitude of impact score******			**6.8**	
Crop lands (current)	30	9	2.7	None (0)
Old/abandoned lands	25	6	1.5	A small part (0.3)
Minimal human disturbance	45	3	1.4	Some (0.6)
HGM 2: Magnitude of impact score******			**5.6**	
Old/abandoned lands	50	6	3	None (0)
Minimal human disturbance	50	3	1.5	A small part (0.3)
HGM 3: Magnitude of impact score******			**4.5**	
Ramkamp				
Old/abandoned lands	8	4	0.32	A small part (0.3)
Shallow flooding by dams	2	4	0.08	None (0)
Eroded areas	10	5	0.5	A small part (0.3)
Minimal human disturbance	80	2	1.6	Some (0.6)
HGM 1: Magnitude of impact score******			**2.5**	

*Intensity of impact is scored from 0 (no impact) to 10 (critical impact).

**Magnitude of impact score is calculated as extent / 100 × intensity of impact.

***The range of multiplier scores are given in Table 5.7 and the rationale for the multiplier scores assigned in column 5 of this table are given in the text following the table.

****Overall magnitude of impact score for the HGM unit = sum of magnitude scores for each disturbance class.

In the areas with minimal human disturbance (i.e. no current or past cultivation), the condition of the vegetation has been low- to moderately-impacted, with an impact score of 2 (out of a maximum of 10) for HGM 1 and a score of 3 for HGM 2 and 3. It is likely that sustained heavy grazing pressure has contributed to the decline in the abundance of indigenous perennial grasses, which affects the condition directly as well as indirectly by reducing the fuel load potentially able to support periodic fires. However, grazing is not considered to be solely responsible for the recorded impact on vegetation condition. The absence of large indigenous herbivores, particularly the mixed feeders and browsers (e.g. black rhino) is also likely to have contributed.

An important factor complicating the assessment of grazing is that the effects of past cultivation of the wetland have compounded the effect of grazing on vegetation. As indicated in Section 2.3, renosterbos is well adapted to colonizing previously cultivated areas, and there is little area of the two wetlands that has not been cultivated at some stage or other. The least cultivated area is in the ram camp section (i.e. the lower section) of the Ramkamp wetland, and this is also the most leniently grazed portion of the wetland.

Table 5.7: Extent to which livestock grazing is responsible for the deviation in vegetation species composition from its natural state

Level of responsibility held by grazing:	None	A small part	Some	Most
Multiplier score:	0	0.3	0.6	0.9

To summarise, in comparison to past and current cultivation, livestock grazing has had a lesser impact on the condition of the wetlands. Nevertheless, it does appear to have impacted upon the condition of the wetland evidenced as long-term impacts on vegetation composition. The livestock owners were questioned as to whether they think that their practices are sustainable. Whilst they acknowledge that some of their practices are not as good as they should be, and that decline in the long term is likely, in the short to medium term, little decline is anticipated.

The most important practice contributing to the negative impacts of livestock on wetlands is probably the high stocking rate. However, it should be highlighted that there are also several practices identified which contribute positively to reducing the impact of livestock grazing on wetlands. The first of these is the seasonal movement of livestock (Box 2). As a result of this seasonal movement, most of the wetland areas are not grazed in the winter[9], which is when they are wettest. This limits the extent of poaching (also known as "pugging"), which refers to the disruption of soil structure as a result of the repeated penetration of hooves into the soil. The poaching of soil results in damage to plants and decreased herbage production and also increases susceptibility to erosion (Wilkins and Garwood, 1986).

In addition, based on discussions with livestock owners, the following practices employed by farmers were identified which potentially contribute to reducing the pressure on wetlands:

- Splitting herds. Sheep cannot reach areas as inaccessible as those goats can reach. Therefore, if the goats are split from the sheep, this allows the utilisation to be better spread across the landscape, and the pressure on the more accessible areas (which includes the wetlands) is lessened.
- Breeding at a specified time. This results in the herd being less restricted by the presence of heavily pregnant ewes to more accessible areas such as the wetlands.

Part of the livestock grazing system is the use of periodic burning of the veld. The timing of burning of the Kamiesberg wetlands (generally towards the end of March) is, according to the conceptual model of Cowling *et al.* (1986), the most favourable time for encouraging a significant grass component in the renosterveld rather than favouring a state dominated entirely by renosterbos (Section 2.3).

5.3.3 Harvesting of wetland plants

The plant species that is locally-favoured for harvesting, *Pseudoschoenus inanus* (matjiesriet), is used to weave mats for the construction of matjieshuise ("mat houses") which have high traditional cultural value (Figure 5.3). Three different widths of mat are used in a matjieshuis: the door section, which is the shortest; the arching section, which is the next widest; and the top section, which is the widest. Although *P. inanus* is absent in the two assessed wetlands, it occurs in nearby wetlands, and the sustainability of harvesting was assessed for these sites (Table 5.8). At all of these sites, *P. inanus* occurs as the dominant plant, and harvesting practices are relatively similar, thus the sites were assessed collectively. The scores for the described metrics are given in Table 5.9. Sustainability is scored for two main aspects: (i) the primary effect on the sustained

[9] Although livestock remains in the ram camp during the winter and therefore has access to the wetland, the stocking density is moderate and there are no cattle, which is the main livestock type that uses the wetland.

production of the species that is being harvested and (ii) the secondary impact on fauna inhabiting the harvested area.

Table 5.8: Nearby wetland sites in which *Pseudoschoenus inanus* is harvested

Site name	**Witsand**	**Bakleikraal 1**	**Bakleikraal 2**	**Bakleikraal 3**	**Bakleikraal 4**
Latitude	30.31411	30.23415	30.2386	30.23229	30.23327
Longitude	18.05923	18.0603	18.07068	18.05899	18.05291
Level of wetness	Temporary, almost non-wetland	Seasonal	Temporary, almost non-wetland	Temporary	Seasonal

The timing of burning (metric 8b in Table 5.9) was omitted because the manner in which the scoring system has been structured for 8b was designed for the summer rainfall situation and does not account well for the situation in the winter rainfall areas.

On a scale of 0 (lowest impact) to 10 (highest impact), the impact score of 3.8 indicates that the impact is moderately low in terms of diminished sustainability of supply. As will be explained below, the impact on sustainability of supply is, in fact, likely to be lower than the score of 3.8 suggests, given that a key factor contributing positively to the sustainability of harvesting is not represented in the protocol of Table 5.9. This factor is that the culms are very selectively harvested and only the mature culms are harvested, which would compensate to some extent for the fact that the individual plants are generally not being rested from harvesting. The very selective approach of harvesting by pulling individual culms (Figure 5.3) is very efficient in terms of usage of harvestable material, and differs from the harvesting generally encountered in KwaZulu-Natal, where harvesting of plants is non-selective. In the case of *Juncus kraussii,* where culms are cut with a sickle as a bunch, a large proportion of the culms (up to 75%) is discarded because they are too young (short), damaged or are flowering culms (flowering *J. kraussii* culms are not used for crafts because they are much more brittle than the non-flowering culms; Heinsohn, 1991; Cunningham and Terry, 2006).

In the case of harvesting of *P. inanus* in the Kamiesberg, only mature culms are harvested after flowering is complete and the flowering culms are used for craft production. Thus, the harvesting of *P. inanus* is likely to be even more sustainable than the impact score of 3.8 suggests.

Figure 5.3: Harvesting of matjiesriet (*Pseudoschoenus inanus*) by plucking (a), harvested culms (b), dried culms that have been sewn together to form a mat (c), and a matjieshuis consisting of several mats fastened over a wooden frame (d) (Photo d: I Samuels).

Table 5.9: Factors contributing to intensity of impact of plant harvesting on wetland integrity, in terms of sediment retention and vegetation structure

Metric	Low 0	2	5	8	10 High	Score
(1) The mix of species growing in the area†	The harvested species completely dominates the cover of the stand. High	Moderately high	Intermediate	Moderately low	The harvested species has a low cover amongst a matrix of other species in the stand	**2**
(2) Height of harvesting in relation to basal growth points of the plants	All above meri-stematic growth		Intermediate		Mainly below the meri-stematic growth	**0**
(3) Discarded material	Little discarded material and/or no suppressing effect		Intermediate		Forms thick layer of surface litter, suppressing growth	**0**
(4) Frequency of harvesting of individual plants	Every third year or more		Every second year		Two or more times a year	**8**
(5) Extent of harvesting within the species	<40% harvested	40-55% harvested annually	56-75% harvested annually	76-90% harvested annually	>90% (of the available material) harvested	**5**
(6) Timing of harvesting in relation to the growing season	Harvesting towards the end of the growing season		Intermediate		Harvesting towards the beginning of the growing season	**0**
Factors relating to other disturbances	**0.5**	**0.7**	**0.9**	**1.0**	**1.2**	
(7) Level of grazing	None	Low	Intermediate	Moderately high	High	1.0
(8a) Level of burning - frequency	Every 3rd year or more		Every second year		annual	0.5
(8b) Level of burning - timing	Late winter/early spring		Winter		Summer/ autumn	
(9) Sustainability in terms of plant production: Average of the 4 highest scoring factors of (1) to (6) × Highest of weighting factors (7) and (8), with (8) determined as the average of (8a) and (8b) = 3.75 × 1.0						**3.8**
(10) Sustainability in terms of minimizing disturbance to fauna: Average of factors (5) and (6) × Highest of weighting factors (7) and (8) = 2.5 × 1.0						**2.5**

†This assumes that harvesting concentrates on the selected species, while generally leaving the other species uncut. If harvesting is non-selective (i.e. all of the plant material in the stand is cut) then omit this factor from the assessment.

The above conclusion was further supported by observations at the sites, which were visited near the beginning of the harvesting time (Table 5.8). Based on a visual estimate, at least 30% of the culms had senesced, suggesting that a reasonable proportion of the culms are maturing, withdrawing their reserves and senescing naturally. This results, in part, from the fact that harvesting is confined to a short season each year. In addition, individuals harvesting the same areas over many years that were interviewed indicated that they have not noticed a decline in the supply of harvestable culms, except where the *P. inanus* stands have been impinged upon by cultivated lands.

The impacts in terms of disturbance to fauna (e.g. birds breeding in the stand) was assessed as low, given the intensity (moderate) and timing (likely to after the breeding time of most birds), although it is not certain which particular species may breed in *P. inanus* stands.

5.4 Resilience of the Socio-Ecological System

Resilience refers to the ability of a system (whether social, ecological or a combination of the two) to recover from a shock or disturbance. Thus, a resilient system's performance will not drop off as rapidly as its non-resilient counterpart when confronted with a shock or disturbance (Anderies *et al., 2*004). Resilient systems are persistent, very often as a result of being variable and adaptive (Walker *et al., 2*002). The resilience of the social-ecological system is discussed for the Kamiesberg wetlands by drawing on the social sustainability assessment (Section 5.2), the ecological sustainability assessment (Section 5.3) and an understanding of the socio-economic context of the Kamiesberg wetlands (Section 2.1) and how they function (Sections 2.2 and 2.3).

From a geomorphological point of view, the wetlands are fairly resilient, partly as a result of their naturally dynamic character, with the location of areas of natural erosion and deposition shifting over time. Given the particular discharges and longitudinal slopes of the wetlands, their vulnerability to erosion is not high, as explained in detail in Section 2.2. This renders the wetlands fairly resilient to disturbance by cultivation and livestock. However, specifically where flow is concentrated in straight diversion channels, erosion is a significant threat.

Vegetation in the wetlands has evolved under the natural disturbances associated with the shifting erosion and deposition described above. This could potentially make it more resilient to human disturbance. However, this would obviously be within certain limits, and would probably not apply if the disturbance was of a much greater magnitude and extent than that which occurs naturally. After it has been cleared and cultivated for a period, the vegetation of the wetland is able to recover, at least in part. However, the capacity of the previously cultivated area to recover depends on the extent to which the wetland has already been disturbed. The smaller the extent of the areas in good condition adjacent to the potentially recovering patch, the more limited will be the supply of propagules for colonisation, and the less complete the recovery is likely to be.

The vegetation also evolved under fairly high grazing pressure from indigenous herbivores (which have now been largely removed) and it is therefore “pre-adapted” to grazing by domestic livestock. Again, this would be within certain limits.

Several features contribute positively to the resilience of the social system associated with the Kamiesberg wetlands. The Leliefontein community has a long history of living in the area and dealing with the shocks and disturbances commonly associated with the natural local environment. There are well-developed customary practices that have evolved over many generations and remain common amongst local people today. Social capital is reasonably abundant as evidenced by the evolution and persistence of a strong local organization (the local farmers' union) dealing with natural resource use.

However, local governance mechanisms are insufficiently strong to deal with some cases of individuals attempting to monopolize or misuse the natural system. It would appear that strengthened partnerships are required, with government departments mandated to regulate the use of land and natural resources.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Major conclusions

This study has involved investigation of the geomorphology, vegetation and utilisation by humans of two wetlands (Langvlei and the Ramkamp) which are situated just outside of Leliefontein in the Kamiesberg area of the Northern Cape. This was accompanied by a literature review of the historical settlement patterns and land-use in the area. The information collected was used to establish the environmental condition of the wetlands, the ecosystem services they are likely to deliver, and the likely sustainability of the use of those systems. Sustainability was assessed from both sociological and ecological points of view. It is hoped that the results of these studies will help inform various conservation initiatives that are being undertaken in the area. These wetlands serve as an invaluable resource to the area and it is essential that they be managed in order to optimize both the preservation of biodiversity and to support the people who depend on these systems for their livelihoods. The main findings of the study are summarised in the rest of this section.

6.1.1 Historical and social context

- There is a long history of use of the wetlands in the Kamiesberg area. Even for the present generation they represent an important resource for a community that in general is relatively poor.
- The Kamiesberg area was initially inhabited by Khoikhoi pastoralists who kept small stock and cattle, and engaged in transhumance to take advantage of seasonal differences in grazing and water resources between the upland and lowland areas. This practice is still continued today by the Namaqua herders of the area.

6.1.2 Geology, geomorphology and soils

- The geomorphological data for Langvlei suggests that erosion is an important process that lowers the elevation of bedrock and leads to reworking of sediments in the valley, creating a low-gradient valley that supports wetland habitats.

- In the case of the Ramkamp, it would appear that sedimentation is taking place preferentially at the head of the valley, which is being held in place by vegetation along the wetland floor.

6.1.3 Vegetation of the area

- The vegetation type in which both wetlands are located is Namaqualand Granite renosterveld, which is characteristically covered with dense, shrubs dominated by renosterbos and other, mainly asteraceous, shrubs.
- It appears that past human use (cultivation and heavy grazing pressure) has contributed to a change in extensive parts of the wetland from a mixed renosterbos/sedge and grass vegetation to vegetation dominated by renosterbos, currently the most abundant plant species in the Kamiesberg wetlands (see Table 2.1).
- A preliminary framework for assessing the condition of wetlands in the Kamiesberg wetlands is proposed (Table 2.2). At present, the wider applicability of the assessment framework beyond the Leliefontein area is unknown, and it is recommended that it be tested in more wetlands as part of a refinement process.

6.1.4 Assessment of environmental condition

- The health scores for the three different components (hydrology, geomorphology and vegetation) assessed using the tool WET-Health are summarised in the table below. The Present State categories and the Trajectory of Change symbols are given. Present State categories can range from A (pristine) to F (severely impacted). A downwards-pointing arrow indicates that the wetland is considered to be on a negative trajectory, a horizontal arrow that the condition is considered to be stable.

Table 6.1: The health scores for the three different components (hydrology, geomorphology and vegetation) assessed using the tool WET-Health for Langvlei and Ramkamp wetlands

	Langvlei				**Ramkamp**
	HGM 1	**HGM 2**	**HGM 3**	**Entire wetland**	
Hydrology	E→	B↓	A→	**B↓**	**A →**
Geomorphology	B→	A↓	B→	**B↓**	**A →**
Vegetation	D→	D→	C→	**C/D→**	**C →**

- The WET-Health assessment indicates that for the Langvlei wetland the condition is considered to be deteriorating with regard to hydrology and geomorphology. Note, however, that this conclusion was reached without consideration of the in-depth geomorphological assessment and in reality, the situation for the hydrology and geomorphology of Langvlei is likely to be better than represented here.

6.1.5 Assessment of ecosystem services provided by the wetlands

- The following ecosystem services (as assessed using WET-EcoServices) were found to be important for Langvlei: streamflow regulation, sediment trapping, phosphate assimilation, erosion control, biodiversity maintenance, harvestable resource provision, cultivated food provision.
- The following ecosystem services were found to be important for Ramkamp: streamflow regulation, sediment trapping, phosphate assimilation, nitrate assimilation, erosion control, biodiversity maintenance, harvestable resource provision.
- The overall the delivery of ecosystem services has been most affected in Langvlei HGM 1, next most affected in HGM 2, followed by HGM 3, and least affected in Ramkamp. In all of the HGM units, the ecosystem service most affected by a change in the ecological state is *biodiversity maintenance*. This highlights that a key aspect of rehabilitation would be to try to shift the vegetation to a state that is less dominated by renosterbos and supports a greater abundance of grasses and sedges.

6.1.6 Assessment of the social sustainability of wetland use

- Information relevant to social sustainability was gathered based on the guiding questions given in WET-SustainableUse relating to tenure, governance and control. Using this information a systems diagram (Figure 5.1) was developed for the Kamiesberg wetlands illustrating the human-wetland interactions at a range of spatial scales.
- The primary direct impacts on the Kamiesberg wetlands result from the direct use of the wetland by local households for cultivation, livestock grazing and harvesting of matjiesriet.
- There are important long-established customary practices that continue to promote sustainable use, and these practices are re-enforced by "peer-pressure" rather than by a formal authority enforcing rules that dictate particular practices. One important customary practice is the movement of livestock from the higher lying areas in summer to lower lying areas in winter.
- In the past, fencing of cultivated lands was not permitted, and after about mid-December, when all of the crops would have been harvested, the crop residues would be available to graze. However, some people are now starting to fence off their croplands, and thus the commonage is becoming more "privatised".

6.1.7 Assessment of the ecological sustainability of wetland use

- The sustainability of wetland-use was assessed from the point of view of impacts to the ecological functioning of these systems. The impacts of three uses were examined, namely: cultivation, grazing and harvesting of vegetation.
- The overall extent of cultivation in the wetlands has declined, and at the time of the assessment, none of the Ramkamp wetland was cultivated, whilst only approximately 9% of the Langvlei wetland was cultivated.

6.1.8 The impact of cultivation

- The impact of cultivation was assessed using various indicators (applicable to Langvlei only, as there is presently no cultivation in Ramkamp).
- The *level of desiccation* resulting from drains associated with the currently cultivated areas is considered to be moderate.
- The *extent of erosion* caused by the cultivation practices is considered to be moderately low at the scale of the individual cultivated plots. Given that cultivation is

confined to a relatively small area (<10%) of the wetland, in terms of the overall geomorphology of the system its effect is relatively small, but this is likely to increase in the future as a result of advancing erosion in some of the drainage channels used to divert water away from the cultivated lands.

- The impact of cultivation on soil organic matter accumulation is considered to be fairly high owing particularly to the high level of tillage and the very limited returning of crop residues to the soil.
- Several factors (including diminished soil organic matter levels) contribute negatively to the impact of cultivation on *nutrient retention*, and consequently the impact of cultivation on nutrient retention is considered to be fairly high.

6.1.9 The impact of grazing

- When considered from the perspective of vegetation structure and sediment retention, livestock grazing was assessed as having a moderately low impact.
- It is likely that sustained heavy grazing pressure (in addition to other factors) has contributed to the decline in the abundance of indigenous perennial grasses, which affects the condition directly, as well as indirectly, by reducing the fuel load potentially able to support periodic fires.

6.1.10 The impact of harvesting of wetland plants

- The very selective approach of harvesting *Pseudoschoenus inanus* (matjiesriet), by pulling individual culms, is very efficient in terms of usage of harvestable material. In addition, only mature culms that have finished flowering and seeding are harvested, which minimises impacts on the plants. Furthermore, the impacts in terms of disturbance to fauna (e.g. birds breeding in the stand) was assessed as low. Thus, impacts from *P. inanus* harvesting are likely to be low.

6.1.11 Resilience of the social-ecological system

- From a geomorphological point of view, the wetlands are fairly resilient, with the location of areas of natural erosion and deposition shifting over time. Their vulnerability to erosion is not high, however, specifically where flow is concentrated in straight diversion channels, erosion is a significant threat.
- The ability of vegetation to recover in previously cultivated areas depends on the extent to which the wetland has already been disturbed. The smaller the extent of

areas in good condition adjacent to the potentially recovering patch, the more limited will be the supply of propagules for colonisation, and the less complete is the recovery likely to be.

- The vegetation evolved under fairly high grazing pressure from indigenous herbivores (which have now been largely removed) and it is therefore "pre-adapted" to grazing by domestic livestock. Nonetheless, it appears to be vulnerable to very high levels of grazing.
- Several features contribute positively to the resilience of the social system associated with the Kamiesberg wetlands, namely: the community has a long history of living in the area and dealing with the shocks and disturbances commonly associated with the natural local environment, there are well developed customary practices and social capital is reasonably abundant.
- However, local governance mechanisms are insufficiently strong to deal with some cases of individuals attempting to monopolize or misuse the natural system. Strengthened partnerships are required with government departments mandated to regulate the use of land and natural resources.

6.2 Key management implications arising out of the findings of the study

- Any special attention given to the sustainable management of the wetlands would be well justified given the important ecosystem services being supplied by the wetlands.
- The component of health having the greatest requirement for rehabilitation is the vegetation. In particular, measures are required to increase the abundance of perennial grasses, e.g. through re-seeding and including a period of more lenient grazing may be required to assist in the rehabilitation of this component.
- The hydrology and geomorphology of the wetlands are largely intact, and these components are moderately resilient to human use. However, a few drainage channels posing an erosion hazard and threatening to further dry out localised portions of Langvlei wetland are likely to be worthy of rehabilitation in collaboration with the wetland users.
- The current use of the wetlands for grazing, sedge harvesting and limited cultivation is generally sustainable, although some specific practices highlighted in Section 4 (e.g. reduced tillage) would further enhance the sustainability of use.
- A wealth of local, traditional knowledge (e.g. surrounding the harvesting of wetland sedges) exists that should be nurtured in support of sustainable use.
- Moderately strong social capital already exists in the area which can be built upon and strengthened to effectively deal with factors (e.g. monopolization of resources by

a few private individuals) threatening the long term sustainable use of the natural resources in the area.

7. REFERENCES

Adey S. 2007. A journey without maps: Towards sustainable subsistence agriculture in South Africa. PhD thesis, University of Wageningen, Wageningen, The Netherlands.

Anderies JM, Janssen MA, Ostrom E. 2004. A Framework to Analyze the Robustness of Social-ecological Systems from an Institutional Perspective. Ecology and Society 9:18. Accessed online at [http://www.ecologyandsociety.org/vol9/iss1/art18].

Archer F, Danckwerts JE, Hoffman MT. 1989. How economic are the farming units in Leliefontein, Namaqualand? Journal of the Grassland Society of South Africa 6: 211-215.
Boonzaier EA. 1987. From communal grazing to 'economic' units: Changing access to land in the Namaqualand reserve. Development Southern Africa 4(3): 419-426.

Boonzaier EA, Malherbe C, Berens P, Smith AB. 1996. The Cape Herders: A History of the Khoikhoi of Southern Africa. David Phillip Publishers, Cape Town, South Africa.

Brechin SR, Wilshusen PR, Fortwangler CL, West PC. 2002. Beyond the Square Wheel: Toward a More Comprehensive Understanding of Biodiversity Conservation as a Social and Political Process. Society and Natural Resources 15: 41-64.

Cowling RM, Esler KJ, Rundel PW. 1999. Namaqualand, South Africa – An overview of a unique winter-rainfall desert ecosystem. Plant Ecology 142: 3-21.

Cowling RM, Pierce SM, Moll EJ. 1986. Conservation and utilisation of South Coast Renosterveld, an endangered South African Vegetation Type. Biological Conservation 37: 363-377.

Cunningham AB, Terry ME. 2006. African Basketry: Grassroots art from southern Africa. Fernwood Press, Simon’s Town, South Africa.

Deacon HJ. 1992. Human settlement. In: Cowling RM (ed.) The Ecology of Fynbos: Nutrients, Fire and Diversity. Oxford University Press, Cape Town, South Africa. pp. 260-270.

Du Toit PCV. 1997. A model to estimate grazing index values for Karoo plants. South African Journal of Science 93: 337-340.

Du Toit PCV. undated. *Objektiewe weidingsindekswaardes van Nama-Karoo plantegroei: grasse en bossies van die Karoo.* National Department of Agriculture, Grootfontein Agricultural Development Insitute, Middelburg, South Africa.

DWAF. 2006. A practical field procedure for identification and delineation of wetlands and riparian areas. Department of Water Affairs and Forestry, Pretoria, South Africa.

Ellery WN, Grenfell SE, Grenfell MC, Jaganath C, Malan H and Kotze DC. 2010. A method for assessing cumulative impacts on wetland functions at the catchment or landscape scale. Report emanating from WRC project K5/1584; Wetlands Health and Importance Research Programme. Water Research Commission, Pretoria.

Erenstein O. 2003. Smallholder conservation farming in the tropics and sub-tropics: A guide to the development and dissemination of mulching with crop residues and cover crops. Agriculture, Ecosystems and Environment 100: 17-37.

Gordon-Gray KD. 1995. Cyperaceae in Natal. National Botanical Institute, Pretoria, South Africa.

Heinsohn RD. 1991. The potential for cultivation of iNcema and other wetland species used for craftwork in Natal/KwaZulu. Department of Development Aid, Pretoria, South Africa.

Helme N, Desmet P. 2007. A description of the endemic flora and vegetation of the Kamiesberg uplands, Namaqualand. Report for CEPF/SKEP, South Africa.

Hilton-Taylor C. 1994. Western Cape Domain (Succulent Karoo). In: Davis ED, Heywood VH, Hamilton AC (eds.) Centres of plant diversity: A guide and strategy for conservation, Vol 1: Europe, Africa, South West Asia and the Middle East. IUCN Publications Unit, Cambridge, UK. pp. 204-217.

Hoffman MT. 1997. Human impacts on vegetation. In: Cowling RM, Richardson DM, Pierce SM (eds.) Vegetation of southern Africa. Cambridge University Press, Cambridge, UK. pp. 507-534.

Hoffman MT, Allsopp N, Rohde R. 2000. An introduction to the history, biophysical and socio-economic/cultural environments of Paulshoek, Namaqualand. In: Proceedings of Global change and subsistence rangelands in southern Africa workshop. Maseru, Lesotho. pp. 14-22.

Hoffman MT, Lindeque L, Ntshona Z. 1997. Desertification in South Africa: Preliminary results from a rapid participatory appraisal. Paper presented at the thirty-third annual congress of the Grassland Society of Southern Africa, Cedara, South Africa, 26-29 January, 1997.

Kotze DC. 2010. WET-SustainableUse: A system for assessing the sustainability of wetland use. Report emanating from WRC project K5/1584; Wetlands Health and Importance Research Programme. Water Research Commission, Pretoria.

Kotze DC, Hughes JC, Klug JR, Breen CM. 1996. Improved criteria for classifying hydric soils in South Africa. South African Journal of Plant and Soil 13: 67-73.

Kotze DC, Marneweck GC, Batchelor AL, Lindley DS, Collins NB. 2008. WET-EcoServices: A technique for rapidly assessing ecosystem services supplied by wetlands. WRC Report No. TT 339/08. Water Research Commission, Pretoria, South Africa.

Kotze DC and Breen CM. 2008. A framework for assessing the effectiveness of wetland management (WET-EffectiveManage) described and applied to 21 wetlands. In: Kotze DC, Breen CM, Nxele SI and Kareko J (eds.) The impact of natural resource management programmes on wetlands in South Africa. WRC Report No. 335/08. Water Research Commission, Pretoria.

Krug RM, Krug CB, Iponga DM, Walton BA, Milton SJ, Newton IP, Farley N and Shiponeni, NN. 2004. Reconstructing West Coast Renosterveld: Past and present ecological processes. In: Mediterranean shrubland of South Africa. In: Arianoutsou M and Papanastasis V (eds.) Proceedings 10th MEDECOS Conference, April 25-May 1, 2004, Rhodes, Greece. Millpress: Rotterdam. pp.108.

Levyns MR. 1926. A preliminary note on the rhenosterbush and the germination of its seed. Transactions of the Royal Society of South Africa 14: 383-388.

Levyns MR. 1929. The Problem of the rhenoster bush. South African Journal of Science 26: 166-169.

Levyns MR. 1956. Notes on the biology and distribution of the rhenoster bush. South African Journal of Science 53: 141-143.

Low AB, Rebelo AG. 1996. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria, South Africa.

Macfarlane DM, Kotze DC, Ellery WN, Walters D, Koopman V, Goodman P, Goge M. 2008. WET-Health: A technique for rapidly assessing wetland health. WRC Report No. TT 340/08. Water Research Commission, Pretoria, South Africa.

McCarthy T, Rubidge B. 2005. The story of earth and life: a southern African perspective on a 4.6- billion-year journey. Struik Publishers, Cape Town, South Africa. 334pp

Mackenzie JA, Jacoby DL, Rogers KH. 2003. Modelling of terrestrialisation and technology transfer to enable management of Kruger National Park rivers. WRC Report No. 1063/1/03. Water Research Commission, Pretoria, South Africa.

May H. 1997. Report on Current Situation Concerning Livestock Farming in Reservations, Municipal Areas (Including Communal Areas) and Areas With Communal Grazing in Namaqualand. Surplus People Project, Cape Town, South Africa.

Mills AJA, Fey MV. 2003. Declining soil quality in South Africa: effects of land-use on soil organic matter and surface crusting. South African Journal of Science 99: 429-436.

Milton SJ. 2007. Rapid Assessment Method for Renosterveld. Unpublished report submitted to WWF, Stellenbosch, for the Renosterveld Assessment Workshop, Worcester, 23 July 2007.

Petersen A. 2004. The vegetation of Paulshoek, Namaqualand: Phytosociology and landscape impacts. Unpublished MSc thesis, University of Cape Town, Cape Town, South Africa.

Ramsar Convention on Wetlands. 2004. New Guidelines for management planning for Ramsar sites and other wetlands. Accessed online at [http://ramsar.org/key_guide_mgt_new_e.htm].

Rebelo AG, Boucher C, Helme N, Mucina L, Rutherford MC. 2006. Fynbos biome. In: Mucina L, Rutherford MC (eds.) The vegetation of South Africa. Strelitzia 19. South African National Biodiversity Institute, Pretoria, South Africa. pp. 53-219.

Rogers KH, Bestbier RR. 1997. Development of a protocol for the definition of the desired state of riverine systems in South Africa. Department of Environmental Affairs and Tourism, Pretoria, South Africa.

Rogers KH, Biggs H. 1999. Integrating indicators, endpoints and value systems in strategic management of the rivers of the Kruger National Park. Freshwater Biology 41: 439-451.

Rutherford MC, Midgley GF, Bond WJ. 2000. South African country study on climate change, impact and adaptation. Department of Environmental Affairs and Tourism, Pretoria, South Africa.

Sahrawat KL. 2004. Organic matter accumulation in submerged soils. Advances in Agronomy 82: 169-201.

Shiponeni NN. 2003. Seed dispersal and banking in renosterveld. Veld and Flora 89(1): 32-33.

Shiponeni NN, Milton S. 2006. Seed dispersal in the dung of large herbivores: implications for restoration of Renosterveld shrubland old fields. Biodiversity and Conservation 15: 3161-3175.

Surplus People Project. 1995. Land Claims in Namaqualand. Surplus People Project, Cape Town, South Africa.

Taylor J. 2007. International best practice: ideas for the UNESCO Water Education for Sustainable Development Working Group. Unpublished report. Wildlife and Environment Society of South Africa, Umgeni Valley, Howick, South Africa.

Thom HB. 1952. Journal of Jan van Riebeek, Vol. 1. Van Riebeek Society: AA Blakema, Cape Town, South Africa. pp 1651-1655.

Thom HB. 1954. Journal of Jan van Riebeek. Vol. 2. Van Riebeek Society: AA Blakema, Cape Town, South Africa. pp 1656-1658.

Walker B, Carpenter C, Anderies J, Abel N, Cumming G, Janssen M, Lebel L, Norberg J, Peterson GD, Pritchard R. 2002. Resilience management in social-ecological systems: a working hypothesis for a participatory approach. Conservation Ecology 6(1): 14.

Walters C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. Conservation ecology 1(2): 1. Accessed online at [http://www.consecol.org/voll/iss2/art1].

Walton BA. 2006. Vegetation patterns and dynamics of renosterveld at Agter-Groeneberg Conservancy, Western Cape, South Africa. MSc thesis, Stellenbosch University, Stellenbosch, South Africa.

Webley L. 1984. Archaeology and ethnoarchaeology in the Leliefontein Reserve and surrounds, Namaqualand. Unpublished MA thesis, University of Stellenbosch, Stellenbosch, South Africa.

Wells MJ, Balsinhas VM, Joffe H, Engelbrecht VM, Harding G, Stirton CH. 1986. A Catalogue of Problem Plants in Southern Africa, incorporating The National Weed List of South Africa. Memoirs of the Botanical Survey of South Africa No. 53. Botanical Research Institute, Pretoria, South Africa.

Wilkins RJ, Garwood EA. 1986. Effects of treading, poaching and fouling on grassland production and utilisation. In: Frame J (ed.) Grazing. British Grassland Society Occasional Report No. 19. Hurley, England.

Wisbrog P, Rohde R. 2003. Debating land reform and rural development. TRANCRAA and communal land rights: Lessons from Namaqualand. Policy Brief No. 4. PLAAS, University of the Western Cape, South Africa.

APPENDIX 1

THE GEOLOGICAL AND GEO-MORPHOLOGICAL HISTORY OF THE KAMIESBERG AREA

by W Ellery

The area of the Northern Cape from Nuwerus northwards (into Namibia) and north-eastwards (as far as Upington) comprises the Namaqua-Natal Metamorphic Province that reflects a complex geological history of continental cratons (stable ancient continental cores) colliding and separating, to make up the rocks of this area (McCarthy and Rubidge, 2005). The Kaapvaal Craton makes up the continental core that underlies the eastern half of South Africa, to the north and north-west of which lie the Zimbabwe and Congo Cratons. These cratons have moved relative to each other, and they have independently collided and separated with other cratons, to leave behind the rocks of the Bushmanland Group and the Namaqua-Natal Province as they are present today.

Rifting of the continental crust about 1500 million years ago led to the formation of a shallow sea across what is now Bushmanland, in which sediment accumulated (the Bushmanland Group). Subsequent formation of the supercontinent of Rhodinia involved collision of the Kaapvaal, Zimbabwe and Congo Cratons with other Cratons (Nena in particular in a relative position to the north-east of the African continent as it exists today) to form the Kibaran Belt of mountains about 1100 million years ago in the region of Bushmanland. Continents again separated and reunited in a new configuration to form Pangea about 500 million years ago through the collision of the Kaapvaal, Zimbabwe, Congo and Atlantica Cratons in a configuration that approximates Gondwanaland (but with Laurasia in a relative position to the north-west of the African continent as it exists today forming a significant part of the supercontinent of Pangea). Laurasia separated from Gondwana first, following which Gondwana started breaking up about 200 million years BP into what now form Australia, South America, Antarctica, Africa, Madagascar and India. Erosion of the mountains formed during the formation of Rhodinia and Pangea left behind the highly metamorphosed rocks of the Bushmanland as we know it today. They comprise mainly metamorphosed granitic (igneous) rocks that are known as gneiss, and metamorphosed sedimentary rocks (“metasediments” including quartzite and shale) that formed in shallow seas.

APPENDIX 2

WET-HEALTH ASSESSMENT TABLES

The assessment tool "WET-Health" (Chapter 3) is a scoring system that makes use of a series of tables to evaluate the environmental condition of a wetland. In order to clarify the reporting of the process, tables that present important results are given in the text. Ancillary tables are presented in this appendix.

Table A2.1: Hydrological vulnerability factor based on the ratio of mean annual precipitation (MAP) and mean annual potential evapotranspiration (PET)

MAP to PET ratio	**>0.6**	**0.50-0.59**	**0.40-0.49**	**0.30-0.39**	**<0.3**
Vulnerability factor	0.9	0.95	1.0	1.05	1.1

Table A2.2: Factors potentially contributing to a decrease or increase of floodpeak magnitude and/or frequency received by the HGM unit

Level of reduction	Low				High	Score
	0	**-2**	**-5**	**-8**	**-10**	
(1) Collective volume of dams in the wetland's catchment in relation to mean annual runoff (MAR)*	<20%	20-35%	36-60%	60-120%	>120%	
(2) Level of abstraction from the dams	Low	Moderately low	Intermediate	Moderately high	High	
(3) Specific allowance for natural floods within the operating rules of the dam**	Good allowance made	Moderate allowance	Limited allowance	Poor allowance	No allowance	

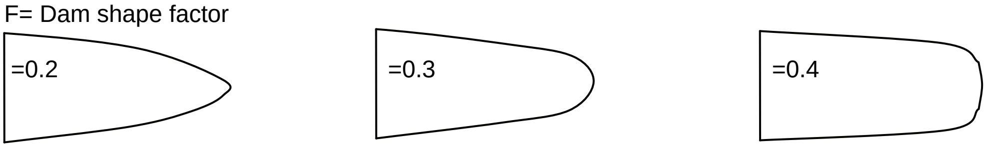
Level of increase***	Low				High	Score
	0	**+2**	**+5**	**+8**	**+10**	
(4) Extent of hardened surfaces in the catchment	<5%	5-20%	21-50%	50-70%	>70%	
(5) Extent of areas of bare soil in the wetland's catchment including that associated with poor veld condition***	<10%	11-40%	41-80%	>80%		

Combined score: [Average of (1), (2) and (3)] + [(4) + (5)] Adjusted**** The combined score will be in the range from -10 to +10 depending on whether the increases in peak flow are greater or smaller than the decreases.	

*Refer to Appendix 2 of WET-Health (Macfarlane *et al., 2*008) to obtain the median annual simulated runoff given in millimeters for the particular quaternary catchment in which the wetland falls. Convert this to metres (÷ 1000) and multiply this by the area of the catchment (converted from ha to m^2 by multiplying by 10 000). For example, if the wetland is in quaternary catchment B60B then the simulated runoff given in Appendix 2 is 251 mm. Assuming in the example that the wetland's catchment is 500 ha, then the MAR = 251 ÷ 1000 X 500 X 10 000 = 1 255 000 m^3.

The volume of a dam is calculated roughly based on the following formula.
Q=FLOD, Where Q=capacity (m^3)

F= Dam shape factor



L= Wall length at full supply level (m); O= Throwback (m); D= Maximum water depth (m)

**This is only applicable where the collective volume of dams is >120% of MAR.

***Excluding very sandy soils with clay contents too low for crusting to occur

****Two factors that may potentially further increase floodpeaks are gullies and roads in the catchment , which serve to increase the delivery of stormflows to the wetland, and inter-basin transfers. If either of these are present then adjust accordingly, with written justification. For example, the extent of hardened surfaces may be only 10% of the catchment (i.e. a score of +2) but an extensive network of roads may act to effectively deliver stormflows to the wetland, and the score is adjusted to +4. Inter-basin transfers are common in urban settings, where water is often transferred into a catchment for industrial and domestic purposes.

Table A2.3: Guideline for assessing the magnitude of impact on the HGM unit based on the joint consideration of hydrogeomorphic type, altered quantity of water inputs and the altered pattern of water inputs.

(b) Other hydrogeomorphic settings, including floodplains and channelled valley bottoms driven primarily by lateral inputs (e.g. from tributaries)

Change in quantity of water inflows	**Alteration to flood-peaks**						
	Large increase (>6)	Moderate increase (4-6)	Small increase (1.6-3.9)	No effect (-1.5 to 1.5)	Small decrease (-1.6 to -3.9)	Moderate decrease (-4 to -6)	Large decrease (<-6)
> 9	6	5	4	3	3	3.5	4
4-9	4.5	4	3	2	3	3	3
1-3.9 (Increase)	3	2	1	1	1	2	2.5
-0.9- +0.9 (Negligible)	2.5	1.5	0.5	0	0.5	1	1.5
-1- -1.9 (Decrease)	3.5	2.5	1.5	1	1.5	2	2.5
-2- -3.9	4.5	3.5	2.5	2	2.5	3	3.5
-4- -5.9	6	5	4	3.5	4	4.5	5
-6- -7.9	-**	-**	-**	5	5.5	6	6.5
-8- -9	-**	-**	-**	-**	-**	7.5	8
< -9	-**	-**	-**	-**	-**	-**	10

Table A2.4: Guideline for interpreting the magnitude of impact on the hydrological integrity of an HGM unit

IMPACT CATEGORY	DESCRIPTION	IMPACT SCORE RANGE	PRESENT STATE CATEGORY
None	No discernible modifications, or the modifications are of such a nature that they have no impact on the hydrological integrity.	0-0.9	**A**
Small	Although identifiable, the impact of the modifications to hydrological integrity are small.	1-1.9	**B**
Moderate	The impact of the modifications to hydrological integrity is clearly identifiable, but limited.	2-3.9	**C**
Large	The impact of the modifications is clearly detrimental to the hydrological integrity. Approximately 50% of the hydrological integrity has been lost.	4-5.9	**D**
Serious	Modifications clearly have an adverse effect on the hydrological integrity. 51% to 79% of the hydrological integrity has been lost.	6-7.9	**E**
Critical	Modifications are so great that the hydrological functioning has been drastically altered. 80% or more of the hydrological integrity has been lost.	8-10	**F**

Table A2.5: Estimate of wetland surface roughness for a channel in the HGM unit

Class	Descriptor
Low	Smooth surface with little or no vegetation to offer resistance to water flow
Moderately low	Vegetation is present but short (i.e. < 500 mm) and not robust (e.g. rye grass)
Moderate	Vegetation offering slight resistance to water flow, generally consisting of short plants (i.e. < 1 m tall)
Moderately high	Robust vegetation (e.g. dense stand of reeds) or hummocks offering high resistance to water flow
High (Score = 0)	Vegetation very robust (e.g. dense swamp forest with a dense understorey) and offering high resistance to water flow.

Note: Where roughness varies across the channel or HGM unit, take the average condition, and where roughness varies over time (e.g. areas which are regularly cut short) take the average condition during the *wet season*.

Table A2.6: Derivation of overall magnitude-of-impact scores through combining the scores obtained from water inputs to the catchment and within-wetland assessments (water distribution and retention patterns). The colour codes correspond to the impact categories given in Table A2.4 Appendix 2.

			Water Inputs (Step 2)					
			None	**Small**	**Moderate**	**Large**	**Serious**	**Critical**
			0-0.9	**1-1.9**	**2-3.9**	**4-5.9**	**6-7.9**	**8-10**
Water distribution and retention patterns (Step 3)	**None**	**0-0.9**	0	1	3	5	6.5	8.5
	Small	**1-1.9**	1	1.5	3.5	6	7	9
	Moderate	**2-3.9**	3	3.5	4	6.5	7.5	9
	Large	**4-5.9**	5	6	6.5	7	8	9.5
	Serious	**6-7.9**	6.5	7	7.5	8	9	10
	Critical	**8-10**	8.5	9	9	9.5	10	10

Table A2.7: Threat scores and classes used to evaluate threats to wetland hydrology

Threat Class	**Description**	**Change Score**	**Class Range**	**Symbol**
Improve	Hydrological condition is likely to improve over the over the next 5 years	+1	0.3 to 1.0	(↑)
Remain stable	Hydrological condition is likely to remain stable over the next 5 years	0	-0.2 to +0.2	(→)
Slowly deteriorate	Hydrological condition is likely to slowly deteriorate over the next 5 years	-1	-0.3 to -1.0	(↓)
Rapidly deteriorate	Rapid deterioration of hydrological condition is expected over the next 5 years	-2	-1.1 to -2.0	(↓↓)

Table A2.8: Guideline for assessing the impacts of activities according to HGM type

HGM type to assess	**Activity/Indicator**
Diagnostic component	
Floodplain	Dams upstream of or within floodplains
Floodplain, channelled valley bottom	Stream shortening or straightening
Floodplain, channelled valley bottom	Infilling that leads to narrowing of the wetland
All non-floodplain HGM's	Changes in runoff characteristics
Indicator-based component	
All non-floodplain HGM's	Erosional features
All non-floodplain HGM's*	Depositional features
All non-floodplain HGM's	Loss of organic sediment

*Consider floodplains if there are large alluvial fans impinging laterally onto them

Table A2.9: Scores used for the intensity and magnitude of impact of erosional features. (The scores for rows 2 and 3 are unscaled for any natural recovery that may have taken place. Factors to use to scale the intensity of impact of erosional features for natural recovery are presented in rows 7 and 8).

Factor	**2**	**4**	**6**	**8**	**10**	**Unscaled Score**
Mean depth of gullies	<0.50 m	0.50-1.00 m	1.01-2.00 m	2.00-3.00 m	>3.00 m	
Mean width of gullies	<2 m	2-5 m	5.1-8 m	8.1-16 m	>16 m	
Number of head-cuts present	1	2	3	4	>4	
Unscaled intensity of impact score: mean score of above 3 rows						
Scaling factor	**0.4**	**0.5**	**0.7**	**0.9**	**1.0**	**Factor**
Extent to which sediment from the gully is deposited within the HGM or wetland downstream of the HGM unit (as opposed to being exported)	Entirely deposited	Mainly deposited	Intermediate	Mainly exported	Entirely exported	
Extent to which the bed and sides of the gully have been colonised by vegetation and/or show signs of natural recovery	Complete	High	Moderate	Low	None	
Scaling factor score: mean of above 2 rows (value is between 0 and 1)						
Scaled intensity of impact score = unscaled intensity of impact score × scaling factor score						
Magnitude of impact score for erosional features: (extent of impact score (see Table 3.17)/100) × scaled intensity of impact score						

Table A2.10: Description of Present Geomorphic State in relation to Impact Scores and Present Geomorphic State Categories for each HGM

IMPACT SCORE	DESCRIPTION	PGS CATEGORY
0-0.9	Unmodified, natural.	A
1-1.9	Largely natural. A slight change in geomorphic processes is discernable but the system remains largely intact.	B
2-3.9	Moderately modified. A moderate change in geomorphic processes has taken place but the system remains predominantly intact.	C
4-5.9	Largely modified. A large change in geomorphic processes has occurred and the system is appreciably altered.	D
6-7.9	Greatly modified. The change in geomorphic processes is great but some features are still recognizable.	E
8-10	Modifications have reached a critical level as geomorphic processes have been modified completely.	F

Figure A2.1: Vulnerability of HGM units to geomorphological impacts based on wetland size (a simple surrogate for mean annual runoff) and wetland longitudinal slope. The line between scores 2 and 5 approximates the equilibrium slope for a wetland of a given size.

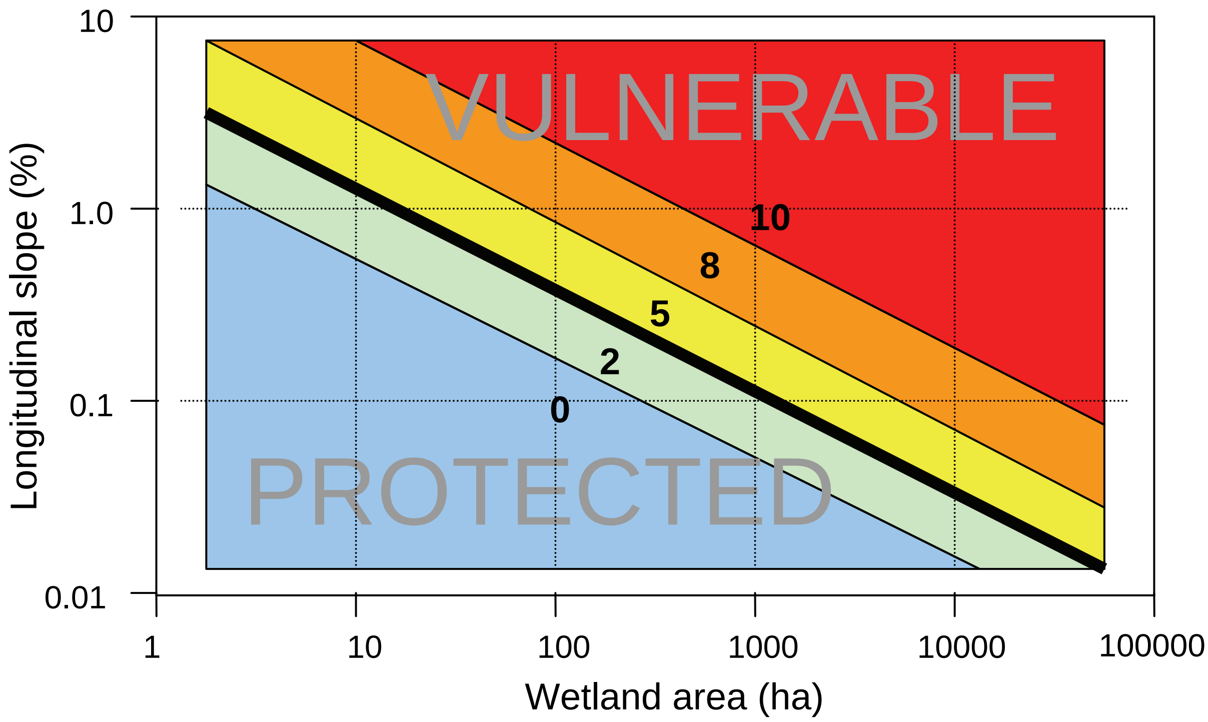


Table A2.11: Trajectory class, change score and symbol used to evaluate the Trajectory of Change to the geomorphology of each HGM unit

Trajectory class	Description	HGM unit change score	Class Range	Symbol
Improve slightly	Geo-morphological condition is likely to improve slightly over the next 5 years	1	0.3 to 1.0	↑
Remain stable	Geo-morphological condition is likely to remain stable over the next 5 years	0	-0.2 to +0.2	→
Deteriorate slightly	Geo-morphological condition is likely to deteriorate slightly over the next 5 years	-1	-0.3 to -1.0	↓
Deteriorate greatly	Geo-morphological condition is likely to deteriorate greatly over the next 5 years	-2	-1.1 to -2.0	↓↓

Table A2.12: Description of common disturbance classes in South African wetlands

Disturbance class	Description
Land uses commonly associated with complete transformation of wetland habitat	
Infrastructure	Includes houses, roads and other permanent structures that totally replace wetland vegetation.
Deep flooding by dams.	This includes situations where flooding is too deep for emergent vegetation to grow.
Land uses commonly associated with substantial-to-complete transformation of vegetation characteristics.	
Crop lands.	These lands are still in use and when active are generally characterized by almost total indigenous vegetation removal (predominance of introduced species). Examples include maize lands, tree plantations, sugarcane lands & madumbe fields etc.
Commercial plantations.	Common plantations include pine, wattle, gum, poplar. Other land uses such as vineyards and orchards may have a similar impact on wetland vegetation.
Annual pastures.	These areas are characterized by frequent soil disturbance with a general removal of wetland vegetation. Some ruderal wetland species may become established but are frequently removed.
Perennial pastures.	Although such areas generally include a high abundance of alien terrestrial grasses or legumes, the reduced disturbance frequency may permit the establishment of some wetland species.
Dense alien vegetation.	Where dense patches of alien plants can be identified within a wetland system, they should be identified as a separate disturbance class and evaluated as a unit.
Shallow flooding by dams.	Such areas can often be identified at the head or tail end or edges of dams.
Sports fields.	These include cricket pitches, golf courses and the like, where a species such as Kikuyu have been introduced and are maintained through intensive management. These are often located within areas of temporary wetland where terrestrial species generally dominate.
Gardens.	Gardens are generally associated with urban environments.
Sediment deposition/ infilling and excavation.	Deposition includes sediment from excessive erosion or human disturbance (e.g. a construction site) upstream of the wetland, which is carried by water and deposited in the wetland. Infilling is the placement by humans of fill material in the wetland (e.g. for a sports field). Excavation is the direct human removal (usually with heavy machinery) of sediment from the wetland, which is commonly associated with mining and sand winning.
Eroded areas.	In wetlands this typically occurs as gully erosion.
Land uses commonly associated with moderate transformation of vegetation characteristics.	
Old / abandoned lands.	These secondary vegetation areas have typically been altered through historic agricultural practices, but are in the process of recovering. They are generally characterized by a high relative abundance of ruderal species, but this abundance may vary greatly depending on time since cultivation ceased. In cases where this varies greatly within an HGM unit, it may be best to distinguish between vegetation classes comprising recently abandoned lands and areas comprising older lands that are at a more advanced successional stage of recovery.
Land uses generally associated with low or no transformation of wetland vegetation.	
Seepage below dams.	Earthen dams used for agricultural purposes often allow water to leak through the wall, creating artificial wetter areas below the dam wall. Such areas are typically characterized by an increase in hydric species.
Minimal human disturbance.	These primary vegetation areas have not been significantly impacted by human activities, but may have been impacted upon by factors such as scattered alien plants. It may include wetland areas within game or extensive grazing management systems. Small pockets of untransformed vegetation may also be set aside as streamside buffers on commercial landholdings.
Note: Scattered alien plants may occur in most of the above disturbance classes. Where this occurs, alien plants are considered as part of the larger disturbance class of which they are part (e.g. scattered bramble occurring within an old land), and the intensity of disturbance score is modified to account for the fine grain disturbances within them.	

Table A2.13: Typical intensity of impact scores for disturbance classes that can be used to inform the vegetation assessment

Disturbance class	Typical intensity scores	Specific factors to consider when assigning the score
Infrastructure	10	N/A
Deep flooding by dams	10	N/A
Shallow flooding by dams	4-8	The impact on vegetation may be less intense where the dams are shallow and emergent plant species are able to persist. The impacts on vegetation depend on the periodicity of flooding and the extent to which seasonal drying out of dam margin occurs
Crop lands	8-10	Impact to wetland vegetation is determined largely by disturbance interval. Drains can also dry out these areas, reducing the likelihood of wetland species persisting in them.
Commercial plantations	7-10	Commercial plantations generally result in a gradual suppression of wetland vegetation as indigenous plants become shaded out by commercial species. Pines tend to have a more detrimental impact on wetland vegetation than wattle, gum or poplar due to the slow decaying litter layer that builds up under such plantations.
Annual pastures	9-10	Small scale patches that can be readily colonised by indigenous vegetation are more likely to have at least a little indigenous vegetation present than large, contiguous cultivated patches
Perennial pastures	4-10	The degree of change is largely dependent on the duration between disturbance events and how long ago the area was tilled. The longer the interval between tillage events, and the further back in time the area was tilled, the lower the impact score.
Dense Alien vegetation patches.	5-10	Degree of change is determined largely by the class of plants and their aerial cover. The longer these plants have persisted, the greater the potential impact on wetland vegetation.
Sports fields	7-10	Dependent on the degree of maintenance and species introduced.
Gardens	6-10	The degree of change is largely dependent on landscaping and the introduction of non-native species.
Areas of sediment deposition/ infilling and excavation	4-10	The longer the time since the past disturbance (e.g. from cultivation, infilling or erosion) and the smaller the extent to which the natural hydrology has been altered, the greater the opportunity provided for recovery towards the natural vegetation, unless the area becomes dominated by aggressive invasive alien plants. In addition, the wetter the area, the more readily it generally recovers to its natural vegetation, as the excessive wetness generally exerts an overriding influence on the other factors.
Eroded areas	3-9	
Old / abandoned lands (Recent)	7-9	
Old / abandoned lands (Old)	3-8	
Seepage below dams	1-5	The greater the changes in water balance in the wetland area below the dam, the greater the potential change in vegetation characteristics. Historically temporary wetland zones will therefore be more severely affected than seasonal / permanent wetland zones.
Minimal human disturbances	0-3	Many of South Africa's wetlands evolved under burning and grazing by indigenous grazers, and are well adapted to moderate grazing intensities. A change in wetland vegetation does become apparent under heavy grazing

		pressure where a decrease in basal cover may even trigger significant erosion. Exclusion of grazing and fire may also have a negative consequence through shading out of grazing tolerant wetland species.

Table A2.14: Present State categories used to define health of wetland vegetation

DESCRIPTION	OVERALL IMPACT SCORE	PRESENT VEGETATION STATE CATEGORY
Vegetation composition appears natural.	0-0.9	A
A very minor change to vegetation composition is evident at the site.	1-1.9	B
Vegetation composition has been moderately altered but introduced alien and/or ruderal species are still clearly less abundant than characteristic indigenous wetland species.	2-3.9	C
Vegetation composition has been largely altered and introduced alien and/or ruderal species occur in approximately equal abundance to the characteristic indigenous wetland species.	4-5.9	D
Vegetation composition has been substantially altered but some characteristic species remain, although the vegetation consists mainly of introduced, alien and/or ruderal species.	6-7.9	E
.Vegetation composition has been totally or almost totally altered, and if any characteristic species still remain, their extent is very low.	8-10	F

Table A2.15: Trajectory classes, change scores and symbols used to evaluate the Trajectory of Change of wetland vegetation

Trajectory Class	Description	Change Score	Class Range	Symbol
Improve markedly	Vegetation is likely to improve substantially over the next 5 years	2	1.1 to 2.0	↑↑
Improve slightly	Vegetation is likely to improve slightly over the next 5 years	1	0.3 to 1.0	↑
Remain stable	Vegetation is likely to remain stable over the next 5 years	0	-0.2 to +0.2	→
Deteriorate slightly	Vegetation is likely to deteriorate slightly over the next 5 years	-1	-0.3 to -1.0	↓
Deteriorate markedly	Vegetation is expected to deteriorate substantially	-2	-1.1 to -2.0	↓↓

APPENDIX 3

WET-ECOSERVICE SCORES FOR LANGVLEI WETLAND

Table A3.1: Sheet for entering the scores, confidence ratings and additional notes for the characteristics assessed. See Kotze *et al*. (2008) for an explanation of scoring

	0	1	2	3	4	Langvlei HGM1			Langvlei HGM2			Langvlei HGM3		
Date of assessment						Nov 2007			Nov 2007			Nov 2007		
Name/s of assessors						D Kotze,H Malan, MI Samuels, L Saul, D Ollis			D Kotze,H Malan, MI Samuels, L Saul, D Ollis			D Kotze,H Malan, MI Samuels, L Saul, D Ollis		
Details of owner/authority						Communual land			Communual land			Communual land		
Wetland name						**Langvlei HGM1**			**Langvlei HGM2**			**Langvlei HGM3**		
Hydro-geomorphic setting of wetland	F=Floodplain, VC=Valley bottom with channell, V=Valley bottom without channel, HW=Hillslope seepage feeding a water course, H=Hillslope seepage not feeding a watercourse, D=Depression					Valley bottom without channel			Valley bottom without channel			Valley bottom with channel		
Size (hectares)						8			14			8		
	0	1	2	3	4	**Score**	**Confidence rating**	**Additional notes**	**Score**	**Confidence rating**	**Additional notes**	**Score**	**Confidence rating**	**Additional notes**
HGM unit'S CATCHMENT														
Average slope of the HGM unit's catchment	<3%	3-5%	6-8%	9-11%	>11%	1	2	Ortho-photos not available. Estimated from 1:50 000 maps	0	2	Ortho-photos not available. Estimated from 1:50 000 maps	0	2	Ortho-photos not available. Estimated from 1:50 000 maps

Inherent runoff potential of the soils in the HGM unit's catchment	Low	Mod low		Mod high	High	3	3	Fairly high because of bare, granite outcrops. Also soils tend to form a surface crust which increases run-off.	3	3	Fairly high because of bare, granite outcrops. Also soils tend to form a surface crust which increases run-off.	3	3	Fairly high because of bare, granite outcrops. Also soils tend to form a surface crust which increases run-off.
Contribution of catchment land-uses to changing runoff intensity from the natural condition	Decrease	Negligible effect	Slight increase	Moderate increase	Marked increase	3	3	See WET-Health assessment	2	3	See WET-Health assessment	2	3	See WET-Health assessment
Rainfall intensity	Low (Zone I)	Moderately low (Zone II)		Mod. high (Zone III)	High (Zone IV)	1	4	Kamiesberg upland area, higher rainfall than surrounding lowlands.	1	4	Kamiesberg upland area, higher rainfall than surrounding lowlands.	1	4	Kamiesberg upland area, higher rainfall than surrounding lowlands.
Extent to which dams are reducing the input of sediment to the HGM unit	High	Mod high	Intermediate	Mod low	Low	4	4	No dams in area	4	4	No dams in area	4	4	No dams in area
Extent of sediment sources delivering sediment to the HGM unit	Low	Mod low	Intermediate	Mod high	High	3	2	Cultivation and erosion gullies.	3	2	Cultivation, erosion gullies, tracks.	2	2	Cultivation and road.
Extent of other potential sources of phosphates in the HGM unit's catchment	Low	Mod low	Intermediate	Mod high	High	2	3	No fertilizer or pesticides used.	1	3	No fertilizer or pesticides used.	1	3	No fertilizer or pesticides used.
Extent of nitrate sources in the HGM unit's	Low	Mod low	Intermediate	Mod high	High	1	3		1	3		1	3	

catchment														
Extent of toxicant sources in the HGM unit's catchment	Low	Mod low	Intermediate	Mod high	High	1	3		1	3		1	3	
HGM unit														
Size of HGM unit relative to the HGM unit's catchment	<1%	1%-2%	3-5%	6-10%	>10%	3	3		3	3		3	3	
Slope of the HGM unit (%)	>5%	2-5%	1-1.9%	0.5-0.9%	<0.5%	1	2		2	2		2	2	
Surface roughness of HGM unit	Low	Mod. low		Mod. high	High	2	3	Renoster-bos	2	3	Renoster-bos	2	3	Renoster-bos
Depressions	None	Present but few or remain permanently filled close to capacity	Intermediate	Moderately abundant	Abundant	0	4		0	4		2	2	Several pools are present in the river channel.
Frequency with which stormflows are spread across the HGM unit	Never	Occasionally but less frequently than every 5 years		1 to 5 year frequency	More than once a year	3	3		3	3		3	3	
Sinuosity of the stream channel	Low	Moderately low	Intermediate	Mod. high	High			N/A Valley bottom without channel. (A straight erosion gully present but this is unnatural).			N/A Valley bottom without channel. Erosion gully present part of the wetland. This is straight.	1	3	

Representation of different hydrological zones	Permanent and seasonal zones lacking (i.e. only the temporary zone present)	Seasonal zone present but permanent zone absent	Permanent and seasonal zones both present but collectively <30%	Seasonal and permanent zone both present and collectively 30-60%	Seasonal and permanent zone both present and collectively >60% of total HGM unit area	1	3		1	3		1	3	
Link to the stream network	No link (i.e. hydrologically isolated)				Linked to the stream system	4	4	Part of Buffels system	4	4	Part of Buffels system	4	4	Part of Buffels system
Presence of fibrous peat or unconsolidated sediments below a floating marsh	Absent	Present but limited in extent/depth		Moderately abundant	Extensive and relatively deep (>1.5 m)	0	4	No peat	0	4	No peat	0	4	No peat
Reduction in evapotranspiration through frosting back of the wetland vegetation	Low	Moderately low	Intermediate	Moderately high	High	2	3	Frost does occur due to high altitude.	2	3	Frost does occur due to high altitude.	2	3	Frost does occur due to high altitude.
HGM unit occurs on underlying geology with strong surface-groundwater linkages	No		Underlying geology quartzite	Underlying geology sandstone	Underlying geology dolomite	3	2	Sandstone	3	2	Sandstone	3	2	Sandstone
Direct evidence of sediment deposition in the HGM unit	Low	Mod low	Intermediate	Mod high	High	0	2		2	2	From aerial photo	1	2	Downstream of road crossing
Flow patterns of low flows within the wetland	Strongly channelled	Moderately channelled	Intermediate	Moderately diffuse	Very diffuse	2	2	Unchannelled system naturally.Eerosion gullies now present.	3	2	Unchannelled system naturally. Erosion gullies now present.	0	3	Channelled.
Extent of vegetation	Low	Mod low	Intermediate	Mod high	High	1	2		2	2		2	2	

cover in the HGM unit														
Contribution of sub-surface water inputs relative to surface water inputs	Low (<10%)	Moderately low (10-20%)	Intermediate (20-35%)	Moderately high (36-50%)	High (>50%)	2	2	Several seeps present indicating sub-surface water entering wetland.	2	2	Several seeps present indicating sub-surface water entering wetland.	2	2	Several seeps present indicating sub-surface water entering wetland.
Application of fertilizers/biocides in the HGM unit	High	Mod high	Intermediate	Mod low	Low	4	3	Cultivation in wetland but levels of fertilizer/biocide low.	4	3		4	3	
Direct evidence of erosion	High	Mod high	Intermediate	Mod low	Low	1	3	Erosion gullies present	2	3	Erosion gullies present	4	3	
Current level of physical disturbance of the soil in the HGM unit	High	Mod high	Intermediate	Mod low	Low	1	4	See WET-Health assessment	2	4	See WET-Health assessment	3	4	See WET-Health assessment
Erodibility of the soil in the HGM unit	Low	Mod low	Intermediate	Mod high	High	3	2	Sandy substrate	3	2	Sandy substrate	3	2	Sandy substrate
Abundance of peat	Absent	Present but limited in extent/depth	Intermediate	Moderately abundant	Extensive and relatively deep (>0.5 m)	0	3	No peat	0	3	No peat	0	3	No peat
HGM unit is of a rare type or is of a wetland type or vegetation type subjected to a high level of cumulative loss	No				Yes	4	4	Not a rare type, but subject to cumulative loss.	4	4	Not a rare type, but subject to cumulative loss.	4	4	Not a rare type, but subject to cumulative loss.

Red Data species or suitable habitat for Red Data species	No				Yes	2	1	Some Red data sp of plants (Helme and Desmet 2007) and insects (J Colville, 2007, pers. comm., Dept Zoology, UCT, Cape Town) have been found in other wetlands of the area. Not clear if in Langvlei.	3	1	Some Red data sp of plants (Helme and Desmet, 2007) and insects (J Colville, 2007 pers. comm., Dept Zoology, UCT, Cape Town) have been found in other wetlands of the area.Not clear if in Langvlei.	4	3	Some Red data sp of plants (Helme and Desmet, 2007) and insects (J Colville, 2007, pers. comm., Dept Zoology, UCT, Cape Town) have been found in other wetlands of the area.Not clear if in Langvlei. HGM 3 vegetation is the least disturbed.
Level of significance of other special natural features	None	Mod low	Intermediate	Mod high	High	1	3		1	3		1	3	
Alteration of hydrological regime	High	Mod high	Intermediate	Mod low	Low/negligible	1	4	See WET-Health assessment	3	4	See WET-Health assessment	4	4	See WET-Health assessment
Complete removal of indigenous vegetation	>50%	25-50%	5-25%	1-5%	<1%	0	4	See WET-Health assessment	1	4	See WET-Health assessment	2	4	See WET-Health assessment
Invasive and pioneers species encroachment	>50%	25-50%	5-25%	1-5%	<1%	3	4	Possibly renosterbos and Carpobrotus (suurvygie)	3	4	Possibly renosterbos and Carpobrotus (suurvygie)	4	4	Possibly renosterbos and Carpobrotu s (suurvygie)
Presence of hazardous/rest rictive barriers	High	Mod high	Intermediate	Mod low	Low/negligible	4	4		3	4	Dirt tracks	2	4	Leliefontein-Kamieskroo n road

Current level of use of water for agriculture or industry	No use	Mod low	Intermediate	Mod high	High	2	3	See WET-Health assessment	1	3	See WET-Health assessment	0	3	See WET-Health assessment
Current level of use of water for domestic purposes	No use	Mod low	Intermediate	Mod high	High	2	3	See WET-Health assessment	1	3	See WET-Health assessment	0	3	See WET-Health assessment
Number of dependent households that depend on the direct provision of water from the wetland	None	1-2	3-4	5-6	>6	2	3		1	3		0	3	
Substitutability of the water resource from the HGM unit	High	Mod high	Intermediate	Mod low	Low	4	4	Arid area.	4	4	Arid area.	4	4	Arid area.
Number of different resources used	None	1		2-3	>3	3	3	Cultivation, grazing, wild mint	3	3	Cultivation, grazing, wild mint	1	3	Grazing
Is the wetland in a rural communal area?	No				yes	4	4		4	4		4	4	
Level of poverty in the area	Low/ neg-ligible	Mod low	Intermediate	Mod high	High	3	4		3	4		3	4	
Number of households who depend on the natural resources in the HGM unit	None	1	2-3	4-5	>6	4	4		4	4		2	2	
Substitutability of the natural resources obtained from the wetland	High	Mod high	Intermediate	Mod low	Low	4	4		4	4		4	4	
Total number of different crops	None	1		2-3	>3	4	4	Oats, cabbages, onions,	4	4	Oats, cabbages, onions,	0	3	None currently

cultivated in the HGM unit								pumpkins, melons, potatoes.			pumpkins, melons, potatoes.			
Number of households who depend on the crops cultivated in the HGM unit	None	1	2-3	4-6	>6	4	4	For selling and for subsistence use.	4	4	For selling and for subsistence use.	0	3	
Substitutability of the crops cultivated in the wetland	High	Mod high	Intermediate	Mod low	Low	3	3		3	3		3	3	
Registered SAHRA site	No				Yes	0	4		0	4		0	4	
Known local cultural practices in the HGM unit	None	Historically present but no longer practised		Present but practised to a limited extent	Present and still actively and widely practised	1	2		1	2		1	2	
Known local taboos or beliefs relating to the HGM unit	None	Historically present but no longer so		Present but held to a limited extent	Present and still actively and widely held	3	4	Snakes associated with wetland areas in Kamiesberg	3	4	Snakes associated with wetland areas in Kamiesberg	3	4	Snakes associated with wetland areas in Kamiesberg
Scenic beauty of the HGM unit	Low/ neg-ligible	Mod low	Intermediate	Mod high	High	2	4		2	4		3	4	
Presence of charismatic species	None present	Very seldom seen	Occasionally present	Generally present	Always present	0	3		0	3		1	3	Possibility that rare/charis matic species are present.. None were obvious.
Current use for tourism or recreation	No use	Mod low use	Intermediate use	Mod high use	High	1	2	Some flower viewing in spring	1	2	Some flower viewing in spring	1	2	Some flower viewing in spring
4. Availability of other natural areas providing similar	High	Mod high	Intermediate	Mod low	Low	2	2		2	2		2	2	

experiences to the HGM unit														
Location within an existing tourism route	Low/neg ligible	Mod low	Intermediate	Mod high	High	1	3		1	3		1	3	
Recreational hunting and fishing and birding opportunities	None	Mod low	Intermediate	Mod high	High	2	2		2	2		3	2	Potential for birding (B van der Walt, 2007, Brian's Birding, Cape Town)
Extent of open water	None	Present, but very limited		Extent somewhat limited	Extensive	0	4		0	4		1	4	Pool areas in river
Current use for education/rese arch purposes	No use	Mod low	Intermediate	Mod high	High	2	3	Several research projects being conducted in the area.	2	3	Several research projects being conducted in the area.	2	3	Several research projects being conducted in the area.
Reference site suitability	Low	Mod low	Intermediate	Mod high	High	0	3	See WET-Health assessment	2	3	See WET-Health assessment	3	3	See WET-Health assessment
Existing data and research	None	Mod low	Intermediate detail/ time period	Mod high	Comp-rehensive data over long period	1	2		1	2		1	2	
Accessibility	Very inaccess -ible	Moderately in-accessible	Intermediate	Moderately accessible	Very accessible	1	4	Remote area far from city. Also communual land and permission required.	1	4	Remote area far from city. Also communual land and permission required.	1	4	Remote area far from city. Also communual land and permission required.
DOWNSTREAM OF HGM UNIT														
Extent of floodable property	Low/ negligibl e	Moderately low		Moderately high	High	0	3		0	3		0	3	

Presence of any important wetlands or aquatic systems downstream	None		Intermediate importance		High importance	2	3		2	3	Langvlei HGM 3	2	3	The Kamiesberg is important for generation of water for lowland towns e.g. Garies.
LANDSCAPE														
Extent of buffer around wetland	Low	Mod low	Intermediate	Mod high	High	0	4		0	4		1	4	
Connectivity of wetland in landscape	Low	Mod low	Intermediate	Mod high	High	3	3		3	3		3	3	
Level of cumulative loss of wetlands in overall catchment	Low	Mod low	Intermediate	Mod high	High	3	4	See report by Helme and Desmet (2007).	3	4	See report by Helme and Desmet (2007).	3	4	See report by Helme and Desmet (2007).
THREATS and OPPORTUNITIES														
Level of threat to existing ecosystem services supplied by the wetland	Low	Moderately low	Intermediate	Moderately high	High	3	2	Erosion gullies	3	2	Erosion gullies	1	2	
Level of future opportunities for enhancing the supply of ecosystem services	Low	Moderately low	Intermediate	Moderately high	High	2	2	Would require rehabilitation	2	2	Would require re-habilitation	1	1	

APPENDIX 4

WET-ECOSERVICE SCORES FOR RAMKAMP WETLAND

Table A4.1: Sheet for entering the scores, confidence ratings and additional notes for the characteristics assessed. See Kotze *et al*. (2008) for an explanation of scoring

		0	1	2	3	4	**Ramkamp**
Date of assessment							Nov 2007
Name/s of assessors							D Kotze,H Malan, MI Samuels, L Saul, D Ollis
Details of owner/authority	O						Communual land
Location (Latitude; Longitude)	O						30° 20' S 18° 05' E
Wetland name	O						Ramkamp
Hydrogeomorphic setting of wetland	R	F=Floodplain, VC=Valley bottom with channell, V=Valley bottom without channel, HW=Hillslope seepage feeding a water course, H=Hillslope seepage not feeding a watercourse, D=Depression					Valley bottom without channel
Size (hectares)							25

O=Data should be obtained in the office through desktop investigation prior to the field assessment. R=Data may be available through desktop investigation but is likely to be revised/refined in the field		0	1	2	3	4	Score	Confidence rating	Additional notes
HGM unit'S CATCHMENT									
Average slope of the HGM unit's catchment	D	<3%	3-5%	6-8%	9-11%	>11%	1	4	
Inherent runoff potential of the soils in the HGM unit's catchment	O	Low	Mod low		Mod high	High	3	3	
Contribution of catchment land-uses to changing runoff intensity from the natural condition	R	Decrease	Negligible effect	Slight increase	Moderate increase	Marked increase	2	4	Large area of catchment historically cultivated, but land now recovering.
Rainfall intensity	O	Low (Zone I)	Moderately low (Zone II)		Mod. high (Zone III)	High (Zone IV)	1	4	Kamiesberg upland area, higher rainfall than surrounding lowlands
Extent to which dams are reducing the input of sediment to the HGM unit	R	High	Mod high	Intermedi ate	Mod low	Low	4	4	No dams
Extent of sediment sources delivering sediment to the HGM unit	R	Low	Mod low	Intermedi ate	Mod high	High	2	3	Higher level of cultivation on upper portion of catchment
Extent of other potential sources of phosphates in the HGM unit's catchment	R	Low	Mod low	Intermedi ate	Mod high	High	1	3	No point sources. Some livestock.
Extent of nitrate sources in the HGM	R	Low	Mod low	Intermedi ate	Mod high	High	1	3	No point sources. Some livestock.

unit's catchment									
Extent of toxicant sources in the HGM unit's catchment	R	Low	Mod low	Intermediate	Mod high	High	0	4	No point sources
HGM unit									
Size of HGM unit relative to the HGM unit's catchment	O	<1%	1%-2%	3-5%	6-10%	>10%	4	4	The catchment is very small
Slope of the HGM unit (%)	R	>5%	2-5%	1-1.9%	0.5-0.9%	<0.5%	1	4	Slope calculated to be 4%
Surface roughness of HGM unit		Low	Mod. low		Mod. high	High	2	3	Intermediate roughness of vegetation
Depressions	R	None	Present but few or remain permanently filled close to capacity	Inter-mediate	Moderately abundant	Abundant	1	4	
Frequency with which stormflows are spread across the HGM unit		Never	Occasionally but less frequently than every 5 years		1 to 5 year frequency	More than once a year	4	4	
Sinuosity of the stream channel	R	Low	Moderately low	Intermediate	Mod. high	High			This characteristic is omitted, since there is no defined channel.
Representation of different hydrological zones	R	Permanent & seasonal zones lacking (i.e. only the temporary zone present)	Seasonal zone present but permanent zone absent	Permanent & seasonal zones both present but collectively <30%	Seasonal & permanent zone both present & collectively 30-60%	Seasonal & permanent zone both present & collectively >60% of total HGM unit area	1	3	
Link to the stream network	R	No link (i.e. hydrologically isolated)				Linked to the stream system	4	4	

Presence of fibrous peat or unconsolidated sediments below a floating marsh	R	Absent	Present but limited in extent/depth		Moderately abundant	Extensive and relatively deep (>1.5 m)	0	4	
Reduction in evapotranspiration through frosting back of the wetland vegetation	R	Low	Moderately low	Intermedi ate	Moderately high	High	2	2	The wetland is at a relatively high altitude and frosts do occur in winter, but not extensive die-back of vegetation
HGM unit occurs on underlying geology with strong surface-groundwater linkages	O	No		Underlyin g geology quartzite	Underlying geology sanstone	Underlying geology dolomite	3	2	
Direct evidence of sediment deposition in the HGM unit		Low	Mod low	Intermedi ate	Mod high	High	1	2	
Flow patterns of low flows within the wetland	R	Strongly channelled	Moderately channelled	Intermedi ate	Moderately diffuse	Very diffuse	4	3	Comparatively small area above road crossing where flow channelled due to erosion gully
Extent of vegetation cover in the HGM unit	R	Low	Mod low	Intermedi ate	Mod high	High	2	3	
Contribution of sub-surface water inputs relative to surface water inputs	R	Low (<10%)	Moderately low (10-20%)	Intermedi ate (20-35%)	Moderately high (36-50%)	High (>50%)	2	2	Several seeps are present, especially in the lower portion of the wetland.
Application of fertilizers/biocides in the HGM unit		High	Mod high	Intermedi ate	Mod low	Low	4	4	No fertilizers/biocides.
Direct evidence of erosion	R	High	Mod high	Intermedi ate	Mod low	Low	4	3	A small erosion gully is present in the wetland, but this is no longer active
Current level of physical disturbance of the soil in the HGM unit	R	High	Mod high	Intermedi ate	Mod low	Low	3	2	Little current agriculture, but some historical disturbance. Grazing by livestock.

Erodibility of the soil in the HGM unit	O	Low	Mod low	Intermedi ate	Mod high	High	2	3	Catchment soils of medium erodibility (Midgeley *et al.*, 1994, Surface Water Resources of South Africa. Vol III. WRC No. 293/3.2/94). HGM unit likely to be similar.
Abundance of peat		Absent	Present but limited in extent/depth	Intermedi ate	Moderately abundant	Extensive and relatively deep (>0.5 m)	0	4	
HGM unit is of a rare type or is of a wetland type or vegetation type subjected to a high level of cumulative loss	O	No				Yes	4	4	Wetland is not a rare type but there is serious cumulative loss of wetlands in the area.
Red Data species or suitable habitat for Red Data species	R	No				Yes	4	3	Some Red data sp of plants and insects found in wetlands in the area. Helme and Desmet (2007)consider Ramkamp to be very important to conserve.
Level of significance of other special natural features	R	None	Mod low	Inter-mediate	Mod high	High	1	3	
Alteration of hydrological regime	R	High	Mod high	Inter-mediate	Mod low	Low/negligible	3	3	See WET-Health assessment.
Complete removal of indigenous vegetation	R	>50%	25-50%	5-25%	1-5%	<1%	3	3	Very few areas with complete removal of vegetation. Road, stock watering ponds.
Invasive and pioneers species encroachment		>50%	25-50%	5-25%	1-5%	<1%	3	3	Renosterbos is likely to be increasing in abundance.
Presence of hazardous/restrictive barriers	R	High	Mod high	Intermedi ate	Mod low	Low/negligible	3	4	Leliefontein-Garies road presents a barrier to movement of fauna. However, not a very busy road.
Current level of use of water for agriculture or industry		No use	Mod low	Intermedi ate	Mod high	High	1	3	At least two stock-watering ponds in wetland.
Current level of use of water for domestic		No use	Mod low	Intermedi	Mod high	High	0	4	No dwellings in catchment.

purposes				ate					
Number of dependent households that depend on the direct provision of water from the wetland		None	1-2	3-4	5-6	>6	0	4	
Substitutability of the water resource from the HGM unit		High	Mod high	Intermedi ate	Mod low	Low	1	4	Although not used for domestic consumption, stock farming is important activity.
Number of different resources used		None	1		2-3	>3	2	4	Water for stock and grazing.
Is the wetland in a rural communal area? (	O	No				yes	4	4	
Level of poverty in the area	O	Low/ negligible	Mod low	Intermedi ate	Mod high	High	3	4	
Number of households who depend on the natural resources in the HGM unit		None	1	2-3	4-5	>6	4	4	Approximately 20 households. The rams are kept separately from rest of stock in the Ramkamp. If they were put with rest of herd there would be stock loss (I Samuels, 2007, pers. comm., U. W. C., Cape Town).
Substitutability of the natural resources obtained from the wetland		High	Mod high	Intermedi ate	Mod low	Low	3	4	Arid area, thus good grazing is limited.
Total number of different crops cultivated in the HGM unit		None	1		2-3	>3	0	4	
Number of households who depend on the crops cultivated in the HGM unit		None	1	2-3	4-6	>6	0	4	
Substitutability of the crops cultivated in the wetland		High	Mod high	Intermedi ate	Mod low	Low	0	4	
Registered SAHRA site	O	No				Yes	0	4	

Known local cultural practices in the HGM unit		None	Historically present but no longer practised		Present but practised to a limited extent	Present & still actively & widely practised	3	4	Ram husbandry (now only carried out by the older generation).
Known local taboos or beliefs relating to the HGM unit		None	Historically present but no longer so		Present but held to a limited extent	Present & still actively & widely held	3	4	Snakes associated with wetland areas in Kamiesberg.
Scenic beauty of the HGM unit		Low/negligib le	Mod low	Intermedi ate	Mod high	High	3	4	
Presence of charismatic species	R	None present	Very seldom seen	Occasion ally present	Generally present	Always present	0	2	Rare species (plants and insects) have been found in the general area. Possibility that some may be found in these wetlands.
Current use for tourism or recreation		No use	Mod low use	Intermedi ate use	Mod high use	High	1	4	Very limited visits in spring during flower season.
4. Availability of other natural areas providing similar experiences to the HGM unit	R	High	Mod high	Intermedi ate	Mod low	Low	2	4	
Location within an existing tourism route	O	Low/negligib le	Mod low	Intermedi ate	Mod high	High	1	4	
Recreational hunting and fishing and birding opportunities		None	Mod low	Intermedi ate	Mod high	High	2	3	
Extent of open water	R	None	Present, but very limited		Extent somewhat limited	Extensive	0	4	
Current use for education/research purposes	R	No use	Mod low	Intermedi ate	Mod high	High	2	4	Several research projects being conducted in area.
Reference site suitability		Low	Mod low	Intermedi ate	Mod high	High	3	4	Good environmental health condition. See WET-Health assessment.
Existing data & research	R	None	Mod low	Intermedi ate detail/ time period	Mod high	Comp-rehensive data over long period	1	3	

Accessibility	R	Very inaccessible	Moderately inaccessible	Intermediate	Moderately accessible	Very accessible	2	4	Communal land so permission required. Also fairly remote.
DOWNSTREAM OF HGM UNIT									
Extent of floodable property	R	Low/ negligible	Moderately low		Moderately high	High	0	4	
Presence of any important wetlands or aquatic systems downstream	R	None		Intermediate import-ance		High importance	2	4	The Kamiesberg is important for supplying water to towns on the lowland area e.g. Garies.
LANDSCAPE									
Extent of buffer around wetland	R	Low	Mod low	Intermediate	Mod high	High	1	3	Upper part (Baileysvlakte) not buffered
Connectivity of wetland in landscape	R	Low	Mod low	Intermediate	Mod high	High	3	3	
Level of cumulative loss of wetlands in overall catchment	O	Low	Mod low	Intermediate	Mod high	High	3	4	See report by Helme and Desmet, 2007 "A description of the endemic flora and vegetation of Kamiesberg uplands, Namaqualand, S.A."
THREATS & OPPORTUNITIES									
Level of threat to existing ecosystem services supplied by the wetland		Low	Moderately low	Intermediate	Moderately high	High	0	4	Fairly low. The erosion gully is stable and no threat of urban expansion. Community is aware of carrying capacity of the wetland (but poor regulation of equitable access to resource – see WET-SustainableUse assessment).
Level of future opportunities for enhancing the supply of ecosystem services		Low	Moderately low	Intermediate	Moderately high	High	2	3	