WETLAND PRESERVATION VALUATION, AND MANAGEMENT PRACTICES APPLIED TO WETLANDS; SOUTH AFRICAN CASE STUDIES.

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REPORT TO THE WATER RESEARCH COMMISSION

WETLAND PRESERVATION VALUATION, AND MANAGEMENT PRACTICES APPLIED TO WETLANDS: SOUTH AFRICAN CASE STUDIES

by

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PREFACE

This document is one of a series arising from a project designed to improve the management of wetlands in KwaZulu/Natal. The project includes the following documents:

WRC REPORT NO. 501/1/94 EXECUTIVE SUMMARY:

KOTZE D C, BREEN C M, and KLUG J R, 1994. A project to improve the management of wetlands in the KwaZulu/Natal Midlands: an overview.

WRC REPORT NO. 501/2/94:

KOTZE D C, BREEN C M, and KLUG J R, 1994. WETLAND-USE: a wetland management decision support system for the KwaZulu/Natal Midlands.

WRC REPORT NO. 501/3/94:

KOTZE D C, and BREEN C M, 1994. Agricultural land-use impacts on wetlands functional values.

WRC REPORT NO. 501/4/94:

KOTZE D C, HUGHES J C, BREEN C M, and KLUG J R, 1994. The development of a wetland soils classification system for KwaZulu/Natal.

WRC REPORT NO. 501/5/94:

OELLERMANN R G, DARROCH M A G, KLUG J R, and KOTZE D C, 1994. Wetland preservation valuation, and management practices applied to wetlands: South African case studies.

KOTZE D C, BREEN C M, and KLUG J R, 1994. A management plan for Wakkerstroom vlei.

KOTZE D C, BREEN C M, and KLUG J R, 1994. A management plan for Ntabamhlope vlei.

KOTZE D C, BREEN C M, and KLUG J R, 1994. A management plan for Mgeni vlei.

KOTZE D C, 1994. A management plan for Blood River vlei.

KOTZE D C, 1994. A management plan for Boschoffsvlei.

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STUDY 1

VALUING PREFERENCES FOR WETLAND PRESERVATION: A WAKKERSTROOM CASE STUDY

1.1 Abstract

Wetland loss rates remain high as the full value of wetland services is understated. This is partly due to the benefits of wetland preservation (non-use) being unpriced, as they are not traded in markets. These benefits are reflected by option, existence and bequest demands for wetland preservation. The Contingent Valuation Method (CVM) was used to estimate the value of non-market wetland preservation benefits, by asking members of the Wakkerstroom Natural Heritage Association (WNHA) to state their willingness-to-pay (WTP) to preserve the Wakkerstroom wetland. For option value, the median WTP class ranged from R17.51 - R20.00 month^{-1}, whilst existence and bequest values had the same median WTP class which ranged from R15.01 - R17.50 month^{-1}. Well designed CVM studies can help to make the public, policy-makers and individual farmers more aware of the benefits of wetland preservation, leading to more informed decisions being made about wetland use.

Additional keywords: bequest value; contingent valuation method; existence value, option value

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1.2 Introduction

Wetland ecosystems account for about 6% of the global land area (Turner 1991a), and can be defined as:

> *"those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life*

in saturated soil conditions" (United States of America Environmental Protection Agency (EPA) cited by Begg 1990).

Wetland ecosystems perform vital ecological and hydrological functions (such as the provision of habitat for many bird and animal species and the purification and storage of water). Despite this, wetland loss rates continue to be high in both developed and developing nations (Turner 1991a). Wetlands on a global scale are now considered to be amongst the most threatened of all environmental resources (Williams 1990; Turner 1991b). In Natal, for example, it is conservatively estimated that over 50% of the wetland resource base has been altered or lost over the last 100 years (Begg 1990).

Reasons for wetland loss include conversion to intensive agriculture, aquaculture or industrial use ('natural' resource -use conflict), a lack of awareness and appreciation of their full value, and other factors such as pollution and recreation pressure (Turner 1988; Turner 1991a). Wetland loss rates could be reduced by informing the public, policy-makers and farmers about the value (benefits) of wetland preservation.

Wetland resources can benefit individuals via the utility or satisfaction gained from direct wetland use (e.g. bird-watching), and the utility gained from wetland preservation (non-use). The values which individuals associate with wetland preservation can be reflected by option, existence and bequest values. Option value is the amount that individuals are willing to pay for the option to visit the wetland in the future (Walsh *et al.* 1984). Option value is thus like an insurance premium to ensure the supply of the wetland when the individual decides to exercise the choice of using it. Existence value refers to the willingness-to-pay (WTP) for the continued existence of the wetland, even though no direct use of the wetland by individuals is contemplated (Young 1991). Finally, bequest value is what individuals are willing to pay for the assurance that the wetland will be preserved for future generations (Pearce & Turner 1990). Unfortunately, these non-use benefits of wetland resources are **not traded** in markets and therefore remain **unpriced**, making it extremely difficult to estimate their values (Brookshire *et al.* 1983; Stoll & Johnson 1984; Young 1991).

This report uses an approach to valuing people's preferences for non-marketed goods, namely the Contingent Valuation Method (CVM) (Mitchell & Carson 1989; Adamowicz 1991), to estimate wetland non-use values, using the Wakkerstroom wetland as a case study. Information like this for other wetlands can make the public, policy-makers and individual farmers more aware of the benefits of wetland preservation, leading to more informed decisions being made about wetland use.

The report consists of four sections. Firstly, it explains the concept of economic valuation on which the CVM is based. Secondly, it outlines the CVM, describes the study area and highlights the biases which can arise when compiling CVM questionnaires. Thirdly, CVM estimates of option, existence and bequest values for the Wakkerstroom wetland are presented. Finally, the implications of the study for future wetland and other environmental resource use decisions in South Africa are considered.

1.3 The concept of economic valuation

Economic valuation in the wetland preservation context entails measuring people's preferences for or against changing the state of the wetland. Valuation is therefore of preferences held by individuals (Pearce 1993). These preferences are reflected by what individuals are willing to pay for the benefits of wetland preservation (non-use). Such benefits relate to the satisfaction which individuals derive from having the option to guarantee their future access to the wetland (option value), knowing that the wetland will be preserved even if no use is intended (existence value) and knowing that future generations will have access to the wetland (bequest value).

WTP for wetland preservation will probably be constrained by annual income levels. Past knowledge and recreational use of wetlands and the availability of substitute environmental amenities may also affect WTP (Walsh *et al.* 1984; Boyle & Bishop 1987; Whitehead 1990). The possible association of WTP for the preservation of the Wakkerstroom wetland with these socio-economic variables was considered in the CVM questionnaire which is described in the next section.

1.4 The contingent valuation method

1.4.1 Outline

The CVM uses survey data which are usually collected by means of a carefully constructed questionnaire. This typically contains questions about the socio-economic characteristics of the survey respondent, followed by the construction of a hypothetical market that describes the proposed policy that will affect the wetland resource. After the hypothetical market has been established, direct valuation questions are presented to survey respondents to elicit WTP bids for wetland preservation (option, existence and bequest values) (Whitehead 1990). The questionnaire design is discussed after the study area description given in the next section.

1.4.2 Study area

The Wakkerstroom wetland (27° 21'S; 30° 08'E) is situated in the uppermost reaches of the Tugela catchment, west of the village of Wakkerstroom. Wakkerstroom is a small town in the south-eastern Transvaal, easily accessible via Volksrust, Piet Retief and Newcastle (or Utrecht) (Begg 1989). The wetland and its immediate surroundings (650 ha in total) are managed by the Wakkerstroom Natural Heritage Association (WNHA). The WNHA has a very diverse membership base, from farmers to academics, living throughout South Africa. Time and research fund constraints limited the study area to the Wakkerstroom wetland and the study population to the WNHA. However, as the wetland is the hub of WNHA activities, this area is suitable for a study designed to estimate people's preferences for wetland preservation.

1.4.3 The questionnaire

Considerable care is required in constructing a questionnaire and in eliciting responses from individuals sampled (Young 1991). Procedures for mail surveys developed by Dillman (1978) and Filion (1978) were closely followed. The questionnaire was pre-tested and designed for clarity and ease of answering. The legitimate scientific purpose of the survey was established by a covering letter with the University of Natal letterhead, which explained the usefulness and importance of the study. Participants were also assured of their anonymity in the survey and reminded that participation was voluntary.

The questionnaire was divided into two main sections. The first section collected information on the socio-economic characteristics of the respondents (e.g. household annual income levels, educational qualifications, age and gender). The second section dealt with eliciting WTP bids from respondents, and was designed using criteria specified by Randall *et al.* (1974) and Bohm (1972) (both cited by Thayer (1981)). The ecological and hydrological services provided by wetlands were first explained to the respondents, after which a contingent market situation was described in detail to ensure uniform perception. This situation was realistic and credible, pointing out that increased demands on the study area's water resources, due to industrial development and population growth, could lead to the flooding of the Wakkerstroom wetland if the capacity of the Zaaihoek dam (situated directly below the Wakkerstroom wetland) was increased. The scenario also indicated the potential wetland functional losses that could be caused by flooding, and stressed that government funding to protect the wetland would probably not be available. Each respondent was then asked to make a market-like decision by stating his/her WTP into a 'special fund' (for each of option, existence and bequest value) to prevent the wetland from being flooded.

Questions to elicit these bids had to be phrased to limit possible strategic, design and mental account bias (Pearce & Turner 1990; Hanley & Spash 1993). Strategic bias occurs when respondents understate their option value WTP if they believe that those who do not pay will still have future use of the preserved wetland (the free-rider problem). Alternatively, if respondents believe that their bids are purely hypothetical, they may overstate WTP for wetland preservation, to increase the probability of preservation. These problems were reduced by stating specifically that only those who paid would have the option to visit the wetland in future, and by describing the credible flooding scenario. The option value bid question, assuming the above scenario, was presented as follows:

> "Would you be willing to pay a certain amount each month into a special fund to secure your own **option** to visit this wetland in the future? *This fund would be used to protect the wetland, and only those individuals who contribute to the fund would have the option of visiting the wetland."*

Design bias can affect responses through the choice of bid 'vehicle' and/or by the bid starting point given to respondents (Thayer 1981; Drake 1992). The bid vehicle used in all three cases was a special fund, because this relatively neutral mechanism avoids the emotional reactions or protests associated with other mechanisms such as entrance fees or sales taxes (Walsh *et al.* 1984). Individuals may resent paying by such direct methods for something 'natural'; the payment debases the recreational experience (Hanley & Spash 1993). In addition, informal talks with a WNHA member indicated that a special fund would be the most likely method to be used in practice.

The bid starting point given to respondents can influence the final bid by suggesting what size of bid is appropriate. Following Mitchell & Carson (1989), this was avoided by dividing potential WTP bids for each non-use value into small classes which began from a very low starting point. In all, there were twenty-one R2.50 month^{-1} interval classes, with the first class ranging from R0.01 to R2.50 month^{-1} and the last class being an 'open ended' class of R50.01 or more month^{-1}. A starting point of as little as R0.01 was less likely to influence the final bid than a very high starting point.

Mental account bias refers to an individual bidding his/her total 'preservation' budget on one environmental good (like a wetland), even though he/she may care about preserving other environmental goods (such as forest sites), thus overstating true WTP. This possibility was limited by asking respondents to check that their bids for each of the three non-use values were affordable, given their annual household income levels.

The contingent valuation questions used to collect estimates of existence and bequest values, given the above design considerations and contingent scenario, were as follows:

- "Would you be willing to pay a certain amount each month into a special fund to be used exclusively to ensure the continued <u>existence</u> of Wakkerstroom wetland. *This value is what you would be prepared to pay to know that the wetland will be preserved, even though you and future generations will never visit it;*" and

"Would you be willing to pay a certain amount each month into a special fund which will ensure that <u>future</u> generations have the opportunity to visit Wakkerstroom wetland?"

1.5 Results and discussion

A total of 69 questionnaires (57%) were returned, of which 66 (54%) were useable. This compares favourably with similar overseas CVM mail studies by Whitehead (1990), Stoll & Johnson (1984) and Walsh *et al.* (1984) which had response rates of 31%, 36% and 41% respectively.

1.5.1 Socio-economic characteristics of respondents

Median household annual income before tax (husband and wife where appropriate) was in the R80 000 - R90 000 range, whilst the majority of sample respondents (78.4%) had tertiary education (either non-degree or a bachelor's degree and/or a post-graduate degree). The median age of survey respondents was in the 48 - 53 years old class, the average household comprised 2.7 persons (standard deviation (SD) = 1.4 persons) and 84.8% of respondents also belonged to other environmental organizations. On average, respondents planned to spend 0.8 days (SD = 0.6 days) per visit to Wakkerstroom participating in the forest walk, 0.7 days (SD = 0.6 days) viewing the bald ibis colony and 1.6 days (SD = 0.9 days) visiting the wetland.

1.5.2 Option, existence and bequest value estimates

Table 1.1 shows the distribution of WTP bids for option, existence and bequest values respectively. Figure 1.1 graphs the distribution of positive (yes) WTP bids for each of the three non-use values.

INSERT TABLE 1.1

INSERT FIGURE 1.1

As shown in Table 1.1, 20 respondents were not willing to pay for option value and 2 respondents gave no option bid at all (i.e. missing values). The 44 respondents who were willing to pay indicated monthly bids that ranged from the R2.51 - R5.00 class to the R50.01 or more class. The R7.51 - R10.00 class had the highest frequency (9 bids). Unfortunately the mean WTP bid could not be calculated for any of the three non-use values, because the bids were divided into classes and the last class, R50.01 or more, was an 'open ended' class. However, the median class could be calculated and was the R17.51 - R20.00 category. With reference to Figure 1.1, there seems to be no evidence of strategic bias in the WTP distribution. The distribution does not flatten between the high and low bids, as there are a considerable number of bids in the middle range classes.

Table 1.1 further shows that 14 respondents were not willing to pay for existence value and 5 respondents indicated no existence bid at all (i.e. missing values). Of the 47 respondents willing to pay, monthly bids ranged from the R2.51 -R5.00 class to the R50.01 or more class. As for option value, the R7.51 - R10.00 class had the highest frequency (9 bids). The median class was the R15.01 - R17.50 category. Given the distribution of existence WTP bids in Figure 1.1, strategic bias again does not seem to be present.

Table 1.1 also identifies 11 respondents as not willing to pay for bequest value and 6 respondents giving no bequest bid at all (i.e. missing values). The 49 respondents willing to pay stated monthly bids ranging from the R0.01 - R2.50 class to the R50.01 or more class. As for option and existence values, the R7.51 - R10.00 class had the highest frequency (9 bids). The median class was the same as for existence value, namely R15.01 - R17.50. Evidence from Figure 1.1 again suggests no strategic bias in the WTP distribution.

The distributions of WTP bids for the three non-use values were similar. In each case the R7.51 - R10.00 class had the highest frequency, and there seemed to be no strategic bias. Existence and bequest values had the same median class, which was slightly lower than the option value median class. The number of non-WTP bids declined from 20 for option value to 14 for existence value and 11 for bequest value. This may be attributed to the age profile of survey respondents, with the median age class being relatively high (48 - 53 years old). Older respondents could have been more concerned about preserving the wetland for use by their descendants rather than for their own future use.

Finally, relating the above WTP bid values to the socio-economic data revealed some statistically significant correlation results. The WTP for option value was positively correlated with (increased with) the household's annual income, the correlation coefficient of 0.20 being statistically significant at the 15% level. The positive relationship with income was expected, as the ability to consume market and non-market goods is subject to an income constraint. Existence value was negatively correlated with household size, with a correlation coefficient of -0.26 which was statistically significant at the 5% level. Larger household's may, *ceteris paribus*, have less funds available to allocate to environmental goods after meeting family expenses. Finally, bequest value had a statistically significant positive relationship with the household's annual income, but was negatively related to household size (the correlation coefficients of 0.21 and -0.21 respectively, were both significant at the 10% level). While all three non-use values were, as expected, positively correlated with age (proxy for past knowledge and use of the wetland) but negatively correlated with membership of other environmental organizations (substitute for wetland use), none of the correlation coefficients were statistically significant at accepted levels.

1.6 Conclusions

Individuals gain satisfaction from both direct use and non-use or preservation of wetland resources. Preservation benefits - reflected by option, existence and bequest values - are not traded in markets and therefore remain unpriced, making it extremely difficult to value them. However, credible hypothetical or contingent markets can be devised for unpriced goods, like preservation benefits, and used in surveys to elicit monetary values which reflect people's preferences for wetland preservation.

Results of this study show that most survey respondents were willing to pay to preserve the Wakkerstroom wetland (they expressed positive preservation benefit values). For option value, the median WTP class ranged from R17.51 - R20.00 $month^{-1}$, whilst existence and bequest values had the same median WTP class which ranged from R15.01 - R17.50 $month^{-1}$. The hypothetical CVM scenario about the potential flooding of the Wakkerstroom wetland thus appeared to be realistic. The WTP bids may be upwardly biased, as time and research fund constraints limited the survey group to WNHA members - they are more likely to favour wetland preservation than non-members. This bias could, however, be less than expected, as between 17% and 30% of WNHA members gave zero WTP bids for the three types of preservation benefits.

The WTP for option and bequest values was positively correlated with the household's annual income, reflecting income constraints. Household size was negatively associated with the WTP for existence and bequest values. Future local research on wetland preservation values could investigate the statistical functional forms underlying such relationships.

Given that the potential biases associated with using the CVM were accounted for in research design as far as possible, the preservation value estimates are plausible. It is recommended that the public, policy-makers and individual farmers be made more aware of preservation values associated with other wetlands, so that they can make more informed decisions about wetland use. Without such information, the value of wetland resources will be understated and wetland loss rates are likely to increase. Although this study focused on wetland preservation, the CVM principles can be used for the economic valuation of other environmental resources in South Africa. Future studies would be incomplete without some reference to the value of people's preferences for or against environmental change.

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Table 1.1 Distribution of willingness-to-pay bids for option, existence and bequest values, Wakkerstroom wetland, 1992/3

Value categories (Rands month^{-1})	Option value No.	Existence value No.	Bequest value No.
Not willing to pay	20	14	11
Willing to pay:			
0.01 - 2.50	0	0	1
2.51 - 5.00	3	4	4
5.01 - 7.50	1	1	2
7.51 - 10.00	9	9	9
10.01 - 12.50	2	6	6
12.51 - 15.00	1	2	2
15.01 - 17.50	2	2	2
17.51 - 20.00	7	5	6
20.01 - 22.50	4	3	2
22.51 - 25.00	1	3	4
25.01 - 27.50	1	1	1
27.51 - 30.00	2	1	1
30.01 - 32.50	0	0	0
32.51 - 35.00	0	0	0
35.01 - 37.50	0	0	0
37.51 - 40.00	2	1	1
40.01 - 42.50	0	0	0
42.51 - 45.00	0	0	0
45.01 - 47.50	0	0	0
47.51 - 50.00	4	4	3
50.01 or more	5	5	5
	--	--	--
	44	47	49
No response (missing)	2	5	6
Total	66	66	66

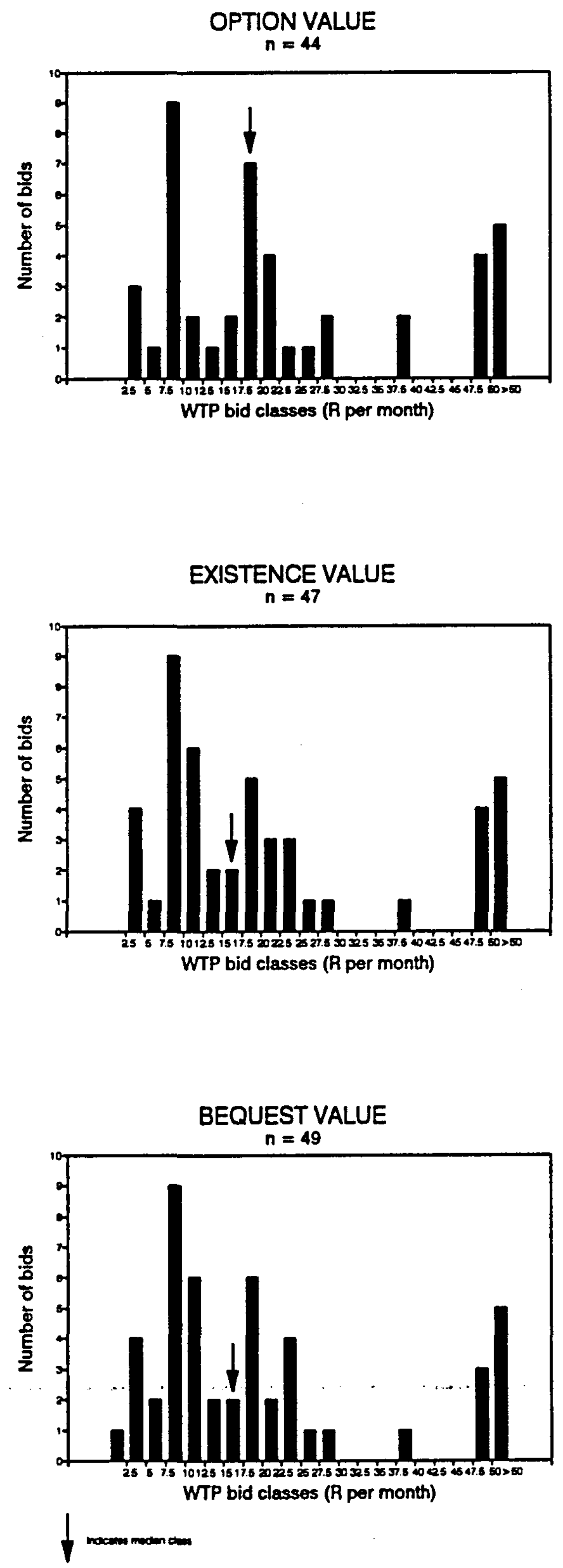

Figure 1.1 Distribution of positive willingness-to-pay bids for option, existence and bequest values, Wakkerstroom wetland, 1992/3.

STUDY 2

MANAGEMENT PRACTICES APPLIED TO NATURAL WETLANDS: SEVEN CASE STUDIES IN SOUTH AFRICA

2.1 Abstract

Many natural wetland resources have been altered and/or lost, as they have high agricultural potentials. Natural wetlands perform important ecological and hydrological functions, making it imperative that correct management practices be applied to them. Farmers in the Natal and Orange Free State provinces of South Africa were interviewed to assess the management practices they apply to privately owned wetlands. Farmers used their wetlands in particular during the nutritious spring period. The degree of wetness of wetland soils had an important effect on vegetation type, grazing capacity, incidence of diseases and management problems of wetlands. The wetlands also seemed to yield more forage than the surrounding veld, and produced similar or better quality forage compared with veld at the time of grazing. Most wetlands were burned annually in the late winter or early spring season. The key role of the wetlands in grazing systems was illustrated by the farmers not planning to lease their wetlands out. Management strategies applied to natural wetlands must take cognisance of (i) the ecological, hydrological and agricultural importance of wetlands, and (ii) the different agro-ecological zones found in individual wetlands, since these zones have different management needs.

Additional keywords: wetland management; grazing and burning practices

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2.2 Introduction

Wetland ecosystems account for about 6% of the global land area (Turner 1991), which is similar to the figure for the Natal province of South Africa (Scotney & Wilby 1983).

Wetlands can be defined as:

> *"those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions"* (United States of America Environmental Protection Agency (EPA) cited by Begg 1990).

Wetlands perform numerous vital ecological and hydrological functions, and may also be valuable agricultural resources, providing for example highly productive grazing-lands for domestic stock (Cooper *et al.* 1957; Richardson & Arndt 1989; Findlayson & Moser 1991). Despite this, wetland loss rates remain high due to conversion to intensive agriculture, aquaculture or industrial use (including waste disposal), or through a more gradual degradation process, caused by pollution, recreation pressure or increased grazing and fishing activities (Turner 1988). It is conservatively estimated, for example, that over 50% of Natal's wetland resource base has been altered or lost over the last 100 years (Begg 1990).

The smaller the benefits that are derived from a wetland used in its natural state, the greater will be the incentive for the owner or potential user to develop that area. More information is thus needed if potential users are to sustainably optimise the benefits they derive from natural wetlands. The aim of this study was to improve the information base concerning the management practices applied to wetlands by individual landowners (farmers).

The study focused on the contribution of wetland areas to overall farm fodder flows, as an aid in achieving the long-term goal of sustainable and optimal use of wetland habitats. Selected farmers in the Natal and Orange Free State (OFS) provinces of South Africa who use wetlands located on their farms, were surveyed. The information presented may reflect some bias as only those farmers who were willing to discuss their management practices were interviewed.

2.3 **Procedure**

2.3.1 Study area

To gain as wide a cross-section of management practices as possible, the study sites were distributed over a large area. Seven case study farms on the eastern seaboard of South Africa were selected for this study. As shown in Table 2.1, four of the study farms were located in Natal and three in the OFS.

INSERT TABLE 2.1

All seven study sites were located in the summer rainfall region of South Africa and the mean annual precipitation for all the sites ranged from 800 to 1 000mm. The percentage deviation from mean annual rainfall was 20 - 30% for sites 1 and 2, and less than 20% for all the other sites. The mean annual surface temperature was 15 - 17.5°C for sites 1, 2, 4 and 5, and 12.5 - 15°C for sites 6, 7 and 8 (Department of Water Affairs 1986).

2.3.2 The survey

The study sites were selected only after extensive consultation with a large number of people closely involved with management-related aspects of wetlands (e.g. local extension officers). All the selected farmers were first telephoned and the study and its purposes carefully explained to them. A meeting was then arranged and personal interviews conducted with the farmers, using the questionnaire outlined below.

2.3.3 The questionnaire

The questionnaire compiled information on farm and farmer characteristics, and the use and management of the wetland in question. The section on wetland use and management identified whether the particular wetland was in a natural or a developed state. For the developed wetlands, provision was made for pastures, crops, afforestation, dams and recreation uses.

This report deals with the results of the undeveloped (natural) wetlands only. The first question in this section dealt with wetland drainage, in order to determine whether or not the wetland had been modified in the past. The farmer was then asked to classify the wetland, in order to see how he sub-divided the wetland. This was followed by a question on the different agro-ecological zones making up the wetland, as classified by Kotze (1993b). A site visit was undertaken to determine the relative extent of these zones and to check for indications of erosional degradation. Livestock grazing management practices were then considered, and information gathered for both 'drought' and normal years. This showed whether or not farmers compensated for good and bad years and relied more heavily on their wetlands in dry years. 'Drought' years in this context were defined as abnormally low rainfall years, occurring approximately one in every five years.

Information was also obtained about other management-related activities, such as haymaking, burning and irrigation. Following these questions, farmers were asked how the quality of the wetland grazing compared with normal veld grazing, and whether additional licks or feeds were needed for the livestock when on the wetland. Thereafter, questions about wetland leasing activities were asked in order to obtain some idea of the value of the wetland area (if possible). Finally, the farmers were asked what they would do if the wetland was not available for use in a given season, so as to assess their perceived importance of the wetland to the overall farm fodder flow.

2.4 Results and discussion

All the wetlands were used for livestock grazing purposes. The wetlands at study sites 1, 2, 4, 5, 7 and 8 were grazed by beef livestock, whilst the wetlands at sites 1, 4 and 5 were also grazed by sheep. The wetlands at study sites 6 and 7 were grazed by dairy livestock, and the only wetland on which hay was made was the one at site 6. At all wetlands fire was used as a management tool.

2.4.1 Agro-ecological zones

The different agro-ecological zones that may be found in local natural wetlands are defined according to the degree of soil wetness, and were identified using soil morphology and vegetation criteria (Kotze 1993b) as illustrated in Figure 2.1.

INSERT FIGURE 2.1

These zones are defined as follows:

(i) wet grassland zone (G) - is temporarily wet and supports a mixture of short ($<$ 1 metre high) hydrophytic plants (restricted to temporarily and seasonally wet areas) and species which are also common to non-wetland areas;

(ii) wet meadow zone (W) - is usually seasonally wet and dominated by short (usually $<$ 1.5 metre high) hydrophytic sedges and grasses restricted to temporarily or seasonally wet areas;

(iii) marsh zone (M) - is usually permanently or semi-permanently wet and dominated by tall (usually $>$ 1 metre high) emergent herbaceous vegetation such as reeds (*Phragmites australis*); and

(iv) open water zone (O) - comprises permanently or semi-permanently flooded areas characterized by the absence (or low abundance) of emergent plants (Kotze 1993b).

2.4.2 Wetlands used for grazing

Tables 2.2 and 2.3 summarize management practices for the grazing of the wetlands by beef, and sheep and dairy livestock respectively. Unless specifically stated in the Tables, all the farmers indicated that they did **not** have **preconceived formal** management strategies for 'drought' and normal years, but rather treated each season on its merits (i.e. they practiced flexible, adaptive management).

INSERT TABLE 2.2

INSERT TABLE 2.3

Note that the information provided about the three livestock enterprises for **each** study site always refers to the same wetland (i.e. the same wetland was used by one livestock enterprise for certain times of the year and by another livestock enterprise for other times of the year). For example, the wetland at study site 4 was used by sheep in winter and by cattle (beef) in spring and summer. This holds true for all study sites **except** for **study site 7**, where the dairy animals used a different wetland to the beef animals.

Only two farmers grazed dairy animals and three farmers sheep on their wetlands, and comparisons were thus limited. Although the time of use varied from site to site, most sites were used in the spring and early summer periods. According to Kotze (1993a), the effect of grazing on the ecological value of wetlands depends on numerous factors (e.g. the intensity and timing of grazing, the type of animal, and whether or not the wetland developed under the influence of natural grazers). Generally, however, the ecological value of wetlands is enhanced by lenient grazing, which results in a mosaic of tall and short vegetation which, in turn, gives rise to a greater variety of habitats. However, these benefits may be lost if the level of use is high relative to plant production, particularly if the wetland developed under low grazing pressure. From the results of this study no firm conclusions regarding the effects of grazing on the ecological value of the study wetlands could be drawn. More detailed investigations would need to be conducted, in order to make any firm conclusions.

Concerning the effect of grazing on the hydrological values of wetlands, Kotze (1993a) maintains that heavy grazing pressure has been shown to have numerous detrimental impacts on the hydrological state of wetlands (e.g. gully erosion, leading to wetland desiccation, or the silting up of pools). Whilst the impact of heavy grazing pressure is often fairly conspicuous, the effect of light or moderate grazing pressure is likely to be far less dramatic and would require detailed hydrological investigations. From an erosion control point of view, grazing is undesirable when wetland soils are saturated. Under saturated conditions, wetland soils are more susceptible to compaction and erosion, than when dry (Wilkins & Garwood 1985). However, because no obvious erosional degradation (e.g. gully erosion) was evident at any of the study wetlands, it seems that none of the farmers were mismanaging their wetlands from an erosion control point of view, even though some used their wetlands in summer when the soil was saturated. Their management practices could, however, have led to the loss of certain other ecological and hydrological values. For example, reduction in vegetation cover, due to grazing, may detract from the habitat value of certain animal species (e.g. the red-chested flufftail (*Sarothrura rufa*) prefers dense vegetation to open vegetation).

The time of grazing of the wetlands was often dependent on the overall livestock management system used by the farmer. All the farmers who grazed their wetlands with livestock in the spring period emphasized the great importance of this grazing period in their overall fodder flow. Traditionally, at this time of the year, forage reserves on the farm have usually dwindled to very low levels. Spring grazing does not generally seem to be detrimental to the wetlands' erosion control functions, as wetland soils are usually not yet saturated at this time.

The grazing capacity (GC) of the wetlands at the different study sites was ascertained by calculating the number of grazing days (GD's) (expressed as AU grazing days ha^{-1}). According to Edwards (1984a) this measure has little value in the absence of data on animal performance. Although no actual figures on animal performance were available from the study results, all surveyed farmers did indicate that their animals either gained or maintained weight whilst on the wetland. The GC of the various wetlands varied from area to area. In aggregate (i.e. summing the GD's calculated for different livestock enterprises at each site, where applicable), the highest GD's (site 6 - 549 AU grazing days ha^{-1} with dairy animals) were recorded in the Harrismith area. No stocking density (SD) data were available for the beef enterprise at site 7, thus the total GD's could not be calculated for this site. The next highest GD's were recorded in the Vrede area (site 8 - 287 AU grazing days ha^{-1} with beef animals), followed by the Mount Currie area (site 1 - 178 AU grazing days ha^{-1} with sheep and beef animals, and site 2 - 174 AU grazing days ha^{-1} with beef animals) and then the Utrecht/Vryheid area (site 5 - 166 AU grazing days ha^{-1} with sheep and beef animals, and site 4 - 165 AU grazing days ha^{-1} also with sheep and beef animals). Interestingly, the GD's totals were similar for the Mount Currie sites (1 and 2) as well as the Utrecht/Vryheid sites (4 and 5).

Many farmers stated that the wetlands were higher yielding relative to surrounding non-wetland veld areas. No data were available from farmers to verify this statement, but if the reported wetland GD's are compared with the potential grazing capacities of veld for the respective areas (as recommended by Edwards in 1984b), the wetlands are clearly stocked far more heavily than the recommended norms for the non-wetland veld areas. For example, the potential grazing capacity of veld in the Utrecht/Vryheid area is 0.4 AU ha^{-1} (Edwards 1984b). Expressed as GD's (assuming that the veld is useable for a period of 180 days $annum^{-1}$), this equates to 72 AU grazing days ha^{-1}. In comparison, the GD's calculated for the study wetlands in this area, being used by sheep and beef animals, were 165 AU grazing days ha^{-1} (for site 4) and 166 AU grazing days ha^{-1} (for site 5) in aggregate. These results must be interpreted with care, however, as there are conceptual problems with the above example (e.g. the length of the useable veld grazing period may vary from year to year, veld condition may vary considerably from the potential grazing capacity of veld for the area, and the farmer may be overgrazing his wetland). The wetland areas could be higher yielding than the surrounding veld areas for the reason that they provide conditions conducive to good vegetation growth, being less moisture limited and often more fertile by nature (e.g. higher base status) than surrounding veld areas (Scotney & Wilby 1983).

Since the different agro-ecological zones at the various study sites were not camped off separately, it is not possible to comment on their relative value. However, based on comments made by the farmers, the marsh areas provided valuable grazing for less extended periods than the wet grassland and wet meadow zones. Wetland sites that consisted of pure or partial wet grassland zones could be grazed during all four seasons of the year. In contrast, wetland sites that comprised predominantly marsh zones were grazed only in spring. This is probably due to the relatively unpalatable nature of most mature marsh plants and the excessive wetness and softness of the soil in certain marshes, which prevents access. The high proportion of indigestible structural material is usually the most important factor rendering marsh plants unpalatable. The cell wall component of *Typha domingensis*, for example, has been shown to comprise over 70% of the dry weight of the plant (Howard-Williams & Thompson 1985). However, young growth of certain marsh species, such as *Phragmites australis*, provide good forage species for domestic stock. In its young stages it has a high crude protein - fibre ratio (23% : 31%) and no known secondary compounds (Duncan & d'Herbes 1982).

The 'wetness limitation' explained above also influenced the incidence of diseases on the wetlands. In most cases, the wet grassland-zoned wetlands had a zero or very low incidence of disease, compared with the marsh-zoned and 'combination-zoned' wetlands. This 'wetness factor' was also associated with management problems on the wetlands, as farmers with the relatively wetter wetlands experienced occasional stock losses due to animals getting bogged down in the wet soil or eating wild tulips (*Moraea* and *Homeria* spp.).

Most farmers agreed that the quality of the wetland forage at the time of grazing was as, or more nutritious than the non-wetland veld. No data are available to verify this finding, but a possible reason for this could be the higher soil fertility often associated with wetland soils due to increased base status (Scotney & Wilby 1983). Although the quality of the wetland forage compared favourably with veld, licks were still fed whilst the animals were on the wetland. These licks were not bought specifically to counteract wetland nutritional deficiencies however, but were routinely fed throughout the year as part of the feeding regime. In most instances, a phosphate supplement was fed in spring and summer and a protein supplement in autumn and winter.

The main reason for not using the wetlands in a <u>normal</u> year was that they were too wet. One of the Harrismith farmers blamed silt accumulation on the grass for non-use. Farmers faced with no wetland grazing would either manipulate (e.g. store, rather than sell grain grown on the farm, and feed it to the animals later) or destock their farming systems. Many of the farmers attached such great importance to their wetlands, that they believed they would not be able to continue farming without their wetlands.

2.4.3 Wetlands used for making hay

Only the site 6 wetland (Harrismith area), consisting of a wet grassland and wet meadow zone, was used for haymaking purposes. Hay was cut during January and/or February with the yield varying between 4 and 6 t DM ha^{-1}. All the hay made on the wetland was fed back on the farm in winter. The farmer rated the quality of the wetland hay as better than non-wetland veld hay, because it contained many nutritious sedges. Other farmers probably did not make hay on their wetlands because their livestock grazing systems did not make provision for this, or the wetland was too wet at the time of the year when hay is usually made.

2.4.4 Burning of wetlands

Table 2.4 provides information about various burning-related activities on the undeveloped wetlands.

INSERT TABLE 2.4

Farmers used fire mainly to remove standing plant litter, as this litter inhibits the production of the new season's growth. Wetlands were also burned to stimulate an 'early bite'. This reason applies especially to marsh areas which are characteristically dominated by tall emergent herbaceous vegetation (such as reeds) and accumulate large amounts of litter. Although not mentioned by any of the farmers, the fire risk posed by wetlands (especially in the dry winter and early spring seasons) may have been another reason why the wetlands were burned. Whilst most of the Natal wetlands were burned annually, the OFS wetlands were burned only periodically when the need arose. Farmers in all areas agreed that burning should take place early in the season (i.e. August or September). Fire was thus widely regarded as an important wetland management tool. According to Kotze (1993b), the late winter/early spring burn seems to have the least negative effects on wetland ecological and hydrological values, as few animal species are breeding at this time of the year and most plant species are still dormant. Thus, the farmers seemed to be burning at the recommended time of the year. However, where farmers were burning annually, this may have detracted from the ecological value of the wetlands, due to the resultant lack of unburnt refuge areas for wetland dependent animals.

2.4.5 Leasing of wetlands

All the farmers indicated that they had never leased their wetlands out, did not plan to lease them out and did not lease any wetland areas from their neighbours. It seems that the economic returns to the farmers were greater if they used their wetlands themselves (for grazing or haymaking for example), instead of leasing them out and having to then find alternative forage sources.

2.5 Conclusions and policy implications

A number of conclusions may be drawn from this study.

Surveyed farmers used their natural wetlands for livestock grazing purposes. The farmers did not have separate wetland management strategies for 'drought' and normal years, but rather treated each season on its merits by applying flexible, adaptive management. In a very dry year, they would graze the wetland for extended periods of time (longer periods than in normal years) because it was the only area on the farm with available forage. The natural wetlands also provided valuable grazing in the spring period, when forage reserves on the farm were very low. Natural wetlands thus formed a key component of farm fodder flows.

The classification system for natural wetlands, developed by Kotze (1993b), which classifies wetlands into different agro-ecological zones according to the degree of soil wetness, explained wetland management practices well. The degree of wetness affected the GC, incidence of diseases, management problems and time of use of the wetlands. Incorporating this system into existing agricultural extension programmes would provide farmers with key information to make more informed wetland management decisions.

Many farmers perceived that natural wetlands produced a greater quantity of forage, as well as forage of a similar or better quality, compared with veld, at the time of grazing. A comparison of wetland grazing days and potential veld grazing capacity for the Utrecht/Vryheid area showed that wetland areas were higher yielding. Possible reasons for this could be the higher soil fertility (e.g. higher base status) and better growing conditions (e.g. less moisture limitations) of the case study wetlands.

The late winter/early spring burn used by farmers seemed to be an effective management practice, as it had the least negative effects on wetland ecological and hydrological values. Surveyed farmers were thus burning at the recommended time of the year. However, the frequency of burns could be reduced, as Kotze (1993b) recommends that burning should occur approximately bi-annually for humid areas (e.g. the Natal study wetlands) and probably even less frequently for drier areas (e.g. the OFS study wetlands).

All the farmers indicated that they had never leased their wetlands out, did not plan to lease them out and did not lease any wetland areas from their neighbours. Farmers thus perceived greater economic returns from using their natural wetlands themselves, rather than leasing them out and having to then find alternative forage sources.

The results of this study apply only to selected cases and do not **necessarily** reflect correct wetland management practices. However, a lack of obvious erosional degradation (e.g. gully erosion) at any of the study wetlands implies that none of the farmers seemed to be mismanaging their wetlands. The effect of the farmers' wetland management practices on the numerous other hydrological and ecological values can, however, only be established by further detailed investigations (e.g. veld condition assessments, hydrological investigations *etc*).

These findings have resulted in the following key policy implications being identified.

Any future policy decisions on wetland legislation should consider the high GC of many wetland areas, which can form an important component of farm fodder flows. Farmers thus need to be consulted on any decisions regarding future wetland use. Policy-makers need to initiate extension programmes stressing correct wetland management practices. As the country's population and therefore food requirements grow, increased pressure will be exerted on natural resources such as wetlands, necessitating well-trained extension staff, for example, to inform both the public and individual landowners (farmers) of the numerous benefits provided by wetlands, and of the wise and sustainable use of wetlands.

Although this study did not address management practices applied to wetlands in communal areas, policy-makers must take note of the potential conflict looming between increasing population pressures competing for productive natural resources, such as wetlands. Strategies will have to be devised whereby these resources are used on a sustainable basis whilst continuing to perform their important ecological and hydrological functions.

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Table 2.1 Details of the wetland areas selected for the study

Study site	Province	Magisterial district	Wetland
1	Natal	Mount Currie	Franklin vlei[a]
2	Natal	Mount Currie	Franklin vlei[a]
4	Natal	Utrecht	Blood River vlei[a]
5	Natal	Vryheid	Blood River vlei[a]
6	OFS	Harrismith	Private wetland
7	OFS	Harrismith	Private wetland
8	OFS	Vrede	Seekoeivlei

[a]The Natal study wetlands all occur on wetlands classified by Begg (1989) as having a priority for attention in terms of management and policy formulation needs.

Table 2.2 Management information about the grazing of undeveloped wetlands by beef livestock

MANAGEMENT INFORMATION	STUDY SITE					
	1	2	4	5	7	8
	Mount Currie	Mount Currie	Utrecht	Vryheid	Harrismith	Vrede
Wetland zone(s) used:[i]	G	M	G (30%) W (5%) M (65%)[a]	G (60%) W (10%) M (30%)[b]	G	G (60%) W (25%) M (15%)[c]
Number of wetland camps:	1	3	1	2	7	4
Grazing system on the wetland:	Continuously grazed the camp	Continuously grazed all the camps	Continuously grazed the camp	Rotationally grazed the camps	Rotationally grazed the camps (7-10 days IN per camp)	Rotationally grazed the camps
Animal class using wetland:	Weaners[d]	Cows and calves	Cows and calves	Cows and calves	Cows and calves	Cows in calf
Season when wetland used:	Summer	Spring	Spring/Summer	Spring/Summer	Spring/Summer/ Autumn	Autumn/Winter/ Spring
Time of year used:						
• Date in	1 January	15 September	20 October[f]	15 September	October	End April
• Date out	31 January	1 November[e]	1 April	1 February	May	End September[g]
Annual days of wetland use in normal years:[ii]	30	45	160	135	90[h]	150
Stocking density (AU ha^{-1}):[iii]	4.1	3.9	0.9	1.2	Information not supplied	1.9[i]
Grazing days (AU grazing days ha^{-1}):	123	174	143	157		287
Performance of animals when on the wetland:	Gained weight	Gained weight	Gained weight	Gained weight	Gained weight	Maintained weight
Quality of wetland forage <u>at the time of grazing</u>, compared with veld:	Similar to better (function of the season)	Better	Early season: better Late season: poorer	Similar	Similar	Information not supplied
Diseases specific to wetland:	None	Conical/liver fluke	None	Internal parasites	None	None
Control of diseases:	--------	Dosed animals	--------	Dosed animals	--------	--------

[i]Wetland agro-ecological zones: G - wet grassland zone; W - wet meadow zone; M - Marsh zone.

[ii]The figures supplied by the farmers about stock numbers and days spent in the wetland were only approximations, since they varied from season to season.

[iii]The stocking density (SD) was calculated using the animal unit (AU) equivalent tables in Meissner *et al.* (1983).

[a]The wetland formed a mosaic of wet grassland (approx. 30%), wet meadow (approx. 5%) and marsh (approx. 65%) areas, but was managed as one area with no camps (i.e. there was no division due to the different agro-ecological zones).

[b]The wetland formed a mosaic of wet grassland (approx. 60%), wet meadow (approx. 10%) and marsh (approx. 30%) areas, but was managed as one area which had been divided into 2 camps (<u>note</u>: these camps had not been divided according to the different agro-ecological zones).

[c]The wetland formed a mosaic of wet grassland (approx. 60%), wet meadow (approx. 25%) and *Cyperus fastigiatus* marsh (approx. 15%) areas, but was managed as one area which had been divided into 4 camps (<u>note</u>: these camps had not been divided according to the different agro-ecological zones).

[d]Although the farmer called these animals 'weaners', they should probably correctly be termed 'long-yearlings'.

[e]In a 'drought' year the animals stayed in the wetland for an extra 14 days (i.e. until 15 November).

[f]In a 'drought' year the animals were put into the wetland 30 days earlier (i.e. from 20 September).

[g]The 'date out' was a function of the season and could occur anytime between August and October, but usually occurred in September. In a very dry year, the animals could stay in the wetland until mid-January.

[h]The wetland camps were rotationally grazed with the surrounding veld for 240 days (i.e. from October to May), with the animals spending an effective 90 days (of the 240 days) on the wetland only.

[i]In very dry years the SD and GD's were reduced to 0.7 AU ha^{-1} and 167 AU grazing days ha^{-1} respectively.

Table 2.3 Management information about the grazing of undeveloped wetlands by sheep and dairy livestock

MANAGEMENT INFORMATION	SHEEP			DAIRY	
	STUDY SITE			STUDY SITE	
	1	4	5	6	7
	Mount Currie	Utrecht	Vryheid[g]	Harrismith	Harrismith
Wetland zone(s) used:[i]	G	G (30%) W (5%) M (65%)[a]	G (60%) W (10%) M (30%)[b]	W M[c]	G
Number of wetland camps:	1	1	2	7	6
Grazing system on the wetland:	Continuously grazed the camp	Continuously grazed the camp	Rotationally grazed the camps	Rotationally grazed the camps	Rotationally grazed the camps (3-4 days IN camp^{-1})
Animal class using wetland:	Ewes and lambs	Wethers	Ewes	Lactating cows	Lactating cows
Season when wetland used:	Spring	Winter	Spring/Summer	Spring / Autumn	Spring/Summer
Time of year used:					
• Date in	15 September	1 May	15 September	October[d] / April	September
• Date out	15 October	1 August	1 February	November / May	February
Annual days of wetland use in normal years:[ii]	30	90	135	120	90[e]
Stocking density (AU ha^{-1}):[iii]	1.8	0.2	0.1	4.6	1.2
Grazing days (AU grazing days ha^{-1}):	55	22	9	549	109
Performance of animals when on the wetland:	Gained weight	Maintained weight	Gained weight	Maintained weight (producing milk)	Maintained weight (producing milk)
Quality of wetland forage <u>at the time of grazing</u>, compared with veld:	Similar to better (function of the season)	Probably better (green undergrowth on wetland fringes is nutritious)	Similar	Spring: better Autumn: better[f]	Similar
Diseases specific to wetland:	None - sometimes slight footrot	None	None	3-day stiff sickness	None
Control of diseases:	-------	-------	-------	Inoculated animals	-------

[i]Wetland agro-ecological zones: G - wet grassland zone; W - wet meadow zone; M - Marsh zone.

[ii]*The figures supplied by the farmers about stock numbers and days spent in the wetland were only approximations, since they varied from season to season.*

[iii]The stocking density (SD) was calculated using the animal unit (AU) equivalent tables in Meissner *et al.* (1983).

[a]The wetland formed a mosaic of wet grassland (approx. 30%), wet meadow (approx. 5%) and marsh (approx. 65%) areas, but was managed as one area with no camps (i.e. there were no division due to the different agro-ecological zones).

[b]The wetland formed a mosaic of wet grassland (approx. 60%), wet meadow (approx. 10%) and marsh (approx. 30%) areas, but was managed as one area which had been divided into 2 camps (<u>note</u>: these camps had not been divided according to the different agro-ecological zones).

[c]The wet meadow zone formed the greater proportion of this wetland.

[d]In a 'drought' year, grazing only began in November (because there was little or no growth before then) and continued until January (i.e. 90 days). In the winter of such years the animals were then fed *Eragrostis* hay on the wetland (no hay was made from the wetland in a 'drought' year, because it was grazed until January).

[e]The wetland camps were rotationally grazed with the surrounding veld for 180 days (i.e. from September to February), with the animals spending an effective 90 days (of the 180 days) on the wetland only.

[f]The quality in autumn was only better if hay was cut from the wetland during that summer.

[g]At this study site sheep and cattle used the wetland simultaneously (see Table 2.2 study site 5 for details of the grazing of this wetland by beef animals).

Table 2.4 Information about the burning of undeveloped wetlands

BURNING INFORMATION	STUDY SITE						
	1	2	4	5	6	7	8
	Mount Currie	Mount Currie	Utrecht	Vryheid	Harrismith	Harrismith	Vrede
Wetland zone(s) burned:[1]	G	M	G (30%) W (5%) M (65%)[a]	G (60%) W (10%) M (30%)[b]	W M[c]	G	G (60%) W (25%) M (15%)[d]
Reason(s) for burning.	Remove old matter	Remove old matter Get an 'early' bite	Remove old matter	Remove old matter	If the season was too wet, too much DM accumulated, which could not be grazed[e]	Silt deposition on grass during wet season, and refusal by animals to graze it	Remove old matter
Time(s) of year burned:	15 August (with special permission)	If snowed: 15 August If no snow: after first 12.5 mm of rain (with special permission)	First or second week in August	August or September (after the first rains)	August	August or September (after the first rains)	Information not supplied
Frequency of burning:	Annually (except if too wet)	Every third year (1 out of 3 camps per annum)	Annually	Annually (try bi-annually)	Periodically (if the summer was too wet)	Periodically (if the summer was too wet)	Periodically (function of the season)

[1]Wetland agro-ecological zones: G - wet grassland zone; W - wet meadow zone; M - marsh zone.

[a]The wetland formed a mosaic of wet grassland (approx. 30%), wet meadow (approx. 5%) and marsh (approx. 65%) areas, but was managed as one area with no camps (i.e. there was no division due to the different agro-ecological zones).

[b]The wetland formed a mosaic of wet grassland (approx. 60%), wet meadow (approx. 10%) and marsh (approx. 30%) areas, but was managed as one area which had been divided into 2 camps (note: these camps had **not** been divided according to the different agro-ecological zones).

[c]The wet meadow zone formed the greater proportion of this wetland.

[d]The wetland formed a mosaic of wet grassland (approx. 60%), wet meadow (approx. 25%) and *Cyperus fastigiatus* marsh (approx. 15%) areas, but was managed as one area which had been divided into 4 camps (note: these camps had not been divided according to the different agro-ecological zones).

[e]No burning was done in a 'drought' year.

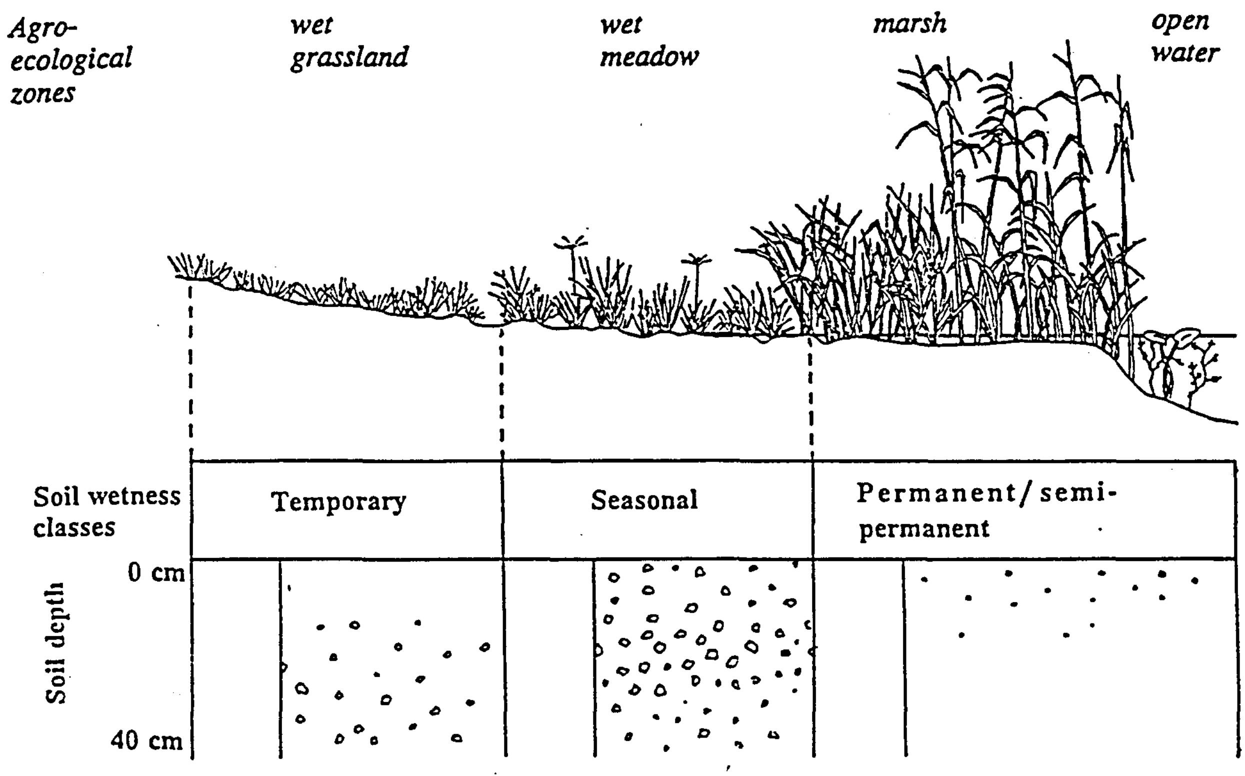

Figure 2.1 Schematic representation of the different agro-ecological zones found in undeveloped (natural) wetlands (Kotze 1993b).

REPORT TO THE WATER RESEARCH COMMISSION

A MANAGEMENT PLAN FOR WAKKERSTROOM VLEI

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EXECUTIVE SUMMARY

Wakkerstroom vlei, ca 950 ha in extent, is situated in the upper Tugela catchment in Bioclimatic Group 4g (mean annual rainfall= 800 mm). The underlying geology is Ecca shale and Katspruit is the predominant soil form. The primary land-use in the catchment is domestic stock grazing, with limited crop and pasture production. The wetland has various vegetation communities including reed marsh, sedge/*Leersia* marsh, wet meadow and wet grassland and supports numerous crowned crane pairs and many other bird species, notably the white-winged flufftail, one of Africa's rarest birds. The wetland has a high water purification and streamflow regulation value, and is of regional significance because there are users downstream, including those supplied by the Zaaihoek dam. The entire Wakkerstroom vlei except the southern-most 30 ha is owned by the Wakkerstroom municipality and leased out for grazing. The predominant land-use occurring in the wetland is grazing of the natural vegetation. Erosional degradation is limited to localized areas, most of which have stabilized and do not pose a threat to the wetland. Very little development of the wetland has occurred.

In order to encourage sustainable use of the wetland while minimizing the loss of wetland functional values, an overall management goal and management objectives are proposed and a series of management guidelines devised describing the actions required to achieve the specific objectives (Fig. 1). The management guidelines, which are summarized below and given in detail in Section 7, relate to:

1. controlling (decreasing) the extent and frequency of burning;

2. controlling (decreasing) the stock grazing pressure and identifying sensitive areas that require very lenient grazing or exclusion from grazing; and

3. enhancing habitat diversity and suitability for birds

Burning

* Do not burn more than 50% of the sedge/bulrush marsh in any one year.

* Preferentially burn areas with abundant dead material that is limiting new growth.

* Protect localized known bird breeding areas, as far as possible, but even these areas may need to be burnt occasionally to stimulate new growth.

* Avoid burning on both sides of the Volksrust road and also on both sides of the Ammersfoort road.

* Harvest wetland plants, as far as is possible, in areas useful for fire-breaks.

* Keep accurate records to help develope an adaptive management strategy.

- Discourage arsonists through education and law enforcement.

- Use cattle grazing to promote patch burns.

Mowing for hay production

Mowing should be excluded from designated areas so as to improve the habitat value for crowned cranes and grass owls.

Natural grazing by stock

The wet grasslands and adjacent non-wetland grasslands are in poor condition because of prolonged heavy utilization in the past. Thus, the stocking rate for these areas should be reduced to 3 ha per AU (121 cattle grazing days per ha).

Cattle should be excluded from the eroded steep sided wetland areas below the township and from the flow concentration area between Sectors 3 and 4 (see Section 8.2.6) and access by cattle to the stream channel in Sector 4 should be controlled.

It is recommended that the grazing pressure be seasonally reduced in the heavily utilized marsh areas. This should be done on a rotational basis such that a given area is leniently grazed or rested completely at least every fourth year and this be continued for a year. Also, an attempt should be made to restrict utilization of marsh areas to periods when the soil is not saturated, in order to minimize the trampling impact.

From the point of view of effective grazing management, the existing fences on the current leasehold land should be maintained for the time being and strategic positioning of licks drinking troughs should be used to assist in reducing selective grazing.

Drainage channels

Although Wakkerstroom vlei has been altered only slightly by drainage channels, further drainage is not recommended and should under no circumstances be implemented without prior consultation with Department of Agriculture personnel and permission from the relevant authorities.

Restrictions to water flow and open water creation

Flow in the main channel has been restricted where it enters Sector 2. This has had a damming effect, decreasing the amount of wet grassland in favour of sedge/bulrush marsh and apparently causing a large open water patch to form below the Amersfoort bridge. In a landscape context, the creation of additional marsh could justifiably be seen as redressing the large-scale loss of marsh areas. It is recommended that, until it is shown that it is adversely affecting the general hydrology of the wetland, the restriction should not be removed.

As channels positioned with the general flow direction may be harmful, it is recommended that if channels/open water areas are created, they be positioned at right angles across the dominant water flow direction. Additional open water areas should be created in the ecotonal zone between reed marsh and sedge marsh rather than in the central reed marsh area, as these will support a higher faunal and floral diversity and abundance.

Tree planting

Attempts have been made to establish both basket willows and poplars in Sector 1. In the interests of maintaining the system in as natural a state as possible, they should be removed.

Crop production

Cropping substantially detracts from a wetland's ecological value and is undesirable from a hydrological and erosion control point of view. No further croplands should be established.

Game-bird shooting

If a sustained yield of yellow-billed duck and Ethiopian snipe could be provided then this may represent an important source of revenue. A specific study should be undertaken to determine sustainable off-take levels.

Wetland plant harvesting

Limited harvesting of wetland plants occurs. It is recommended that this could be expanded to the controlled harvesting of both reeds and sedges on a larger scale for domestic and craft sales purposes. Due to the abundance of *P. australis*, it is recommended that the feasibility of a small paper making industry be investigated.

Birding

An extremely rare endemic species, the white-winged flufftail, has recently been discovered in the wetland. Because this bird must be disturbed and flushed to be seen, birders should be encouraged to be satisfied with hearing the call. The construction of a hide next to a sedge/bulrush marsh open water area by the Wakkerstroom Natural Heritage Association is supported.

Cultural enrichment

The cultural value of the wetland should be enhanced by continued involvement of the local community in wetland management decisions and by education. The education centre developed by the Wakkerstroom Natural Heritage Association is supported.

OVERALL MANAGEMENT GOAL: Maximise the direct benefits derived by the different users of the wetland without significant loss of the wetland's hydrological, erosion control and ecological values, which benefit the local community and society at large.

MANAGEMENT OBJECTIVES — SUMMARIZED MANAGEMENT GUIDELINES

Protect the hydrological and erosion control values

- Exclude grazing from hydrologically sensitive areas.
- Prevent further drainage channel construction.
- Observe the recommended stocking rate.
- Rotate and closely monitor high stock utilization areas designed to enhance habitat diversity.

Protect the ecological values

- Protect the hydrological and erosion control values.
- Leave at least half of the wetland unburnt each year in order to provide cover for wetland dependant species and also ensure that half the tall reed marsh is left unburnt in order to favour reed breeding species such as the Purple Heron.
- Maintain populations of red data and other species considered to be of particular value.
  - * Burn the *Carex* marsh such that half is burnt each year and ensure that grazing pressure is maintained at a low level in this area, in order to favour the White-winged Flufftail.
  - * Exclude grazing from designated likely breeding areas and exclude mowing from all sedge meadow areas in order to favour the Grass Owl.
  - * Exclude grazing from the grassland areas considered important for Crowned Crane chick survival and also undertake education and law enforcement initiatives to further reduce the high incidence of chick mortality.
- Maintain and enhance habitat diversity through rotational burning, carefully planned and positioned high intensity grazing, and limited open water creation and maintenance.

Allow controlled use of the wetland's resources through the following activities:

* grazing

- Maximise the grazing value of the wetland by using marsh areas (as far as accessibility will permit) in preference to sedge meadow and hygrophilous grassland areas during spring.
- Observe the recommended stocking rates.
- Exclude grazing from designated ornithologically or hydrologically sensitive areas, or use these areas for low intensity grazing if recommended by the WNHA (Wakkerstroom Natural Heritage Association) technical committee.

* hay cutting

- Exclude hay cutting from designated ornithologically or hydrologically sensitive areas, and mow after January.
- Mow only hygrophilous grassland, unless the WNHA technical committee recommends that mowing specified sedge meadow or marsh areas is acceptable.

* plant harvesting

- Exclude wetland plant harvesting from designated sensitive areas, unless advised otherwise by the WNHA technical committee.
- As far as is possible, harvest in areas advantageous from a fire control point of view.
- Rotate the harvesting areas, rather than harvesting in the same places each year.

* eco-tourism & education

- Protect the ecological values
- Ensure that all visitors follow the ethical code of conduct drawn up by the WNHA.
- Provide features such as hides, strategically placed open water areas, and an information centre that enhance the eco-tourism and education potential of the wetland.

* hunting

- Conduct a feasibility study to determine sustainable harvest levels.
- Hunt only those species approved by the WNHA and monitor hunted species populations.

* community development

- Make optimal use of harvested plants by producing marketable products such as reed-paper.
- Ensure that local people derive maximum benefit from eco-tourism and hunting through employment opportunities.

Fig. 1 Wakkerstroom vlei management framework

ACKNOWLEDGEMENTS

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Advice and comments given by the following individuals towards the development of the Wakkerstroom vlei management plan are gratefully acknowledged: Mrs E Kotze, Dr W Tarboton, Mr J Wyatt, Dr G W Begg and Mr C Smit. The Wakkerstroom vlei lessees are thanked for their co-operation and friendliness, and the Kotzes are thanked for their generosity and wonderful hospitality.

The valuable contributions made by Prof K Gordon-Gray and Mrs J Browning in the identification of plant species is acknowledged.

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1. MANAGEMENT OBJECTIVE

The management objective for Wakkerstroom vlei is to optimize, sustainably, the direct benefits derived by the different users of the wetland without resulting in significant loss of the wetland's indirect benefits for the local community and for society.

The Wakkerstroom vlei users are stock farmers, birders, water users, hunters and reed harvesters. Indirect benefits include the following functional values:

1. hydrological values (water purification, enhancement of sustained stream flow and water storage);

2. erosion control value; and

3. ecological value (maintenance of biotic diversity through the provision of habitat for wetland dependent species)

2. GENERAL SITE DESCRIPTION

Wakkerstroom vlei, approximately 950 ha in extent, is situated in the upper Tugela catchment west of, and immediately adjacent to, Wakkerstroom village (27°21'S; 30°08'E)(Fig. 2). The main body of the wetland extends 9 km from its upstream end (1760 m) to its outlet (1737 m), giving a total slope of 0.26%.

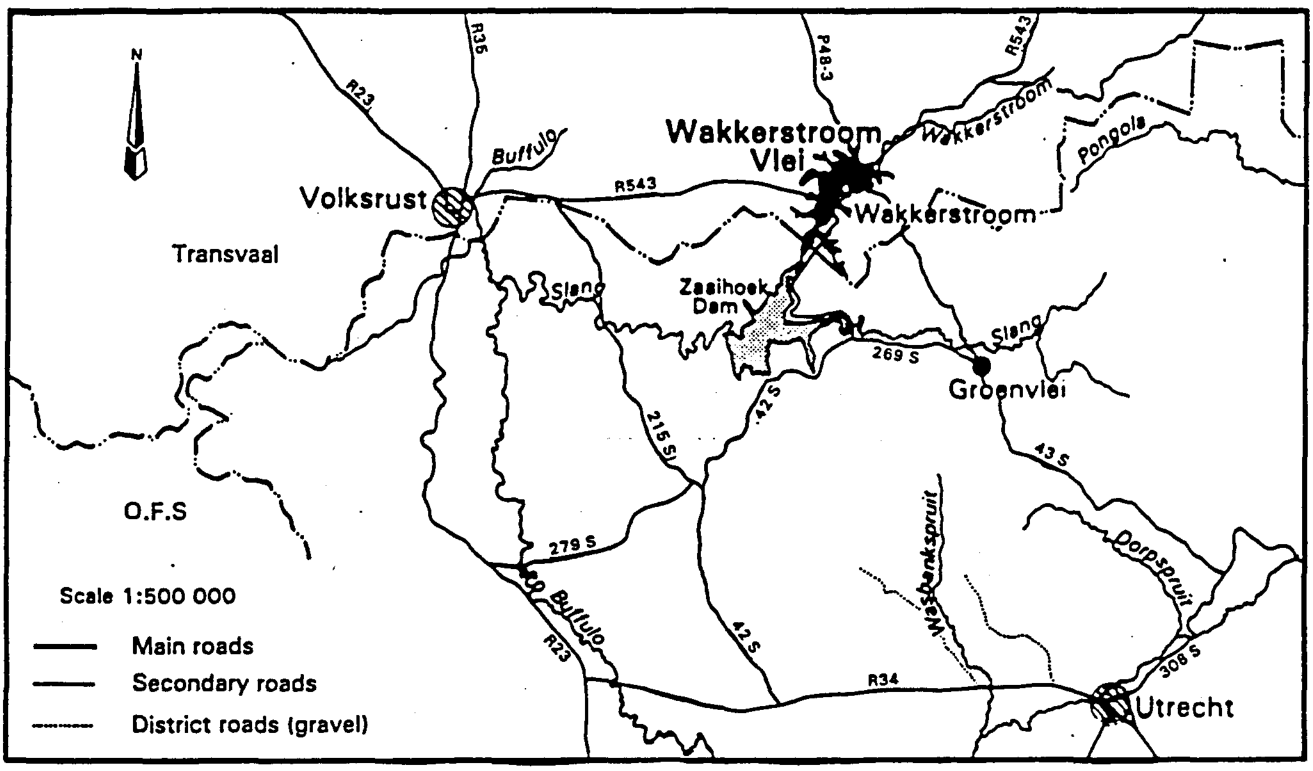


Fig. 2 Location of Wakkerstroom vlei (from Begg, 1989)

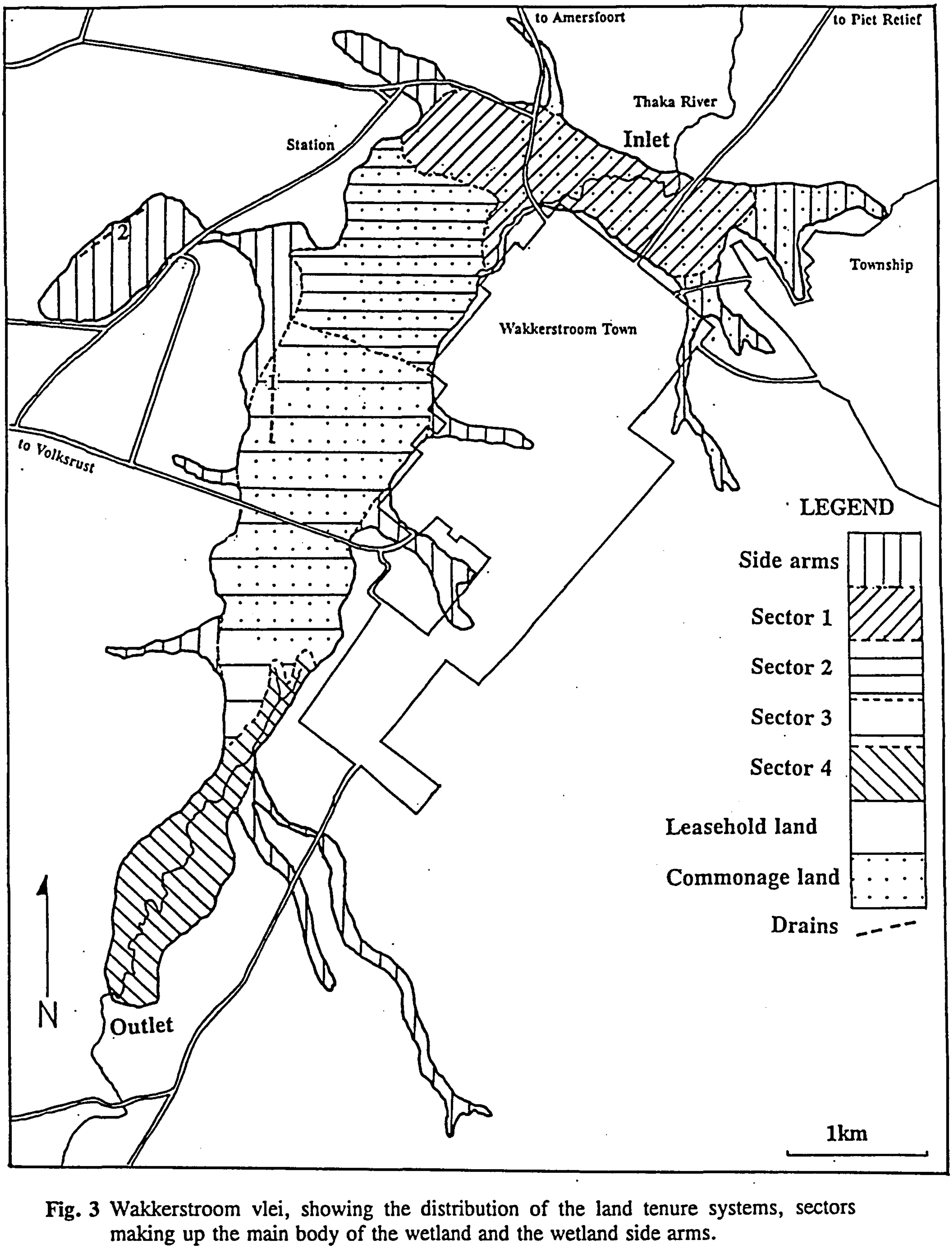


Fig. 3 Wakkerstroom vlei, showing the distribution of the land tenure systems, sectors making up the main body of the wetland and the wetland side arms.

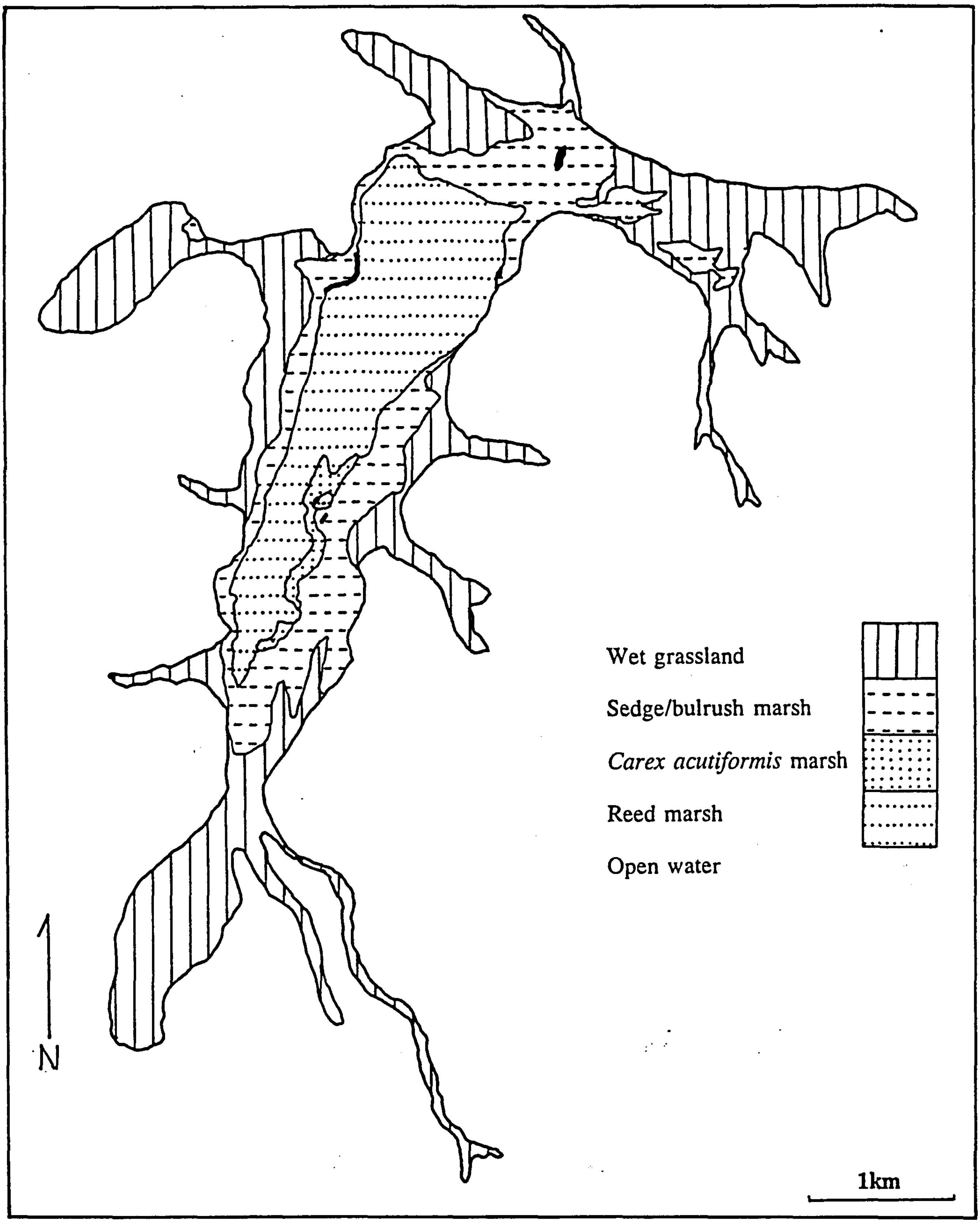


Fig. 4 Distribution of vegetation types occurring in Wakkerstroom vlei.

Six principal vegetation types (described briefly in Section 6 and in detail in Appendix 1) occur in Wakkerstroom vlei:

reed marsh;
Carex acutiformis marsh;
sedge/bulrush marsh;
sedge meadow;
wet (hygrophilous) grassland; and
open water.

The main body of the wetland can conveniently be divided into four main sectors (Fig. 3) based on the distribution of these vegetation types (Fig 4).

Sector 1 is dominated by wet grassland on the main channel levees and higher lying flood plain areas and by sedge/bulrush marsh on the lower lying flood plain areas. In Sector 1, surface water flow is largely contained within a central meandering channel.

Sector 2 is dominated almost entirely by reed marsh. Sector 3 comprises reed marsh on the western side, grading into a narrow strip of *Carex acutiformis* marsh in the centre which in turn grades into sedge/bulrush marsh on the eastern side. In Sectors 2 and 3, although there are primary channels on the western and eastern edges of the marsh, water flow is predominantly diffuse.

Sector 4 is dominated almost exclusively by wet grassland with patches of non-wetland grassland. Streamflow is contained within a central meandering channel. Although they are similar to those of Sector 1, the river banks are higher. Bank overflow occurs far less frequently than in Sector 1, usually only under exceptional (one in ten year) flood events.

In addition to the main body of the wetland, there are numerous side-arms and these are largely dominated by wet grassland, sedge meadow and sedge/bulrush marsh. The side arms tend to have steeper slopes than the main body (between 1% and 5%).

The wetland is underlain almost entirely by Ecca shale (of the Volksrust formation), but the southern third of Sector 4 and the two northern-most side-arms are underlain by Karroo dolerite (Begg, 1989). The wetland soils are predominantly acidic. In the permanently to semi-permanently saturated/flooded areas, they consist of a complex of the Champagne form and the Katspruit form (Lammersmoor family). In the seasonally and temporarily saturated/flooded areas, soils are predominantly of the Katspruit form (Lammersmoor family).

3. CATCHMENT DETAILS

The Wakkerstroom vlei catchment occurs within veld type 57 (North-Eastern Sandy Highveld) (Acocks, 1953) and Bioclimatic Region 4g (mountain highland)(Phillips, 1973). Mean annual rainfall is approximately 800 mm, relative humidity 65-70%, annual potential evapotranspiration 1650 mm, mean annual temperature 13.5°C, and extreme daily temperatures 35°C and -11°C (Phillips, 1973).

The catchment area is 207 km^2 of which 5% is occupied by the wetland. The mean annual run-off from quaternary sub-catchment VO51, in which Wakkerstroom vlei lies, is estimated to be 102 x 10^6 m^3 (Pitman *et al.*, 1981, as cited by Begg, 1989). Judging from the extent of the catchment behind Wakkerstroom vlei, Begg (1989) estimates that approximately 30 x 10^6 m^3 of the runoff is generated upstream of the wetland.

The principal current land-use in the catchment is sheep and cattle farming, using natural veld grazing. Cropping and planted pasture production takes place, but on a much smaller area. No afforestation, apart from very limited areas next to the town, has occurred in the catchment.

Both the town and township have operative sewage treatment works and fertilized fields are not particularly extensive in the catchment. Wetland inflows are likely to contain low pollutant and sediment levels resulting from these activities.

4. REGIONAL SIGNIFICANCE OF THE WETLAND

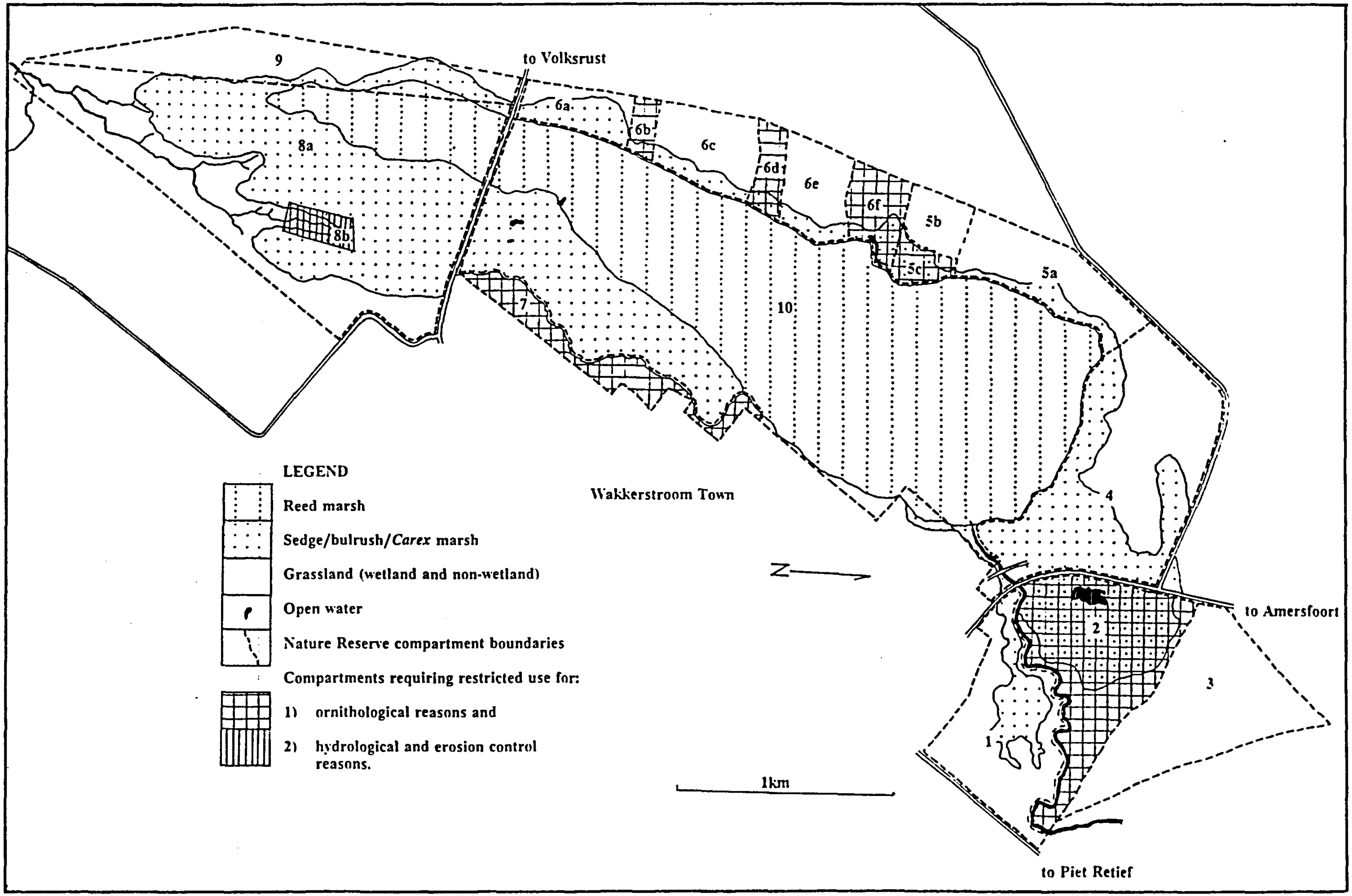
Wakkerstroom vlei has been recognized by Begg (1989) as one of Natal's priority wetlands. As it has a large surface area, low slope and high surface roughness (provided mainly by tall dense plant growth in the reed marsh areas), Wakkerstroom vlei is considered to have high water purification and stream flow regulation values. The wetland is of regional significance because of the variety of water users downstream dependent on assured yields of good quality water, including those supplied by the Zaaihoek Dam. Begg (1989) concludes that it occupies a key position in the catchment of the Tugela River.

The plant species richness of Wakkerstroom vlei is relatively low compared with some of the other priority wetlands in the same bioclimatic region. However, the wetland is significant in providing large areas of unique habitat, much of which has been lost in the Natal catchment. It also supports numerous crowned crane pairs and many other wetland bird species, notably the white-winged flufftail (*Sarothrura ayresi*), which is one of Africa's rarest bird species and was once thought to be extinct in South Africa.

5. LAND OWNERSHIP AND LAND TENURE

The entire Wakkerstroom vlei except the southern-most 30 ha of Sector 4 is owned by the Wakkerstroom municipality. Two systems of land-usage control operate on the municipal land. The first involves a commonage system whereby residents may buy grazing rights on a per head of cattle basis. The second is a lease-hold system, whereby residents lease portions of the municipal land. The council has the right to serve three months notice on any land user abusing the land, and to cancel the lease agreement. Most of the main body of the wetland is commonage, while some of the peripheral parts of the main body and most of the side arms are leased out to specific individuals. The downstream 490 ha of the commonage is currently used by residents of the town and the downstream 120 ha by residents of the township. Four lessees, Messrs. Roos, Koors, Van der Merwe and Van Zyl, currently lease portions of the wetland, each of which is individually fenced. Although not specifically divided into camps, the commonage is effectively "camped off" into four sections by the three roads that traverse the wetland.

Fig. 5 Wakkerstroom vlei nature reserve



Land-use control of Sectors 2 and 3 and most of Sector 1 changed on 1 July 1992, when the Wakkerstroom Natural Heritage Association initiated a 10 year renewable lease with the town council for 650 ha of Wakkerstroom vlei and the immediate surrounds (Fig. 5). The rights to graze and cut hay from this area has remained with the current lessees. However, certain restrictions, arrived at through agreement by the parties concerned, apply to utilization in these areas. The main objective of these restrictions are to enhance the wetland's value for wetland-dependent birds.

6. WETLAND VEGETATION TYPE DESCRIPTIONS

Six vegetation types have been defined for the purposes of management (Table 1). Reed marsh and *Carex acutiformis* marsh occur in permanently to semi-permanently flooded/saturated areas. The soils in these areas have a high abundance of roots forming what is sometimes referred to as a root or floating mat. Although large areas are firm enough to provide cattle with easy access, other areas give way easily under foot and exclude cattle.

Sedge/bulrush marsh is the most widespread vegetation type, with soils that range from permanently flooded to seasonally saturated.

Sedge meadow is transitional between marsh and wet grassland in terms of plant species composition, soil characteristics and water regime. It occurs as a very narrow zone between these two types. Plant species richness is relatively high, probably because it is an ecotonal zone.

Wet grassland forms the transitional zone between the wetland and non-wetland and is confined to temporarily flooded/saturated areas. Species consist of a mixture of hydrophytes which are restricted to seasonally or temporarily saturated areas, and characteristic dryland species.

Approximately 2 ha of Wakkerstroom vlei comprises permanent open water. The open water areas positioned in the reed marsh areas tend to have fewer mud-banks and aquatic plants and have a lower diversity and abundance of birds than those positioned in or adjacent to sedge/bulrush marsh areas.

Table 1 Dominant plant species, water regimes and soil characteristics of Wakkerstroom vlei vegetation types used in the management plan

Vegetation type	**Dominant plant species**	**Water regime and soil characteristics.**
Tall reed marsh	*Phragmites australis*	Permanently to semi-permanently saturated/ flooded; upper B horizon soft and unconsolidated to >1.0m depth; A horizon with very abundant roots; gleyed to the surface.
Short reed marsh	*Phragmites australis*; *Carex acutiformis*	As for tall reed marsh but unconsolidated B horizon usually deeper (>2.0 m).
Very short reed marsh	*Phragmites australis*	As for short reed marsh.
Carex acutiformis-marsh	*Carex acutiformis*	As for short reed marsh.
Sedge/bulrush marsh	*Cyperus fastigiatus; Schoenoplectus corymbosus; Eleocharis spp.; Typha capensis*	Permanently to seasonally saturated/ flooded; B horizon often not soft and unconsolidated, but if so then <2.0 m depth; A horizon with abundant roots; usually gleyed to the surface.
Sedge meadow	*Andropogon appendiculatus Eleocharis spp.; Pycreus macranthus; Kyllinga erecta*	Intermediate between sedge/bulrush marsh and hygrophilous grassland.
Wet grassland	*Eragrostis plana; Eragrostis planiculmis; Andropogon appendiculatus; Hermarthria altissima*	Temporarily flooded/saturated; upper B horizon always hard and consolidated; A horizon with relatively few roots; gleying seldom within uppermost 10 cm of soil.
Open water	*Largarosiphon major; Potamogeton thunbergii;*	permanently flooded; soft upper unconsolidated B horizon < 1.0 m.

7. CURRENT AND PAST USE OF THE WETLAND AND RECOMMENDATIONS FOR FUTURE USE

Both consumptive uses (e.g. stock grazing) and non-consumptive uses (e.g. birding) as well as land-use related activities (e.g. burning) have been and are being applied to the wetland. These are described in terms of their effect on the hydrological, erosion control and ecological values of the wetland. Following each description, recommendations for future use are made.

Given the current socio-economic conditions in South Africa and the Wakkerstroom area, a preservationist, non-utilitarian policy towards the management of Wakkerstroom vlei is not appropriate. Consequently, possible resources have been identified which, given the right set of circumstances, could be used on a sustainable basis.

7.1 Burning

Because there is often lightning in the area, lightning fires would have occurred in the past, even if they were infrequent. Indigenous peoples and, later, European settlers, would have increased the fire frequency. However, it appears that human-induced fires occurred less frequently than annually until about 50 years ago. Since then the wetland (usually including at least 60% of the marsh) has been burnt almost every year.

Burning has both negative and positive effects on the wetland's functional values. It leads to increased evapotranspiration and, in some cases, possibly to a reduced soil organic matter content. However, unless the wetland is burnt in a particularly dry year and the fire burns down into the soil, burning is considered to have a negligible impact on the wetland's hydrological values.

By temporarily removing cover, burning may detract from the habitat value for birds and small mammals. However, provided adequate unburnt areas are left from which recolonization of the burnt areas may occur, burning is unlikely to have an overall negative effect on the habitat provision value of the wetland. In reducing the shade provided by the accumulation of old leaf material from emergent wetland plants, burning increases the growth rate of new leaves. This, in turn, may be beneficial to animals dependant on these plants. For example, a controlled burning programme, as opposed to complete protection, was shown to increase the value of sedge marsh for red-chested flufftail (Taylor, 1992).

By removing unpalatable old growth and stimulating new, fire is useful to the stock farmers who lease grazing rights in the commonage area. A decrease in the fire frequency would diminish the grazing value of the wetland.

It appears that in the recent past, fires have often been caused by arson on the town-side of the wetland, and by run-aways when farmers burn the surrounding grasslands on the opposite side of the town. Because of these unpredictable events, it will be impossible to impose a rigid prescribed burning programme. Instead, the following guidelines are recommended:

1. do not burn more than 50% of the sedge/bulrush marsh in any one year;

2. preferably burn areas with abundant dead (moribund) stem and leaf material that is limiting new growth;

3. as far as possible, protect localized known bird breeding areas - although even these areas may need occasional burning to stimulate new growth if reed density is reduced markedly;

4. avoid burning the entire Sector 3 by not burning on both sides of the Volksrust road; similarly, do not burn on both sides of the Amersfoort road, which divides Sector 1 in half;

5. burn in late winter to early spring, under conditions of high humidity and low air temperature, and preferably shortly after rain, in order to achieve a cool burn;

6. harvest wetland plants, as far as is possible, in areas useful for fire-breaks;

7. divide some of the tall reed marsh areas into burning blocks, with 20 m wide fire breaks cut on the western side;

8. keep accurate records to help develope an adaptive management strategy. For example, recommendations to cut fire breaks for the protection of the tall reed marsh areas are not based on documented cases. Accurate records must be kept to test their effectiveness;

9. discourage arsonists through education and law enforcement; and

10. cattle, by reducing the fuel load and creating puddles, can be used to good effect in promoting patch burns.

7.2 Mowing for hay production

Second to grazing, hay is probably the most important resource obtained from the wetland. Hay cutting is restricted to wet grassland, but in extreme drought years, is also cut in the marsh zone.

Current mowing practices are not considered to be detracting significantly from the hydrological values of the wetland. If kept to times when the soil is relatively dry, mowing is less likely to have a soil compacting effect than grazing, which occurs during both wet and dry periods.

Tarboton (1992) considers mowing to detract from the habitat value of Wakkerstroom vlei for birds where it:

1. removes cover from certain strategic wet grassland areas required by crowned crane chicks; and

2. extends into sedge meadow areas, an important habitat for Grass Owls.

Tarboton (1992) has set limits in consultation with the lessees concerned, to ensure that strategic corridors for the crowned crane chicks and sedge meadow areas for the grass owls are left unmown.

7.3 Natural grazing by stock

The most important resource currently obtained from the wetland is natural grazing for stock, which occurs in all the vegetation types. Impact will be considered separately for grassland and marsh areas.

7.3.1 Impact on wet and non-wetland grassland areas

The most significant effect of heavy grazing pressure on wet grasslands is ecological, involving a dramatic change in the species composition of the dominant grasses. An assessment of the veld condition of the non-wetland grassland surrounding Wakkerstroom vlei by the TPA Nature Conservation Department showed almost the entire area to be in very poor condition (de Wet, 1991).

Investigation of the wet grassland areas not assessed by de Wet (1991) showed them to be in a similarly poor condition. *Eragrostis plana*, an increaser II species adapted to both dryland and wet grassland conditions, is the most common dominant species in these areas. *Eragrostis planiculmis*, a wetland restricted increaser II species, is second in occurrence.

Generally speaking, prolonged heavy grazing also decreases the plant species richness of grasslands (Scott-Shaw, 1992) and this is likely to have occurred in Wakkerstroom. As far as is known, no Red Data plant species occurred in these areas. However, a more detailed investigation may show otherwise.

Serious gully erosion has occurred in some of the side arms, during periods when it appears that the wetland was even more heavily utilized than at present. Most of these have now stabilized and no local actively eroding areas are visible, except for those below the township. It is recommended that cattle be excluded from the eroded steep sided wetland areas below the township. At present, it appears that although increasing the rate of soil loss and degree of soil compaction, heavy utilization of most wet grassland areas by cattle does not pose an immediate threat to the wetland.

Where cattle congregate around open water areas, they may significantly lower the water quality through urination, dunging and trampling. Indications are that this may be occurring in Sector 4 of the wetland. This is more serious than if it were occurring in Sector 1 because any potential buffering effect the wetland may have on water quality cannot be exploited. Consequently the access of cattle to the stream channel in Sector 4 should be controlled.

7.3.2 Impact on marsh areas

Begg (1989) considers the main body of the wetland to be in a highly acceptable condition, and that this is testimony to the effectiveness of the land tenure system that was operative in the wetland. However, the condition of the wet grassland areas have subsequently been found to be very poor (see Section 7.3.2), which may suggest otherwise. In addition, the apparently acceptable condition of the marsh areas may be attributable to: low slope; lack of impact from drainage channels (due to their limited extent and positioning); the unpalatability of most mature marsh plants and the excessive wetness and softness of the soil in some areas which reduce the desirability of the area for cattle. Loss of stock, as a result of sinking into the soft soil still occurs sometimes in Wakkerstroom vlei.

The preference of cattle for marsh areas is strongly dependent on the quality and quantity of food in the surrounding non-wetland areas. Only in spring when the wetland areas commence growth before non-wetland grasslands, are all accessible marsh areas grazed readily by cattle. During the rest of the year, most sedge/bulrush marsh and very short reed marsh areas continue to be subject to prolonged use, but less heavily than the grasslands. Most tall reed marsh, short reed marsh and *Carex acutiformis* marsh areas remain unutilized until the following spring.

During drought years, however, the value of all the marsh types for stock grazing increases because of the lack of food in the non-wetland areas. During drought years the wetland has supplied adequate grazing for up to 2500 head of cattle (Begg, 1989).

Examination of sedge marsh areas subject to prolonged heavy use, showed the soil surface to have been trampled down and puddled. This is undesirable hydrologically and from the point of view of erosion control.

Where utilization is heavy, grazing combined with trampling may reduce cover to below the requirements of certain bird and small mammal species. This appears to be occurring in some of the sedge/bulrush marsh areas in Wakkerstoom vlei. Here it is likely to detract significantly from the breeding habitat value for species such as red-chested flufftail (Taylor, 1992) and ducks (where these areas occur adjacent to open water) (Tarboton, 1992). As the utilization of *C. acutiformis* marsh by cattle is low, cattle are unlikely to pose a threat to the white-winged flufftail, which shows a preference for this vegetation type and is an important Red Data species.

The reduction in aerial cover of the dominant plant species and an increase the extent of exposed puddles caused by grazing often favours some wetland-dependent species (e.g. mud-probing birds such as snipe, and aquatic plants, as well as the fauna dependent on these plants) (Neely, 1968; Duncan and D'Herbes, 1982). In addition, the removal of above-ground material through grazing often enhances new plant growth, as with burning. This, in turn, may positively affect animal species dependant on these plants. Currently, heavy grazing and trampling occurs in only <20% of the marsh areas, which is considered acceptably small. Although difficult to determine, it appears that the root mat making up the uppermost layer in the reed marsh soils, is largely unaffected by trampling associated with lenient grazing pressure. This is unlikely to be so for high grazing pressure.

Another important effect of cattle which is of potential hydrological and ecological significance is the influence on nutrient cycling. Through dunging and urination, grazing animals decrease the time that nutrients in the above-ground plant parts take to reach the soil. This speeds up the cycling process and increases the exposure of nutrients to leaching (Jensen *et al.*, 1987).

High grazing pressure is said to affect ground orchids detrimentally, as these plants are trampled and grazed by cattle (Scott-Shaw, 1991). It has been suggested that the lack of orchids in Wakkerstroom vlei is due to frequent burning and heavy grazing. However, no evidence can be found to show that orchids were once abundant in Wakkerstroom vlei. Also, observation of habitats in which orchids occur in other Natal wetlands, such as Mgeni vlei, suggest that the lack of orchids in Wakkerstroom vlei is due more to a lack of suitable microhabitat than to management-related factors such as burning and grazing.

7.3.3 The stocking rate and grazing system

Due to the over-all poor condition of the surrounding non-wetland grassland, de Wet (1991) recommends that the non-wetland stocking rate be decreased to 6 ha per AU (animal unit), which is a third of the norm. Recent developments in veld recovery research (Morris, Hardy and Tainton, 1992) suggest that, while a degree of destocking is certainly appropriate, the drastic reduction called for by de Wet (1991) would probably be counterproductive. The stocking rate for the surrounding non-wetland grassland should be reduced to 3 ha per AU which is 67% of the norm. This translates into 121 grazing days per hectare.

No guidelines exist concerning the carrying capacity of southern African wetlands, and estimates have to be based largely on observations made at Wakkerstroom. From a grazing point of view, the wet grassland areas are similar to the surrounding non-wetland grasslands. However, they probably have a higher potential productivity due to their positions in bottomland situations. A stocking rate of 3 ha per AU (121 grazing days/ha) is also recommended for these areas.

Unlike wet grasslands, the grazing potential of marsh differs from that of upland grasslands. Marsh areas should be utilized opportunistically in the early grazing season and in droughts, as previously. However, the grazing pressure should be seasonally reduced in localized areas subject to prolonged heavy utilization. This should be done at least every fourth year and be continued for a period of a year.

Rotational grazing, achieved most effectively through camping, is the most effective means of minimizing area and species selection. The proposed nature reserve border fence is positioned in such a way that it incorporates a narrow strip of grassland around the central marsh area. It is impractical to camp off the grassland areas and the fences on the current leasehold land should be maintained for the time being.

Also, licks and drinking troughs should be strategically positioned to help reduce area and species selective grazing. In this way, cattle could be encouraged to use specific areas, which could be altered from year to year by simply moving the licks.

It has been shown that both mineral and organic soils become more susceptible to compaction and damage that could lead to erosion (e.g. truncation) when they are wet (Bayfield, 1973; Bryan, 1977; Wilkins and Garwood, 1988; Stewart and Cameron, 1992). Because rainfall events sufficient to saturate the soil are unpredictable, it is inappropriate to make prescriptive recommendations here concerning grazing of wetland areas. Stock farmers should remain flexible and, as far as possible, confine utilization to periods when the soil is not flooded or saturated.

7.4 Drainage channels

Two drainage channels have been dug in the broad western side arm (Fig. 3). Drainage channel 1 has not been maintained and due to the gentle slope in this area, this drain appears to have little effect on the general hydrology of the wetland.

Drainage channel 2 reduces the quantity of water feeding the wet grassland area and makes it marginally drier than would occur naturally, but without any reduction in surface roughness. This channel is being maintained to make provision for hay-cutting in an area which would otherwise be too wet to permit access by machinery in average to wet years. It detracts from the hydrological functions of the area, but is not as serious as it might be if the area had been marsh, and/or if more drains were required for utilization. No Red Data species appear to be affected, but the channel has probably increased the relative proportion of dryland plant species. While this may appear insignificant, a wider occurrence in Wakkerstroom vlei would certainly constitute a significant loss of habitat. Drainage channels may also increase the susceptibility of wetland areas to erosion.

Wetland drainage channels, however small their influence, should not be encouraged, and no further draining activities should be undertaken without prior consultation with Department of Agriculture personnel and permission from the relevant authorities.

7.5 Roads

Wakkerstroom vlei is traversed by three road crossings. These certainly modifying the hydrology of the wetland because road embankments have a damming effect. Comparison of the up-stream and down-stream areas of the Volksrust road during an exceptionally dry period in January 1992, showed the water table to be significantly higher in the up-stream area. The increased frequency, in recent years, of open water patches in the reed marsh above the Volksrust road may have been promoted by the damming effect.

In addition to the damming effect upstream, road causeways may concentrate wetland water flow down-stream, detracting from the hydrological values of the wetland. This concentrating effect appears to occur only below the Volksrust road, and even here, field observation and photo-comparison show the effect to be small.

7.6 Restrictions to water flow and open water creation

Flow in the main channel has been restricted where it enters Sector 2 on the western side of the wetland, as a result of the establishment of willow trees and the dumping of rubble to form a wall. This has had a damming effect, decreasing the amount of wet grassland in favour of sedge/bulrush marsh and apparently causing a large open water patch to form below the Amersfoort bridge. This open water area is at its largest in the 1953 and 1961 airphotos. In the 1969 airphotos the patch is approximately halved in area, because of colonisation by emergent marsh plants. In 1979 it is fragmented and considerably smaller, as it is now. The flow restriction has also decreased the quantity of water carried by the primary channel on the western edge of the wetland, and the lost water is now carried by the channel at the eastern edge of the wetland. Although no observable effects of decreased water input to the western side of Sector 3 are indicated by airphoto-comparison, long-term effects may become apparent.

An additional open water patch above the Amersfoort road also appears to have been caused by this flow restriction, but the Amersfoort road embankment and a recent channel switch may also have contributed.

It may be argued that if the management objective of Wakkerstroom vlei includes maintaining the system in as near to its "natural state" as possible, the damming should be removed to allow the system to revert to its previous condition. It may conversely be argued that seen in a landscape context, where many marsh areas have been lost to agricultural development and mismanagement, creation of additional marsh could be seen as restoring what has been lost in the wider landscape. Until it is shown that the damming adversely affects the general hydrology of the wetland, this restriction should be retained.

Proposals have been made by the Wakkerstroom Natural Heritage Association for the creation of open water patches and channels orientated approximately with the general water flow direction. This would have a concentrating (channelizing) effect on the water flow which would detract from the hydrological values of the wetland, and might also lead to further incision of the channel which would detract from these values even more. It is recommended that any channels/open water areas be positioned at right angles across the dominant water flow direction (see Kotze, 1991).

Alternatives exist for siting the open water patches. Comparison of the existing reed marsh open water patches with the western ecotonal open water patch, shows that the reed marsh patches have fewer mud-banks and aquatic plants, and that they support fewer species and numbers of birds. Although not quantified, these reed marsh open water patches have fewer frogs, fish and insects such as dragonflies. These differences may be due to hydrological and substratum differences, already discussed.

While open water patches in the central reed marsh area may enhance the overall diversity of the wetland, this might better be achieved by sighting the open water patches in the zone between reed marsh and sedge marsh. Consideration should be given to creating an additional open water patch in this ecotonal zone rather than concentrating all open water patches in the central reed marsh zone. This would also enhance the ecotourism potential more because of the greater faunal and floral diversity and easier access.

7.7 Erosion

Begg (1989) notes that the "dryness" of Sector 4 of the wetland is puzzling and should be investigated. The soil features in this Sector match the current vegetation and water regime, suggesting that little alteration in the hydrology of this Sector has occurred in at least the last 50 years. This is confirmed by the airphoto comparison.

Generally speaking, the zone most vulnerable to erosion in a wetland is at what is termed the flow concentration zone or "key point", positioned between Sectors 3 and 4 in Wakkerstroom vlei. Here, the slope tends to steepen, and diffuse water-flow in a marshy area becomes more channelized. In Wakkerstroom vlei, airphoto comparison show no indication of incision back into the key point of the marsh area, as commonly occurs in many eroding wetlands. However, field inspection in 1994 showed active erosion to be occurring. Thus, it is recommended that it be fenced off and grazing be excluded and that any necessary erosion control structures be constructed in co-operation with the Directorate of Resource Conservation.

Airphoto comparison shows two channel switches, apparently associated with erosional and depositional factors, to have occurred below the township. A superficial examination shows that these changes pose no threat to the wetland, and no remedial action is recommended other than de-stocking.

7.8 Tree planting

Attempts have been made to establish both basket willows and poplars in Sector 1, adjacent to and above the Amersfoort road. Very small areas were planted and proved unsuccessful. The trees are still standing and should be removed.

7.9 Crop production

Limited cultivation occurs in Sector 4 at the northern-most end where the soils overlie dolerite and are probably more fertile than those upstream. Because this is limited and because flooding is rare (less than every 1 in 10 years) it is unlikely to significantly detract from the hydrological values of the wetland, especially as the area is a mosaic of wet grassland and non-wetland. Nevertheless, because the conversion of wetland to croplands involves complete removal of the natural vegetation, it detracts from the ecological value. Considering this and the fact that cropping of wetlands is generally undesirable, no further cropland should be established.

7.10 Game-bird hunting

At present, there is no authorised shooting of game birds in the wetland, but illegal shooting of ducks, mainly yellow-billed duck (*Anas undulata*), has occurred.

In certain European wetlands, snipe are important game-birds and large numbers of Ethiopian snipe (*Gallinago nigripennis*) are found in Wakkerstroom vlei. High concentrations (>20 birds per ha) usually occur in certain sedge/bulrush marsh areas with short vegetation and soft liquid mud (usually caused by heavy grazing pressure). There are also large numbers of yellow-billed duck, attracted to the open water areas.

If a sustained yield of yellow-billed duck and snipe could be provided annually for paying hunters, this might become an important source of revenue to be directed into wetland management. This general study indicates that there are likely to be sufficient snipe to support limited hunting, and a specific study should be undertaken in order to determine sustainable off-take levels.

7.11 Wetland plant harvesting

Very limited harvesting of wetland plants occurs: township residents occasionally harvest reeds mainly for making reed screens. At the low level at which it occurs, this is considered to have no significant impact on the wetland. The present harvesting of reeds could possibly be expanded to the harvesting of both reeds and sedges for domestic and craft sales purposes. Species such as *Schoenoplectus corymbosis are* abundant enough that their controlled harvesting would not compromise the hydrological or ecological objectives for the area. Indeed, such harvesting could be useful by increasing habitat diversity and controlling fire.

Phragmites australis can be used to produce a high-quality paper. *Phragmites australis* is dominant throughout the reed marsh areas, the development of a small paper making industry in Wakkerstroom should be considered, as suggested by Kotze (1992).

7.12 Water extraction

Extraction of water within the wetland is limited and occurred on a large scale only during the drought of 1983 when Wakkerstroom vlei supplied Volksrust with water for domestic consumption.

7.13 Dung collection

Collection of dung for fuel by township residents occurs intensively in the township commonage and adjacent areas of the town commonage.

7.14 Birding

The Wakkerstroom district is well known among birders for its rare endemic non-wetland species, and although the wetland is visited by birders about twice each week, the wetland is not the prime ornithological attraction in the area. This may change with the recent discovery of an extremely rare species, the white-winged flufftail (*Sarothrura ayresi*) in the wetland. Unfortunately, observation of this bird requires that it be disturbed and flushed, and this would have an adverse effect on the flufftails (Taylor, 1992). As such, it cannot be permitted. Birders should be encouraged to be satisfied with hearing the flufftails calling. Once the habits of the flufftails are better understood, it may be possible to attract them to a hide without harm. A hide should be built next to a sedge marsh open water area (as has been undertaken by the Wakkerstroom Natural Heritage Association) where general bird viewing is considered to be relatively good.

7.15 Cultural enrichment

Cultural value for local residents and visitors is very difficult to quantify or even to define. It is linked to historical and aesthetic aspects of the wetland, and could be enhanced through continued involvement of the local community in wetland management decisions and through education. In this regard, the Wakkerstroom Natural Heritage Association has established an interpretative centre for improving knowledge, awareness and conservation of the area's natural heritage.

8. RECOMMENDATIONS FOR FURTHER RESEARCH

This work did not include an investigation of fauna, other than birds, and a more comprehensive faunal inventory is essential.

A more detailed investigation of the effects of grazing and trampling by domestic stock on soil, hydrological and habitat features is also recommended. This would probably best be achieved through a system of exclusion plots and should, if possible, be linked with a study on the effect of grazing on snipe and other birds considered to require special management.

Records should be kept of vegetation and climatic conditions (wind strength and direction, air temperature and humidity) at the time of burning and the severity, distribution and extent of the burn. This will allow for assessment of any control measures (e.g. fire breaks) and the development of an adaptive burning strategy. Depending on the resources available, a burning strategy assessment would be greatly enhanced by an investigation of the effect of burning on the fauna and flora. This is likely to involve burning exclusion plots and would be a long-term, and possibly costly, exercise.

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10. GLOSSARY OF TERMS

A horizon: the uppermost horizon in a given soil. Horizons are layers of soil that have fairly uniform characteristics.

Animal unit (AU): an animal unit is defined as a an animal with a mass of 450 kg and which gains 0.5 kg per day on forage with a digestible energy percentage of 55%. Other types of animals are related to such a unit according to the relationship between the three-quarter power of the mass of such animals and a similar function of the mass of a 450 kg animal, i.e. an animal with a mass *m* constitutes:

$$\frac{m^{0.75}}{450^{0.75}} \text{ of an animal unit}$$

Decreaser species: generally highly palatable plant species that dominate in well managed veld where grazing pressure is moderate, but which decrease in abundance under heavy grazing pressure.

Gleying: soil features that reflect reduction as a result of prolonged waterlogging. Grey colours predominate in gleyed soil but mottles (yellow, orange, red, brown or black) may be present and indicate localized areas of better aeration.

Hydrophyte: any plant that grows in water or on soil that is at least seasonally deficient in oxygen as a result of waterlogging.

Increaser II species: plant species that tend to be less palatable and/or perennial than decreaser species and increase in abundance in mismanaged veld where grazing pressure is heavy.

***n* Value:** the relationship between the percentage of water under field conditions and the percentages of inorganic clay and humus and can be approximated in the field by a simple test of squeezing the soil in the hand. It is helpful in predicting the degree of subsidence that will occur after drainage and whether the soil may be grazed by livestock or will support other loads (Pons and Zonneveld, 1965; Soil Survey Staff, 1990).

Water regime: this describes when and to what extent the soil is saturated or flooded (i.e. it describes the rise and fall of the water table through time).

APPENDIX 1: WETLAND VEGETATION TYPE DESCRIPTIONS

It should be emphasised that the six vegetation types, defined for the purposes of management and described below, do not exist as discrete entities in reality. They are defined separately for the purposes of management.

1. Reed marsh

This type is characterized by the dominance of *Phragmites australis* (the common reed), which almost always occurs as the tallest species. The most commonly occurring co-dominant species is *Carex acutiformis*, particularly in the central areas of Sectors 1 and 2, which are far from the primary channels. Soils are generally characterized by an A horizon with abundant roots, chroma less than 1, and few to no mottles indicating these areas are permanently to semi-permanently saturated. The soft unconsolidated upper B horizon is generally deep (usually >1.5 m and often exceeding 2.5 m). Soft refers to the fact that the *n* value is high and that an iron rod or auger is easily pushed in the full depth without twisting. The first 60 cm of the soil profile usually has a relatively high abundance of roots that form what is sometimes referred to as a root or floating mat. This mat varies in the degree to which it quakes when jumped upon and in its firmness. Large areas are firm enough to provide cattle with easy access, but, other areas, such as above the Volksrust road, give way easily under foot and prevent access by cattle.

Reed marsh can be divided into three sub-types, tall reed marsh, short reed marsh and very short reed marsh. These divisions are made on the basis of height and thickness of individual reeds, co-occurring dominant plants and characteristics of the soil. Reed marsh sub-types have been distinguished as they have relevance to management of the wetland.

In the tall reed marsh, which is generally close to the main channel, the reeds are tall (> 3 m) and thick stemmed (> 10 mm diameter) and species characteristic of the sedge/bulrush marsh are usually co-dominants. The soils in the tall reed marsh generally have a moderately shallow upper soft layer and resemble that found in sedge/bulrush marsh.

In short reed marsh, which is generally in the central and eastern zone far from the main channel, the reeds are generally short (1.2-2.0 m) and thin (5-8 mm diameter). Plant and bird species richness is very low and *Carex acutiformis* is usually the dominant co-occurring species.

Very short reed marsh resembles short reed marsh but reeds tend to be shorter (< 1.2 m), thinner (<5 mm) and less dense and plant species diversity is greater. Two species, *Satyrium hallachii* (an attractive pink ground orchid) and *Kniphofia multiflora* (the tallest member of the red-hot poker genus) are largely restricted to this sub-type. Very short reed marsh provides the easiest access for cattle and is the most intensively grazed reed marsh sub-type. Both grazing and burning have been shown to result in shorter thinner reed shoots, but while spring burning enhances performance by increasing the density of shoots, moderate to high grazing pressure decreases reed performance by suppressing the density of shoots (Duncan and D'Herbes, 1982; Thompson and Shay, 1985). It appears that reed performance in very short reed marsh has been suppressed by heavy grazing pressure, but it should be remembered that physical site and microhabitat factors also influence reed performance.

2. *Carex acutiformis* marsh

Carex acutiformis marsh is very restricted, occurring only in the centre of Sector 3. This vegetation type is dominated almost exclusively by *C. acutiformis* which forms a dense uniform cover (ca 1 m high). As in short reed marsh, plant and bird species richness is extremely low. These areas are very stagnant and, having minimal direct channel inputs, probably have a relatively low nutrient status. It certainly has the lowest plant and bird species diversity. However, it does provide some ideal habitat for white-winged flufftail, particularly at the transition zone with the sedge/bulrush marsh (Taylor, 1992). The soils in this vegetation type closely resemble those in the short reed marsh zone.

3. Sedge/bulrush marsh

This is a widespread vegetation type occurring in:

1. the wetter areas of Sector 1;
2. Sector 2, as narrow fringing zones on the western and eastern edges of the reed marsh;
3. Sector 3, as a narrow fringing zone on the eastern edge and a wide fringing zone on the western edge; and
4. the wetter areas of the side arms.

Sedge/bulrush marsh spans the widest range of water regimes and plant communities, and includes three sub-types: *Cyperus fastigiatus/Schoenoplectus corymbosis* marsh, bulrush (*Typha capensis*) marsh and *Eleocharis spp.* marsh. Interspersion of these three subtypes, particularly the first two, is high, making it impossible to map them separately at the chosen scale. *Cyperus fastigiatus/Schoenoplectus corymbosis* marsh, and bulrush marsh, occur under permanent to semi-permanent saturation/flooding, with *Eleocharis spp.* marsh usually dominating under drier conditions (i.e. semi-permanently to seasonally saturated/flooded). One often finds wet grassland or wet meadow grading into a *C. fastigiatus/S. corymbosis*/bulrush/*Eleocharis spp.* marsh mosaic through an area dominated by *Eleocharis spp.* marsh.

Sedge/bulrush marsh soils are characterized by a shallow upper, soft layer, and intermediate abundance of roots in the upper layer. Root mats occur less frequently in this vegetation type than in reed marsh. Gleying occurs all the way to the surface.

4. Sedge meadow

This vegetation type is transitional between marsh and wet grassland in terms of plant species composition and water regime. Plant species richness is relatively high in sedge meadow, probably because it occurs in an ecotonal zone.

Where sedge meadow is hummocked, it is fairly clearly defined and easy to recognize. However, distinguishing wet meadow visually is difficult in Wakkerstroom vlei, because there are no hummocked areas. It occurs mainly as a narrow transitional area between sedge/bulrush marsh and wet grassland and in small localized wetter patches within areas of wet grassland. Sedge meadow areas have been excluded from the map, not because they are considered unimportant, but because they are too small to map at the chosen scale. A detailed higher resolution description would be required in order to delineate sedge meadow accurately.

5. Wet grassland

This vegetation type forms the transitional zone between the wetland and non-wetland and is confined to temporarily flooded/saturated areas. The outer perimeter wetland area comprises wet grassland. The width of this zone varies greatly from 1-20 m in those areas where the adjacent non-wetland areas are sloped (>2%), to over 500 m where the adjacent areas are flat (<2%). In addition, wet grassland occurs on the drier areas of Sector 1, over most of Sector 4, on the wide side arm extending from the western edge of Sector 2, and in all the other narrower side arms where, together with sedge/bulrush marsh, it predominates.

Soils in the wet grassland have few roots in the A horizon and gleying that usually starts below 10 cm. Although all wetland areas are characterized by gleying within the upper 50 cm of soil, at the dry extreme of the wet grassland, gleying occurs only below 40cm. This range of wetness is reflected in the vegetation species composition. At one extreme, species commonly occurring outside of wetland areas, such as *Eragrostis plana*, are dominant but occasional hydrophytes occur. These hydrophytes consist predominantly of species such as *Bulbostylis schoenoides, Fuirena pubescens, Kyllinga erecta, Schoenoplectus decipiens, Hermarthria altissima, Andropogon appendiculatus* and *Eragrostis planiculmis* all of which are restricted to seasonally or temporarily saturated areas (as inferred from the appearance of the soil). At the other extreme, the above hydrophytes dominate and the less wetland-restricted species, although not dominating, still occur frequently.

6. Open water

Open water refers to permanently or semi-permanently flooded areas with very sparse or no emergent plants. Approximately 2 ha. of Wakkerstroom vlei comprises permanent open water. Two patches each occur in Sectors 1 and 3 and a single large patch in Sector 2 on the western edge of the reed marsh zone.

The airphotos indicate that the formation of open water patches and their demise because of colonization by mat-forming emergent plants is common in the reed marsh area. Two open water patches present above the Volksrust road in 1969 had been lost by 1979 (presumably through colonization by emergent plant such as reeds) and replaced by a single patch in the centre of the reed marsh area. By 1990 this, in turn, had been lost and replaced by two new patches, in different positions from those of 1979. No reed marsh open water patches are discernable in the 1938, 1953 and 1961 airphotos. While this may be due to the poor quality of the 1953 and 1961 photos, the 1938 photos are clear.

The most important factor causing the formation of open water patches is fire that burns down into the upper root-rich soil layer. This is a rare event, occurring only in exceptionally dry years when the upper root layer dries out.

REPORT TO THE WATER RESEARCH COMMISSION

A MANAGEMENT PLAN FOR NTABAMHLOPE VLEI

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EXECUTIVE SUMMARY

Ntabamhlope vlei, ca 285 ha in extent, is situated in the upper Little Bushman's River catchment (which falls within the Tugela catchment) in Bioclimatic Group 4e (mean annual rainfall= 980 mm). The underlying geology is Beaufort Group Sandstone, and Katspruit is the predominant soil form. The primary land-use in the catchment is forestry, with much of the area having recently been afforested. The wetland has various vegetation communities including reed marsh, sedge/*Leersia* marsh, wet meadow and wet grassland. It supports two breeding pairs of the endangered wattled crane. Due to the very comprehensive long-term hydrological modelling that has occurred in the Ntabamhlope vlei catchment, the wetland has a high research value. It is also considered to have a high water purification and streamflow regulation value.

Most of Ntabamhlope is government owned land controlled by the Department of Works and Land Administration, and the rest is owned by a forestry company, Masonite. The predominant land-use occurring in the wetland is grazing of the natural vegetation. Erosional degradation is largely absent from the wetland and little development has occurred.

In order to encourage sustainable use of the wetland while minimizing the loss of wetland functional values, an overall management goal and management objectives are proposed and a series of management guidelines have been devised indicating how to achieve the specific objectives (Fig. 1). The management guidelines which are given in more detail in Section 7 and summarized in Table 1, relate primarily to:

1. controlling the extent and frequency of burning;

2. controlling the intensity and timing of grazing;

3. enhancing habitat diversity and suitability for birds; and

4. giving consideration to the research value of the wetland.

OVERALL MANAGEMENT GOAL: Maintain the wetland and its catchment as a research site and maximise the direct benefits derived by different users of the wetland without significantly detracting from the wetland's ecological, hydrological, erosion control and research opportunity values, which benefit society at large.

MANAGEMENT OBJECTIVES | **SUMMARIZED MANAGEMENT GUIDELINES**

Protect the hydrological and erosion control values

- Where drainage channels are not being used to enhance sustainable utilization, block the drains to reclaim the wetland.
- Prevent further drainage.
- Apply the recommended stocking rate norms to the hygrophilous grassland areas.
- Utilize marsh and wet meadow areas provided that it does not lead to puddling of the soil.
- As far as is possible avoid grazing flooded or saturated areas.
- Restrict grazing in hydrologically sensitive areas (i.e. seepage slope areas).
- Ensure judicious catchment management.

Protect the ecological values

- Protect the hydrological and erosion control values because the greater the hydrological disruption, the greater will be the likely impact on the ecological values.
- Attempt to leave at least half the wetland unburnt each year in order to provide cover for wetland dependant species. Consult an ornithologist to determine which protected areas would be most beneficial.
- Maintain populations of red data species and other species considered to be of particular importance. At present the only species identified as requiring individual attention are the Wattled Crane and Grass Owl. The following recommendations have been developed for these species.

<u>The Wattled Crane</u>

* Monitor breeding success.
* Avoid mortalities of chicks due to fire by:
  - considering delaying burning if chicks are still unable to fly
  - observing where the chick/s are at the proposed time of burning and, if possible, burn strategically; and
  - if eggs are present and likely to be burnt, temporarily remove them.
* Upland grassland slopes adjacent to wetland areas that are used for breeding by Wattled Cranes should not be afforested as this will detract from the habitat value.
* Consult an ornithologist.

<u>The Grass Owl</u>

* Leave at least 30% of the wet meadow areas unburnt.
* As far as is possible, burn biennially in early spring with occasional winter fires to enhance diversity.
* Leave at least 50% of wet meadow areas leniently grazed, particularly in the late summer, to allow for the accumulation of adequate cover for autumn breeding.

Allow controlled use of the wetland through the following activities:

* **Early winter burning for fire control purposes**
  - Where possible burn fire breaks around wetland areas.
  - Leave at least 30% of the wet meadow and marsh areas unburnt in a given year.
* **Domestic stock grazing**
  - Maximise the grazing potential by using marsh areas (as far as wetness and accessibility will permit) in preference to wet meadow and hygrophilous grassland areas during spring.
  - Minimize the impact on hydrological and erosion control values by following the guidelines already given.
  - Minimize the direct impact on ecological values by following guidelines already given.
* **Research**
  - Encourage further research at Ntabamhlope Vlei due to the comprehensive wetland monitoring network present and the importance of this research.

Fig. 1 Ntabamhlope vlei management framework

Table 1 Summary of the principal management recommendations

Burning	*	Unless in an area where fire risk is particularly high, burn biennially in early spring, with occasional winter fires to enhance diversity.
	*	Leave at least 20% of the sedge meadow areas unburnt that fall within high fire risk areas burnt annually in early winter.
	*	Avoid burning the entire main body of the wetland in any one year.
	*	Burn under conditions of high humidity and low air temperature.
	*	Preferentially burn areas with abundant dead material.
	*	Keep accurate records.
Grazing	*	Apply the standard stocking rate norms to hygrophilous grassland areas.
	*	Marsh and sedge meadow areas may be utilized provided it does not lead to excessive trampling.
	*	If possible, avoid grazing flooded or saturated areas.
	*	Enhance diversity by having some areas very leniently grazed.
Research	*	Because of the comprehensive wetland hydrology monitoring network, further research should be encouraged at Ntabamhlope Vlei.
	*	Monitor land-use changes in the wetland and the catchment.
Drainage reclamation	*	Where drainage channels are not being used to enhance sustainable utilization, block the drains to reclaim the wetland.

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1. OVERALL MANAGEMENT GOAL

The overall management goal for Ntabamhlope vlei is to maintain the wetland and its catchment as a research site and to optimize the wetland benefits derived by the different users of the wetland without significantly detracting from the wetland's research usefulness and its ecological, hydrological and erosion control values, which benefit society.

2. GENERAL SITE DESCRIPTION

Ntabamhlope vlei, approximately 285 ha in extent, (29°03'S; 29°39'E) is situated in the upper Little Bushmans River catchment (which falls within the Tugela catchment) (Fig. 2). The wetland extends 8km from its inlet (1510 m) to its outlet (1450 m) (Fig. 3). This gives an average slope of 0.8%. It is underlain predominantly by Beaufort Group Sandstone of the Karroo Supergroup. The wetland soils are acidic. In the permanently to semi-permanently saturated/flooded areas, they consist of a complex of the Champagne form and the Katspruit form (Lammersmoor family). In the seasonally and temporarily saturated/flooded areas, soils are predominantly of the Katspruit form (Lammersmoor family) and, to a lesser extent the Westleigh form.

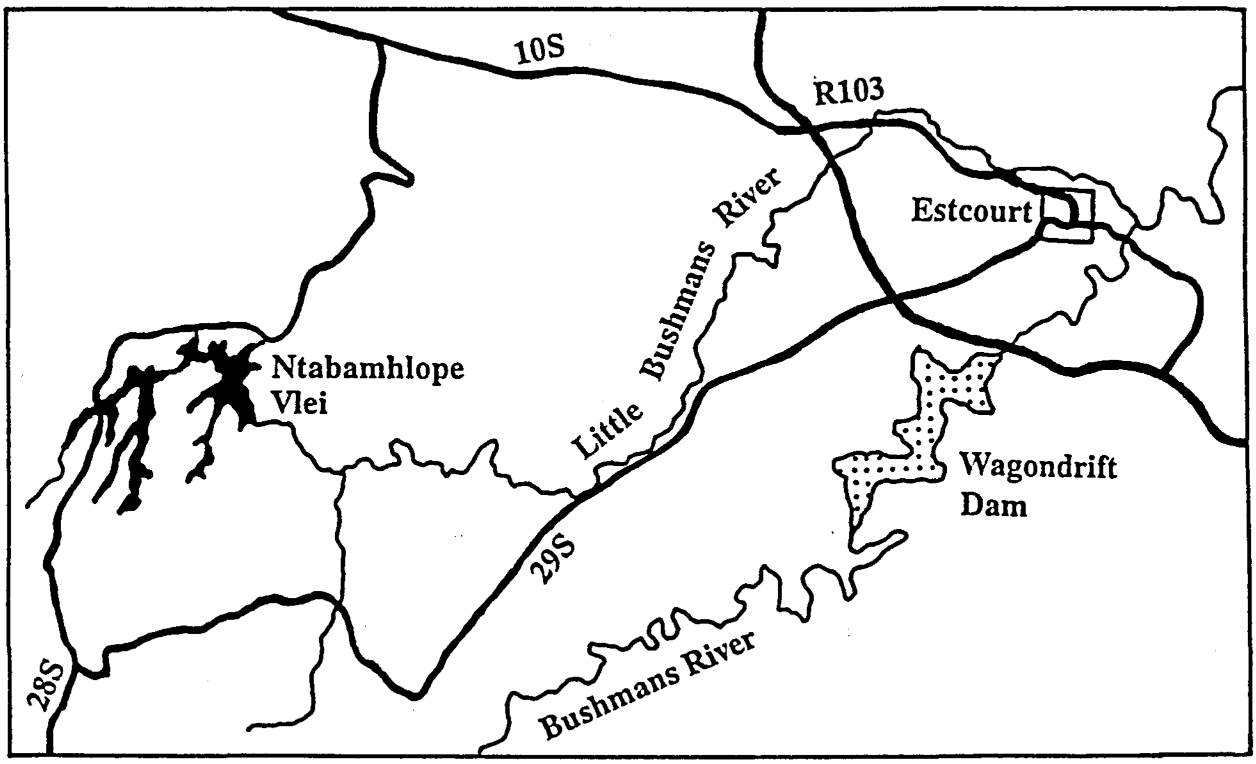

Fig. 2 Location of Ntabamhlope vlei

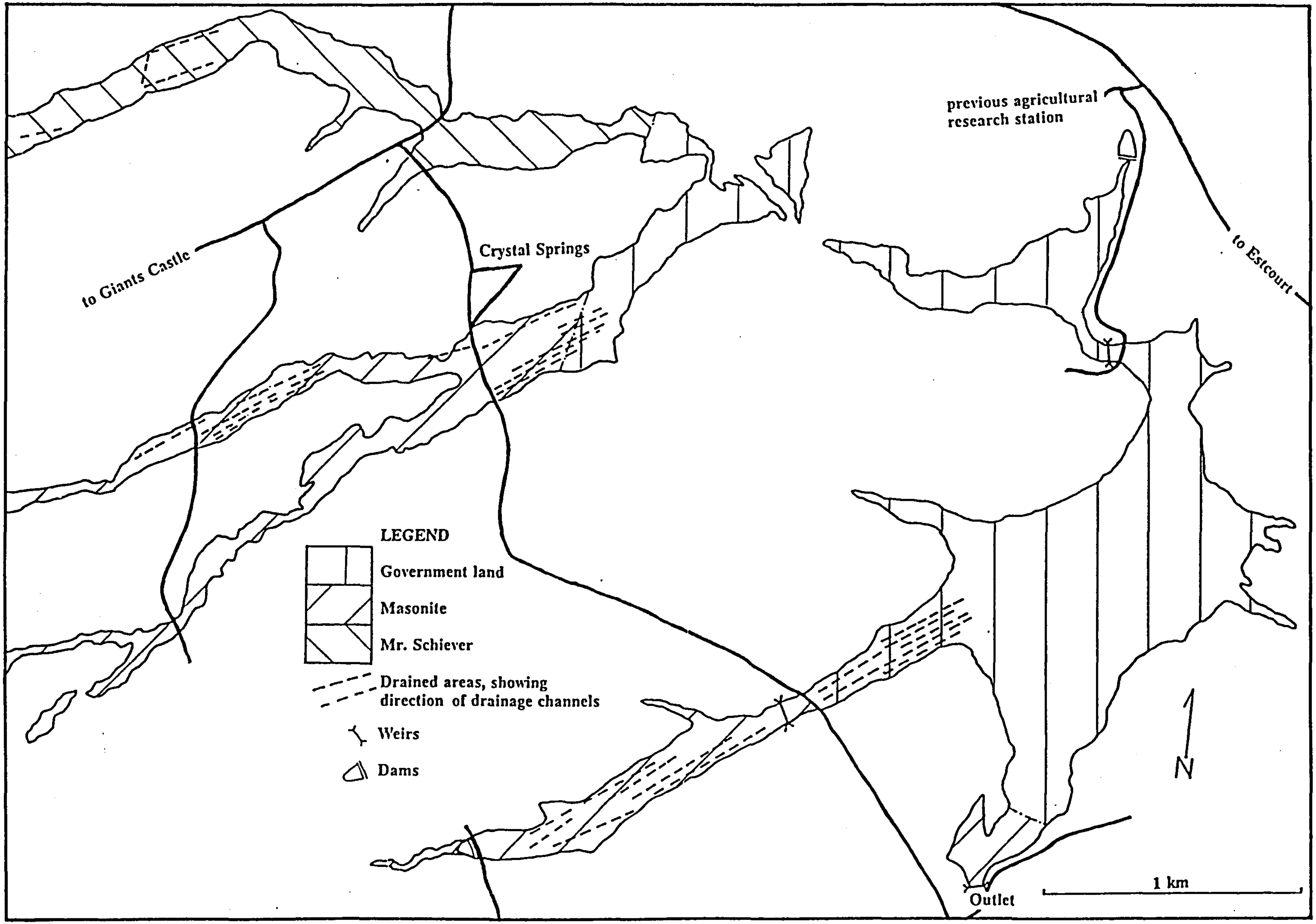

Fig. 3 Ntabamhlope vlei, showing land ownership (as in 1992) and wetland alterations.

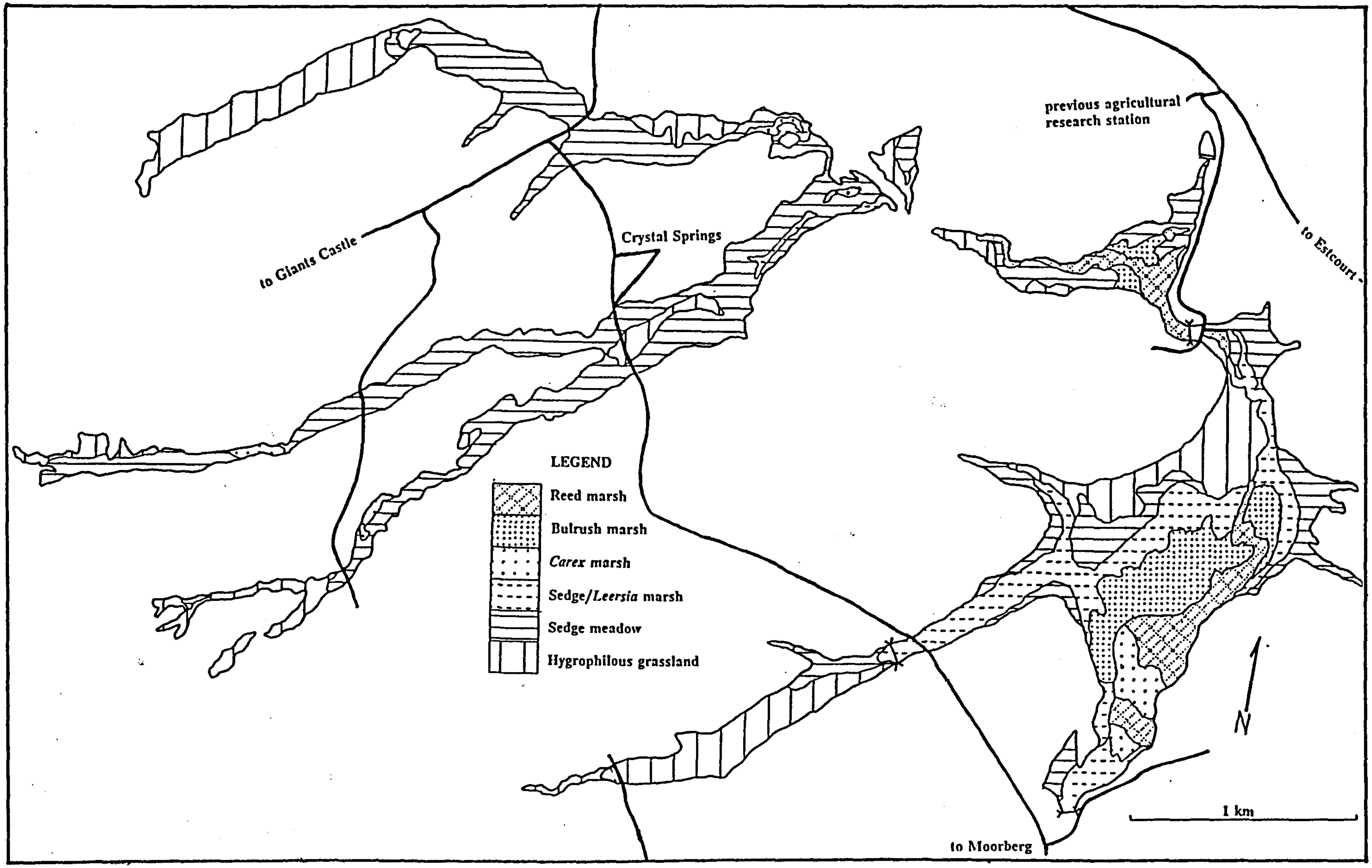

Fig. 4 Distribution of vegetation types occurring in Ntabahlope vlei.

The main body of the wetland, lies at its lower end. Branching side arms extend from this main body. Seven principal vegetation types (the distribution of which is given in Fig. 4) are found in Ntabamhlope vlei:

reed marsh,
bulrush marsh,
Carex marsh,
sedge/*Leersia* marsh,
wet meadow,
wet grassland, and
open water.

3. CATCHMENT DETAILS

The Ntabamhlope vlei catchment occurs within veld type 44a (Highland Sourveld) (Acocks, 1953) and Bioclimatic Region 4e (highland-montane) (Phillips, 1973). Mean annual rainfall is approximately 980 mm (82% in summer); relative humidity 70-75 %; mean annual temperature 15°C. Extreme daily temperatures may be 40°C and -12°C (Phillips, 1973).

The wetland occupies approximately 4.8% of its 3395 ha catchment. The predominant land-use in the catchment is forestry, with cultivation of eucalypts. Stock farming using natural veld, planted pastures and fodder crops is second in importance. The most important effect of afforestation on the wetland is the reduction in water input due to increased transpirative loss by the trees. As the trees are evergreen, their effect in reducing ground water would be most apparent during the dry season, when grasslands are largely dormant and non-transpiring, but trees continue to actively transpire. No apparent change in plant community distribution that may be attributable to reduced water input appears to have occurred in the last 30 years. The farms Springbok, Crystal Springs and Moorberg have recently been afforested. These farms include a large area of the catchment and, as such, the effects on the wetland may become apparent later.

Afforestation also disadvantages certain wetland dependant species, such as the wattled crane (*Grus carunculata*), which utilize the adjacent grassland.

4. REGIONAL SIGNIFICANCE OF THE WETLAND

As it has a large surface area, low slope and high surface roughness, Ntabamhlope vlei is considered to have high water purification and streamflow regulation values. Because of the water users downstream who are dependant on assured yields of good quality water, the wetland is of regional significance. Begg (1989) recognizes it as one of KwaZulu/Natal's priority wetlands. Seen in the context of the overall Bushman's River catchment, the positive influence that the wetland has on water quality is impaired by mismanagement of the catchment further downstream, where the climate is more arid and severe soil erosion is occurring.

Due to extensive long-term hydrological monitoring in the Ntabamhlope vlei catchment, this wetland is an extremely valuable wetland research site.

It supports 2 breeding pairs of the endangered wattled crane (*Grus carunculata*), as well as breeding grass owls (*Tyto capensis*), another important bird species from a conservation point of view.

5. LAND OWNERSHIP AND LAND TENURE

Approximately 80 ha of Ntabamhlope vlei is owned by Masonite. The remaining 205 ha is government owned land now controlled by the Department of Works and Land Administration pending a decision on its future use. Of the 205 ha, 156 ha were previously part of the Department of Agricultural Development Research Farm, now leased out as grazing land, and 49 ha were previously owned by a farmer, Mr. Schiever, who now leases them (Fig. 3).

6. WETLAND VEGETATION TYPE DESCRIPTIONS

Seven vegetation types have been defined for the purposes of management (Table 1). Reed marsh, *Carex* marsh and bulrush marsh occur in permanently to semi-permanently flooded/saturated areas. The soils in some of these areas are characterized by a relatively high abundance of roots forming what is sometimes referred to as a root or floating mat. Sedge/*Leersia* marsh has the widest range of water regimes, from permanently flooded to seasonally saturated.

Wet meadow is transitional between the marsh vegetation types and wet (hygrophilous) grassland in terms of plant species composition, soil characteristics and water regime. It includes hummocked wet meadow, which has vegetation covered earth-hummocks, and non-hummocked wet meadow, which lacks hummocks. Hummocked wet meadow is far more extensive than non-hummocked wet meadow. Because of the variety of microhabitats and the ecotonal nature of this vegetation type, plant species richness is relatively high.

Wet grassland forms the transitional zone between the wetland and non-wetland (dryland) and is confined to temporarily flooded/saturated areas. Species consist of a mixture of those species that occur predominantly outside wetland areas (e.g. *Tristachya leucothrix)* and hydrophytes restricted to seasonally or temporarily saturated areas (e.g. *Arundinella nepalense*).

Approximately 0.8 ha of Ntabamhlope vlei comprises permanent open water: the areas occurring in the reed marsh tend to be much deeper than the open water in the bulrush marsh.

Table 1 Dominant plant species, water regimes and soil characteristics of Ntabamhlope vlei vegetation types

Vegetation type	**Dominant plant species**	**Water regime and soil characteristics.**
Reed marsh	*Phragmites australis; Leersia hexandra; Carex acutiformis; Carex cognata*	Permanently to semi-permanently saturated/ flooded; upper B horizon soft and unconsolidated to >1.0m depth; A horizon with very abundant roots; gleyed to the surface.
Carex marsh	*Carex acutiformis; Carex cognata*	As for reed marsh.
Bulrush marsh	*Typha capensis; Leersia hexandra*	Permanently to semi-permanently saturated/ flooded; B horizon often not soft and unconsolidated, but if so then <1.5 m; A horizon with abundant roots; usually gleyed to the surface.
Sedge/*Leersia* marsh	*Carex cognata; Cyperus fastigiatus; Leersia hexandra; Schoenoplectus corymbosus*	As for bulrush marsh but permanently to seasonally saturated/ flooded
Sedge meadow	*Andropogon appendiculatus; Aristida junciformis; Kyllinga erecta; Leersia hexandra*	Intermediate between sedge/*Leersia* marsh and hygrophilous grassland.
Wet grassland	*Agrostis eriantha; Andrapogon appendicularis; Aristida junciformis; Arundinella nepelense; Kylinga erecta;*	Temporarily flooded/ saturated; upper B horizon always hard and consolidated; A horizon with relatively few roots; gleying seldom within uppermost 10 cm of soil.
Open water	*Largarosiphon major;*	permanently flooded; soft upper unconsolidated B horizon < 1.0 m.

7. CURRENT AND PAST USE OF THE WETLAND AND RECOMMENDATIONS FOR FUTURE USE

This section describes those land-uses that have been, and still are being applied to the wetland and makes recommendations for future use. It also deals with activities that are not land-uses *per se* but are associated with one or more of the land-uses (e.g. burning). All these land-uses and land-use related activities are described in terms of their effect on the hydrological, erosion control and ecological values of the wetland.

7.1 Burning

7.1.1 The effect of burning on the wetland's functional values

Because of the high lightning frequency in the area, lightning fires are certain to have occurred in the past, and are likely to have had an important effect on the wetland, even if they were infrequent. Indigenous inhabitants of the surrounding area, and later European settlers, are likely to have increased fire frequency. It appears that the wetland has been burnt relatively frequently for at least the last 60 years. Downing (1966) records that the lower portion was burnt annually in September since 1937.

Those side-arm portions falling within the afforested land owned by Masonite are currently burnt annually in early winter (May/June). This is done to reduce the high fire risk caused by these areas being unburnt for the whole fire season. The least frequently burnt areas are some of the wetland areas leased by Mr. Schiever. The fire frequency of the Government owned land has been decreased only in the very recent past, with no burns occurring in 1989 and 1990. A run-away fire burnt almost all the main wetland body in September 1991. In 1992 this area remained unburnt but was again burnt in a run-away fire in 1993.

By temporarily removing cover, burning diminishes the habitat value for birds and small mammals, with winter breeding birds being particularly severely affected (Johnson, 1991). However, provided adequate unburnt areas are left from which recolonization of the burnt areas may occur, burning is unlikely to have a substantial negative effect on the habitat provision value of the wetland. In reducing the shading effect caused by the accumulation of old leaf material from emergent wetland plants, burning generally increases the growth rate of new leaves (Johnson and Knapp, 1993). This, in turn, may positively affect the animals dependent on these plants. For example, a controlled burning programme, as opposed to complete protection, was shown to increase the value of sedge marsh for the red-chested flufftail (Taylor, 1991).

By removing unpalatable old growth and stimulating new, fire improves the grazing value of wetlands, serving the interests of stock farmers. Thus, a decrease in the fire frequency would be detrimental to the grazing value of the wetland. It has been shown that in order to maintain Highland Sourveld grasslands in a healthy vigorous state, regular burning in the dormant season is desirable (Tainton, 1981). While this may be true for certain wetland types, particularly wet grassland, the effect on other types is unclear due to the lack of relevant research in KwaZulu/Natal wetlands.

In assessing the impact of burning, consideration must be given to the season in which it occurs. Both spring and early winter fires occur in Ntabamhlope vlei. In grasslands, autumn burning may lower the veld condition because if it stimulates an autumn flush, this weakens the competitive ability of the grass plants in the following growing season and favours unpalatable species (Tainton, 1981). However, provided the burn occurs in the plants' dormant period, as would be the case in June (when Masonite burn), it is unlikely to affect the condition of the grassland. In addition, a burn at the beginning of the dry season is more likely to be patchy than one at the end of the dry season. Indications are that this is usually the case in Ntabamhlope. The disadvantage of burning at this time would be that species with breeding seasons that overlap this period, such as the grass owl (*Tyto capensis*), would be affected negatively. Another important factor is the time taken for re-establishment of cover. In early spring burning, cover is re-established in about one month, whereas in early winter burning, re-establishment occurs only after about four months.

In marsh, where the water table remains close to the surface through the dry season, standing plant material reduces evaporation through its high reflectivity and protection of the soil surface from wind. Thus, its removal by fire at the beginning of the dry season is likely to result in an increase in evaporative loss from the wetland which, in turn, could cause reduced early wet season flows. Increased dry season evaporative loss caused by early dry season burning is also likely to occur from wet meadow areas, but to a smaller extent. Unfortunately very little work has been done on this aspect of burning. Therefore it is impossible to begin to quantify the water losses being incurred by early dry season burning to avert fire risk.

There are no studies of the ecological effect of fire on KwaZulu/Natal wetlands. Observations made on some of Ntabamhlope vlei side arms which have been protected from fire for some years suggest that the exclusion of fire results in an increase in alien "weedy" species such as *Verbena bonariensis*. Personal observation of very infrequently burnt portions of Memel vlei, Orange Free State, and Boschoffsvlei, KwaZulu/Natal confirms this observation. In the Highland Sourveld areas it has been clearly demonstrated that fire may assist greatly in preventing alien plant invasion. Thus, fire could be useful in controlling alien plants in wet grassland and wet meadow areas. Alien plant invasion is generally not a problem in marsh areas of Ntabamhlope vlei because there are few invasive plants adapted to these cold and extremely wet conditions.

7.1.2 Burning recommendations

A recommendation of biennial or triennial early spring burning is made on the grounds of maintaining grass vigour, controlling invasive plants, having minimal impact on the breeding of wetland dependant birds and enhancing grazing value. However, it is recognized that early winter burning of the wetland in the afforested areas is required because of the fire risk. Because these practices may have negative effects (discussed in section 7.1.1) a meeting was held with Masonite field and management staff and Natal Parks Board personnel. It was decided that strip burning would be the best means of achieving a compromise between maximising fire risk reduction and minimizing the loss of wetland habitat and hydrological values.

Block burning, while being easier to implement and equivalent to strip burning in terms of minimizing the loss of hydrological and habitat values, would be less effective from a fire protection point of view.

Strip burning will probably best be approached by using a herbicide to kill only the aerial portions (e.g. Gramoxen) to prepare a burning trace. Where the wetland tongue is wide (>500 m), it should be divided into three strips, but where narrow, two strips will do. The strips could then be burnt alternately on a rotational basis such that in any year all tongues have at least one strip burnt. In order to protect breeding Grass Owls, the following steps should be taken:

1. identify those areas used by the grass owl for breeding; and

2. check these areas for breeding owls before burning. This may be done by having 'beaters' 10 m apart walking through the area and examining sites where grass owls are flushed (Johnson, pers comm.). Areas where chicks have still not fledged would then be left unburnt for that year, or, if possible, burning for that year could be delayed.

The following general burning guide-lines are also recommended for both early winter and early spring burns:

1. avoid burning the entire main body of the wetland by burning on both sides of the road that divides it into the up-stream and downstream portions;

2. burn "cool", i.e., under conditions of high humidity and low air temperatures, preferably shortly after rain;

3. areas with abundant dead (moribund) stem and leaf material that is obviously limiting new growth should be burnt preferentially;

4. by reducing the fuel load and creating puddles, cattle can be used to promote patchy burns;

5. if wetland plants are to be harvested, this should be done, whenever possible, in areas useful for fire-breaks; and

6. keep accurate burning records to help develop an adaptive management strategy.

Due to the winter breeding habits of wattled crane, chicks may still be unable to fly at the recommended burning time. In order to avoid burning mortalities the Natal Parks Board should be consulted and the following recommendations should be adhered to:

1. consider delaying burning if the chick is close to flying;

2. locate the chick at the time of burning and avoid the location by burning strategically; and

3. if eggs are present and likely to be burnt, temporarily remove them and replace them in the nest after the burn.

7.2 Stock grazing and hay cutting

7.2.1 The effect of hay cutting and stock grazing on the wetland's functional values

Currently, hay cutting occurs only on a 12 ha area of the side arm within the Schiever farm. Stock grazing occurs here, as well as on the main body of the wetland, principally in the wet meadow and wet grassland areas. Most of the side arm portions are owned by Masonite, and here, no hay cutting and extremely limited grazing occurs. Because there is limited hay cutting occurring, this practice is unlikely to detract significantly from the functional values of the wetland. If it is confined to times when the soil is relatively dry, mowing would compact and disrupt the soil less than grazing which occurs during wet and dry periods.

Downing (1966) records that the lower portion was once intensively grazed by sheep, horses and cattle, but that since the erection of a fence around the wetland in 1937 only cattle have grazed here. Given high soil erodibility and/or steep slopes, high levels of wetland utilization by cattle can easily lead to the formation of rapidly incising erosion channels which may ultimately dry out the wetland. However, factors such as low slope and moderately low soil erodibility in Ntabamhlope vlei have prevented this from occurring so far. In addition, being in the Highland Sourveld, the decrease in basal cover associated with decreased veld condition is very small in comparison to that which occurs in more arid veld types. Thus, the danger of excessive erosion occurring as a result of over-utilization is lower than in the neighbouring De Hoek area.

The effect of cattle grazing and trampling in marsh areas is generally to decrease aerial cover of the dominant plant species and to increase the extent of exposed mud puddles (Appendix 2). This tends to increase the diversity of microhabitats, which is seen as favourable. However, prolonged heavy grazing disadvantages species such as the grass owl, which requires tall dense cover for nesting. Heavy, prolonged grazing disturbs the soil and so detracts from the hydrological and erosion control values of the wetland, particularly if the soils are wet at the time of use. However, most mature marsh plants are unpalatable and marshes are generally difficult to access by cattle. Marsh utilization may therefore be too low to detract significantly from the erosion control value of the wetland.

Downing (1966) also attributes hummock/depression morphology found in hummocked wet meadow to trampling by cattle. However, it appears that other more important site specific factors, such as the building activities of ants and earthworms (Edwards, 1963; pers. obs., 1991), are responsible for the development of this morphology in Ntabamhlope vlei (see Appendix 2).

Migratory herds of large indigenous grazers that may have once utilized the wetland no longer do so. The effect of these animals could, to some extent, be simulated by domestic stock. Thus, it is probably more natural to have moderate numbers of stock grazing the wetland than to exclude them.

Grazing-resistant perennial grasses, such as *Eragrostis plana*, occur as dominants in less than 10% of the wet grassland areas, suggesting that prolonged heavy grazing of these areas may have been fairly limited. However, *Aristida junciformis* (which is undesirable from an agronomic point of view because of its very low palatability) occurs as a dominant or co-dominant species over approximately 45% of the wet grassland areas. It is difficult to manage for the demise of *A. junciformis* as it may increase in abundance under both heavy and very light grazing pressure. Because of this, its abundance is not necessarily an indication of past heavy utilization.

7.2.2 General recommendations for stock grazing

From the discussion so far, it would appear that the diversity of the over-all system would be enhanced by having domestic stock in Ntabamhlope vlei. Thus, it is recommended that the main wetland body and the immediate surrounding catchment area continue to be leased out for stock grazing.

Bench-marks have not been described for the wetland areas within the different bioclimatic regions of KwaZulu/Natal, nor have any recommended stocking rates been proposed. Thus, the WETLAND-USE system (described in Kotze, 1992) was used to recommend a provisional stocking rate for Ntabamhlope vlei. From a grazing point of view, the wet grasslands are similar to the surrounding non-wetland grasslands. Thus, the same recommended stocking rate norms (as given by Tainton *et al.*, 1980) may be applied to wet grasslands, provided attention is given to the potential detrimental effects to the soil when wet. The recommended stocking rate norms for the area, which apply to veld in good condition, should be reduced by an amount proportional to the relative abundance of Increaser II species present.

In the mid and late grazing season, domestic stock tend to select strongly for wet grassland and less strongly for wet meadow. They avoid marsh. This is mainly because most mature marsh plants are unpalatable and because certain marshes are inaccessible when wet. Usually it is only in the early growing season when the wetland areas often commence growth before the dryland areas that accessible marsh areas are grazed by cattle. The stocking rate needs to be decreased by an amount proportional to the amount of marsh and wet meadow. The calculations for Ntabamhlope vlei are as follows:

Stocking rate norm for the area: 0.7 AU/ha
Corrected stocking rate (CSR): 0.7 x 0.8* = 0.56

Total number of animals = (0.56 x total ha of grassland and wet grassland) + (0.56 x total ha of accessible marsh x 0.4) + (0.56 x total ha of wet meadow x 0.6)

* 0.8 was chosen because the contribution of Increaser II species ranges between 30 and 50% for the different wet grassland areas of the wetland.

Where wetland areas occur in non-afforested areas, it is recommended that they be fenced off separately from the non-wetland grasslands. Fencing of the grassland areas (including wetland areas) into grazing camps would provide a greater degree of livestock control, allowing for the resting of specified areas. However, fences would have the following disadvantages:

1. the areas to be fenced have irregular, awkward shapes;

2. fencing is expensive; and

3. fences may interfere with the movement of wildlife (Johnson, pers comm., Natal Parks Board, P O Box 662, Pietermaritzburg, 3200)

As an alternative to fences, the movement of livestock could be controlled through such measures as herding, the strategic placement of licks and the strategic use of fire. Unburnt areas would tend to be avoided by livestock because of accumulation of dead material. Such unburnt areas could be rotated as required. A flexible rotational system is recommended, whereby the wetland area is grazed until a predetermined level of use or disturbance is achieved, beyond which continued use is likely to begin detracting from the hydrological and ecological values of the wetland, and often its current production potential. A full 12 months rest is included every 4 years. It is very difficult to prescribe a threshold level of use, as it will depend on the vegetation type and no guidelines exist. A suggested level is when the sward has been grazed to an average height of 8 cm and/or when the most favoured plants have been grazed to 5 cm high.

Rotational grazing should, as far as is possible, be continued only until the soil becomes flooded or wet to the surface, at which stage it is recommended that grazing the wetland areas be avoided until they dry out again. It has been widely shown that both mineral and organic soils become more susceptible to compaction and damage (e.g. truncation) when they are wet (Bayfield, 1973; Bryan, 1977; Stewart and Cameron, 1992). This should be avoided because it not only decreases herbage production, but it also increases the susceptibility of the soil to erosion.

The exclusion proviso based on soil wetness may appear to be over-conservative and difficult to implement. However, it is important to note that when the need for grazing to supplement drought limited upland grazing is high then grazing of the wetland is usually permissable. This is because it generally corresponds to times when the wetland soils are least susceptible to erosion and are considered to be acceptably dry for use. In contrast, when the use of the wetland is likely to have the greatest impact (because it is wet to the surface) the need for wetland grazing is likely to be low because it usually corresponds with wet periods when non-wetland production is high and the need to use the wetland is lowest.

7.2.3 Recommendations for use of the Masonite area by neighbouring communal graziers

The Masonite property lies adjacent to a communally grazed KwaZulu area, where there is a great demand for grazing lands. As one of the means of fostering good neighbour relations, a proposal has been made to allow controlled grazing of the non-afforested areas on the Masonite property. Successful implementation of controlled usage of the grazing resource in this area will involve:

1. recommending an appropriate stocking rate and grazing system; and

2. adopting an effective means of dealing with the neighbouring community and regulating use of the resource.

7.2.3.1 Recommending an appropriate stocking rate and grazing system for the Masonite area

General recommendations have already been made concerning stocking rate and grazing system and these should be adhered to. There are, however, certain recommendations unique to this situation that must be added.

The lenient grazing of the Masonite areas is likely to be currently favouring the grass owl. Should grazing pressure increase, then specific measures should be taken to ensure the continued success of this species. Identified breeding areas should be grazed leniently to allow for accumulation of sufficient dense growth required by Grass Owls when they breed, with the peak laying time occurring from February to April (Steyn, 1982). As recommended for burning, a breeding census of these birds would assist in identifying the areas where highest returns would be derived from protection. Rotational burning could be used effectively to encourage cattle to leave long-grass areas. Those areas remaining unburnt in a given area would be less heavily used by cattle than the burnt areas (provided that the stocking rate was within the recommended levels) and would be so allowed to accumulate more herbage..

Masonite may wish to restrict the time for when grazing is allowed. It is important to note that utilization of wetland areas in winter is least likely to result in significant impact because:

1. soils are at their driest and least prone to damage leading to excessive soil erosion; and

2. vegetation, particularly in the marsh areas, is in its least acceptable state for grazing.

In contrast, optimal utilization requires that the highest levels of utilization be in spring when the wetland vegetation is in its most acceptable state. At this time, the soils are usually still relatively dry and less prone to erosion than later in the growing season.

7.2.3.2 Applying an effective means of regulating stock numbers in the Masonite area

Controlling stock numbers is likely to be one of the major difficulties involved in allowing grazing of the Masonite areas. If discontent is to be avoided this needs to be done fairly. Possibly the fairest method is to sell the grazing rights on the open market to neighbouring cattle owners. The funds raised could then be used for community projects, so as to be seen to be of direct benefit to the community.

It is suggested that at first the stocking rate permitted on the Masonite area should be below the recommended norm. This would make it easier, from a neighbour acceptance point of view, to increase allowable grazing at a later stage.

7.3 Drainage channels

Approximately 57 ha of the wetland have been altered by drainage channels (Fig 2). These generally consist of primary channels (>50 cm deep) and secondary channels (ca.20 cm deep), usually parallel and spaced between 20- 100 m apart. By removing standing water more rapidly and decreasing the retention time of water moving through the wetland, the drainage channels are considered to detract from the hydrological and ecological values of these wetland areas. The channels are not being maintained and some are gradually decreasing in depth, through colonization by vegetation and sediment deposition. Their impact is decreasing, but this is a very slow process and is not occurring throughout this area.

When the water table of a wetland soil is artificially lowered, wetland soils tend to retain visible indicators of the natural or prior water regime long after the hydrology has been altered. A comparison of the soils with the current water regime (as indicated by the present vegetation) tends to indicate that while these areas are unnaturally dry, the water table has not been lowered drastically.

The channels were dug to intensify land-use, presumably for the planting of pastures. This land-use has been discontinued in most drained portions and the channels are no longer being used either. In view of this, and of the detrimental effect the channels have on the ecological and hydrological values of the wetland, it is recommended that these channels be blocked. It is encouraging to note that Masonite have begun this process on its property. On completion this should:

1. increase the hydrological value of these areas;

2. increase the habitat value by restoring the wetland areas to their original condition, which is likely to favour species such as the grass owl;

3. render the areas less prone to invasion by alien plants not adapted to waterlogged conditions, making alien plant control easier; and

4. decrease susceptibility to erosion.

Building rubble is readily available and has already been used successfully by Masonite for blocking some drains. This should continue to be used for plugging the drains. "Rubble plugs" alone are not entirely successful: complete occlusion occurs when sediment has been trapped and plants have become established. This could be hastened by placing soil with a high clay content on the upstream side of the rubble pugs.

7.4 Roads and other man-induced restrictions to water flow

The wetland is traversed by roads in six places. These road crossings undoubtedly modify the hydrology of the wetland because the road embankments have a damming effect. In addition, at some of the crossings, flow has been made more canalized downstream of the causeways. Flow has also been restricted by two small dams and measuring weirs (Fig. 3). However, these alterations appear to have very localized effects and are not large enough to constitute a threat to the wetland.

7.5 Crop production

No crop production occurs within Ntabamhlope vlei. This activity is considered unsuitable over almost all wet grassland areas in Ntabamhlope vlei because of frequent flooding or relatively steep slopes, which would result in significant loss of erosion control and hydrological values. Generally speaking, cropping also substantially detracts from a wetland's ecological value.

7.6 Ecotourism

Although Ntabamhlope vlei supports several crowned crane breeding pairs as well as two pairs of wattled crane, almost no bird-watching occurs in the wetland. Cranes are large, elegant and conspicuous birds. However, disturbance of wattled cranes is undesirable at the nesting stage of the breeding cycle, which usually occurs from June to August, and it is recommended that during this time, human presence be minimized near the nest, even though birding may be encouraged at other times.

Ntabamhlope vlei is one of the few priority wetlands in the KwaZulu/Natal midlands that has deep (>3 m) clear open water patches. These have high aesthetic value and may be good for swimming. Access is relatively easy as they are close to steeply sloped dry grassland. Flowers such as those provided by *Tulbaghia natalensis* and *Cyrtanthus breviflorus*, both common in wet meadow areas, also add to the aesthetic appeal of the wetland. However, the beauty of the wetland is diminished by features such as the afforestation of the immediate surrounds, and buildings and old lands close by.

Because it is near the White Mountain Inn, the ecotourism potential of Ntabamhlope vlei might be exploited, but access roads are poor. Visitor use would obviously need to be controlled through pre-arranged groups, for example, and could be confined to the non-fire season, if so required.

7.7 Research considerations

Reviews of hydrological literature have not shown the existence of a comparable network for monitoring so many aspects of a hydrological system around a wetland as at Ntabamhlope vlei. Thus, this wetland is an invaluable asset and it important to maintain it as a research catchment (Begg, 1989; Chapman, 1990). With this in mind, it is recommended that all land-use changes occurring in the catchment be monitored so as to make maximum use of the ongoing hydrological measurements.

It would be desirable to obtain the original plant community data that could serve as a baseline for the monitoring of vegetation changes, as the original survey markers used for the transects examined by Downing (1966) are still in place.

7.8 Game-bird hunting

Consideration is currently being given to the hunting of Ethiopian Snipe (*Gallinago nigripennis*) and Yellow-billed Duck (*Anas undulata*) by paying hunters at Wakkerstroom vlei, where they occur in relatively large numbers. Ethiopian Snipe are relatively common in sedge/*Leersia* marsh of the main Ntabamhlope wetland body and Yellow-billed duck are found in some of the open water areas. However, it appears that neither species occurs in sufficiently large numbers to make shooting ventures commercially viable.

7.9 Harvesting of wetland plants

No known harvesting of wetland plants occurs. Harvestable species, such as *P. australis* (the common reed), are abundant and controlled harvesting of wetland plants could be undertaken on a sustainable basis.

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10. GLOSSARY OF TERMS

Animal unit (AU). An animal with a mass of 450 kg and which gains 0.5 kg per day on forage with a digestible energy percentage of 55%. Other types of animals are related to this unit according to the relationship between the three-quarter power of their mass and a similar function of the mass of a 450 kg animal. An animal with a mass *m* constitutes:

$$\frac{m^{0.75}}{450^{0.75}} \text{ of an animal unit}$$

Bioclimatic regions. Phillips (1973) classified the extremely varied natural resources of KwaZulu/Natal into 11 bioclimatic regions based primarily on climatic parameters. These groups provide convenient natural resource classes in terms of which management guidelines can be formulated.

Chroma. This refers to the relative purity of the spectral colour, which decreases with increasing greyness.

Decreaser species: generally highly palatable plant species that dominate in well managed veld where grazing pressure is moderate, but decrease in abundance under heavy grazing pressure.

Dominant plant species. The dominant plant species are those overstory species that contribute most cover to the area, compared to other overstory species (Barbour, Burk and Pitts, 1984.

Ecological value. This refers to the value of the wetland in maintaining the biotic diversity of the area. Biotic diversity can be measured at many different levels making it almost impossible to prescribe a standard method to describe it. Its assessment may be simplified by determining the degree to which management is affecting biological integrity and populations of valued species.

Flats. Flats refer to a flat areas with slopes of less than 1%, usually situated in a bottomland positions.

Hydric soil. Soil that in its undrained condition is saturated or flooded long enough during the growing season to develop anaerobic conditions favouring the growth and regeneration of hydrophytic vegetation (vegetation adapted to living in anaerobic soils).

Hydrology. Hydrology is the study of water, particularly the factors affecting its movement on land.

Hydrophyte: any plant that grows in water or on soil that is at least seasonally deficient in oxygen as a result of waterlogging.

Increaser II species. plant species that tend to be less palatable and/or perennial than decreaser species and increase in abundance in mismanaged veld where grazing pressure is heavy.

Marsh zone. The marsh zone is dominated by tall (usually >1 m) emergent herbaceous vegetation, such as the common reed (*Phragmites australis*). Some marsh zone areas are seasonally wet but most are permanently or semi-permanently wet.

Mottles. soils with variegated colour patterns are described as being mottled, with the most abundant colour referred to as the matrix and the other colour/s as mottles.

***n* Value.** The *n* value refers to the relationship between the percentage of water under field conditions and the percentage of inorganic clay and humus and can be approximated in the field by a simple test of squeezing the soil in the hand. It is helpful in predicting the degree of subsidence that will occur after drainage (Pons and Zonneveld, 1965; Soil Survey Staff, 1990).

Open water zone. The open water zone comprises permanently or semi-permanently flooded areas characterized by few or no emergent plants.

Red data species. Red data species refer to all those species included in the categories of endangered, vulnerable or rare, as defined by the International Union for the Conservation of Nature and Natural Resources (Smithers 1986).

Soil saturation. the soil is considered saturated if the water table or capillary fringe reaches the soil surface (Soil Survey Staff, 1990).

Stocking rate. The stocking rate (SR) refers to the number of AUs per unit of land for a specified period of time. SR may be expressed in terms of number of land units per AU.

Wet grassland zone. The hygrophilous grassland zone is usually temporarily wet and supports a mixture of: 1) plants which are common to non-wetland areas and 2) short (< 1m) hydrophytic plants (predominantly grasses) common to the wet meadow zone.

Wet meadow zone. The wet meadow zone is usually seasonally wet and dominated by short (usually < 1.5 m) hydrophytic sedges and grasses common to temporarily or seasonally wet areas.

Wetland. Land where an excess of water is the dominant factor determining the nature of the soil development and the types of plants and animals living at the soil surface (Cowardin *et al.*, 1976).

Wetland functional values. Where wetland functions (e.g. the trapping of sediment) are of value to society, they are termed functional values. Wetland functions refer to the many physical, chemical and biological processes that take place in wetlands.

APPENDIX 1: VEGETATION TYPE DESCRIPTIONS

Downing (1966) provides a detailed description of the vegetation communities of the main wetland body. It should be emphasised that the seven vegetation types, described below, do not exist as discrete entities in reality but are defined for the purposes of management.

1. Reed marsh

This vegetation type is characterized by the dominance of *Phragmites australis* (the common reed), which occurs as the tallest species. The next most common species are *Leersia hexandra, Carex acutiformis, Carex cognata* and *Cyperus fastigiatus*. Soils are generally characterized by an A horizon with abundant root material, chromas of less than 1 and few to no mottles, indicating that these areas are permanently to semi-permanently saturated/flooded. In some areas the abundant roots form what is sometimes termed a "root mat", that quakes when jumped upon. The B horizon tends to be soft and unconsolidated to a depth of >1.2 m. Soft refers to the fact that an iron rod or auger is easily pushed in the full depth without twisting.

2. Carex marsh

Like the reed marsh, *Carex* marsh occurs in the central permanently to semi-permanently saturated/flooded wetland areas. It is dominated by *Carex acutiformis* and to a lesser extent *by Carex cognata.* Plant and bird species richness is the lowest of all vegetation types. Although it may provide habitat for white-winged flufftail, one of Africa's rarest birds, no records of these birds exist for Ntabamhlope. The soils in this vegetation type closely resemble those found in the reed marsh.

3. Bulrush marsh

Bulrush marsh, which occurs under permanently to semi-permanently saturated/flooded conditions, is dominated by *Typha capensis*, with *Leersia hexandra* occurring as the next most common species. Bulrush marsh soils resemble the soils found in reed marsh but tend to have a shallower upper unconsolidated soft B layer.

4. Sedge/*Leersia* marsh

This vegetation type spans the widest range of water regimes and plant communities, ranging from permanently flooded to seasonally flooded/saturated. *Leersia hexandra* is the dominant species over the widest area. Sedge species vary from locality to locality. The most common species are *Carex cognata, Carex acutiformis, Cyperus fastigiatus* and *Schoenoplectus corymbosus subsp. brachyceras*. Sedge/*Leersia* marsh soils are generally characterized by a relatively shallow upper unconsolidated soft layer, that is often absent. Gleying is present all the way to the surface.

5. Wet meadow

Wet meadow includes two sub-types: hummocked wet meadow, which is characterized by vegetation covered earth hummocks over 20 cm high and 50 cm in diameter, and non-hummocked wet meadow.

Non-hummocked wet meadow is very restricted to a narrow transitional zone between wet grassland and marsh, and is difficult to recognize. In contrast, hummocked wet meadow, which is very extensive in Ntabamhlope vlei, is fairly clearly defined and easy to recognize. Owing to their elevated position in relation to the water table, hummocks experience less prolonged periods of saturation than the inter-hummock depressions. This increases the microhabitats available in theses areas. The hummock plant communities resemble the wet grassland communities, while the channel communities resemble sedge/*Leersia* marsh.

6. Wet grassland

This vegetation type forms the transitional zone between the wetland and dryland (non-wetland) and is confined to temporarily flooded/saturated areas. As such, the outer perimeter of the wetland area comprises wet grassland. The width of this zone varies greatly from 1-20 m in those areas where the adjacent dryland areas are sloped (>2%), to over 300 m where the adjacent areas are flat.

Soils in the wet grassland have relatively few roots in the A horizon, and gleying that usually starts below 10 cm from the soil surface. Although all wetland areas are characterized by gleying within the upper 50 cm of soil, at the dry extreme of the wet grassland, gleying occurs only below 40cm. This range of wetness is reflected in the vegetation species composition. At one extreme, species which occur predominantly outside wetland areas, such as *Tristrachya leucothrix*, are dominant, but occasional hydrophytes occur. These hydrophytes include predominantly species such as *Arundinella nepalense, Bulbostylis schoenoides, Fuirena pubescens, Kyllinga erecta, Hermarthria altissima, Andropogon appendiculatus* and *Eragrostis planiculmis* all of which are restricted to seasonally or temporarily saturated/flooded areas (as inferred from the appearance of the soil). At the other extreme, the above hydrophytes dominate, and dryland species, although not dominating, still occur frequently.

7. Open water

Approximately 0.8 ha of Ntabamhlope vlei comprises patches of permanent natural open water. These occur in the main wetland body as a chain along the channel course in the reed marsh (average depth ca 4.5 m) and as a patch in the bulrush marsh (average depth ca1.5 m). It appears that the depth of the reed marsh patches restricts the aquatic vegetation (largely submerged species such as *Lagarosiphon major*) to the edges. In addition, open water has been created by two measuring weirs in the main wetland portion and by two small dams in the side arms.

Photographic comparison has shown that the reed marsh open water areas have remained unaltered in size and distribution since 1976. In contrast, the bulrush open water area has decreased in extent due to colonization by emergent aquatic plants, principally *Leersia hexandra*. This difference is likely to be due to the shallowness of the open water patches in the bulrush marsh areas.

APPENDIX 2: GRAZING AND TRAMPLING EFFECTS OF CATTLE ON MARSH AND WET MEADOW AREAS

Downing (1966) attributes hummock/depression morphology to trampling by cattle. However it appears that other more important site specific factors, such as the building activities of ants and earthworms (Edwards, 1963; pers. obs., 1991), are responsible for the development of this morphology in Ntabamhlope vlei. Although Downing (1966) found no ants in Ntabamhlope vlei hummocks, ants were observed there in 1992. Observation of similar hummocks in Mgeni vlei, suggest that these may have also been the result of ant or earthworm activity rather than resulting from the trampling down of the depression areas. Some *Cyperus unioloides* plants growing in hummocks have vertically orientated rhizomes with new growing points positioned several centimetres higher than older points. This sequence suggests that these mounds have been increasing in height recently.

No studies have been undertaken in any KwaZulu/Natal wetlands to determine the effect of stock grazing and trampling. However, comparison of two adjacent marsh areas on Mr. Schiever's portion of Ntabamhlope vlei that have been subject to different grazing treatments, allow some tentative conclusions to be drawn. One area has been moderately grazed; the other, separated by a farm boundary fence, has been protected from grazing. Physical factors such as hydrology and soils appear to have been the same for both sites. Thus, any observed features of the grazed area lacking in the ungrazed area can largely be attributed to grazing and trampling. When compared with the ungrazed areas, these grazed areas were found to have:

1. a less dense and less uniform aerial cover (provided by the dominant species);

2. a higher occurrence and greater extent of exposed mud puddles; and

3. greater plant species richness, probably as a result of the decreased cover which allows for the establishment of creeping semi-aquatic plants such as *Ludwigia palustris*, and disturbance which favours such species as *Echinochloa crus-galli*.

The creation of mud puddles, reduction in tall dense cover and maintenance of short vegetation areas by grazing stock improves the habitat for mud-probing birds such as the Ethiopian snipe (*Gallinago nigripennis*). However, bird species such as grass owl (*Tyto capensis*) (which require dense cover for nesting) and flufftails (which require this cover for nesting and foraging) would be disadvantaged by prolonged heavy stock grazing.

REPORT TO THE WATER RESEARCH COMMISSION

A MANAGEMENT PLAN FOR MGENI VLEI

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EXECUTIVE SUMMARY

Mgeni vlei, ca 300 ha in extent, is situated near the source of the Mgeni River in Bioclimatic Region 4e (mean annual rainfall= 980mm). It is underlain by Karoo dolerite and the soil is a complex of the Champagne and Katspruit forms. The wetland has various vegetation communities, principally *Carex* marsh and sedge meadow and is one of South Africa's most important wattled crane breeding areas. Its hydrological value is high because it is at the head of the important Mgeni catchment. Mgeni vlei is under conservation management by the Natal Parks Board and is undeveloped. However, it was used in the recent past as a natural grazing area for domestic stock. The management guidelines ask if past burning and grazing management would be of use in maintaining the conservation objectives of the area. It appears that grazing and burning practices have been important in enhancing the ecological value of the wetland.

To protect the ecological and hydrological values of the wetland, an overall management goal and management objectives are proposed. Also, a series of management guidelines have been devised showing the actions neccessary to achieve the specific objectives (Fig. 1). These include the following principal recommendations:

1. biennial cool spring burning is advocated, with half the wetland being burnt each year. Occasional autumn and winter fires should also be included (at an average interval of approximately 5-10 years) to enhance diversity;

2. as yet, there is no evidence to show that controlled grazing by domestic stock is contrary to the conservation objectives of Mgeni vlei. It may, in fact, enhance the ecological value of the wetland. Thus, it is recommended that this be allowed, but closely monitored;

3. as conservation of the Wattled Crane was one of the primary reasons for the expropriation of the Mgeni vlei area, it is strongly recommended that the breeding success of this bird be monitored here; and

4. because of the high ecotourism potential of the area it is recommended that the public be provided access. It is recommended that the a hiking trail which includes some of the surrounding farm/s be developed soon.

Fig. 1 Mgeni vlei management framework

OVERALL MANAGEMENT GOAL: Ensure the long term protection of the wetland's ecological, hydrological and erosion control values.

MANAGEMENT OBJECTIVES

SUMMARIZED MANAGEMENT GUIDELINES

Protect the hydrological and erosion control values

- Prevent disruption of the hydrological regime through drainage channels or other means.
- Monitor any actions (e.g. stock grazing) taken to enhance habitat diversity.
- Ensure judicious catchment management.

Protect the ecological values

- Protect the hydrological and erosion control values, because the greater the hydrological disruption, the greater will be the likely impact on the ecological values.
- Divide the wetland into two burning blocks and alternately burn each half, so that in any given year at least half the wetland is left unburnt.
- Aim for cool early spring burns, with the inclusion of occasional autumn and early winter fires (at an average interval of approximately 5 years) to enhance diversity.
- Maintain populations of Red Data species and any other wetland-dependent species considered to be important. At present the only species identified as requiring individual attention is the wattled crane. The following recommendations have been developed for this species:
  - Monitor breeding success.
  - Avoid burning mortalities of chicks by:
    - considering delaying burning if chicks are still unable to fly;
    - observe where the chick/s are at the proposed time of burning and, if possible, burn strategically; and
    - if eggs are present and likely to be burnt, temporarily remove them.

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Natal Parks Board
Natal Town and Regional Planning Commission
Renfreight Wetlands Campaign
South African Timber Growers Association
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Umgeni Water
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1. OVERALL MANAGEMENT GOAL

The overall management goal for Mgeni vlei is to ensure the long term protection of the wetland's ecological (biotic diversity), hydrological (water purification, stream flow regulation and water storage) and erosion control values.

2. GENERAL SITE DESCRIPTION

Mgeni vlei, approximately 300 ha in extent, is situated near the source of the Mgeni River (29°29'S;29°49'E) (Figs. 2 and 3). The wetland extends 3.4 km from its inlet (1840 m) to its outlet (1828m) giving a slope of 0.4%. It is underlain by Karroo dolerite. The wetland soils are acidic. Permanently to semi-permanently saturated/flooded areas consist predominantly of the Champagne form, while seasonally to temporarily saturated/flooded areas comprise a complex of the Champagne form and the Katspruit form (Lammersmoor family). Mgeni vlei falls within the Mgeni "sponge", an 8093 ha area climatically and geologically conducive to wetland formation and which has 12-15% of its area occupied by wetlands (Begg, 1989; Smith, 1953).

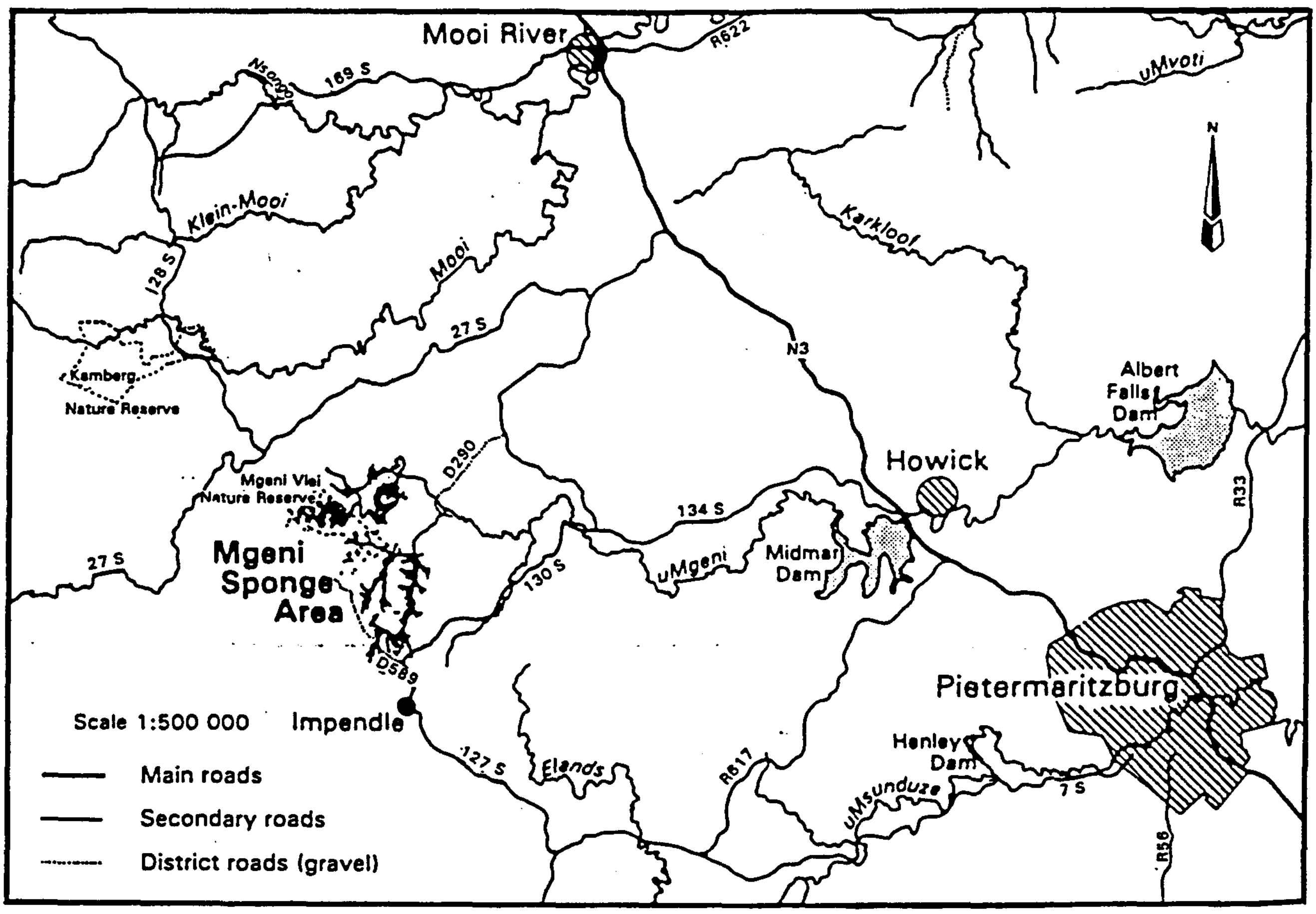

Fig. 2 Location of Mgeni vlei in the Mgeni catchment (From Begg, 1989).

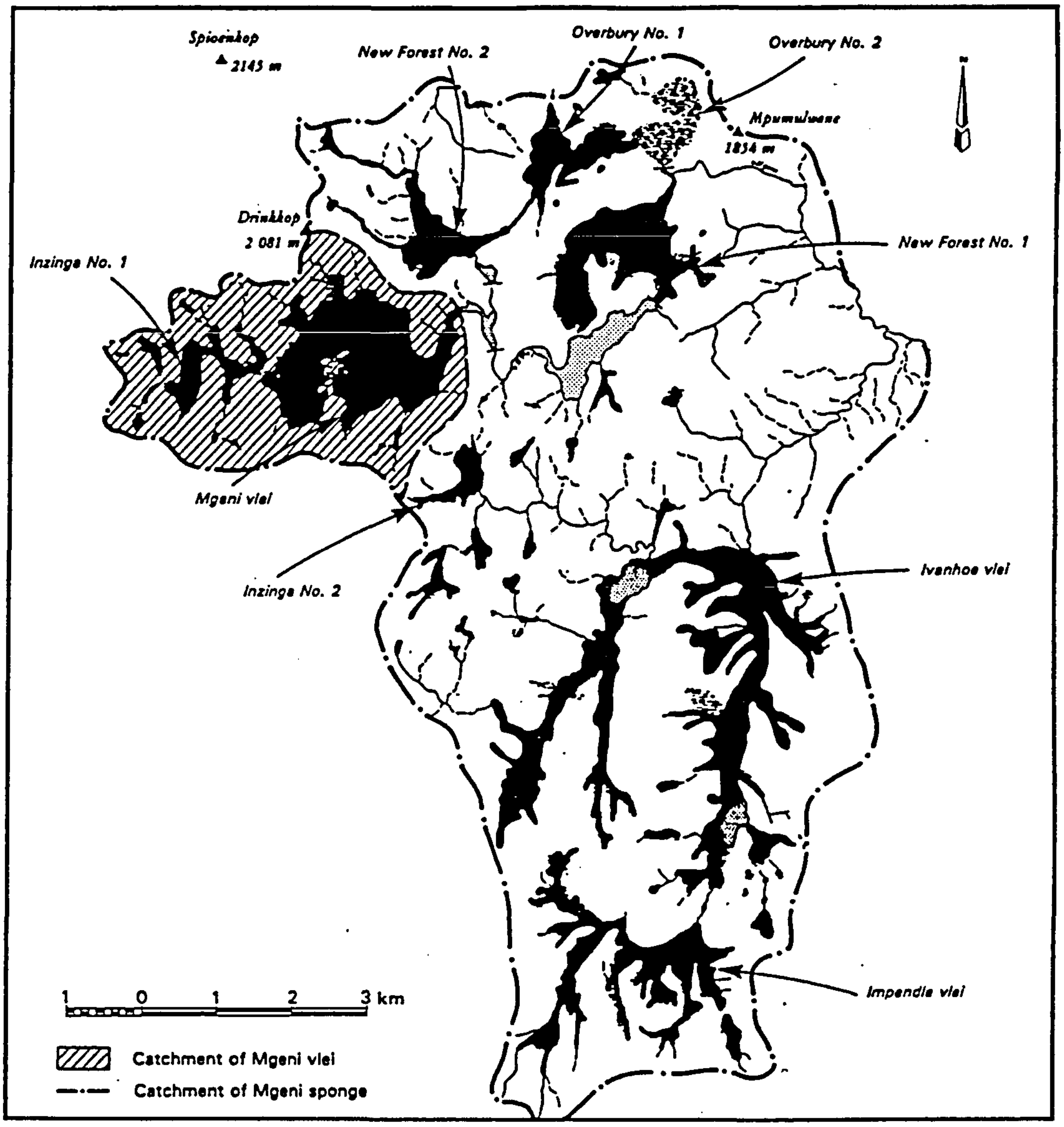

Fig. 3 Location of Mgeni vlei in relation to the other wetlands in the Mgeni "sponge" (From Begg, 1989).

Four principal vegetation types are found in Mgeni vlei. *Carex acutiformis* marsh and *Carex cognata* marsh mosaic occur in the central permanently to semi-permanently wet zone. The outer less wet zone is occupied by sedge meadow in the lower lying (seasonally wet) areas and wet (hygrophilous) grassland on the higher lying (temporarily wet) areas (Fig. 4)

Although Mgeni vlei is an undeveloped wetland under conservation management, the other wetlands in Mgeni "sponge" vary from undeveloped wetlands utilized for stock grazing to wetlands developed and planted to pastures (see Begg, 1989).

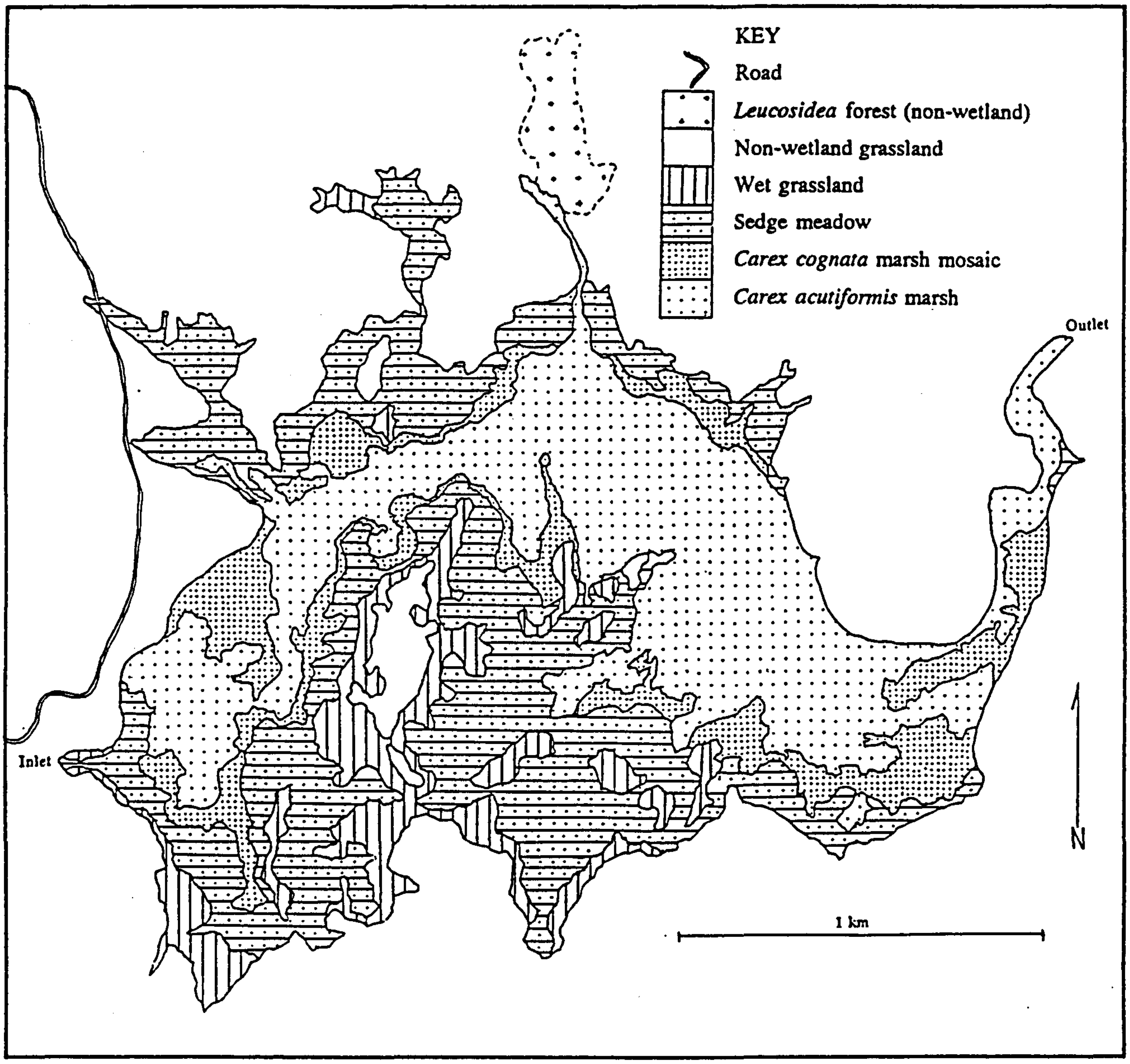

Fig. 4 Distribution of vegetation types occurring in Mgeni vlei.

3. CATCHMENT DETAILS

The Mgeni vlei catchment occurs within veld type 44a (Highland Sourveld) (Acocks, 1953) and Bioclimatic Region 4e (highland-montane) (Phillips, 1973). Mean annual rainfall is approximately 980 mm (82% in summer); relative humidity 70-75 %, mean annual temperature 15°C; extreme daily temperatures -12°C and 40°C (Phillips, 1973). The catchment is approximately 1100 ha, of which 27% is occupied by Mgeni vlei. Thus, of KwaZulu/Natal's priority wetlands, it has the second highest wetland/catchment surface area ratio (0.27: 1).

The Principal land-uses in the surrounding catchment are nature conservation and stock farming on natural veld. No crop or planted pasture production or afforestation is practised in the wetland catchment.

4. REGIONAL SIGNIFICANCE OF THE WETLAND

The Mgeni catchment is recognized as one of the most important river systems in South Africa because approximately 20% of South Africa's gross national product is generated within the catchment (Breen *et al.*, 1985). The Mgeni vlei and other wetlands in the "sponge" are considered to have an important role in the provision of high quality water for human consumption. They have a strategic position at the source of this catchment, so that any detrimental effects to the wetlands in the "sponge" might be felt throughout the rest of the catchment (Begg, 1989).

Mgeni vlei is one of South Africa's most important breeding areas for the endangered wattle crane (*Grus carunculata*) and is one of the few priority wetlands in KwaZulu/Natal that have not been altered in some way through the construction of artificial drainage channels.

5. LAND OWNERSHIP

The Natal Parks Board owns and controls 98% of Mgeni vlei. The remaining 2%, situated at the wetland outlet, is owned by Mr. G N Ross. Of the other wetlands in Mgeni "sponge", Mpendle vlei falls within a communal grazing area formerly in KwaZulu and the rest are privately owned.

6. VEGETATION TYPES

Four principal vegetation types, described below and summarized in Table 1, were defined for the purposes of management. Begg (1989) suggests that burning, and grazing by domestic stock may have caused the current vegetation zonation. However, although cattle have been shown to increase the extent of open water in wetlands, there is no evidence to support Begg's suggestion. The zonation appears to be primarily related to the water regime (see Table 1).

Table 1 Dominant plant species, water regime and soil characteristics of Mgeni vlei vegetation types

Vegetation type	**Dominant plant species**	**Water regime and soil characteristics.**
Carex acutiformis marsh	*Carex acutiformis*	Permanently to semi-permanently saturated/flooded; upper B horizon soft and unconsolidated to >1.0m (but seldom >1.8m); A horizon with abundant roots, gleyed to the surface.
Carex cognata marsh mosaic	*Carex cognata; Cyperus unioloides; Juncus oxycarpus; Largarosiphon major; Pycreus sp.*	As for *Carex acutiformis* marsh but unconsolidated B horizon shallower.
Sedge meadow	*Andropogon appendiculatus; Aristida junciformis; Festuca caprina Pycreus sp.; Scleria welwitschii*	Intermediate between sedge/bulrush marsh and hygrophilous grassland.
Wet grassland	*Aristida junciformis; Festuca costata; Scleria welwitschii; Tristachya leucothrix;*	Temporarily flooded/ saturated; upper B horizon always hard and consolidated; A horizon with relatively few roots; gleying seldom within uppermost 10 cm of soil.

6.1 *Carex acutiformis* marsh

Carex acutiformis marsh is dominated almost exclusively by *C. acutiformis* and occupies the central wetland areas, which are permanently to semi-permanently saturated or flooded. This is reflected in the soils which have an A horizon with abundant roots and chromas of 1 or less. The soft, upper unconsolidated B horizon usually extends more than 1 m below the soil surface, but seldom more than 1.8 m below.

These areas generally lack hummocks and open water patches and are very stagnant, lacking oxygenated water input. Consequently the soil in *Carex acutiformis* marsh is uniformly very anaerobic and few microhabitats are available as compared with the sedge meadow. It appears that these factors account for the very low plant and animal species richness of this vegetation type.

6.2 *Carex cognata* marsh mosaic

Carex cognata marsh, *Juncus oxycarpus* marsh and open water tend to occur as a mosaic, fringing the *Carex acutiformis* marsh. For convenience this mosaic will be referred to as *Carex cognata* marsh mosaic, named for the most widely occurring component.

Carex cognata marsh mosaic not only has a greater proportion of open water than *Carex acutiformis* marsh but it also receives more direct input of oxygenated water from tributary streams, thereby making it less stagnant. Submerged aquatic plants, such as *Lagarosiphon major* and *Utricularia vulgaris*, which are largely absent in *Carex acutiformis* marsh open water areas, occur frequently in *Carex cognata* marsh mosaic open water areas. *Carex cognata* marsh is also characterized by the more frequent occurrence of raised hummocks which, because of their elevated position relative to the open water, provide microhabitats for species typically found in sedge meadow areas. It appears that the higher species diversity in the *Carex cognata* marsh mosaic is due to the less stagnant conditions and the greater variety of microhabitats.

Soils in *Carex cognata* marsh mosaic resemble those in *Carex acutiformis* marsh and are permanently to semi-permanently saturated/flooded, but tend to have a shallower soft upper unconsolidated B horizon.

6.3 Sedge meadow

This vegetation type is transitional between marsh and wet (hygrophilous) grassland in terms of plant species composition and water regime. It includes two sub-types: hummocked sedge meadow, which has vegetation covered earth hummocks over 15 cm high and 50 cm in diameter, and non-hummocked sedge meadow, without hummocks. Non-hummocked sedge meadow is restricted to a very narrow transitional zone between wet grassland and marsh, and is not easily visible. In contrast, hummocked sedge meadow is very extensive in Mgeni vlei and is easy to recognize.

Because they are mostly above the water table, hummocks experience less prolonged periods of saturation than do the inter-hummock depressions. This increases the number of microhabitats available in theses areas, with the hummock plant communities differing from the channel communities. The hummock communities show greater resemblance to the wet grasslands, while the channel communities show greater resemblance to the marsh vegetation types.

6.4 Wet grassland

This vegetation type forms the transitional zone between the wetland and non-wetland and is confined to temporarily flooded/saturated areas. The outer perimeter and elevated areas within the more central wetland area comprise wet grassland.

Soils in the wet grassland have relatively few roots in the A horizon and gleying usually at least 10 cm below the surface. Although all wetland areas are characterized by gleying within the upper 50 cm of soil, at the dry extreme of the wet grassland, gleying occurs only below 30cm. This range of wetness is reflected in the vegetation species composition. At one extreme, species that occur predominantly outside of wetland areas, such as *Tristachya leucothrix*, are dominant but occasional hydrophytes occur. These hydrophytes consist predominantly of species which are restricted to seasonally or temporarily saturated/flooded areas (e.g. *Bulbostylis schoenoides, Fuirena pubescens, Scleria welwitschii, Andropogon appendiculatus* and *Eragrostis planiculmis*). At the other extreme, the above hydrophytes dominate, and dryland species, although not dominating, still occur frequently.

7. CURRENT ECOLOGICAL STATE OF THE WETLAND WITH PARTICULAR REFERENCE TO THE WATTLED CRANE

* Is Mgeni vlei in a satisfactory condition from a nature conservation point of view?

* Were the burning, and the grazing management of the past influential in a positive way?

* What management practices should be continued and what adjustments need to be made?

The World Conservation Strategy provides two objectives relating to the assessment of ecological condition. These are:

1. the conservation of genetic (biotic) diversity; and

2. allowing ecological processes to operate.

Objective 1 offers many alternatives concerning the scale at which it should be assessed, from genes and gene complexes through to communities, ecosystems and biomes. Objective 2 is also open to interpretation depending on what the assessor sees as important. Consequently, objectives 1 and 2 cannot be clearly and simply defined in such a way that allows for them to be readily evaluated (i.e. they are not workable objectives).

The situation is further complicated by the fact that bench-mark areas where the conservation of genetic diversity and the operation of ecological processes are being satisfactorily achieved, have not been identified for KwaZulu/Natal. In addition, these wetlands have been very poorly studied and fundamental data concerning how different land-use practices affect ecological processes and genetic diversity are lacking.

A preliminary assessment of Mgeni vlei has been carried out using only the following criteria:

1. status of the wattled crane breeding population;

2. disruption of the hydrological regime. Since an excess of water is the dominant factor affecting the plant and animal communities in a wetland (Cowardin *et al.*, 1979) a general assumption can be made that the greater the disruption of the

hydrological regime the lower will be the degree to which natural ecological processes are allowed to operate in wetlands; and

3. assessment of the veld condition of grassland areas. Although veld condition assessment techniques have been developed for agronomic purposes they are, nevertheless, ecologically based and of relevance.

The large number of breeding wattled crane at the time of proclamation (up to 5 breeding pairs in the wetland), no evidence of hydrological regime disruption, and the moderate to good condition of most of the grassland areas suggests that the previous management was not contrary to the conservation objectives of Mgeni vlei.

Begg (1989) also considered Mgeni vlei to be in a satisfactory condition, adding that this was testimony to the burning and grazing management applied before expropriation. Begg suggests that should these management practices cease, Mgeni vlei (with particular reference to the plant and animal communities) may well alter. He recommends that "if the breeding success of wattled crane at Mgeni vlei and the present environmental quality of the system are interpreted as favourable biotic responses to the past usage of Mgeni vlei, serious consideration will have to be given to continued use of fire and grazing animals as management 'tools' in the future. Providing the intensity and duration of grazing can be controlled, use of the vlei by livestock should not conflict with its hydrological, conservation or recreational potential."

In the years following proclamation, the Natal Parks Board chose to decrease the fire frequency and to exclude domestic grazing animals rather than continue with a management strategy similar to the previous one. wattled crane breeding records have not been kept for Mgeni vlei, but it certainly appears that there have been fewer pairs breeding in the wetland in the last three years than at the time of proclamation. It has been suggested that burning and grazing favour the wattled crane. Possible factors which may contribute to this are:

1. reduction of aerial cover and maintenance of a short sward by fire and grazing stock, which may improve the feeding potential of the area for wattled cranes. In 1991, for the few weeks following the burning of Mgeni vlei in September, the numbers of wattled crane increased three-fold, as birds from the surrounding areas congregated at the burnt wetland (Vermeulen, 1991; Kotze, pers obs); and

2. disturbance caused through trampling, which may also improve the feeding potential.

It has also been suggested that stock farmers, by controlling predators such as caracal (*Felis caracal*) and black-backed jackal (*Canis mesomelas*), may assist in lowering chick and egg predation. However, no evidence has been produced to show that these species prey on wattled crane chicks (Johnson, 1992). It must be noted that, as yet, there is no conclusive evidence to show that a change in the burning and grazing regime has led to fewer breeding pairs at Mgeni vlei. This may be a function of external factors (e.g. climatic trends). However, it appears fairly certain that grazing and burning, provided they do not involve direct excessive disturbance or harm to the birds, do not detrimentally affect wattled cranes.

8. PAST AND CURRENT USE OF THE WETLAND AND RECOMMENDATIONS FOR FUTURE USE

8.1 Natural grazing by domestic stock

Before the 1987 expropriation of the wetland, stock grazing was its main land-use. Approximately 2000 sheep grazed the wetland and surrounding non-wetland grasslands annually for 6-7 months, and ca 400 cattle grazed on a rotational basis (for one week out of every five) (Begg, 1989).

Most of the wet grassland and surrounding non-wetland grasslands have a moderate to high proportion of decreaser species, notably *Tristachya leucothrix*, and are in a moderate to good condition.

The effect of cattle grazing and trampling in marsh areas is to decrease aerial cover of the dominant plant species and to increase the extent of exposed puddles. This often favours mud-probing birds such as snipe, and aquatic plants, as well as the fauna which depend on them (Neely, 1968; Duncan and D'Herbes, 1982). This tends to increase the diversity of microhabitats. However, prolonged heavy grazing disadvantages species such as the red-chested flufftail which require cover for breeding and as protection from predators. Because of the high degree of soil disturbance associated with heavy prolonged grazing, this grazing also detracts from the hydrological and erosion control values of the wetland. Most mature marsh plants are unpalatable to cattle, and most *Carex acutiformis* marsh and *Carex cognata* marsh mosaic areas are inaccessible. Thus, utilization levels are likely to have been sufficiently low so as not to detract significantly from the erosion control value of the wetland.

Downing (1966) attributes hummock/depression morphology to trampling by cattle. However, it appears that other more important site-specific factors, such as the workings of ants and earthworms (Edwards, 1963; pers. obs., 1991), are responsible for the development of this morphology in Mgeni vlei.

There has been little research, and so far no evidence has been produced to show that moderate grazing pressure by domestic stock negatively affects the ecological value of wetlands in the KwaZulu/Natal Midlands. It could be argued that a source of revenue, and goodwill from the adjacent farmers might be derived from letting the farmers use the area for controlled grazing without compromising the conservation objectives of the reserve. Some form of exchange agreement or tender is suggested.

Some large grazers which are indigenous to the Mgeni vlei area, such as Eland (*Taurotragys oryx*), no longer have access to Mgeni vlei. Thus, even before the arrival of any indigenous peoples and their stock, these areas are likely to have been grazed more heavily than at present. It could be argued, then, that by having limited controlled grazing by domestic stock, a more "natural" situation would exist. However, any estimation of the pre-historic grazing pressure would be extremely speculative.

8.2 Burning

Lightning is frequent in the area. Lightning fires are certain to have occurred in the past, and are likely to have had an important effect on the wetland, even if they occurred infrequently. Indigenous inhabitants, and later European settlers, will have increased the frequency of fires.

For at least 20 years prior to is proclamation as a nature reserve, Mgeni vlei was burnt annually to enhance its grazing value. Following proclamation, the Natal Parks Board divided the nature reserve into two blocks, with the entire Mgeni vlei falling into the first block, and other smaller wetlands into the second. The original burning strategy has changed somewhat from a triennial burning of each block (with the proviso that in no one year are both blocks burnt) to a biennial burning of each block with the same proviso. This has ensured that in any given year there is always some wetland area left unburnt.

By removing old leaf and stem material and stimulating early growth in spring, fire acts to increase water loss through evapotranspiration from the wetland. In addition, fire may sometimes decrease the organic matter input into the soil. However, little evidence exists to show that these potentially negative influences detract significantly from the hydrological value of the wetland. Unless it leads, either directly or indirectly, to a lowering of the long-term state of health of the vegetation, frequent burning is unlikely to have a significant detrimental effect on the long term hydrology of the wetland.

By temporarily removing cover, burning has a negative effect on the habitat value for birds and small mammals, and winter breeding birds are particularly severely affected (Johnson, 1991). However, provided adequate unburnt areas are left from which recolonization of the burnt areas may occur, and providing burning occurs in early spring, burning is unlikely to have a negative effect on the habitat provision value of the wetland. In reducing the shading effect caused by the accumulation of old leaf material from emergent wetland plants, burning generally increases the growth rate of new leaves (Johnson and Knapp, 1993). This in turn may positively affect the animals dependent on these plants. For example, a controlled burning programme, as opposed to complete protection, was shown to increase the value of sedge marsh for red-chested flufftail (Taylor, 1991).

The greatest negative effect of burning wetlands is the temporary removal of cover for animals, particularly winter-breeding ones. In order to take this into account in a burning programme, three alternatives exist for Mgeni vlei:

1. divide the wetland into two burning blocks and alternately burn each half, such that in any given year at least half the wetland is left unburnt;

2. alternate between, in one year, burning the Mgeni vlei and leaving the other nearby wetland areas that fall within the nature reserve unburnt; and, in the next burning year, burning the nearby wetlands and leaving Mgeni vlei unburnt; or

3. burn in autumn when the vegetation would be less dry and the water table higher than at the end of winter, resulting in a patch burn.

In autumn, certain vegetation types are far more susceptible to burning than others. Thus, this burning strategy is likely to result in the consistent burning of certain vegetation types and wetland areas while others are left unburnt. Animals adapted to living in the regularly burnt vegetation types may be deprived of cover. In addition, birds with breeding seasons that overlap this period, such as the grass owl (*Tyto capensis*), are likely to be affected negatively by repeated autumn burning. In grasslands, autumn burning may affect veld condition detrimentally because if it stimulates an autumn flush, this weakens the competitive ability of grass plants in the following growing season and favours unpalatable species (Tainton, 1981).

By use of the first alternative, burnt and unburnt areas would be adjacent, and animals deprived of cover by burning would be able to take refuge close by. The second alternative, with burnt and unburnt areas at a distance from each other, may deprive all but the more mobile animals of this opportunity.

Another factor to consider is the time taken for re-establishment of cover. After early spring burning, cover is re-established in about one month, whereas after autumn or early winter burning, cover is re-established only after about 5 months. Although an occasional autumn fire should be incorporated into a burning programme in order to increase diversity, repeated autumn burning is not recommended because of the potentially negative impacts mentioned above.

Fire may assist in preventing alien plant invasion (Kotze, 1992; Otter, 1992). Unless the water regime is altered, alien plant invasion is generally not a problem in marsh areas occurring in the Highland Sourveld, due to the lack of invasive plants adapted to these cold and extremely wet conditions. However, wet grasslands and surrounding non-wetland grasslands may be prone to invasion and in these areas fire could be useful in helping to prevent invasion.

It has been shown that in order to maintain Highland Sourveld grasslands in a healthy vigorous state, regular burning in the dormant season is desirable (Tainton, 1981) particularly if grazing levels are very low. While this may be true for certain wetland types, particularly wet grassland, the effect on other types is, as yet, unclear. Biennial early spring burning is suggested in the interests of sward vigour, control of invasive plants and minimizing impact on the breeding of wetland-dependent birds. Burning should take place under conditions of high humidity and low air temperatures, preferably shortly after rain, in order to achieve a cool burn. Occasional autumn/winter fires should also be included (at an average interval of approximately 10 years) to enhance diversity.

Wattled cranes are winter breeders, and chicks may still be unable to fly at the recommended burning time. In order to avoid burning mortalities the following recommendations are made:

1. consider delaying burning if any chicks are still unable to fly;

2. observe where the chick/s are at the proposed time of burning and, if possible, burn strategically; and

3. if eggs are present and likely to be burnt, remove them temporarily and replace them after the burn.

8.3 Ecotourism

The following features are considered important in contributing to the high ecotourism potential of the wetland and surrounding areas:

1. it is on an undeveloped plateau, near to the Drakensberg, and the surrounding hills are curved as in an amphitheatre. The immediate surrounds lack almost any signs of development and magnificent views of the wetland can be seen from the top of some of the surrounding hills;

2. attractive flowering plants are abundant, particularly in the sedge meadow, where there are some six species of ground orchid;

3. open water areas with interesting features exist, including hummocks with conspicuous flowering plants such as *Dierama pauciflorum*;

4. there are many breeding wattled crane here;

5. an attractive *Leucosidea sericea* forest is situated immediately adjacent to the wetland;

6. it is closer to Pietermaritzburg than any other Drakensberg reserve; and

7. there is an old house that could be converted to a hikers' overnight stop.

Public funds were used for the purchase and maintenance of Mgeni vlei, and public access is recommended, unless it can be shown that this would be detrimental to the conservation objectives.

There is unfortunately no public access road, and at present, access is via a private farm road which is often in very poor condition and has special conditions attached to its use, so that only organised visits by specialist groups such as bird or orchid clubs are possible. General public access could be provided quite easily by including the wetland on a hiking trail. This would obviously require the co-operation of one or more of the adjacent farmers. Specialist scientists of the Natal Parks Board would also need to be involved in planning of the trail. The ornithologist, for example, might deem it necessary to restrict hiking activities during the wattled crane nesting period.

Tourism development in many parts of the KwaZulu/Natal Drakensberg is considerable (White, 1991) and suggestions have been made that tourism be promoted in nearby areas that have potential. The promotion of tourism at Mgeni vlei is both desirable and feasible, but development should not spoil the wildness of the area.

8.4 Reedbuck hunting

There have been suggestions that hunters might pay to shoot reedbuck at Mgeni vlei. The small area occupied by the Nature Reserve could support only limited hunting and there is the danger of disturbing important species such as the wattled crane. Thus, hunting is not recommended.

8.5 Harvesting of wetland plants

Reeds, *Schoenoplectus corymbosis*, and *Juncus effesus* are widely harvested in the KwaZulu/Natal midlands for craft and building purposes. In Mgeni vlei, there are no reeds and the other two species are relatively infrequent.

9. RECOMMENDATIONS FOR FURTHER RESEARCH

This survey does not include a description of the Mgeni vlei fauna. A faunal survey is essential and should be done in relation to the vegetation types.

Considering that the wattled crane was one of the primary reasons for declaring the Nature Reserve, it is strongly recommended that records be kept of the breeding success of this species. An attempt should be made to relate these results to management actions, particularly burning. It is also recommended that a broader study be undertaken in the region to assist in determining the effect of burning and grazing on the breeding success of the wattled crane.

If a decision is taken to allow domestic stock to graze the wetland then it is recommended that exclusion camps be fenced off so as to include all the main vegetation types and these areas, as well as comparable grazed areas, be monitored in terms of species composition and vegetation structure.

10. RECOMMENDATIONS CONCERNING LAND-USE IN THE MGENI "SPONGE"

Utilization of Mgeni "sponge" has given rise to much debate because of its strategic position at the source of the Mgeni catchment (Scotney, 1970). Despite many requests for wetland-related research and a proposal for an experiment to study the effect of wetland development (Pegram, 1969), Scotney (1970) indicated that very little scientific data were available on which recommendations could be based. Now, over twenty years later, the situation is hardly better.

Nevertheless, Scotney (1970) states that preliminary investigations show that drained wetlands contribute more water per hectare than undrained wetlands. Citing James (1968), Scotney concludes that these preliminary results had not yet indicated the detrimental effects generally attributed to drainage.

Scotney (1970) also observed that planted pastures on the Ivanhoe wetland, which is part of the Mgeni "sponge", have proved highly successful in carrying large numbers of livestock with apparently very little soil loss. Scotney recommends that development of wetland areas within the "sponge" should be permitted provided it is in accordance with sound development principles.

In response to Scotney's (1970) conclusion and recommendation, it should be noted that although the net yield of water from a drained wetland planted to pastures is probably greater, yield during the critical low flow winter period is likely to be less, particularly if the pasture is a temperate winter one.

Also, as Scotney (1970) noted, the extent to which current intensified usage of the wetland is detracting from the quality of water yielded by the Mgeni "sponge" is not known. Pasture production involves drainage, which decreases the water retention time and nutrient trapping capacity of the wetland, and application of fertilizers, which may elevate nutrient levels in the water due to leaching. It can be appreciated that pasture production could potentially lower the quality of water yielded by the Mgeni "sponge". Begg (1989) observed the turbidity of water yielded by the developed portion of Ivanhoe vlei to be higher than that yielded by the undeveloped portion. Due to the importance of high quality water for human consumption, special attention should be given to water quality in the Mgeni catchment.

Water quality monitoring some way below the Mgeni "sponge" indicates that to date, the sponge has yielded good quality water (Umgeni Water, 1992). Thus, if any lowering of water quality, resulting from pasture production, occurs it is likely that this is being effectively buffered by undeveloped wetlands and riparian areas in and below the "sponge".

In conclusion, it appears that the current level of development does not detract substantially from the hydrological functions of the wetlands in the Mgeni "sponge". However, further development is not recommended until the hydrological impact of drainage and pasture production has been fully investigated.

This recommendation for limiting future development is also made on the grounds that development will detract from the ecotourism potential and ecological values of the area. Scotney's (1970) suggestion that a large part of Mgeni "sponge" be incorporated into a "sanctuary" area to be developed for recreation and wildlife is supported because of the high ecotourism potential of this area.

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REPORT TO THE WATER RESEARCH COMMISSION

A MANAGEMENT PLAN FOR BLOOD RIVER VLEI

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EXECUTIVE SUMMARY

Blood River vlei, ca 6000 ha in extent, is situated in the upper Tugela catchment in Bioclimatic group 8a (mean annual rainfall= 835 mm). It consists of two main parts: the Blood River vlei proper and the Lynspruit vlei. The underlying geology is Ecca shale and Karoo dolerite and the predominant soil forms are Katspruit and Rensburg. The wetland provides a wide variety of habitats including permanently wet reed marsh, temporarily wet grasslands, seepage slope areas and several oxbow "lakes" of various depths and water regimes. Blood River vlei is recognized as a top priority wetland of critical importance to KwaZulu/Natal (Begg, 1989). The wetland has a high water purification and streamflow regulation value due to such factors as its large size and hydrological control areas.

Blood River vlei falls within the boundaries of over 50 farms and is currently being used as: (1) a very important natural grazing area for domestic stock, (2) a water source for irrigation and (3) for waterfowl hunting.

In order to encourage sustainable use of the wetland while minimizing the loss of wetland functional values, an overall management goal and management objectives are proposed and a series of management guidelines describing the actions necessary to achieve the objectives is given (Fig. 1, and see Section 11 for details).

At present, grazing appears not to have substantially detracted from the functional values of the wetland. However, it has contributed to erosion in several areas, some of which are still active and posing a threat to extensive areas of the wetland. Remedial measures are required urgently in these areas.

The wetland should be grazed at the recommended stocking rate (2 ha/AU), accounting for veld condition, susceptibuility to erosion (excluding animals from areas with particularly high erosion hazards) and the relative proportions of wet grassland, wet meadow and marsh on the farm (see Section 11.2.3.1). Wetland areas should preferably be fenced off as special use camps. Where this is impractical, other means of ruducing the use of wetlands should be employed when necessary (e.g. ensure water availability in other areas, herd animals). Rotationally graze wetland areas, withdrawing the animals when the soil becomes wet and puddled.

Although the level of hydrological alteration due to drainage channels is low, there are some drainage channels (described in Section 11.5) which require remedial action.

Approximately 38 small (< 5 ha) farm dams and 6 large (> 5 ha) farm dams have been built within the wetland. Water extraction from the wetland and its catchment has increased markedly in the last decade and appears to be detracting significantly from the wetland's value. Afforestation of the catchment is also increasing. Thus, it is recommended that an overall plan regarding damming and water extraction be formulated and that these practices be discouraged as far as possible.

Crop production is very limited in the wetland and due to the potentially negative effects of cropping, the establishment of further croplands is not recommended

Blood River vlei appears to have a relatively high potential for supporting waterfowl hunting, but hunting is taking place on only a very limited scale. The potential of the wetland for commercial waterfowl hunting should be investigated. Blood River vlei has certain features (e.g. large populations of water birds and places of historical interest) which enhance its ecotourism potential.

Extensive areas of the wetland are burnt annually. It is recommended that the extent of burning in these areas be reduced and that the burning of more than 60% of any sector in a given year be avoided. Burning should take place in late winter to early spring, preferably every second or third year, under conditions of high humidity and low air temperature and using a head fire.

OVERALL MANAGEMENT GOAL: optimize, on a sustainable basis, the direct benefits derived by different on-site and off-site users of the wetland without significant loss of the wetland's hydrological and ecological values, which benefit society at large.

MANAGEMENT OBJECTIVES:

MANAGEMENT GUIDELINES:

Protect the hydrological values:

- Do not drain, chanalize or otherwise alter the flow regime of the wetland
- Prevent erosion within the wetland
  - Ensure stock stream crossings do not lead to gully erosion^
  - Preferably do not graze wetland areas when they are wet and susceptible to puddling^
  - Do not exceed the recommended stocking rate^
- Ensure the stability of any potential or existing headcut erosion sites
  - Design and install appropriate erosion control structures for the headcuts
  - Exclude cattle from the headcut areas^
- Maximize the natural runoff from the wetland catchment (including the wetland itself)
  - Discourage the construction of more dams in the catchment, particularly in the wetland itself.
  - Minimize the volumes extracted, particularly during low flow periods (e.g. by maximizing the water use efficiency of agricultural practices)#
  - Restrict afforestation to designated areas in the surrounding catchment
- Prevent excessive sediment input from the surrounding catchment
  - Follow wise soil conservation practices

Protect the ecological values:

- Follow the burning guidelines
  - Leave at least 50% of the wetland unburnt in any one year; do not burn during the growing season etc.#
- Hunt wisely
  - Sustainably hunt only those species recommended as suitable by the Natal Parks Board and monitor hunted species populations ✿
- Protect the hydrological values, because the greater the hydrological disruption, the greater the impact on the ecological values

Wisely use the wetland:

* as a natural grazing area for domestic stock (see ^ guidelines);
* as a water source for stock watering (see # guidelines); and
* for waterfowl shooting (see ✿ guidelines).

Regulate damming, water extraction, mining, afforestation and crop production activities in the surrounding catchment. Although these are not direct uses of the wetland, they have been included because they have an important effect on the wetland.

Fig. 1 Blood River vlei management framework

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1. OVERALL MANAGEMENT GOAL

The overall management goal for Blood River vlei is to optimize, on a sustainable basis, the direct benefits derived by the different users of the wetland without diminishing the wetland's indirect benefits to society.

The primary users are stock farmers who use the wetland in its natural state for grazing. Other users include crop farmers (who extract water from the wetland) and waterfowl hunters. The indirect benefits include the following functional values:

1. hydrological values (water purification, water storage and enhancement of sustained streamflow);

2. erosion control value; and

3. ecological value (maintenance of biotic diversity through the provision of habitat for wetland-dependent species).

2. GENERAL SITE DESCRIPTION

Blood River vlei, approximately 6000 ha in extent, is situated in the upper Tugela catchment between Utrecht and Vryheid (27°48'S; 33°36'E) about 20 km from the source of the Blood River (Fig. 2).

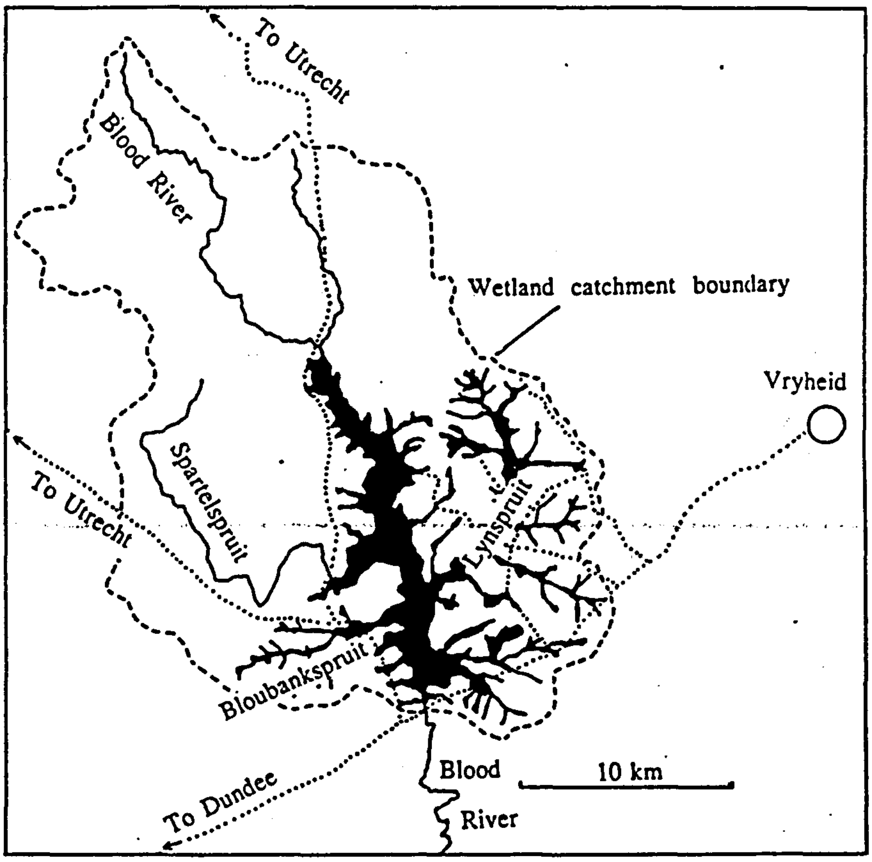

Fig. 2 Location of Blood River vlei.

The wetland consists of two main parts: the Blood River vlei proper and the Lynspruit vlei. The Blood River vlei proper extends 18 km from its upstream end (1215 m) to its outlet (1183 m), giving a total slope in the direction of water flow of 0.19%. The Lynspruit vlei extends 13 km from its upstream end (1350 m) to its junction with the main Blood River vlei (1187 m), giving a total slope of 1.25%.

Seven principal vegetation types (described in Section 9) occur in Blood River vlei. For the purposes of management and land-use planning, they have been grouped into three agro-ecological zones (Table 1).

Table 1 Agro-ecological zones and vegetation types occurring in Blood River vlei

Vegetation types	Agro-ecological zones
Open water	MARSH
Reed marsh	MARSH
Sedge/bulrush marsh	MARSH
Cyperus latifolius marsh	MARSH
Sedge meadow	WET MEADOW
Miscanthus junceus meadow	WET MEADOW
Wet grassland	WET GRASSLAND

The wetland may conveniently be divided into 9 main sectors (Figs. 3 and 4) based on land form, soil type, and the distribution of the agro-ecological zones (Fig. 5).

Sector B1 comprises a wet grassland-dominated flat[1] bisected by the well defined main channel (2-4 m deep) of the Blood River. Surface water flow is predominantly channelized and diffuse flow occurs, on average, about once every few years when runoff from the catchment is sufficient to cause bank overspill. Soils are mainly alluvial and medium to course textured (loam/ sandy loam). Interspersed in the wet grassland areas are non-wetland areas, as well as marsh and wet meadow areas. The marsh and wet meadow areas are set away from the main channel in the "backswamp" areas, which are the parts of the flats with the lowest elevations (excluding the channels) and are the least well drained. In contrast, the non-wetland areas occur adjacent to the channel on levees which have the highest elevation in the flats and are the best drained. These are the only areas in the wetland that support indigenous trees in abundance, mainly *Acacia sieberana* and *Acacia karroo.*

[1] A flat is a flat area, usually in a bottomland position, with a slope of less than 1%.

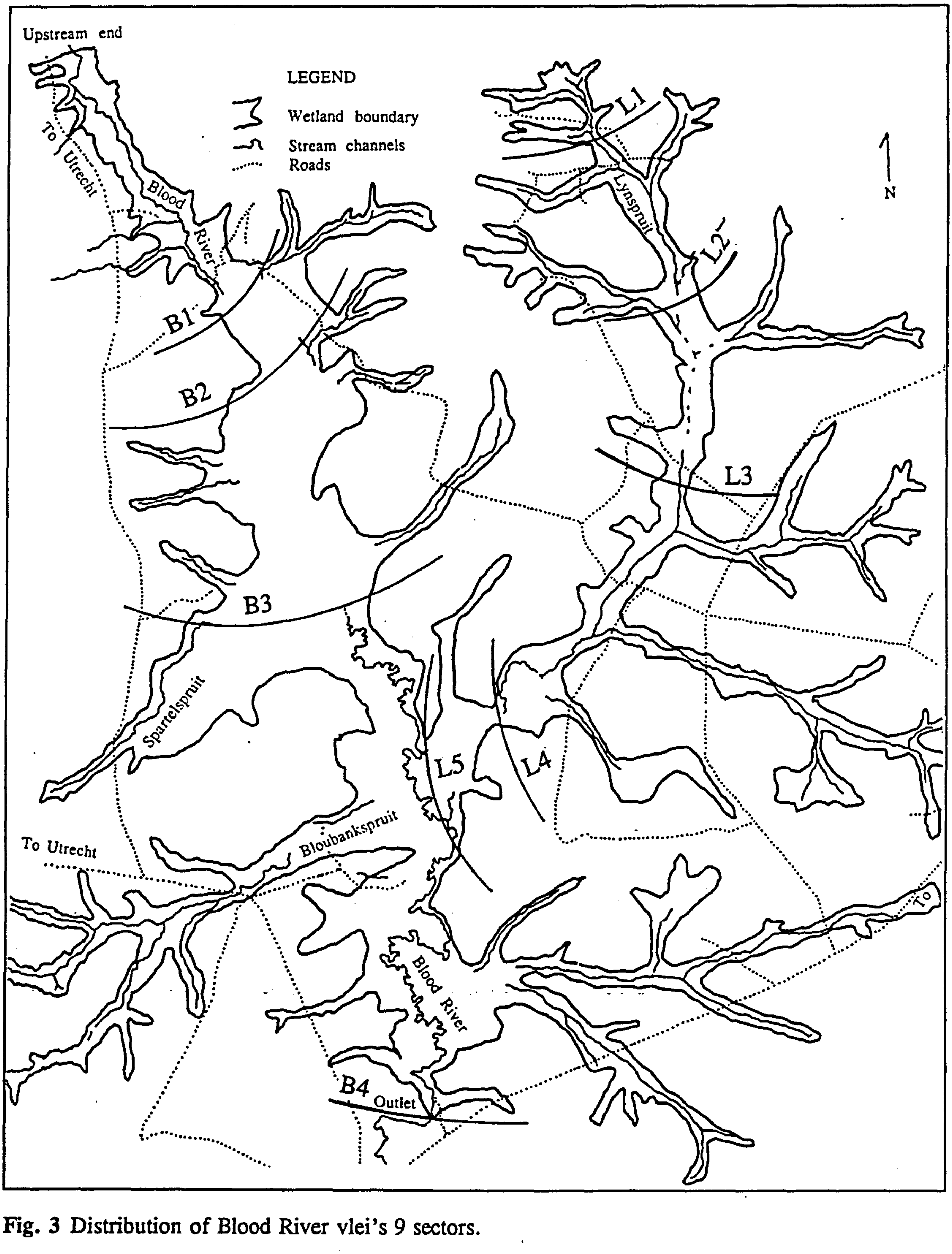

Fig. 3 Distribution of Blood River vlei's 9 sectors.

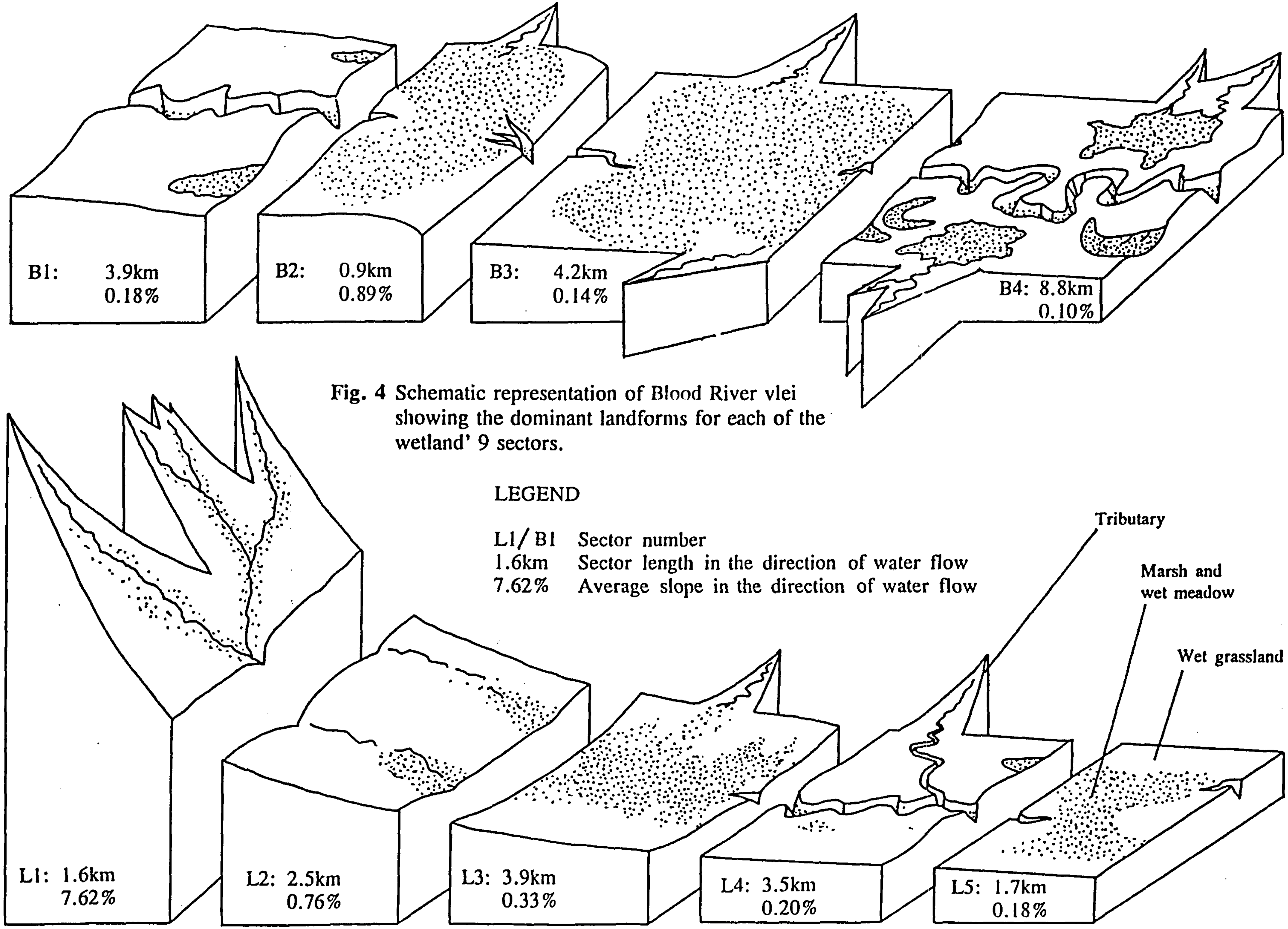

Fig. 4 Schematic representation of Blood River vlei showing the dominant landforms for each of the wetland' 9 sectors.

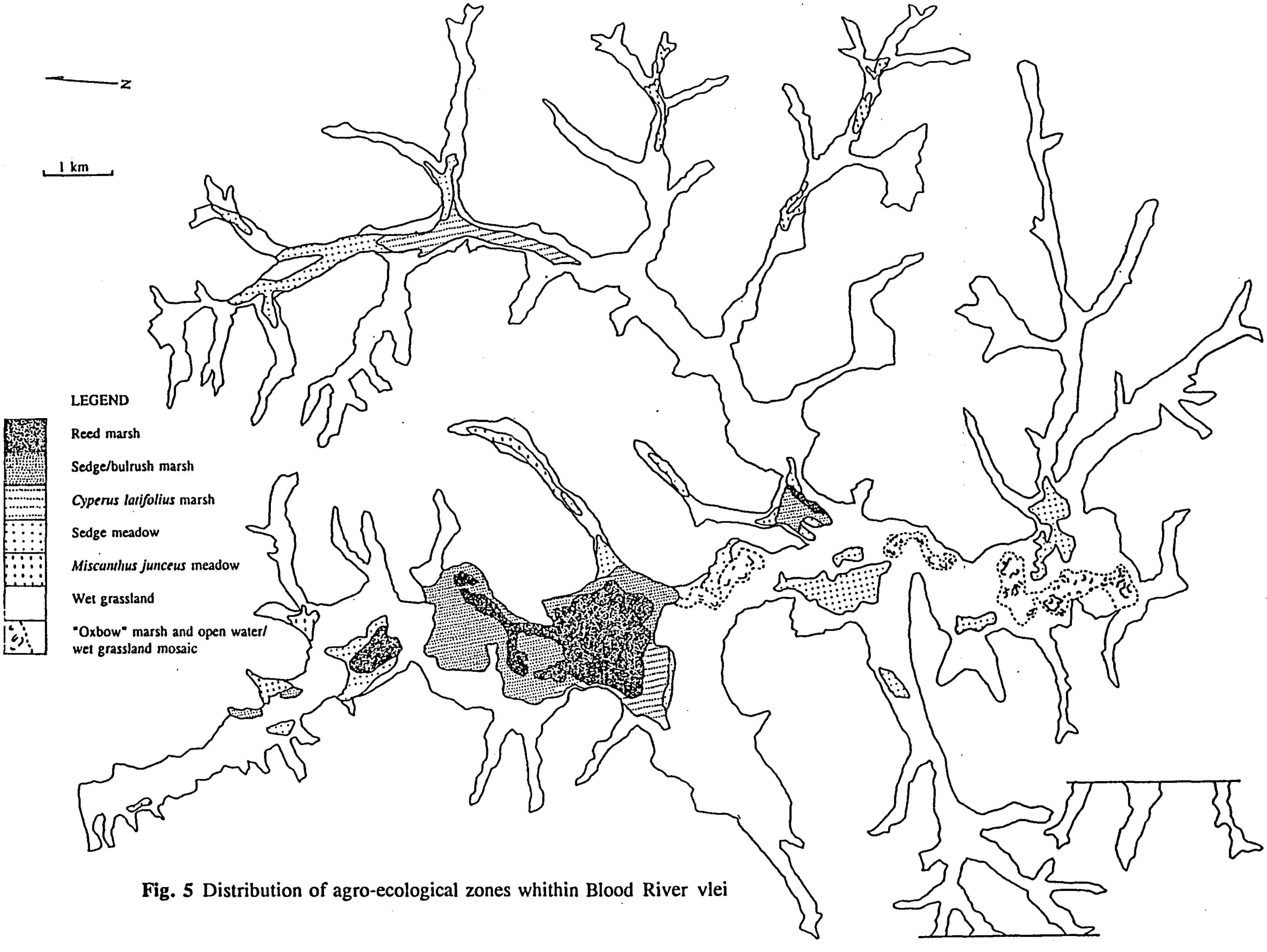

Fig. 5 Distribution of agro-ecological zones whithin Blood River vlei

Sector B2 and B3 comprise marsh-dominated bottomland flats which are largely unchannelled but are fed and drained by channels (i.e. they are channel-disrupting flats). A small portion between Sector B2 and Sector B3 is however channelized. Starting from the upstream end of Sector B2, flow becomes predominantly diffuse (there is no channel) and it continues for ca 0.9 km. At the change from Sector B2 to B3, which is associated with a sudden drop in elevation of over 5 m within a horizontal distance of less than 100 m, flow becomes channelized. This continues for ca 1.1 km into Sector B3 and then becomes diffuse, remaining diffuse for 3.1 km to the end of Sector B3 where flow again becomes channelized as it enters Sector B4.

Sector B4 resembles Sector B1 in that it comprises a wet grassland-dominated flat bisected by a well-defined main channel (2.5-5 m deep). However, it differs in that the flat is wider, its slope in the direction of the flow is gentler, the main channel is more sinuous and oxbow lakes and wet meadow areas are more common.

Sector L1 comprises wet grassland and *Miscanthus junceus (besemgras)* meadow-dominated slopes with clearly defined channels. The slope in the direction of flow is the steepest of all sectors in the wetland (see Fig. 4).

Sector L2 resembles L1, in that flow is still channelized and wet grassland and *Miscanthus junceus* meadow still predominate. However, it is flatter, interspersed marsh areas are more common and the channel is less deeply incised.

Sector L3 comprises a marsh-dominated bottomland flat which has predominantly diffuse flow and is fed and drained by the main channels of L2 and L4 respectively. This channel disrupting flat differs from those found in Sectors B2 and B3 in that the slope in the direction of flow is steeper and although a clearly defined channel is not present, flow is more concentrated in the central area (i.e. it is less diffuse).

Sector L4 resembles Sector B1 in that it comprises a wet grassland-dominated flat bisected by a well defined main channel (2-3.5 m deep). It differs in that the *Acacia*-dominated elevated areas are absent, which may be partly because it is in a different veld type, in which there are fewer trees.

Sector L5 has a very small area but has been recognized because it is markedly different from the contiguous sectors, Sectors B4 and L4. It comprises a marsh-dominated, unchannelled flat, fed and drained by channels and with an elevated wet grassland area adjacent to Sector B4.

3. SOILS OF THE WETLAND

Blood River vlei comprises a mosaic of different soil forms, varying according to the agro-ecological zones they typically occupy (Fig. 6). By far the most widespread soil forms are the Katspruit and Rensburg forms. The properties of the Katspruit form vary greatly because it occurs across all three soil wetness zones.

```
               |           AGRO-ECOLOGICAL ZONES
SOIL FORM      |  Marsh     Wet meadow     wet grassland:
               |                           flat   sloped
               |-------------------------------------------
Katspruit      |==========================================
Rensburg       |      -----=========================----
Kroonstad      |                            -----========
Longlands      |                            -----========

==========        frequent occurrence
----------        infrequent occurrence
```

Fig. 6 The range of agro-ecological zones in which the soil forms found in Blood River vlei commonly occur.

4. GEOLOGY OF THE WETLAND

The underlying geology of Blood River vlei is Ecca shale (of the Vryheid formation) and Karoo dolerite (Fig. 7). According to Begg (1989) the system owes its existence to a sill of dolerite lying across the outlet of the wetland that has resisted down-cutting of the river channel. Begg also draws attention to a fault located at the head of the vlei, and to coal outcrops in the wetland catchment which act as a source of sulphate (Brand *et al.*, 1967).

5. LOCAL CLIMATE

Blood River vlei occurs within Bioclimatic Group 8a (upland) (Phillips, 1973) for which the following is characteristic:

Annual precipitation:	836 mm (mean); 750-900 mm (range)
Relative humidity:	60-65%
Temperature:	17°C (mean annual); 39,5°C (extreme maximum); -6°C (extreme minimum)
Annual potential evapotranspiration:	1720 mm

Because the wetland is large, the surrounding topography varies from area to area within it, giving rise to differences in local climate. Sector B1 falls within a rainshadow and has the lowest mean annual rainfall (ca 800 mm). In contrast, Sectors L1 and L2 appear to have the highest mean annual rainfall (ca 950 mm) because of their favourable aspect and, possibly, also their higher altitude.

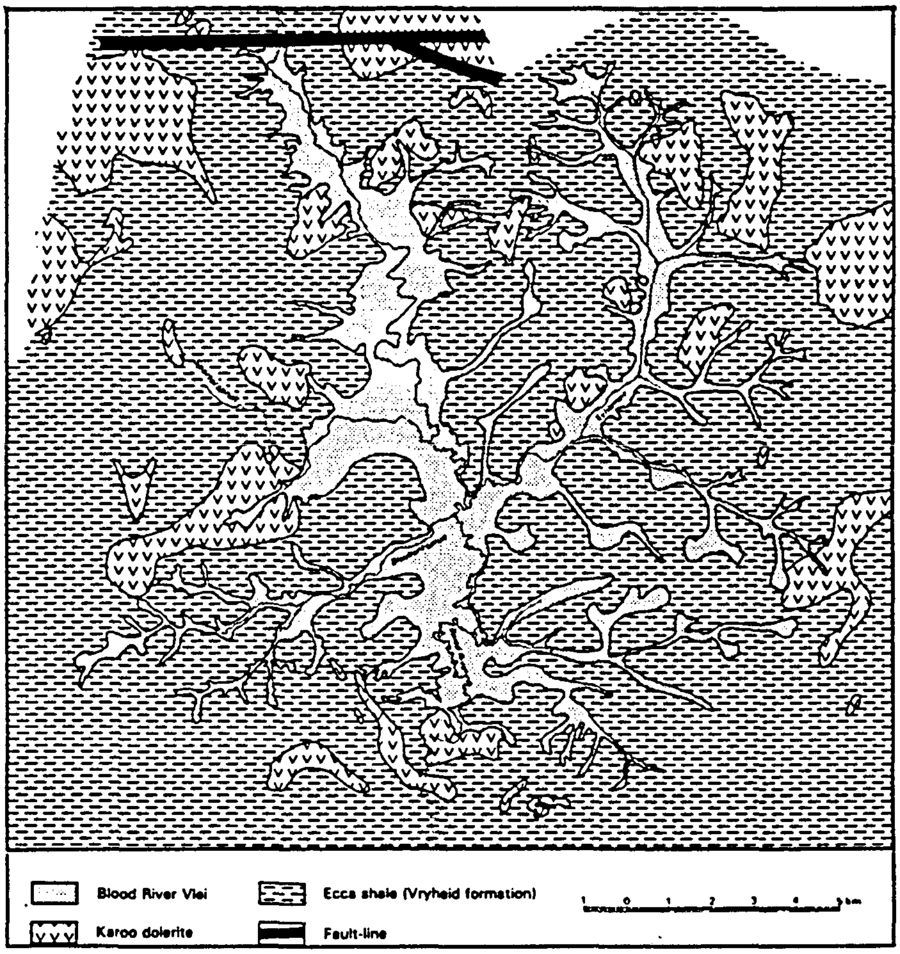

Fig. 7 Geology of Blood River vlei (from Geological Survey Department, as represented by Begg, 1989).

6. CATCHMENT DETAILS

Blood River vlei catchment is 557 km^2 of which 11% is occupied by the wetland. The estimated mean annual runoff from quaternary sub-catchment VO61, which corresponds with the wetland catchment, is 54 x 10^6 m^3 (Pitman *et al.*, 1981). The catchment extends across four different veld types: 57 (North Eastern Sandy Highveld), 64 (Northern Tall Grassveld), 65 (Southern Tall Grassveld) and 66 (Natal Sandy Sourveld) (Acocks, 1953).

The principal land-uses occurring in the catchment (expressed as approximate percentage areas of the catchment) are:

1.	natural veld grazing	ca 60%
2.	cropland and planted pastures	ca 35%
3.	afforestation	ca 5%

These land-uses have a variety of impacts on the wetland, summarized in Table 2. At present, commercial afforestation is confined primarily to the Lynspruit catchment, with 11%

of this catchment having been afforested. Numerous farm dams occur in the Blood River vlei catchment and, as is the case within the wetland, many of these dams were built in the last ten years. The primary reason for this appears to be the sudden increased demand for irrigation water, since Escom power became available in the 1980's.

Table 2 Current land-use impacts on Blood River vlei (subjectively assessed based on their extent in the catchment and on generally demonstrated effects of individual land-uses)

	LAND-USE			
IMPACT	Natural grazing	Crops	Dams	Afforestation
Increased sediment loads	1	2	0	0/1
Increased nutrient loads	0/1	2	0	0
Decreased water input	0	2/3	2	1
Altered water input timing	0/1	1	2/3	1

Level of impact 0= negligible 1= low
2= moderately high 3= very high

The most important effects of natural veld grazing in the catchment likely to influence Blood River vlei are:

1. increased soil loss, which increases the sediment loads in the wetland's receiving waters. Excessive soil loss from veld was probably at its worst in the 1930's. Most of the large donga areas present today had already undergone considerable erosion before 1944, as is discernible from the aerial photographs taken in that year; and

2. decreased infiltration by decreasing vegetal cover (particularly basal cover) and through trampling-induced compaction of the soil, resulting in water inputs into the wetland being less attenuated.

However, grazing induced degradation of the catchment, visible from a brief visual appraisal, was found to be localized to small areas. On the whole, vegetal cover is good for most of the veld areas of the catchment (Colvin, 1985; Smith, 1986). Present grazing practices appear not to be causing a substantial increase in sediment loads entering the wetland.

The principal effects of crop production are:

1. increased soil loss leading to increased sediment loads. It has been shown that even if lands are protected, and acceptable levels of soil loss are occurring, soil loss is still likely to be greater than that which would occur off well-managed natural veld (Verster *et al.*, 1992). Thus, where lands are inadequately protected, as discovered by Mynhardt (1993) in some areas of the catchment, the potential impact may be

considerable; and

2. a reduction in the surface and ground water input into the wetland, caused through increased evapotranspirative loss when crops are irrigated.

Probably the most important effect of dams is in reducing early season flow (see Section 11.5.1). Dams are also commonly used for water storage and extraction for irrigation. Through this and through evaporative losses from the dam surface, dams decrease the total water inputs into the wetland. Afforestation of catchments also causes a reduction in stream yields. At present, the afforested areas constitute only a small proportion of the catchment and it is unlikely that they are having a significant impact on the wetland. However, should this area substantially increase, the impact will also increase.

7. REGIONAL SIGNIFICANCE OF THE WETLAND

Begg (1989) recognized Blood River vlei as a top-priority wetland of critical importance to KwaZulu/Natal, by virtue of its key position in the Tugela catchment, its large size and favourable present day condition. Its large surface area, high surface roughness and important hydrological control areas (notably Sector B3), give the wetland a high water purification and streamflow regulation value. The immediate downstream users who benefit from the hydrological values of the wetland include farmers who extract water for stock watering and crop production, as well as potable water users in the Nkande rural area.

The wetland provides a wide variety of habitats ranging from permanently saturated reed marsh to temporarily wet grasslands, and from seepage slope areas rich in plant species to many small oxbow lakes of various depths and water regimes. It supports a wide range of plant and animal species, notably *Barbus palidus* (a fish species with a very restricted distribution in KwaZulu/Natal), and is well known for its large populations of waterfowl.

The wetland occurs in veld type 66, which is endemic to KwaZulu/Natal and under-represented in formally conserved areas. In addition, 90% of this veld type has been degraded (Colvin, 1985).

8. LAND OWNERSHIP

Portions of Blood River vlei fall within the boundaries of over 50 farms and involve some 40 farmers (Fig. 8). The proportion of individual farms occupied by wetlands range from about 2% to 55%, averaging about 20%. Generally speaking, the farm boundaries do not correspond with natural landform and vegetation boundaries within the wetland. Farmers managing the largest portions of the wetland are:

	Approximate size (ha)		
	Owned	Leased	Total
Claasen G H and Claasen G	390	740	1130
Human J	300	695	995
Knoetze S and Steenkamp N	400	-	400
Becker W J	350	-	350
Fourie P S (manager for Steenkamp F)	300	-	300

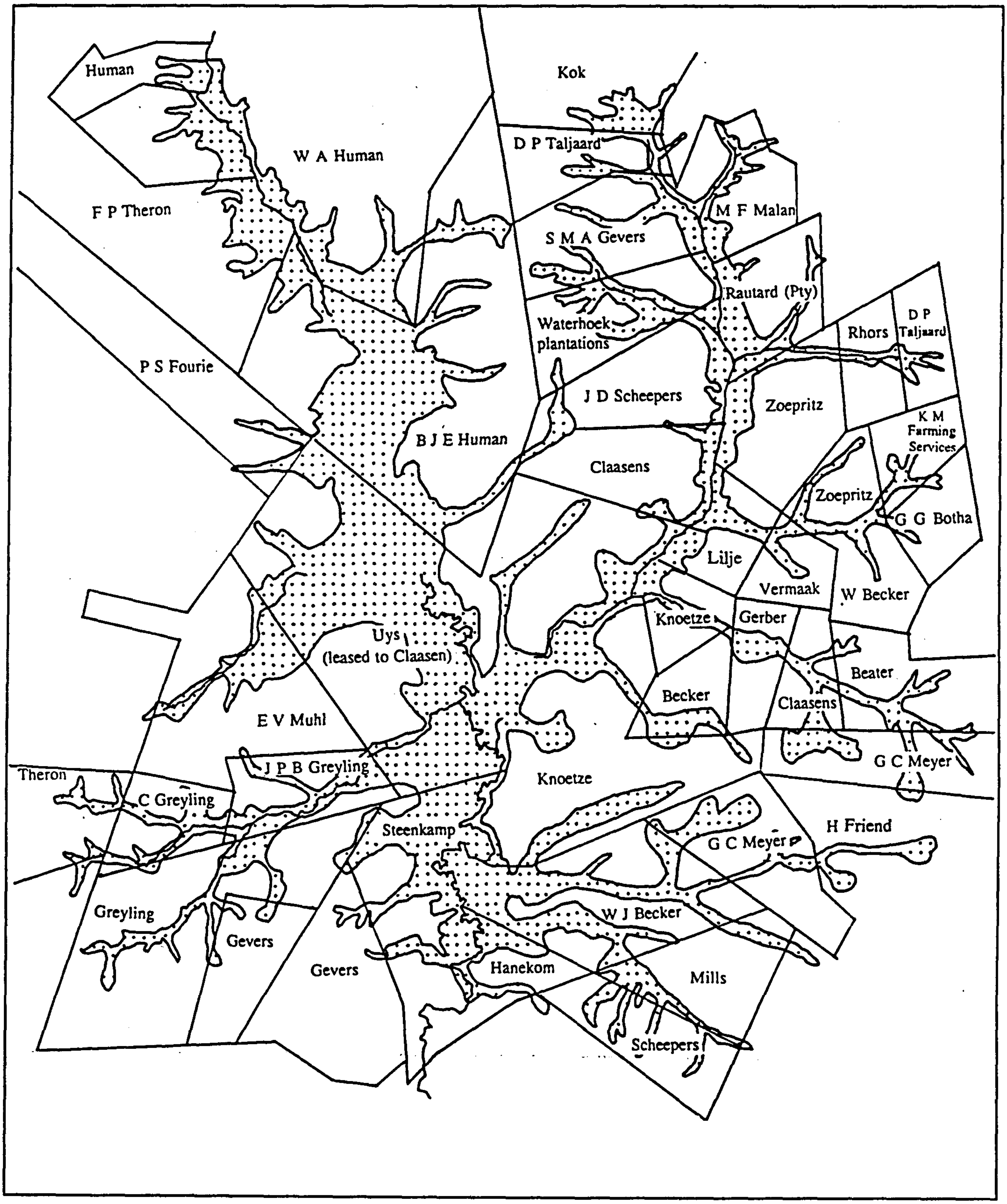

Fig. 8 Land ownership map of Blood River vlei. (as in 1993)

9. WETLAND FLORA, INCLUDING A DESCRIPTION OF WETLAND VEGETATION TYPES

The wetland is botanically undescribed, and no threatened plant species have yet been identified as occurring in it. According to Acocks (1953) most of Blood River vlei occurs within Veld Type 66 (Natal Sour Sandveld) but Sectors B1 and L1 occur within Veld Type 64 (Northern Tall Grassveld).

For the purposes of management, eight vegetation types have been identified based primarily on the dominant species (Table 3). These types vary according to where they commonly occur on the wetness continuum (Fig. 9) and which landform settings they typically occupy. Reed marsh typically occurs on unchannelled flats. Sedge/bulrush marsh also occurs on these settings as well as in basins and "backmarsh areas" situated on channelled flats. *Cyperus latifolius* marsh commonly occurs on channel-disrupting flats, but is absent from the wettest "core areas". Sedge meadow occurs in all the landform settings found in Blood River vlei but is most prevalent on the flats of Sector B4. *Miscanthus junceus* meadow is most common on slope and stream channel settings, particularly in Sectors L1 and L2, and also occupies the mid zone of basin settings. Although wet grassland occurs on slopes, channel banks, and in the outermost zone of basin settings, it is considerably more common on channelled flats than on any other setting.

```
VEGETATION TYPE                         WATER REGIME
                         Permanent/      Seasonal     Temporary
                         Semi-permanent

Reed marsh              =================----

Open water              =================----

Sedge/bulrush marsh     =================----

Cyperus latifolius             -============----
marsh

Sedge meadow                         -----============---

Miscanthus junceus                 -----------==========-------
meadow

Wet grassland                                       ----==========


============   frequent occurrence

------------   infrequent occurrence
```

Fig. 9 The range of water regimes across which the different vegetation types of Blood River vlei commonly occur.

Table 3 Dominant plant species, water regimes and soil features characterizing the different vegetation types found in Blood River vlei

VEGETATION TYPE	DOMINANT PLANT SPECIES	WATER REGIME AND SOIL FEATURES
Reed marsh	*Phragmites australis*	Permanently/semi-perm. wet. Wet to surface. A horizon: high OM, high root abundance, often sulphidic. B horizon: high/intermediate *n* value.
Open water	*Potomageton thunbergii* *Lagarosiphon sp.*	As for reed marsh but roots usually not abundant.
Sedge/bulrush marsh	*Cyperus fastigiatus* *Typha capensis* *Leersia hexandra*	Usually permanently/semi-perm. wet. Wet to surface. A horizon: see reed marsh. B horizon: intermediate *n* value.
Cyperus latifolius marsh	*Cyperus latifolius*	Semi-permanently wet. Wet to surface. A horizon: high OM, high root abundance, seldom sulphidic. B horizon: intermediate *n* value.
Sedge meadow	*Eragrostis planiculmis* *Eleocharis dregeana* *Leersia hexandra*	Seasonally wet. Wet to surface. A horizon: high OM, intermediate root abundance, non-sulphidic. B horizon: intermediate *n* value..
Miscanthus junceus meadow	*Miscanthus junceus* *Phragmites mauritianus*	See sedge meadow and wet grassland
Wet grassland	*Eragrostis plana* *Andropogon appendiculatus* *Eragrostis planiculmis*	Temporarily wet. Usually not wet to surface. A horizon: low/intermediate OM, Low/intermediate root abundance, non-sulphidic. B horizon: low *n* value.

Legend for Table 3

Permanently wet: the soil is flooded or wet to the soil surface throughout the year except in extreme drought years, when it may dry out.

Semi-permanently wet: the soil is flooded or wet to the soil surface throughout the wet season and often well into the dry season of most years.

Seasonally wet: the soil is flooded or wet to the soil surface for extended periods (>1 month) during the wet season, in most years, but is predominantly dry during the dry season.

Temporarily wet: the soil close to the surface (i.e. within 40 cm) is occasionally wet for periods > 3 weeks during the wet season, in most years. However, it is seldom flooded or wet at the surface for longer than a month.

Wet refers to soil that is saturated or close to saturation, such that anaerobic conditions will develop if the wetness state persists.

Wet to surface: indicators of anaerobic conditions (e.g. root channel mottling) are present through the upper profile and to the soil surface.

High OM: soil organic carbon levels are greater than 5%, often near 10%
Low OM: soil organic carbon levels are less than 5%, usually 2% or lower.

High root abundance: roots dominate the soil matrix in terms of volume, often forming a dense mat.

Sulphidic soil material has sulphides present which give it a characteristic "rotten egg smell".

n Value: the amount of water in the soil under field conditions relative to the percentage of clay and humus. It can be approximated in the field by squeezing the soil in the hand. Soils with high *n* values tend to be relatively unconsolidated, have a low load bearing strength, and undergo considerable subsidence when drained (Pons and Zonneveld, 1965; Soil Survey Staff, 1990).

10. WETLAND FAUNA

As yet, the fauna of Blood River vlei is very poorly described and only an inventory of the avifauna has been compiled (Appendix A). However, on the basis of known distributions and habitat preferences, a checklist of animals found in and around Blood River vlei (Anon, 1985, as cited by Begg, 1989) includes:

* 5 fish species
* 18 amphibian species
* 13 lizard species

* 28 snake species
* 49 mammal species

Of note amongst the species dependent on the habitat provided by the wetland is *Barbus palidus*. This species, which inhabits pools of slow-flowing streams, has a very restricted distribution in KwaZulu/Natal occurring only in the Blood River and upper Pivaan catchments (Coke, 1990).

11. CURRENT AND PAST USE OF THE WETLAND AND RECOMMENDATIONS FOR FUTURE USE

A variety of land-uses and land-use related activities have been and are being applied to the wetland. These are described in terms of their effect on the hydrological, erosion control and ecological values of the wetland. Following each description, recommendations for future use are made.

All of Blood River vlei is owned by commercial farmers, many of whom need to utilize their portions of the wetland for their livelihood. Thus, a non-utilitarian policy towards the management of Blood River vlei would be inappropriate. The recommendations given attempt to encourage sustainable utilization with the minimum of loss of the wetland's functional values.

11.1 Burning

11.1.1 Current burning practices and the effect of burning on the wetland's functional values

Blood River vlei is likely to have evolved under a burning regime because of lightning-induced fires. The burning activities of indigenous people and, later, European settlers, would have caused an increase in the numbers of fires. The burning regime now applied to the wetland varies from area to area, depending on the predominant vegetation type and the burning policy of the manager.

Sector B1 is burnt annually, mainly to allow for its utilization in the following season, because large areas are dominated by *Hyparrhenia* (thatch grass). If left unburnt, the stems from the previous season's growth detract from the grazing value of these grass areas.

Sectors B2 and B3, both comprising predominantly marsh, are also burnt annually. Cattle are seldom able to keep marsh areas short and palatable into the latter growing season (i.e. after December). Thus, large amounts of loose surface and standing litter accumulate. If these areas are not burnt before the beginning of the next growing season, this remaining litter limits the next season's growth. By removing unpalatable old growth and stimulating new growth, the grazing value is increased, which serves the interests of stock farmers. Burning also reduces fire risk.

Most of the Lynspruit sectors are burnt annually to increase their grazing value and to reduce fire risk. Some farmers in these sectors have their wetland areas burnt more frequently than they would otherwise choose, because intentional wetland fires occurring in neighbouring farms are inadequately contained. This usually occurs where a marsh area forms the border between farms because it is very difficult to maintain a firebreak within a marsh area.

Sector B4 is the least frequently burnt part of the wetland. It consists mainly of wet grassland, much of which is grazed moderately to heavily through to the end of the grazing season and beyond. Furthermore, dry-matter production is lower than that in marsh areas. Large amounts of unpalatable old growth that would otherwise limit the new season's growth do not accumulate as readily. Consequently there is less reason to burn to improve grazing than in Sectors B1, B2 and B3, unless grazing pressure is lenient. Farmers in this sector tend to burn only when the amounts of accumulated standing dead material are sufficient to inhibit the coming season's growth. This occurs at intervals of about two to four years, usually after a wet year when dry matter production is particularly high.

A few farmers consider burning to be harmful and prefer to use other methods. They may spray foliar nitrogen on the standing dead material to encourage stock to utilize it, rather than burning it.

Burning has both positive and negative effects on the wetland's functional values. For example, controlled regular burning increases the breeding habitat value of sedge marsh for red-chested flufftail (B Taylor, 1991. pers. comm. Department of Zoology and Entomology, University of Natal, Pietermaritzburg). Although little work has been done in KwaZulu/Natal on the recovery of wetland-dependent species populations following fire, it appears that a fire return frequency of 2 years is unlikely to have a major detrimental effect on any of the known wetland-dependent species in the humid to sub-humid areas of KwaZulu/Natal. However, the population recovery rate of wetland-dependent species may depend on the presence of unburnt refuges from which recolonization may occur (D Johnson, 1991. pers. comm. Natal Parks Board, Pietermaritzburg). If extensive areas are burnt, as occurs in some areas of Blood River vlei, this is likely to detract from the wetland's ecological value. In September 1993, almost all of Sectors B2 and B3 were burnt. Nevertheless, in Blood River, although large contiguous areas of the wetland are burnt, fires may be patchy, particularly in marsh areas. The extent and patchiness of fire in Blood River vlei should be studied so that the burning practices may be more reliably assessed.

Timing of burning is important. Early winter burning adversely affects winter-breeding animal species (e.g. the Marsh Owl: *Asio capensis*) and summer burning is obviously detrimental to summer-breeding species. Late winter/early spring burning (as currently occurs for most of Blood River vlei) is least likely to impact on breeding animals as the majority of winter breeders have completed breeding and the summer breeders have yet to begin.

By causing an exposed blackened soil surface and enhancing early spring growth of wetland vegetation, burning promotes evapotranspirative loss of water from wetlands, but this effect should not persist for more than a few weeks. Although the period is short, some farmers in the Lynspruit Sectors report that burning sometimes causes a sudden decrease in streamflow in response to this increased water loss.

11.1.2 Burning recommendations

Because vegetation types and farming practices are so varied, and because the effects of burning are incompletely understood, it is inappropriate to make overly prescriptive burning recommendations. Some guidelines are given which concern: (1) timing and frequency of burns; (2) influencing fire behaviour; and (3) co-operative rotational burning strategies.

1. Burning should take place in late winter to early spring as burning at this time is likely to have the least ecological and hydrological impact. A burning frequency of every second or third year is preferable.

2. Preferably burn under conditions of high humidity and low air temperature, in order to achieve a cool burn.

3. Preferentially burn areas with abundant dead (moribund) standing material and loose surface litter that is obviously limiting new growth.

4. If conditions are undesirable for burning (e.g. if the soil is very dry and susceptible to sub-surface fires or if the weather conditions are consistently unsuitable), delay burning until the following year.

5. Head fires (burning with the wind) are generally preferable to back fires (burning against the wind). Temperatures at ground level tend to be higher in back fires and the impact on the growing points of plants is greater. Although the fire front advances less rapidly in a back fire, it is more difficult to predict the direction of the fire. In addition, because the fire front advances more rapidly in a head fire, particularly if the wind speed is high, the fire has less time to spread sideways. Head fires can be used more effectively for burning portions of the wetland without the use of fire breaks. However, this method depends on factors outside the manager's control, such as wind direction changes, and cannot be relied upon for consistent block burning.

6. Keep records of management practices, to monitor progress.

7. Take into account localized known important bird breeding areas (e.g reed marsh areas used by Purple Heron [*Ardea purpurea]* for breeding should not be burnt every year).

8. Cattle can be used in promoting patch burns by reducing the fuel load and creating puddles.

9. Work out burning strategies on a sector basis. In any one year preferably not more than 65% of any sector should be burnt. Because it is difficult to maintain fire breaks through marsh areas, biennial burning will require that all of a given area of continuous marsh be protected every second year. Although this may not be feasible in Sector B3, due to its large area of marsh under different ownership, Sectors B2 and L5 have smaller marsh areas which are under single ownership, making biennial burning more feasible.

11.2 Natural grazing by domestic stock

11.2.1 Current grazing practices

The wetland provides natural grazing for stock, which graze on all the vegetation types. The level and timing of utilization does, however, vary according to vegetation type. Some of the marsh areas, particularly reed marsh, are inaccessible to cattle because their soil is soft and unconsolidated. Accessible marsh areas are generally only used in the early growing season. The preference of cattle for marsh areas depends, in part, on the quality and quantity of food in the surrounding non-wetland areas. Only in the early growing season when wetland areas start to grow before non-wetland areas, are accessible marsh areas grazed readily by cattle. Later in the year when the marsh vegetation becomes less palatable to stock, marsh areas are less utilized. Appreciable utilization of marsh areas during the mid and late grazing season, usually only occurs when the food is in short supply in the surrounding areas. This is commonly caused by drought, when marsh areas may provide a valuable source of forage. It also occurs on heavily stocked farms, causing food to frequently be in short supply outside the marsh areas, even in non-drought periods. Although the majority of farms in Blood River are not stocked to this level, some appear to be.

Wet grassland, sedge meadow and *Miscanthus junceus* meadow areas are used throughout the growing season. However, the dominant species in *Miscanthus junceus* meadow, *M. junceus*, is very coarse textured and not a favoured grazing species. Sedge meadow has more palatable species and is of greater grazing value, but appears to be of less value than wet grassland. Provided that the area is not degraded, forage quality of wet grasslands appears to be comparable with that of non-wetland grassland. Wetland areas also usually have a higher base status than the surrounding non-wetland areas, which may enhance forage quality. Because wet grasslands are less limited by moisture deficiencies than non-wetland grasslands, forage production is usually higher and this is of particular value in the early grazing season, when food shortages are most likely. Although there is as yet no published evidence to support it, wet grasslands appear to have higher grazing potentials than non-wetland areas.

11.2.2 The impact of natural stock grazing on the wetland's functional values

Veld condition assessments (using a rapid cover abundance method) show that ca >50% of the wet grassland areas in Blood River Vlei are dominated by Increaser II species, most importantly *Eragrostis plana*. Some of these areas were previously cultivated (as shown by examination of 1944 airphotos) which may be why they are now dominated by *E. plana*. Most of these areas were not previously cultivated and it is probably inappropriate grazing practices (primarily heavy stocking) that has lead to a reduction in the abundance of Decreaser species (principally *Andropogon appendiculatus*), favouring Increaser II species. Where there was information about the past history of areas retaining a high abundance of Decreaser species, it indicated that they had been leniently grazed.

Once *A. appendiculatus* has largely been lost from an area, and has been replaced by *E. plana*, it is very difficult to manage the area so as to improve the veld condition.

Andropogon appendiculatus has a high forage value, and grazing heavily enough to decrease its abundance reduces the animal production potential and profitability, besides being ecologically undesirable.

Some of the sedge meadow areas have been heavily utilized. Because they are wet for much of the growing season, the effect of trampling is relatively high and likely to result in the soil being subjected to poaching (deep treading). Poaching, which occurs when soils are wet, refers to the disruption of soil structure caused by repeated trampling. In this state the soils become more vulnerable to erosion and compaction (Bryan, 1977; Wilkins and Garwood, 1986). This is undesirable, particularly if it occurs on a landform setting which is erosion-prone (e.g. a slope). However, most sedge meadow utilization occurs on landform settings not prone to erosion and they are currently not detracting significantly from the wetland's functional values. Trampling of the vegetation also decreases plant productivity, thereby reducing forage production (Wilkins and Garwood, 1986) and profitability.

Although most marsh areas are very leniently utilized, some marsh areas are moderately to heavily used, particularly in drought years. Such use results in:

1. a reduction in vegetal cover in patches;
2. trampling down of the soil surface, often in localized areas along paths; and
3. soil poaching (see above paragraph dealing with sedge meadows describing the consequences of this).

From an ecological point of view, reduced vegetation cover and poaching of the soil may be advantageous, as it enhances the heterogeneity of the system. Areas that have been grazed short and subjected to poaching, are favoured by probing feeders such as snipe (Neely, 1968). In Blood River Vlei, Ethiopian snipe (*Gallinago nigripennis*) occurred in high numbers in some grazed areas.

Smith (1986) records that soils within the wetland had been compacted by grazing animals because he found them very hard to auger. It should be noted, however, that most wetland soils such as the Katspruit and Rensburg forms tend to have inherently low infiltration capacities (Schulze *et al.*, 1989) and low compaction potentials. Decreased infiltration is more commonly a feature of injudicious management of the wetland catchment. Fine sandy alluvial soils do however generally have a higher compaction potential. Thus, within Blood River Vlei, grazing induced compaction would probably have occurred in localized areas with alluvial soils, but there is as yet no substantiating evidence.

On the whole, there has been little loss of the wetland's hydrological and erosion control values, although there has been localized serious gully erosion (see Section 11.3). Heavy grazing by domestic stock in the past was probably the main cause of this.

Cattle paths incised into high streambanks are common in Sectors B1, B4 and L4, and some of these could develop into dongas.

11.2.3.1. Recommended stocking rate

Unfortunately, veld condition bench-marks have not been described for wetland areas, nor have grazing potentials been determined. The recommended stocking rate for the particular Veld Type in which the wetland occurs is 3 ha AU^{-1} (G Hatch, 1993, pers. comm. Grassland Science Department, University of Natal, Pietermaritzburg). Although there is no published evidence, wet grasslands appear to have higher grazing potentials than non-wetland areas (see Section 11.2.1). Because of this, the recommended stocking rate for wet grassland areas in Veld Type 66, which is 3 $haAU^{-1}$ could probably be safely increased to 2 $haAU^{-1}$. However, veld condition must be taken into account, as well as factors contributing to the susceptibility of wetland areas to erosion. The following are recommended:

1. reduce the recommended stocking rate by an amount proportional to the relative abundance of Increaser II species present (Table 4) to give the corrected stocking rate (CSR); and

2. reduce the CSR to account for the susceptibility of the wetland area to erosion (Table 5).

Table 4 Recommended stocking rate adjusted to account for veld condition

Percentage of Increaser II species	Corrected stocking rate (expressed as a percentage of the potential grazing capacity for the given Bioclimatic Group)
0- 30%	100%
30-60%	85%
>60%	70%

Table 5 Stocking rate correction to account for landform setting and slope (expressed as a percentage of the corrected stocking rate)

Landform settings with intermediate erosion potentials: slope (<10%), frequently flooded flat	80%
Landform settings with high erosion potentials: channel (streambank), slope (>10%)	60%

Areas considered to be particularly susceptible to erosion (such as where active erosion is occurring) (see Section 11.4), should be excluded entirely from grazing.

In the mid and late grazing season, domestic stock select strongly for wet grassland areas, less strongly for wet meadow, and avoid marsh areas. If a given wetland area were stocked without consideration for agro-ecological type then the effective stocking densities in the wet grassland areas in the mid and late grazing season would be very high. The magnitude of this would obviously depend, in part, on the proportion of the wetland surface area occupied by wet grassland. Take for example, a 30 ha wetland area consisting of 10 ha of wet grassland and 20 ha of marsh and at a stocking rate of 3 ha AU^{-1}. Because the animals concentrate on the wet grassland area in the mid and late season, the effective stocking rate would be in excess of 2 $haAU^{-1}$ on the wet grassland areas. Consequently, the stocking rate calculation must be based on the proportion of wet grassland area.

The extent to which marsh and wet meadow areas should be excluded in the calculation of stocking rate will be determined by the degree to which these areas are selected against. If it can be demonstrated for the given wetland area that during early spring, livestock do not show a strong preference for wet grassland, wet meadow and marsh areas should be included in the stocking rate calculations for the early grazing season only. Later in the season when these areas become less acceptable, they should be excluded from the calculation.

11.2.3.2. Fencing of wetlands and other means of reducing area selective grazing

Because wetland grazing areas have special management requirements, it is beneficial to fence them off as special use camps. If it is impractical to do this, the following guidelines aimed at reducing the activity of cattle in wetland areas, should be considered:

1. herd animals managed under a herding system away from wetland areas into non-wetland areas at the desired times;

2. assure water availability in adjoining non-wetland sites. Where this is not possible, it is very important that the number of drinking-point access paths down to the streams in the wetland be limited and that those used be carefully monitored and kept stable (e.g. with stone packing);

3. place supplementary feed in non-wetland areas where grazing is desired and minimize its location near and within wetland areas; and

4. cut herbage for hay or green chop, or mow old grass to attract more grazing to under-utilized areas in the farm.

If the stocking rate for the overall area is excessive, there will be few under-utilized areas anywhere in the landscape, diminishing the effectiveness of these measures. This, again, emphasises the importance of maintaining reasonable stocking rates.

11.2.3.3. The grazing system

The wetland should be rotationally grazed using a flexible system, whereby the area is grazed until a predetermined level of use or disturbance is achieved, beyond which continued use of the wetland is likely to begin detracting from the hydrological and ecological values, and in many cases its current production potential. A full 12 months rest should preferably be included every 4 years. It is very difficult to prescribe a threshold level of use, as it will depend on the vegetation type. A suggested level is when the sward has been grazed to an average height of 8 cm and/or when the most favoured plants have been grazed to a height of 4 cm.

Grazing should be discontinued when the soil becomes flooded or wet to the surface, at which stage grazing livestock should be taken out of the wetland area until it dries out again. Soils are more susceptible to poaching when wet (Wilkins and Garwood, 1986) (see Section 11.2.2, para. 2).

The exclusion proviso based on soil wetness may appear to be over-conservative and unjustifiably deny the farmer a valuable grazing source. It should be noted that when the need for grazing to supplement drought-limited non-wetland grazing is high, then grazing of the wetland is usually permissible. This is because it generally corresponds to times when the wetland soils are least susceptible to erosion and are acceptably dry for use. In contrast, when the use of the wetland is likely to have the greatest impact, as a result of being wet to the surface, then the need for wetland grazing is likely to be low. This is because it usually corresponds with wet periods when non-wetland forage production is high.

11.3 Erosion

11.3.1 A description of eroded areas in the wetland

Although there are several erosion sites within Blood River vlei, erosional degradation has as yet not detracted substantially from the wetland's functional values. However, active gully erosion in some sites is threatening large portions of the wetland (Fig. 10). An investigation of the erosion status of Blood River vlei by Wilmot *et al.* (1994) suggests remedial measures for these and other less serious sites.

11.3.1.1 The Sector L3 gully (E1)

The most rapidly eroding area in the wetland is on the main Lynspruit stream, where the flow in Sector L3 concentrates to become channelized in Sector L4. Dicks (1992) who described this area in detail, points out that the donga head is eating back into the unchannelled marsh area of Sector L3 at the alarming rate of ca 15 m a year. It has already altered ca 150 ha of wetland and is currently posing a threat to ca 400 ha of marsh.

11.3.1.2 The Sector B2 gully (E2)

As described, Sector B2 consists of a 0.9 km flat followed by a sudden drop in elevation of over 5 m within a horizontal distance of less than 100 m. This, in turn, is followed by another flat (Sector B3). The upstream part of B3 is channelled and it is the head of this channel which is cutting back into the marsh-dominated flat of B2. If this continues it will exert a tremendous draining effect on this area: the channel elevation is over 5 m lower than Sector B2, and threatens the whole of Sector B2. Although its rate of advance is slower than that of the Sector L3 gully, airphoto comparison indicates that it has advanced ca 50 m at two head points in the last 45 years. Field examination (January, 1993) indicates there was no recent back-cutting: large cracks (> 50 cm wide) and slumping were visible, but no blocks of soil had freshly broken away from the face.

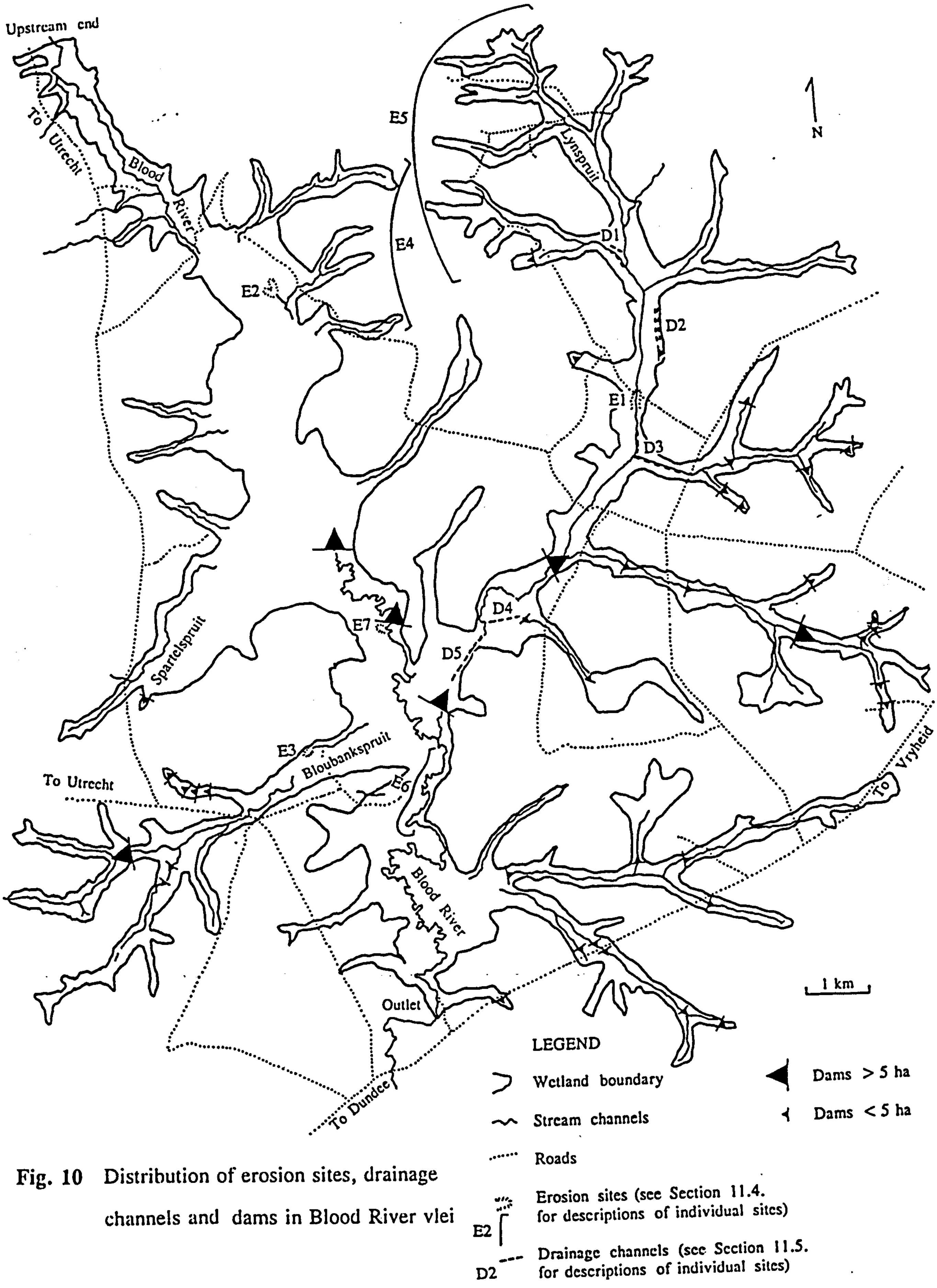

Fig. 10 Distribution of erosion sites, drainage channels and dams in Blood River vlei

Although cattle have now largely been excluded from the gully head region, they may have contributed to erosion in the past. Airphoto comparison suggests that a channel switch, caused by excess deposition of sediment, may also have contributed to the erosion by causing a greater concentration of flow in the eroding area.

11.3.1.3 The Bloubankspruit gully (E3)

The situation here resembles that of the Sector B2 gully in that a channel is cutting back into a flat (dominated by marsh and sedge meadow). It differs in that:

1. the wetland area being threatened is smaller; and
2. the difference between the upstream flat elevation and the elevation of the bottom of the channel draining it is smaller.

11.3.1.4 The tributary gullies of Sectors B2 and B3 (E4)

Three deep and severely eroded gullies extend out from the eastern margin of Sectors B2 and B3. These constitute some of the most serious erosion to have occurred in and around the vlei in the last 100 years, and have caused the deposition of considerable amounts of sediment in Sectors B2 and B3. Most of this gully erosion occurred prior to 1944 when the area was very heavily stocked, and although sediment lost during Demoina floods was very high (Smith, 1986), rapid head-cutting and widening of the gullies no longer occurs. However, soil loss from these areas is still likely to be relatively high because most of the gully sides are bare.

11.3.1.5 The Sector L1 gullies (E5)

Sector L1 has the steepest gradient in the wetland, which has probably aggravated it susceptibility to gully erosion. This was extensive prior to 1944. Although rapid head cutting and widening of these gullies appears to have stopped (some of the gully sides are well vegetated) there are bare areas likely to be contributing sediment loads greater than is desirable.

11.3.1.6 The Sector B4 gullies (E6 and E7))

Three gullies have eroded out from the main Blood River Channel in Sector B4 below the junction with the Lynspruit (E6), and a single gully has eroded out from the channel above the Lynspruit junction (E7). The former three are old and are present in the 1944 airphotos. Field inspection shows that active erosion of the head, outward movement of the sides and down-cutting of the gully bottom are fairly limited. However, soil loss from these areas is still likely to be high because large areas of the gully sides are bare.

The gully above the Lynspruit junction (E7) appears to be very new, and is not visible in the 1976 air photos or 1984 orthophotos. Field inspection shows active gully erosion to be occurring at the gully head and sides. This gully occurs just below a dam wall built across the Blood River vlei in the 1980's. It appears that during high flow periods the dam not only overflows at the concrete outflow but also around the side of the earth wall (on the opposite side to the outflow) and down the route of what is now the actively eroding donga.

11.3.2 Recommendations concerning the gullies

Because the Sector L3, Sector B2, Bloubankspruit and active B4 gullies threaten areas of functioning wetland, it is recommended that they, as well as those identified by Wilmott *et al.* (1994) as having priority, be stabilized as a matter of urgency. Measures should be taken to reduce the level of erosion from the other areas (e.g. through revegetation).

11.4 Drainage channels

11.4.1 A description of drainage channels in the wetland

For its large area, Blood River vlei has very few drainage channels. Those present (see Fig. 10) are all found in the Lynspruit sectors and include:

The drainage channels in Sector L2 dug between 1944 and 1976. These have not been maintained and, now well colonized by wetland vegetation, are less than 50 cm deep. Although they appear to be slightly decreasing the water retained in this sector, their influence is likely to be small and they do not appear to pose an erosion threat.

The recently-dug contour drainage channels in Sector L3. These are narrow (ca 1 m) and shallow (ca 50 cm), run along the approximate contour of the slope and currently have a relatively small impact on the area. This may change with time. It should also be noted that these channels occur in the largest known area of sloped wetland in Blood River vlei. It has a high species richness and an assemblage of plant species resembling little else found in the wetland, and is of high conservation importance.

The drainage channel in Sector L4 dug prior to 1944. This channel, which has now eroded to over 2 m deep appears to have had a significant impact on the wetland by contributing to the Sector L3 gully (see section 11.3.1.1).

The cross channel in Sector L4 dug prior to 1984. This leads from downstream of a small dam on a tributary of the Lynspruit to the main Lynspruit stream channel. Active erosion is occurring at its lower end.

The bypass drainage channel dug in 1992 in Sector L5. Prior to construction of this channel, surface water flowing from the large dam in Sector L4 to the dam in Sector L5 passed through the extensive marsh area of Sector L5. The drainage channel was constructed to bypass the marsh and make the flow between the two dams more direct. Mynhardt (1993), who describes the channel and its likely consequences, considers that it will not only be detrimental to the water regime of the present marsh area but that it is also an erosion hazard.

11.4.2 Recommendations concerning drainage channels

Remedial action is essential to overcome the threats posed by the drainage channels in Sector L3 (contour channels), Sector L4 (cross channel) and Sector L5 (bypass channel). Plans for such action are currently being developed by the Directorate of Resource Conservation. (See Section 11.3.1.1. for recommendations regarding the L4 main channel).

11.5 Dams, weirs and water extraction

11.5.1 Extent of dams and their effect on the functional values of the wetland

Approximately 38 small (< 5 ha) farm dams have been built on various small streams within the wetland. Six large (> 5 ha) farm dams have been built at various positions on the Blood River, Lynspruit and on other large streams (Fig. 10) within the wetland. There are two small weirs in Sector B4.

All of the large dams have been built since 1984, and this is also common to the Blood River vlei catchment. As with the catchment dams, the primary motivation behind dam construction was the sudden increased demand for irrigation water, since Escom power became available in the 1980's. Another reason for the construction of some of the dams (e.g. the dam between Sectors B3 and B4) was to increase the waterfowl populations, thereby increasing the area's hunting potential.

While dams perform certain wetland functions (e.g. sediment trapping and water storage), they cannot fulfill others. Although the open water habitat associated with dams benefits certain species, e.g. spur-wing geese (*Plectropterus gambensis*), the habitats of specialised wetland-dependent species are frequently lost. The characteristic wetland vegetation may be partly compensated for by that which develops around the shoreline, but this is often a poor substitute, particularly where frequent large drawdowns and wave action hinder emergent plant establishment and growth.

Dam walls also obstruct the movement of aquatic animals, especially fish. This applies particularly to dams that lack adequate fish ladders and which cause periodic cessation of flow. This applies to the two main dams built in the Blood River stream. Coke (1990) considers damming of the Blood River stream a threat to *Barbus palidus*, an important species occurring in Blood River vlei (see Section 10).

Although individually the effect of small farm dams is small, where a series of dams occurs along a stream, the cumulative effect in reducing the flow may be considerable, particularly where there is extraction (Bruwer and Ashton, 1989). Dams can, however, increase dry season flow if water extraction is low, and outflow of water collected in the wet season is facilitated through the dam wall outlet or seepage through the wall. However, irrespective of whether dams increase or decrease dry season flow, the first wet season flows are often retained in the dam until it has filled, because levels have been depleted at the end of the dry season. This is likely to be detrimental to the river biota and to downstream users (Bruwer and Ashton, 1989). The bursting of small dams is an additional disadvantage, and may contribute to flood damage and sediment release.

It has often been argued that water resources could be conserved by flooding wetlands with a dam, since transpiration by wetland plants increases water loss to the atmosphere. However, many workers (e.g. Eisenlohr, 1966; Paijmans 1985; Chapman, 1990) have reported losses from vegetated wetlands to be less than from open water, particularly in winter when standing dead and loose surface litter reduces evaporative loss from the wetland.

The dam between Sectors B3 and B4 has been the subject of much controversy (see Begg, 1989 and Mynhardt, 1993). Without a proper impact assessment it is difficult to comment on the impact of the dam, but it seems that, provided that the dam is not used for water extraction, and that the water level remains below the agreed upon limit, it is not substantially detracting from the functional values of Blood River vlei. Although the loss of ecological integrity at a local scale is high, the extent to which the dam is detracting from the overall ecological value of the wetland appears to be low. S de Jager (1993, pers comm. Natal Parks Board, P O Box 224, Vryheid, 3100) notes that the dam supports large populations of a range of water birds. However, it is important to note that should the building of such dams set a precedent in the wetland, the cumulative effect of several such dams would substantially detract from the hydrological and ecological value of the wetland. Assessment of proposals for further damming of the wetland should not be undertaken on a site-by-site basis, but should be evaluated from the perspective of the overall wetland.

11.5.2 Recommendations concerning dams and water extraction

There is every indication that new dams will continue to be constructed in the wetland and its catchment. This is worrying because of the potentially negative effects of dams, as discussed above. Thus, it is recommended that a policy/plan should be formulated concerning the construction of dams and extraction of water from Blood River vlei and its catchment. A hydrological study should be undertaken to determine the effects of current damming, extraction and afforestation activities on catchment runoff, and to predict the effect of further developments.

11.6 Roads

Roads cross Blood River vlei's small tributaries in about 10 places. The main body of the wetland is crossed at two places across Blood River and at 4 places across the Lynspruit. These road crossings are likely to modify local water flow in the wetland. In addition to having a damming or draining effect on the flow upstream of the road, causeways often concentrate water flow downstream, and detract from the ecological and hydrological values of the wetland. From a superficial examination of the road crossings, their effects appear to be very localized and they do not effect wide areas of the wetland. However, if more road crossings are built, these should be carefully planned and controlled (Mynhardt, 1993).

11.7 Crop production

Examination of the 1944 airphotos shows that wetland cropping was more prevalent than now. Very limited areas of the wetland, comprising non-wetland/wet grassland mosaics are now cultivated, mainly for maize production. At present these limited areas are unlikely to be detrimental to the wetland's functional values. However, as cropping generally detracts greatly from a wetland's ecological value and is undesirable from a hydrological and erosion control point of view, no further croplands should be established. Furthermore, the inclusion of ley cropping or the conversion of cropland to perennial pastures should be considered as this would reduce the environmental impact of current crop production practices.

11.8 Waterfowl hunting

Blood River vlei is regarded as one of the best localities in the region for the shooting of waterfowl (Begg, 1989). Waterfowl numbers decline in dry years because of the drying up of open water as the water table falls. If open water could be artificially maintained during these dry periods, bird numbers would be more consistent. This was the reason for the construction of the 2 dams across the Blood River in Sector B4. However, as discussed in Section 11.6, dams detract from other wetland values.

Hunting of ducks has been on both an informal basis as well as on a formal commercial basis, involving outside paying hunters. Some farmers believe that the commercial shooting enterprise led to the demise of the wetland's duck population. However, there is no conclusive proof to substantiate this. Other factors such as successive dry years and the pesticide poisoning of birds on croplands may have resulted in the population decline. Sustainable harvesting of resources from wetlands in their natural state is a sound and desirable policy. Thus, it is recommended that an investigation of the waterfowl-shooting potential of Blood River vlei and its relationship with other land-use activities, such as burning and crop production, be undertaken and an overall plan for the shooting of waterfowl in Blood River vlei be drawn up.

11.9 Ecotourism

Colvin (1985) considers Blood River vlei to have a low tourism value unless included with the more scenically appealing Skurweburg. However, the wetland does have several features which enhance its eco-tourism potential, including:

1. a variety of wetland habitats, e.g. oxbow lakes;

2. large populations of water birds; and

3. places of historical interest, e.g. the site of the Battle of Blood River Poort, which is adjacent to Sector B1.

The greater the benefits that are derived by a wetland owner from a functioning natural wetland, the smaller will be the incentive to develop/intensify use of the wetland.

Consequently, the loss of value of the wetland to society at large that would occur with development, would be avoided. If managed correctly, ecotourism represents a means of utilizing a natural area on a sustainable basis, with a relatively small loss in the integrity of the area. Thus, it is recommended that the ecotourism potential of Blood River vlei be investigated more thoroughly and that ecotourism be actively promoted.

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13. GLOSSARY

Animal unit (AU). An animal with a mass of 450 kg and which gains 0.5 kg per day on forage with a digestible energy percentage of 55%. Other types of animals are related to this unit according to the relationship between the three-quarter power of their mass and a similar function of the mass of a 450 kg animal. An animal with a mass *m* constitutes:

$$\frac{m^{0.75}}{450^{0.75}} \text{ of an animal unit}$$

Bioclimatic regions. Phillips (1973) classified the extremely varied natural resources of KwaZulu/Natal into 11 bioclimatic regions based primarily on climatic parameters. These groups provide convenient natural resource classes in terms of which management guidelines can be formulated.

Chroma. This refers to the relative purity of the spectral colour, which decreases with increasing greyness.

Dominant plant species. The dominant plant species are those overstory species that contribute most cover to the area, compared to other overstory species (Barbour, Burk and Pitts, 1984.

Ecological value. This refers to the value of the wetland in maintaining the biotic diversity of the area. Biotic diversity can be measured at many different levels making it almost impossible to prescribe a standard method to describe it. Its assessment may be simplified by determining the degree to which management is affecting biological integrity and populations of valued species.

Flats. Flats refer to a flat areas with slopes of less than 1%, usually situated in bottomland positions.

Hydric soil. Soil that in its undrained condition is saturated or flooded long enough during the growing season to develop anaerobic conditions favouring the growth and regeneration of hydrophytic vegetation (vegetation adapted to living in anaerobic soils).

Hydrology. Hydrology is the study of water, particularly the factors affecting its movement on land.

Marsh zone. The marsh zone is dominated by tall (usually > 1 m) emergent herbaceous vegetation, such as the common reed (*Phragmites australis*). Some marsh zone areas are seasonally wet but most are permanently or semi-permanently wet.

Mottles: soils with variegated colour patterns are described as being mottled, with the most abundant colour referred to as the matrix and the other colour/s as mottles.

***n* Value.** The *n* value refers to the relationship between the percentage of water under field conditions and the percentage of inorganic clay and humus and can be approximated in the field by a simple test of squeezing the soil in the hand. It is helpful in predicting the degree of subsidence that will occur after drainage (Pons and Zonneveld, 1965; Soil Survey Staff, 1990).

Open water zone. The open water zone comprises permanently or semi-permanently flooded areas characterized by few or no emergent plants.

Pans. Pans are natural shallow depressions in the earths surface which have no outlets and are flooded for varying periods in the wet season. They usually dry up seasonally through loss of water by evaporation.

Red data species. Red data species refer to all those species included in the categories of endangered, vulnerable or rare, as defined by the International Union for the Conservation of Nature and Natural Resources (Smithers 1986).

Soil saturation: the soil is considered saturated if the water table or capillary fringe reaches the soil surface (Soil Survey Staff, 1990).

Stocking rate. The stocking rate (SR) refers to the number of AUs per unit of land for a specified period of time. SR may be expressed in terms of number of land units per AU.

Wet grassland zone. The hygrophilous grassland zone is usually temporarily wet and supports a mixture of: 1) plants which are common to non-wetland areas and 2) short (<1m) hydrophytic plants (predominantly grasses) common to the wet meadow zone.

Wet meadow zone. The wet meadow zone is usually seasonally wet and dominated by short (usually <1.5 m) hydrophytic sedges and grasses common to temporarily or seasonally wet areas.

Wetland. Land where an excess of water is the dominant factor determining the nature of the soil development and the types of plants and animals living at the soil surface (Cowardin *et al.*, 1976).

Wetland functional values. Where wetland functions (e.g. the trapping of sediment) are of value to society, they are termed functional values. Wetland functions refer to the many physical, chemical and biological processes that take place in wetlands.

APPENDIX A:

Birdlist for Blood River Vlei catchment

* Recorded within Blood River vlei

* 008 Dabchick
* 055 Whitebreasted Cormorant
* 058 Reed Cormorant
* 060 Darter
* 062 Grey Heron
* 063 Blackheaded Heron
* 064 Goliath Heron
* 065 Purple Heron
* 066 Great White Egret
* 067 Little Egret
* 068 Yellowbilled Egret
* 071 Cattle Egret
* 072 Squacco Heron
* 076 Blackcrowned Night Heron
* 081 Hamerkop
* 083 White Stork
* 091 Sacred Ibis
092 Bald Ibis
* 093 Glossy Ibis
* 094 Hadeda Ibis
* 095 African Spoonbill
* 099 Whitefaced Duck
* 102 Egyptian Goose
* 103 South African Shelduck
* 104 Yellowbilled Duck
* 105 African Black Duck
* 107 Hottentot Teal
* 108 Redbilled Teal
* 112 Cape Shoveller
* 116 Spurwinged Goose
118 Secretary Bird
* 127 Blackshouldered Kite
131 Black Eagle
* 148 African Fish Eagle
149 Steppe Buzzard
152 Jackal Buzzard
* 165 African Marsh Harrier
180 Eastern Redfooted Kestrel
181 Rock Kestrel
* 199 Swainson's Francolin
* 200 Common Quail
* 201 Harlequin Quail
203 Helmeted Guineafowl
* 208 Blue Crane
* 209 Crowned Crane
* 213 Black Crake
* 217 Redchested Flufftail
* 223 Purple Gallinule
* 226 Moorhen
* 228 Redknobbed Coot
233 Whitebellied Korhaan
238 Blackbellied Korhaan
* 249 Threebanded Plover
255 Crowned Plover
* 257 Blackwinged Plover
* 258 Blacksmith Plover
* 260 Wattled Plover
* 264 Common Sandpiper
* 266 Wood Sandpiper
* 269 Marsh Sandpiper
* 270 Greenshank
* 274 Little Stint
* 284 Ruff
* 286 Ethiopian Snipe
* 295 Blackwinged Stilt
297 Spotted Dikkop
* 349 Rock Pigeon
352 Redeyed Dove
* 354 Cape Turtle Dove
355 Laughing Dove
356 Namaqua Dove
377 Redchested Cuckoo
378 Black Cuckoo
385 Klaas's Cuckoo
386 Diederik Cuckoo
* 392 Barn Owl
* 393 Grass Owl
* 395 Marsh Owl
401 Spotted Eagle Owl
405 Fierynecked Nightjar
415 Whiterumped Swift
416 Horus Swift
417 Little Swift
418 Alpine Swift
* 428 Pied Kingfisher
* 429 Giant Kingfisher
* 431 Malachite Kingfisher
435 Brownhooded Kingfisher

451 Hoopoe
452 Redbilled Woodhoopoe
464 Blackcollared Barbet
465 Pied Barbet
469 Redfronted Tinker Barbet
473 Crested Barbet
494 Rufousnaped Lark
507 Redcapped Lark
* 518 European Swallow
* 520 Whitethroated Swallow
* 526 Greater Striped Swallow
* 527 Lesser Striped Swallow
* 533 Brownthroated Martin
* 534 Banded Martin
* 541 Forktailed Drongo
547 Black Crow
568 Blackeyed Bulbul
588 Buffstreaked Chat
595 Anteating Chat
* 596 Stonechat
* 631 African Marsh Warbler
* 635 Cape Reed Warbler
* 638 African Sedge Warbler
* 642 Broadtailed Warbler
* 661 Grassbird
* 664 Fantailed Cisticola
* 677 Levaillant's Cisticola
* 679 Lazy Cisticola
710 Paradise Flycatcher
* 713 Cape Wagtail
* 716 Richard's Pipit
* 727 Orangethroated Longclaw
* 732 Fiscal Shrike
736 Southern Boubou
741 Brubru
744 Blackcrowned Tchagra
746 Bokmakierie
758 Indian Mynah
* 759 Pied Starling
764 Glossy Starling
769 Redwinged Starling
792 Black Sunbird
796 Cape White-eye
801 House Sparrow
803 Cape Sparrow
* 814 Masked Weaver
* 821 Redbilled Quelea
* 824 Red Bishop
* 826 Golden Bishop
* 828 Redshouldered Widow
* 831 Redcollared Widow
* 832 Longtailed Widow
* 846 Common Waxbill
* 852 Quail Finch
* 854 Orangebreasted Waxbill
* 860 Pintailed Whydah
869 Yelloweyed Canary
884 Goldenbreasted Bunting

Compiled by Warden S de Jager
Natal Parks Board - Vryheid Zone

REPORT TO THE WATER RESEARCH COMMISSION

A MANAGEMENT PLAN FOR BOSCHOFFSVLEI

KOTZE D C

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1994

EXECUTIVE SUMMARY

Boschoffsvlei, ca 1800 ha in extent, is situated in the upper Tugela catchment immediately west of Utrecht in Bioclimatic Group 8b (mean annual rainfall= 771 mm). The wetland comprises two main parts: the Wasbankspruit portion and the Dorpspruit portion. Ecca shale is the underlying geology and Katspruit and Rensburg are the predominant soil forms. The primary land-use in the catchment is domestic stock grazing. There is also crop and pasture production. The wetland has various vegetation communities including reed marsh, sedge/*Leersia* marsh, wet meadow and wet grassland. The Wasbankspruit portion, in particular, has a high water purification and streamflow regulation value.

Approximately 30 ha at its upstream end belongs to the Utrecht municipality and the rest of the wetland is privately owned. The predominant land-use occurring in Boschoffsvlei is grazing of the natural vegetation by stock. Extensive cutting for hay also occurs. Severe erosional degradation has occurred in some of the tributary extensions of the wetland, but erosion in the main body of the wetland has been limited. Very little intensification of the wetland has occurred and few dams have been constructed. Certain areas are heavily infested with alien plants and these require attention.

Until recently sand has been excavated from alluvial deposits of the Dorpspruit at its junction with the Wasbankspruit. No further excavation should occur here because this is a hydrologically sensitive area.

In order to encourage sustainable use of the wetland while minimizing the loss of wetland functional values, an overall management goal and management objectives are proposed and a series of management guidelines which describe the actions required to achieve the specific objectives have been devised (Fig. 1). The management guidelines are given in more detail in Section 10.

The wetland should be grazed at the recommended stocking rate (2 ha/AU), accounting for veld condition, susceptibuility to erosion (excluding animals from areas with particularly high erosion hazards) and the relative proportions of wet grassland, wet meadow and marsh on the farm. Wetland areas should preferably be fenced off as special use camps. Where this is impractical, other means of ruducing the use of wetlands should be employed when necessary (e.g. ensure water availability in other areas, herd animals). Rotationally graze wetland areas, withdrawing the animals when the soil becomes wet and puddled.

Crop production is very limited in the wetland and due to the potentially negative effects of cropping, the establishment of further croplands is not recommended.

OVERALL MANAGEMENT GOAL: optimize, on a sustainable basis, the direct benefits derived by different on-site and off-site users of the wetland without significant loss of the wetland's hydrological and ecological values, which benefit society at large.

MANAGEMENT OBJECTIVES:

Protect the hydrological values

- Do not drain, channelize or otherwise alter the natural flow regime of the wetland
- Prevent erosion within the wetland
  - Ensure stock stream crossings do not lead to gully erosion^
  - Preferably do not graze wetland areas when they are wet and susceptible to puddling^
  - Do not exceed the recommended stocking rate
- Ensure the stability of the flow concentration zone or any other potential headcut erosion sites
  - Control the use of potential erosion sites by cattle^
  - Prevent any disturbance of the flow concentration area
- Maximize the natural runoff from the wetland catchment (including the wetland itself)
  - Discourage the construction of more dams in the catchment, particularly in the wetland itself.
  - Minimize the volumes extracted, particularly during low flow periods (e.g. by maximizing the water use efficiency of agricultural practices)
  - Restrict afforestation to designated areas in the surrounding catchment
- Prevent excessive sediment input from the surrounding catchment
  - Follow wise soil conservation practices

Protect the ecological values

- Follow the burning guidelines
  - Leave at least 60% of the wetland unburnt in any year; do not burn during the growing season etc.#
- Follow the mowing guidelines
  - Do not mow when the soils are susceptible to erosion; mow $\leq$50% of all vegetation types in a given year; etc. ~
- Follow the guidelines for controlling alien plants
  - Minimize disturbance; encourage the vigorous growth of the natural vegetation; conduct eradication where necessary; etc.
- Protect the hydrological values, because the greater the hydrological disruption, the greater the impact on the ecological values

Wisely use the wetland:

* as a natural grazing area for domestic stock (see ^ guidelines);

* as a water source for stock watering (see # guidelines); and

* as a source of hay for domestic stock (see ~ guidelines).

Regulate damming, water extraction, mining, afforestation and crop production activities in the surrounding catchment. Although these are not direct uses of the wetland, they have been included because they have an important effect on the wetland.

MANAGEMENT GUIDELINES: (as listed above under each objective)

Fig. 1 Boschoffsvlei management framework.

ACKNOWLEDGEMENTS

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The Wildlife Society of Southern Africa
Umgeni Water
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1. OVERALL MANAGEMENT GOAL

The proposed overall management goal for Boschoffsvlei is to optimize, on a sustainable basis, the direct benefits derived by the different users of the **wetland** without causing significant loss of the wetland's indirect benefits to society.

The primary direct users of the wetland are stock farmers. Boschoffsvlei has also recently been used for sand extraction. The indirect benefits include the following functional values: (1) hydrological values (water purification, water storage and enhancement of sustained streamflow); (2) erosion control value; and (3) ecological value (maintenance of biotic diversity through the provision of habitat for wetland-dependent species).

2. GENERAL SITE DESCRIPTION

Boschoffsvlei, approximately 1800 ha in extent, is situated in the upper Tugela catchment immediately west of Utrecht (27°40'S; 30°14'E) (Fig. 2). The wetland extends 12 km from its upstream end (1195 m) to its outlet (1165 m) at the confluence of the Dorpspruit and Buffalo rivers, giving a total slope in the direction of water flow of 0.25%.

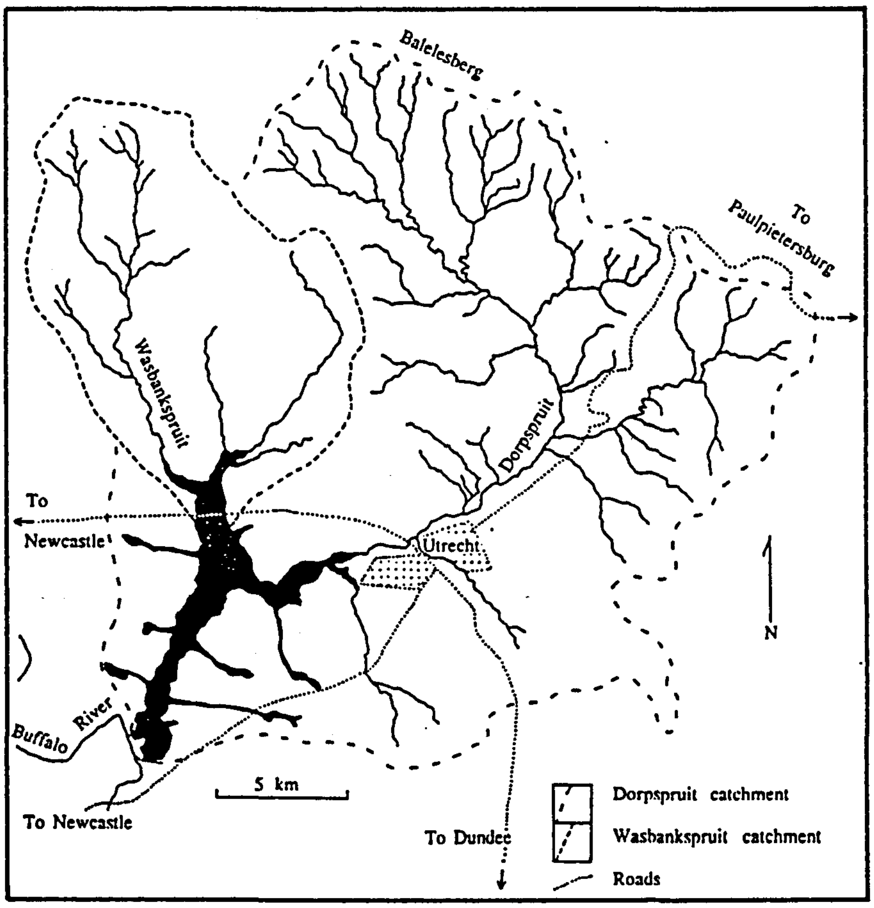

Fig. 2 Location of Boschoffsvlei and its catchment

Six vegetation types (described in Section 8) occur in Boschoffsvlei (Table 1). For the purposes of management and land-use planning, they have been grouped into three agro-ecological zones: wet grassland (in temporarily waterlogged areas), wet meadow (in seasonally waterlogged areas) and marsh (in seasonally to semi-permanently waterlogged areas). Permanently wet areas are largely lacking in the wetland.

Table 1 Agro-ecological zones and vegetation types occurring in Boschoffsvlei

Vegetation types	Agro-ecological zones
Reed marsh Sedge/*Leersia* marsh	MARSH
Sedge meadow *Miscanthus* meadow	WET MEADOW
Short wet grassland Tall wet grassland	WET GRASSLAND

The main body of the wetland may conveniently be divided into 4 main sectors (Fig. 3) based on landform, soil type, and the distribution of the agro-ecological zones (Fig.4).

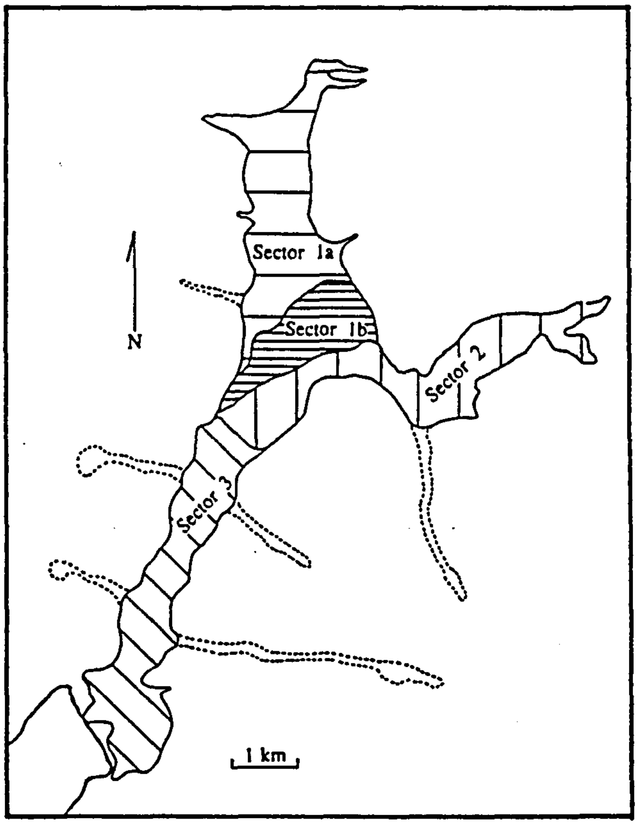

Fig. 3 Distribution of Boschoffsvlei's 4 sectors

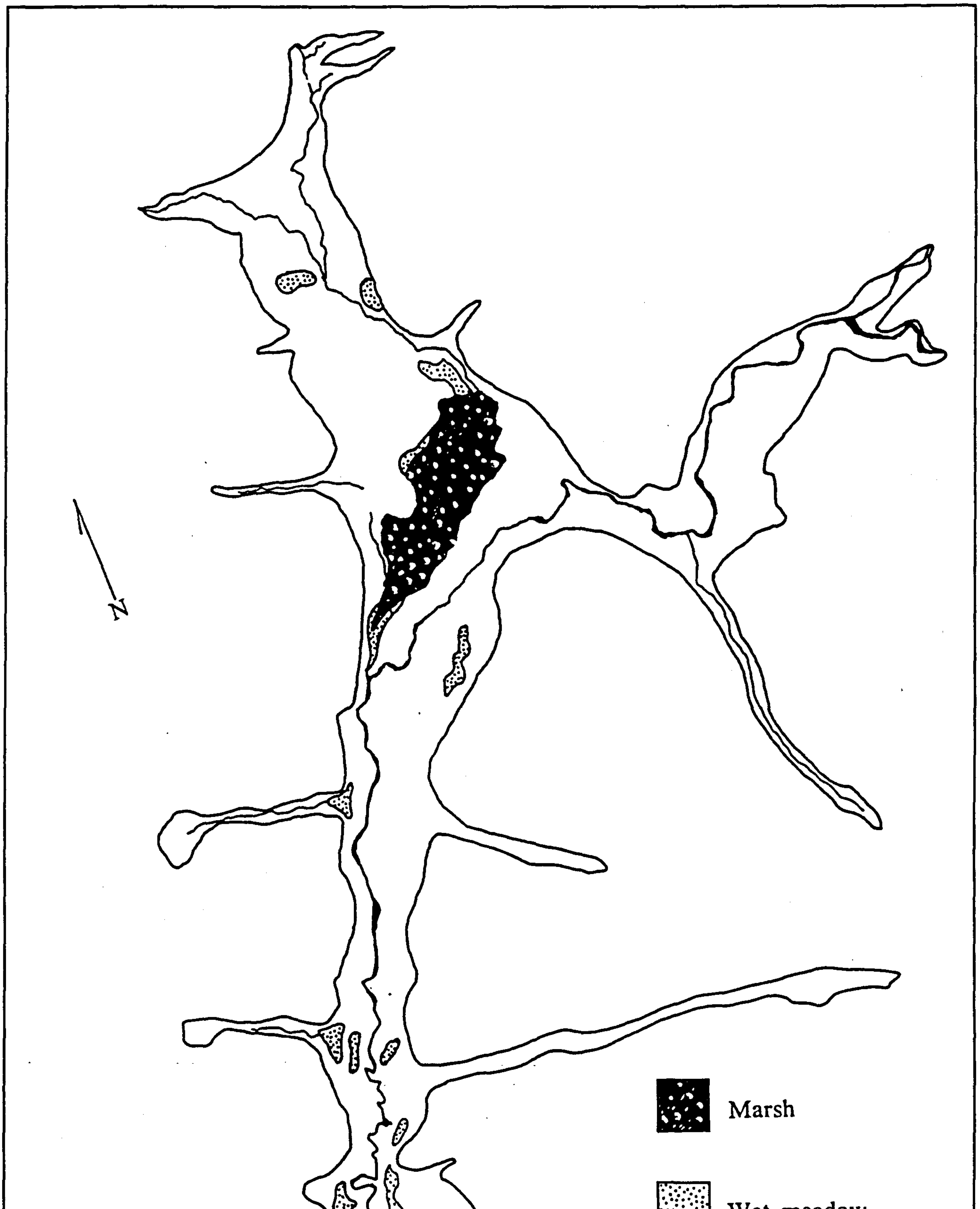

Fig. 4 Distribution of agro-ecological zones found in Boschoffsvlei

Sectors 1a and 2 each comprise a wet grassland dominated **flat** containing a few non-wetland and wet meadow areas and bisected by a well defined main stream channel ca. 2-3 m deep. In the case of Sector 1a, the main channel is the Wasbankspruit and for Sector 2 it is the Dorpspruit. Surface water flow is predominantly channelized and substantial diffuse flow occurs very seldom, when runoff from the catchment is sufficient to cause bank overspill from the main channel.

Sector 1b is a marsh-dominated flat which is largely unchannelled. It is fed by the Wasbankspruit channel at its upstream eastern end and drained at its downstream western end by the re-formed Wasbankspruit channel. Because of its low gradient and the fact that there is no channel connecting the upstream and downstream portions of the Wasbankspruit, flow within Sector 1b is diffuse and occurs across a wide area (> 500 m wide). As such, large areas of Sector 1b are fed by the Wasbankspruit even when flow levels are well below those required for bank overspill to occur in the other sectors. Consequently, the degree of wetness of this sector is higher than in the other sectors of the wetland.

Sector 3 resembles Sectors 1a and 2 in that it comprises a wet grassland-dominated flat dissected by a well defined main channel (2-4 m deep). It differs in that the wet meadow areas are more extensive and marsh is present in some "backswamp" areas.

Tributary arms, usually less than 20 m wide and dominated by wet grassland, extend out from the main body of the wetland.

Some isolated **pans**, which are a feature of the central and western parts of South Africa (e.g. the western Orange Free State), occur in the surrounding landscape and within Boschoffsvlei.

The wetland's potential for improving water quality in the Wasbankspruit is enhanced by the fact that streamflow in the Wasbankspruit becomes disrupted and spread out across the wetland (in Sector 1b) irrespective of the amount of streamflow. This contrasts with the Dorpspruit where streamflow is spread across the wetland only during high flow periods when the capacity of the channel is exceeded and bank overspill occurs. As such, the wetland is likely to be less effective in the retention of sediments, nutrients and other pollutants from the Dorpspruit than from the Wasbankspruit.

3. GEOLOGY AND SOILS OF THE WETLAND

The underlying geology of Boschoffsvlei is entirely Ecca shale (of the Vryheid formation). The wetland comprises a mosaic of different soil forms that vary according to the agro-ecological zones they typically occupy (Fig. 5). Irrespective of soil form, certain features characterize the soils of each of the different vegetation types (see Table 3). Thus, properties of the Katspruit form vary greatly due to the fact that it occurs across all three zones.

```
                   AGRO-ECOLOGICAL ZONES
SOIL FORM | Marsh  Wet meadow  Wet grassland:  Non-
          |                    flat   sloped   wetland
          |-----------------------------------------------
Katspruit |=================================
          |
Rensburg  |      ----=========================-----
          |
Estcourt  |                          -----=============
          |
Dundee    |                                ----========
          |

==========      frequent occurrence

----------      infrequent occurrence

                absent
```

Fig. 5 The range of agro-ecological zones in which the soil forms found in Boschoffsvlei commonly occur.

In Sectors 1a, 2 and 3, soils on the levees, immediately adjacent to the channel, are more elevated in relation to the water table and are sandier than those soils situated further from the main channel. Thus, the soils on these areas tend to be non-hydric (usually of the Dundee form). This contrasts with the soils situated further away from the main channel which consist of a mosaic of non-hydric soils and temporarily wet and seasonally wet soils (Dundee, Rensburg and Katspruit forms).

Of the soil mapping units described by Van der Eyk *et al.* (1969) for the Tugela catchment, two units are included within the boundary of the main body of Boschoffsvlei: H1 (clayey and loamy margalitic and non-margalitic gley soils) and L1 (clayey, loamy and sandy non-gley soils of alluvial land) (Fig. 6). Almost all of Sectors 2 and 3 have been mapped as L1 (i.e. non-hydric alluvial land). However, at least 50% of this area is, in fact, more correctly described as H1. In addition, extensive channel and abandoned channel areas in Sectors 1a and 1b comprise loamy and sandy alluvial soils. However, these probably comprises less than 20% of the total area of Sectors 1a and 1b.

Soils in the tributary arms are predominantly of the Estcourt form and to a lesser extent the Katspruit form. Most of these areas have been severely eroded (see Section 10.4). The soils of Boschoffsvlei tend to be neutral to alkaline, but not strongly alkaline.

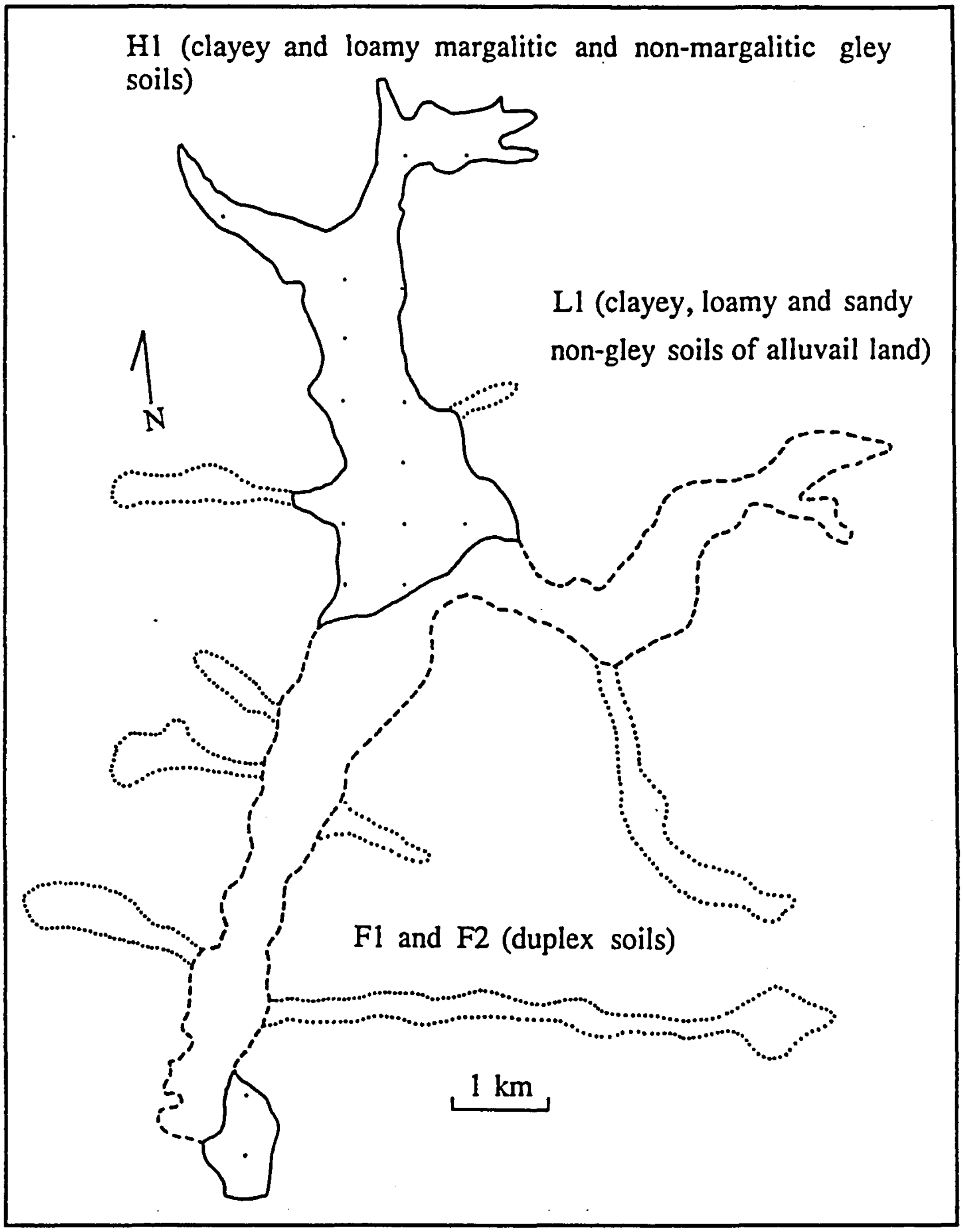

Fig. 6 Distribution of soil units described by van Eyk *et al.* (1969) within Boschoffsvlei.

4. LOCAL CLIMATE

Boschoffsvlei occurs within Bioclimatic region 8b (dry upland) for which the following is characteristic:

Annual precipitation:	771 mm (mean);	700-900 mm (range)
Relative humidity:	60-65%	
Temperature:	17°C (mean annual) 39°C (extreme maximum) -8°C (extreme minimum)	
Annual potential evapotranspiration:	1700 mm	

The annual precipitation decreases with decreasing altitude and increasing distance from the Balelesberg. The average annual rainfall measured by Mr. C F Pitout in Sector 3, which is the lowest lying area, for the period 1983-1992 was 611 mm.

5. CATCHMENT DETAILS

Boschoffsvlei is fed by two main streams, the Dorpspruit and its tributary the Wasbankspruit. Boschoffsvlei catchment includes the entire Dorpspruit catchment and is 526 km^2, of which ca. 20% is occupied by the Wasbankspruit catchment and 11% occupied by the wetland. The mean annual runoff from quaternary sub-catchment VO58, which corresponds with the wetland catchment, is 78 x 10^6 m^3 (Pitman *et al.*, 1981). The catchment comprises mainly veld type 66 (Natal Sandy Sourveld) but also extends across three other veld types: 23 (Valley Bushveld), 57 (North Eastern Sandy Highveld) and 65 (Southern Tall Grassveld) (Acocks, 1953).

The principal land-uses occurring in the catchment (expressed as an approximate percentage area of the catchment) are:

1.	natural veld grazing	ca 94%
2.	cropland and planted pastures	ca 3%
3.	urban and mining	ca 2%
4.	afforestation	ca 1%

Several (in excess of 20) farm dams occur in the catchment, but most are less than 2 ha in size. The catchment has also been subject to mining activity, with a colliery situated just north of Utrecht. The effects on the wetland of these land-uses are summarized in table 2.

The most important effects of natural veld grazing in the catchment likely to influence Boschoffsvlei are:

1. increased soil loss, increasing the sediment loads entering the wetland. Excessive soil loss from veld was probably worst in the early 1900's, because most large dongas

present today are already visible in the 1935 airphotos; and

2. decreased infiltration caused by decreased vegetal cover and trampling-induced compaction of the soil, which has reduced the attenuation of water entering the wetland.

Table 2 Impacts on Boschoffsvlei of current land-uses in the catchment (subjectively assessed, based on generally demonstrated effects of individual land-uses and their extent in the catchment).

	LAND-USE			
IMPACT	Natural grazing	Crops	Dams	Mining
Increased sediment loads	1	1	0	1/2
Increased nutrient/ toxicant loads	0/1	1	0	2
Decreased water input	0	1	1/2	1
Altered water input timing	1	0	1/2	1/2

Level of impact: 0= negligible 1= low 2= moderately high 3= very high

The principal effects of crop production are: (1) increased soil loss leading to increased sediment loads. It has been shown that even if lands are protected and soil losses are of acceptable levels, loss is still likely to be greater than that which occurs off from well managed natural veld (Verster *et al.*, 1992); and (2) a reduction in the surface and ground water input into the wetland, because of increased evapotranspirative loss from irrigated crops. It should be noted, however, that the extent of croplands is far less than was the case previously. Much of the land shown to be cultivated in the 1980 orthophotos is longer so.

Dams are commonly used for water storage and irrigation. Through this extraction and through evaporative losses from the dam surface, dams decrease the total water inputs into wetlands. Probably the most important effect of dams is that they reduce early season streamflow (see Appendix 1). Afforestation of catchments has a similar effect. At present, the afforested areas constitute only a very small proportion of the catchment and it is unlikely that they are having a significant impact on the wetland. However, should the area substantially increase, this is likely to change.

In addition to high concentrations of sulphate, iron and other metals, and the low pH of the mine drainage waters, mining activities also increase the amount, and alter the particle size distribution of sediment inputs (Briones, 1987). Through these chemical and physical changes to the input water, coal mining in the catchment of a wetland may have a profound effect on wetland functioning. However, as already discussed in Section 2, the Dorpspruit portion of Boschoffsvlei is naturally channelled, limiting the extent to which the wetland would be affected by mine-influenced drainage from the Dorpspruit catchment. In addition, no mining has occurred in the Wasbankspruit catchment and mining in the Dorpspruit catchment and has now largely been discontinued.

6. REGIONAL SIGNIFICANCE OF BOSCHOFFSVLEI

Boschoffsvlei is recognized by Begg (1989) as one of the priority wetlands of KwaZulu/Natal. It is an important hydrological control area, particularly in Sector 1b, and is likely to have a high water purification and streamflow regulation value for the Wasbankspruit catchment in particular.

The wetland occurs in veld type 66, which is endemic to KwaZulu/Natal and under-represented in formally conserved areas. Also, 90% of this veld type has been degraded (Colvin, 1985). Boschoffsvlei is also one of the few priority wetlands in KwaZulu/Natal with strong similarities to the wetlands of the western parts of the country.

7. LAND OWNERSHIP

Ten landowners are involved in the various properties across which Boschoffsvlei extends, including 8 farmers, AECI, and the Utrecht Municipality (Fig. 7). Of the various properties that include portions of the wetland, the proportion occupied by wetland area ranges from 1% to 28%. Managers of the largest portions of the wetland are:

	Approximate area (ha)		
	Owned	Leased	Total
Pitout C F	390	740	1130
Kemp D L	300	695	995
Davel J C	400	-	400
Potgieter J	350	-	350
van Deventer W C	300	-	300

8. WETLAND FLORA, INCLUDING A DESCRIPTION OF WETLAND VEGETATION TYPES

Apart from the investigation undertaken for preparation of this document, the wetland is botanically undescribed. No Red Data plant species have yet been identified as occurring there. According to Acocks (1953) most of Boschoffsvlei occurs within Veld Type 66 (Natal Sour Sandveld) but the upstream ends of Sectors 1 a and 2 fall within Veld Type 65 (Southern Tall Grassveld).

For the purposes of management, three agro-ecological zones, each including two vegetation types, have been identified based primarily on the dominant species (Table 3). These types vary according to where on the wetness continuum they commonly occur (Fig. 8).

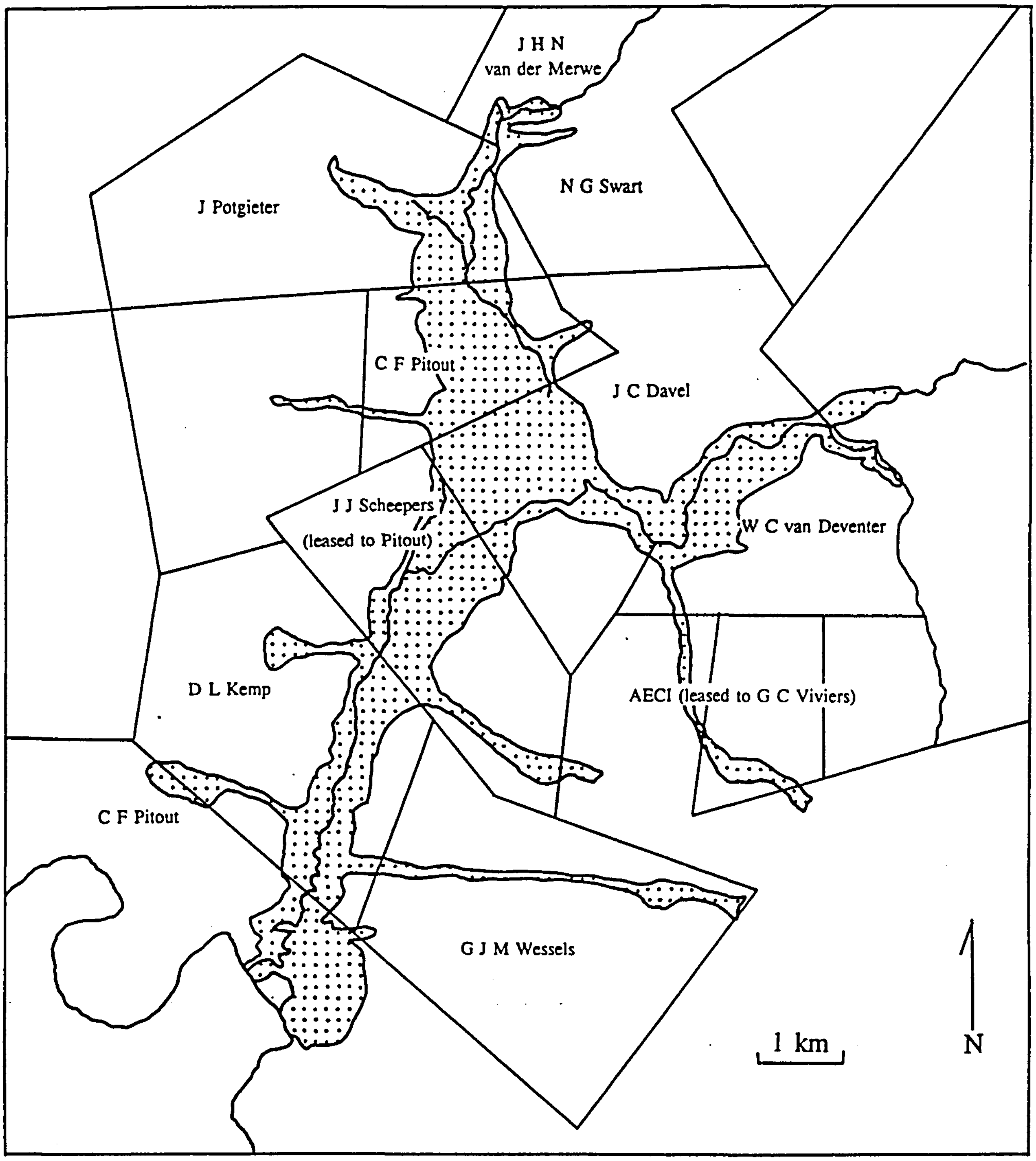

Fig. 7 Land ownership of Boschoffsvlei (as in 1993)

Table 3 Dominant plant species, water regimes and soil features characterizing the different vegetation types found in Boschoffsvlei

VEGETATION TYPE	DOMINANT PLANT SPECIES	WATER REGIME AND SOIL FEATURES
Reed marsh	*Phragmites australis*	Semi-permanently wet. Wet to surface. A horizon: high OM, high root abundance, seldom sulphidic. B horizon: intermediate/high *n* value.
Sedge/ *Leersia* marsh	*Leersia hexandra* *Cyperus fastigiatus* *Typha capensis*	Semi-permanently to seasonally wet. Wet to surface. A horizon: high OM, high root abundance, seldom sulphidic. B horizon: intermediate *n* value.
Sedge meadow	*Eragrostis planiculmis* *Eleocharis dregeana* *Leersia hexandra*	Seasonally wet. wet to surface. A horizon: intermediate OM, intermediate root abundance, non-sulphidic. B horizon: intermediate/low *n* value.
Miscanthus meadow	*Miscanthus junceus,* *Imperata cylindrica*	See sedge meadow
Short wet grassland	*Eragrostis plana* *Andropogon appendiculatus*	Temporarily wet. Usually not wet to surface. A horizon: low OM, Low/intermediate root abundance, non-sulphidic. B horizon: low *n* value.
Tall wet grassland	*Hyparrhenia dregeana* *Cynodon dactylon*	As for short wet grassland but soils tend to be sandier

KEY

Semi-permanently wet: the soil is flooded or wet to the soil surface through most of the wet season and often well into the dry season of most years.

Seasonally wet: the soil is flooded or wet to the soil surface for extended periods (>1 month) during the wet season, in most years, but is predominantly dry during the dry season.

Temporarily wet: the soil close to the surface (i.e. within 40 cm) is occasionally wet for periods > 3 weeks during the wet season, in most years. However, it is seldom flooded or wet <u>at</u> the surface for longer than a month.

Wet refers to soil that is flooded or saturated or that is close to saturation, such that anaerobic conditions will develop if the wetness state persists.

KEY: continued

Wet to surface: indicators of anaerobic conditions (e.g. root channel mottling) are present through the upper profile and to the soil surface.

High OM: soil organic carbon levels are greater than 5%

Low OM: soil organic carbon levels are less than 2%.

High root abundance: roots dominate the soil matrix in terms of volume, often forming a dense mat.

Sulphidic soil material has sulphides present which give it a characteristic "rotten egg smell".

n Value: the amount of water in the soil under field conditions relative to the percentage of clay and humus. It can be approximated in the field by squeezing the soil in the hand. Soils with high *n* values tend to be relatively unconsolidated, have a low load bearing strength, and undergo considerable subsidence when drained (Pons and Zonneveld, 1965; Soil Survey Staff, 1990).

```
VEGETATION TYPE                    WATER REGIME
                  Semi-permanent   Seasonal   Temporary   Non-
                                                        wetland
Reed marsh        ================------

Sedge/Leersia     ===================--------
marsh

Sedge meadow                   ----===========-----

Miscanthus                 -------=============----
meadow

Short wet                             -------==========--
grassland

Tall wet                           --------===========------
grassland

============      frequent occurrence

------------      infrequent occurrence
```

Fig. 8 The range of water regimes across which the different vegetation types of Boschoffsvlei commonly occur.

Although Boschoffsvlei occurs in the same veld type as Blood River vlei, its local climate is more arid and there are the following differences:

1. permanent standing water areas are less prevalent and aquatic plants less abundant;

2. permanently waterlogged marsh areas are considerably less prevalent; and

3. it has more features in common with the wetlands of the central parts of the country, including the occurrence of pans and the species commonly associated with these areas (e.g. *Diplachne fusca*).

9. WETLAND FAUNA

Although the fauna of Boschoffsvlei is still extremely poorly described, it is clear that the wetland provides important habitat for a wide range of animal species. Notably, many palaearctic waders, herons and spawning barbel were observed in February 1993 in an area of seasonal sedge/*Leersia* marsh which had been recently flooded.

10. CURRENT AND PAST USE OF THE WETLAND AND RECOMMENDATIONS FOR FUTURE USE

A variety of land-uses and land-use related activities have been and are being applied to the wetland. These are described in terms of their effect on the hydrological, erosion control and ecological values of the wetland. Following each description, recommendations for future use are made.

More than 90% of Boschoffsvlei is owned by commercial farmers, many of whom need to utilize their portions for their livelihood. A non-utilitarian policy towards the management of Boschoffsvlei would be inappropriate. The recommendations given attempt to encourage sustainable utilization of the wetland's resources with the minimum loss of the wetland's functional values.

10.1 Burning

10.1.1 Current burning practices and the effect of burning on the wetland's functional values

Boschoffsvlei is likely to have evolved under a burning regime due to lightning-induced fires. The burning activities of indigenous peoples and European settlers would have been responsible for an increased fire frequency. The current burning regime applied to the wetland varies from area to area depending on the policy of the manager and whether or not particular areas are mown. The primary reason for burning is to improve the grazing value of the area. To this end, early spring burning is carried out to remove the previous season's old growth. In mown areas there is generally less old growth present. As such, mown areas tend to be burnt less often because little is gained from burning these areas. Although most managers practise annual or biennial early spring burning in unmown areas, Mr D L Kemp considers fire to be harmful and has practised fire exclusion for the last 15 years.

Burning may have both a positive and a negative effect on the functional values of wetlands. For example, controlled regular burning has been shown to increase the breeding habitat value of sedge marsh for red-chested flufftail (B Taylor, 1991. pers. comm. Department of Zoology and Entomology, University of Natal, Pietermaritzburg). Although little work has been done in KwaZulu/Natal on the recovery of wetland-dependent species populations following fire, it appears that a fire return frequency of 2 years is unlikely to have a major detrimental effect on any of the known wetland-dependent animals in the humid to mild subarid areas of KwaZulu/Natal. However, the population recovery rate of wetland-dependent species may depend on the presence of unburnt refuges from which recolonization may occur (D Johnson, 1991. pers. comm. Natal Parks Board, Pietermaritzburg). If refuges are lacking, this is will detract from the wetland's ecological value.

Timing of burning is important. Early winter burning adversely affects winter-breeding animals (e.g. the marsh owl: *Asio capensis*), and summer burning disadvantages summer breeders. Late winter/early spring burning (as currently occurs for most of Boschoffsvlei) is least likely to affect breeding animals because most winter breeders have completed breeding and summer breeders have yet to begin.

Fire modifies wetland plant communities. Comparison of the unburnt and burnt portions of Boschoffsvlei revealed that for a given degree of wetness, as indicated by soil morphology, some of the unburnt areas support a more hydric vegetation than do comparable burnt areas. *Phragmites australis*, for example, occurs relatively frequently in some of the temporarily wet areas that have not been burnt for the last 15 years. This species is entirely absent from frequently burnt areas with a comparable degree of wetness (as indicated by soil morphology). This may be due to the fact that fire, by removing old growth, would directly increase water loss by increasing exposure of the soil surface, and would indirectly increase transpirative water loss by increasing plant productivity.

A comparison of burnt and unburnt areas in Nylsvlei, Transvaal (Otter, 1992), Memel vlei, Orange Free State (pers. obs., 1993) and Ntabamhlope vlei, KwaZulu/Natal (Kotze, 1992) suggest that fire can be used to control alien plants. However, for this to be effective, indigenous herbaceous vegetation must still be present (see Section 10.6). It would appear that the exclusion of fire from the farm of Mr. Kemp has been partly responsible for an increase in abundance of alien plants.

10.1.2 Burning recommendations

Because of the variety of vegetation types and utilization practices of different farmers, and because of our limited understanding of the effects of burning, it is inappropriate to make overly prescriptive burning recommendations. However, some guidelines are given which concern: (1) timing and frequency of burns (2) influencing fire behaviour; and (3) co-operative rotational burning.

1. Burn in late winter to early spring, as burning at this time is likely to have the least ecological and hydrological impact. Burning every second or third year is recommended.

2. Burn under conditions of high humidity and low air temperature, preferably shortly after rain, in order to achieve a cool burn.

3. Preferentially burn areas with abundant dead (moribund) standing material and loose surface litter that is obviously limiting new growth.

4. If conditions are undesirable for burning (e.g. if the soil is very dry and susceptible to sub-surface fires or if the weather conditions are consistently unsuitable), delay burning until the following year.

5. Although head fires (burning with the wind) may be undesirable from the point of view of preventing run-away fires, they are generally preferable to back fires (burning against the wind). Temperatures at ground level tend to be higher in back fires and consequently the impact on the growing points of plants is greater.

6. Keep records of management practices, to monitor progress.

7. Use fire to encourage the vigorous growth of indigenous herbaceous vegetation, so minimizing the opportunity for alien plant invasion (see Section 10.6).

8. Be aware of localized known important bird breeding areas (at present none of these areas has been identified but they may be revealed once a more thorough faunal inventory has been undertaken).

9. Cattle, by reducing the fuel load and creating puddles, can be used in promoting patch burns.

10. Work out burning strategies on a sector basis. Preferably not more than 65% of any sector should be burnt in any one year.

10.2 Natural grazing by domestic stock

10.2.1 Current grazing practices

The most important resource currently obtained from the wetland is natural grazing for stock, which occurs in all the vegetation types. The level and timing of utilization does, however, depend on the policy of each manager. Most of the wetland is used as a winter and early spring grazing resource. In some farms, such as that of Mr J C Davel, the stock are removed for the entire summer period. In contrast, other farms are used for both winter/early spring and summer grazing areas.

The preference of cattle for marsh areas depends, in part, on the quality and quantity of food in the surrounding non-wetland areas. Only in the early growing season when wetland areas commence growth before non-wetland areas, are marsh areas grazed readily by cattle. Later in the year when the marsh vegetation becomes less palatable, marsh areas are utilized less readily.

Wet grassland, sedge meadow and *Miscanthus* meadow areas are used throughout the growing season. However, the dominant species in *Miscanthus* meadow, *Miscanthus junceus* (besemgras), is very coarsely textured and not favoured for grazing. Sedge meadow has more palatable species and is of greater grazing value, but appears to be of less value than wet grassland. Provided the area is not in a degraded state, forage quality of wet grasslands appears to be comparable with that of non-wetland grassland. Wetland areas also tend to have a higher base status than the surrounding non-wetland areas, which may enhance forage quality. Because wet grasslands are less limited by moisture deficiencies than non-wetland grasslands, forage production is usually higher and this is of particular value in the early grazing season, when food shortages are most likely to occur. Thus. it appears that wet grasslands tend to have higher grazing potentials than non-wetland areas, although conclusive proof of this is lacking.

10.2.2 The impact of natural stock grazing on the wetland's functional values

Veld condition assessments undertaken during this survey (mostly using a rapid cover abundance method) showed that ca 60% of the wet grassland areas in Boschoffsvlei are dominated by Increaser II species, most importantly *Eragrostis plana* (Taaipol). Some of these areas were previously cultivated (as shown by examination of 1935 airphotos), which is probably why they are now dominated by these pioneer species. However, most wet grassland areas were not previously cultivated and injudicious grazing practices (primarily stocking at heavy rates) appear to have led to a reduction of palatable species (principally *Andropogon appendiculatus*), favouring Increaser II species. Many of the surrounding non-wetland grasslands are also in a poor condition.

Once *A. appendiculatus* has been largely replaced by *E. plana* it appears very difficult to manage the area so as to improve the veld condition. Considering the high forage value of *A. appendiculatus*, heavy grazing pressure is not only ecologically undesirable but also reduces the animal production potential and the profits a farmer may derive. It is important, therefore, to encourage lenient grazing.

Although marsh areas tend to be grazed less intensively than wet grassland, some of the marsh and most of the sedge meadow areas have been relatively heavily utilized, particularly in drought years. Because these areas are wet for much of the growing season, the effect of trampling is high and likely to result in the soil being subjected to poaching (deep treading) also referred to as puddling. Poaching, which occurs when soils are wet, refers to the disruption of soil structure resulting from repeated trampling. In this state the soils are rendered more vulnerable to erosion and compaction (Bryan, 1977; Wilkins and Garwood, 1985). This is undesirable, particularly if it occurs on a landform setting which is erosion prone (e.g. a slope).

Most marsh and sedge meadow utilization occurs on landform settings which do not pose an erosion threat, and is not detracting significantly from the wetland's functional values.

However, particular caution should be exercised in utilizing the wet meadow and marsh areas at the flow concentration zone of Sector 1b (i.e. where the natural Wasbankspruit channel re-forms shortly before its junction with the Dorpspruit) due to the high erosion hazard associated with the position of this area. Poaching of the soils in this sensitive area is likely to cause increased erosion. This, in turn, could lead to a retreat of the channel head into Sector 1b, increasing the draining effect of the channel and reducing the degree of wetness of Sector 1b. Clearly, this would detract greatly from the hydrological and ecological value of this area.

Puddling and trampling of the vegetation has the added disadvantage of decreasing plant productivity, thereby decreasing forage production (Wilkins and Garwood, 1985) and potential profitability.

The reduction in plant cover associated with grazing of marsh areas may, however, enhance the ecological value of a wetland. This appears to be the case in Boschoffsvlei where observation of an intensively grazed area of marsh near the outlet of Sector 1b in February 1993 showed large numbers of palaearctic waders to be present. This is considered acceptable as long as it does not detract significantly from the hydrological and erosion control values of the wetland, and provided that sufficient areas are left very leniently grazed, to enhance the heterogeneity of the wetland.

Most wetland soils such as the Katspruit and Rensburg forms have inherently low infiltration capacities (Schulze *et al.*, 1989) and high bulk densities. Consequently, these soils have low compaction potentials. Decreased infiltration is more often a result of poor management of the wetland catchment. Fine sandy alluvial soils may, however, have a high compaction potential. Thus, it appears that within Boschoffsvlei, grazing induced compaction has occurred mainly in localized areas with sandy loam soils, usually alluvial deposits adjacent to stream channels. However, there is as yet no conclusive evidence for this.

On the whole, loss of the wetland's hydrological and erosion control values has not occurred in the main body of Boschoffsvlei. In contrast, considerable gully erosion has occurred in many of the tributary extensions of the wetland and injudicious management of domestic stock in the past is very likely to have contributed to this (see Section 10.4).

Cattle drinking from streams with high banks may eventually make incised paths. These are not a problem at present, but should be watched as they may develop into erosion gullies.

10.2.3 Recommendations for future use

10.2.3.1 Recommended stocking rate

Unfortunately, veld condition bench-marks have not been described for wetland areas, nor have grazing potentials been determined. The recommended stocking rate for the particular Veld Type in which the wetland occurs is 3 ha AU^{-1} (i.e. 3 ha is required for each animal unit) (G Hatch, 1993, pers. comm. Grassland Science Department, University of Natal, Pietermaritzburg). Because wet grassland areas are likely to have higher grazing capacities than non-wetland areas (see Section 10.2.1) the recommended stocking rate for wet grassland areas in Veld Type 66 could probably be safely increased to 2 haAU^{-1}. However, account needs to be taken of veld condition and factors contributing to the susceptibility of wetland areas to erosion. Thus, the following are recommended:

1. reduce the recommended stocking rate by an amount proportional to the relative abundance of Increaser II species present (Table 4) to give the corrected stocking rate (CSR); and

2. reduce the CSR to account for the susceptibility of the wetland area to erosion (Table 5).

Table 4 Recommended stocking rate adjusted to account for veld condition

Percentage of Increaser II species	Corrected stocking rate (expressed as a percentage of the potential grazing capacity for the given bioclimatic region)
0- 30%	100%
30-60%	85%
>60%	70%

Table 5 Stocking rate correction to account for landform setting and slope (expressed as a percentage of the corrected stocking rate)

Landform settings with intermediate erosion potentials: slope (<10%), frequently flooded flat	80%
Landform settings with high erosion potentials: channel (streambank), slope (>10%)	60%

Areas considered to be extremely susceptible to erosion, such as those where active erosion is occurring (see Section 10.4), should, however, be excluded entirely from grazing.

In the mid and late grazing season, domestic stock tend to select strongly for wet grassland, less strongly for wet meadow and to avoid marsh. Thus, if a given wetland area was stocked without consideration for agro-ecological type then the effective stocking densities in the wet grassland areas in the mid and late grazing season would be very high. How high would depend, in part, on the proportion of the wetland surface area occupied by wet grassland. Consider a 30 ha wetland area consisting of 10 ha of wet grassland and 20 ha of marsh and at a stocking rate of 2 ha AU^{-1}. Because the animals concentrate on the wet grassland area in the mid and late season, the effective stocking rate would be in excess of 1 haAU^{-1} on the wet grassland areas. Clearly, the stocking rate needs to be calculated taking into account the proportion of wet grassland.

The extent to which marsh and wet meadow areas should be excluded will be determined by the degree to which these areas are selected against. If it can be demonstrated for the given wetland area that during early spring, livestock do not show a strong preference for wet grassland, it is recommended that wet meadow and marsh areas be included in the stocking rate calculations for the early grazing season only. Later in the season when these areas become less acceptable, they should be excluded from the calculation.

10.2.3.2 Fencing of wetland areas and other means of reducing area selective grazing

Because of the special management requirements of wetlands, they should preferably be fenced off as special use camps. If it is impractical to do this, the following guidelines aimed at controlling the activity of cattle should be considered:

1. herd animals managed under a herding system away from wetland areas into non-wetland areas at the desired times;

2. ensure water availability in adjoining non-wetland sites. Where this is not possible, limit the number of drinking point access paths down to the river and ensure the stability of those that are used (e.g. with stone packing);

3. minimize the location of supplementary feed near and within wetland areas during times when the grazing of wetlands is not considered desirable; and

4. cut herbage for hay or green chop, or mow old grass, to attract more grazing to under-utilized areas in the farm.

If the stocking rate for the overall farm is excessive there will be few under-utilized areas anywhere, and this will diminishing the effectiveness of these measures. This, again, emphasises the importance of maintaining reasonable stocking rates.

10.2.3.3 The grazing system

The wetland should be rotationally grazed using a flexible system, whereby the area is grazed until a predetermined level of use or disturbance is achieved, beyond which continued use of the wetland is likely to begin detracting from the hydrological and ecological values of the wetland, and in many cases its current production potential. A full 12 months' rest should preferably be included every 4 years. It is very difficult to prescribe a threshold level of use, as this has not been established and will depend on the vegetation type. A suggested level is when the sward has been grazed to an average height of 8 cm and/or when the most favoured plants have been grazed to 4 cm.

Grazing should be discontinued when the soil becomes flooded or wet to the surface and vulnerable to poaching (see Section 10.2.2), at which stage it is recommended that grazing livestock be taken out of the wetland area until it dries out again.

The exclusion proviso based on soil wetness may appear to be over-conservative and unjustifiably deny farmers valuable grazing. However, it is important to note that when the need for grazing to supplement drought-limited non-wetland grazing is high then grazing of the wetland is usually permissible. This is because it generally corresponds to times when the wetland soils are least susceptible to erosion and are considered to be acceptably dry for use. In contrast, when the use of the wetland is likely to have the greatest impact, as a result of being wet to the surface, then the need for wetland grazing is likely to be low because it usually corresponds with wet periods when non-wetland forage production is high.

10.3 Mowing

Mowing is practised widely: 20-30% of the wetland is mown. Mowing is confined mainly to wet grassland areas, and current mowing practices are not considered to be detracting significantly from the hydrological values of the wetland. If it is confined to times when the soil is relatively dry, mowing is likely to have less of a soil compacting and disrupting effect than grazing which occurs during wet and dry periods. Extensive removal of cover is, however, disadvantageous from an ecological point of view. If most of the wet grassland areas of the wetland were mown, it would seriously detract from the ecological value of the wetland.

10.4 Erosion

Erosional degradation of the main body of the wetland has been limited. However, serious gully erosion has occurred in the tributary extensions of the wetland, where soils are of the Estcourt form and have a very high erosion hazard. Much of this erosion is already evident in the 1935 airphotos of the wetland. Airphoto-comparison and ground inspection showed that rapid headcutting and widening of the gullies no longer occurs. However, soil loss from these areas is still likely to be moderately high because most of the gully sides are bare. Plant growth on the gully sides and the exclusion of cattle from these areas, should be encouraged.

The building of a new bridge for the upgraded R34 in 1956 helped confine water flow to the main channel, thereby causing downcutting of the streambed (Begg, 1989). This presumably resulted in a reduction in the frequency at which bank overspill occurred, and decreased the wetness of the affected area. At the request of the Department of Agriculture and farmers adjoining the wetland, a weir equipped with gauge plates was built across the Wasbankspruit upstream of the bridge to prevent further downcutting and to restore the wetland to its previous condition (Begg, 1989). The project was successful.

10.5 Drainage channels

Four drainage channels in Sector 1b, dug prior to the 1970's, are orientated so as to concentrate the flow of water in the naturally unchannelled area between the inlet and outlet channels of Sector 1b (Fig. 9). The plan was to reduce the degree of wetness of Sector 1b. However, the channels have not achieved this because: (1) sediment deposition in the

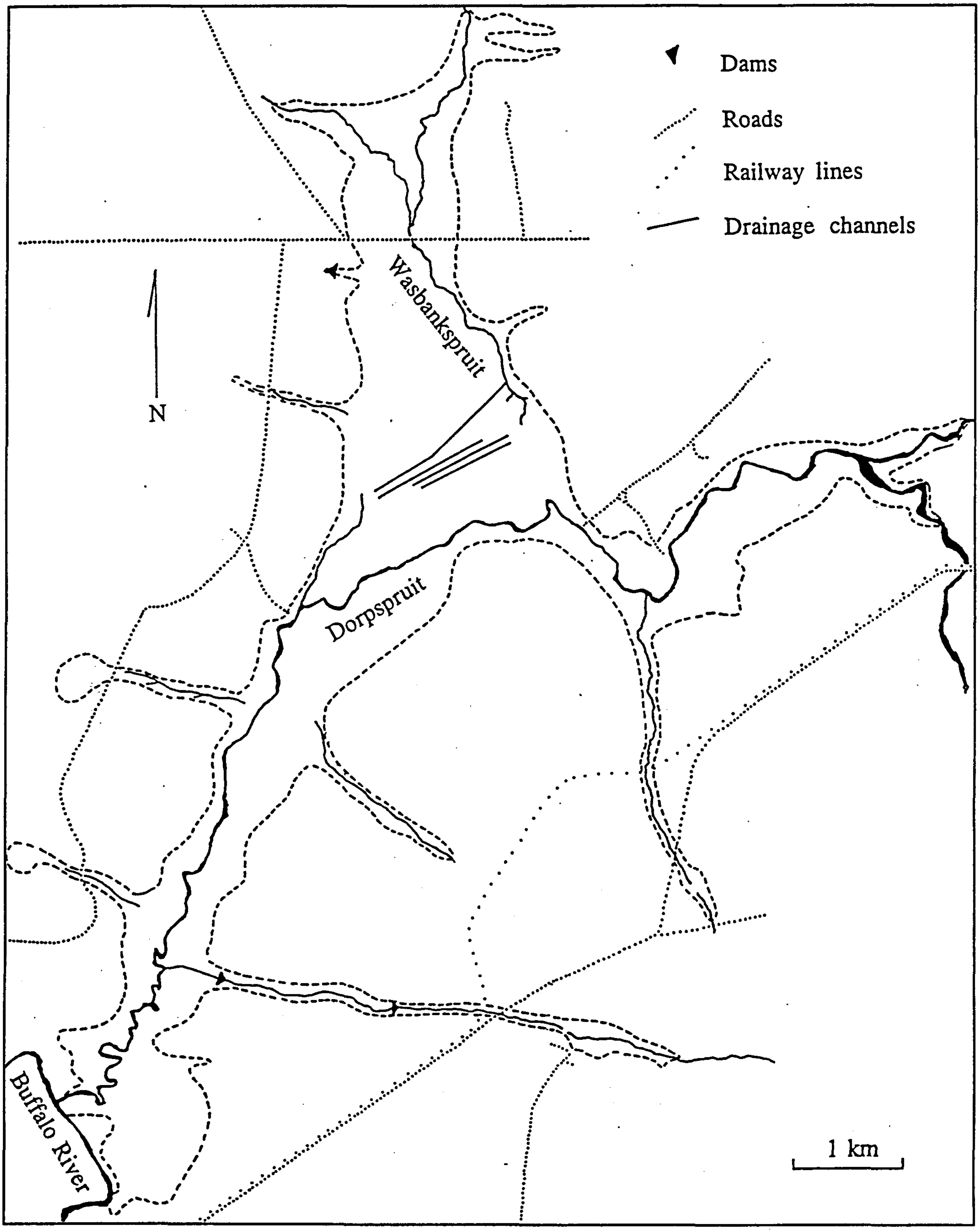

Fig. 9 Distribution of dams, drainage channels, roads and railway lines in Boschoffsvlei

channels has reduced their depth and resultant draining capacity; and (2) they do not straddle the full length of the unchannelled wetland area between the inlet and outlet channels of Sector 1b. Due to the importance of Sector 1b as a hydrological control area, it is strongly recommended that these drains not be opened and/or extended.

There are two short drainage channels associated with croplands in Sector 1a. These are relatively shallow and do not connect with the main channel. As such, their effect appears to be negligible. Nevertheless, further construction of wetland drainage channels, however small their influence, should definitely not be encouraged. Any further draining activities should under no circumstances be implemented without prior consultation with Department of Agriculture personnel and permission from the relevant authorities.

10.6 Alien invader plants

The invasion of alien plants is considered under the land-use section as it is associated with land-use activities. Certain areas of Boschoffsvlei are heavily infested with alien plants.

1. Sector 1a has ca 10 ha heavily infested with thistle (*Cirsium vulgare*).

2. Sector 2, and in particular Sector 3, have in total ca 50 ha heavily infested with cosmos (*Bidens formosa*).

Most of the channel banks are well vegetated with indigenous herbaceous plants, providing little opportunity for the establishment of alien invader plants. As such, alien plant invasion of these areas is low. Infestation by *Sesbania punicea* is high only in small isolated areas in all the sectors, usually where disturbance has occurred. Large willows (*Salix babylonica*) are common along the channel areas in Sectors 2 and 3 and black wattle (*Acacia mearnseii)* trees are common along the channel in the upstream end of Sector 1a.

Factors that may have contributed to the abundance of alien plants in certain areas of the wetland are:

1. a poor state of health of the indigenous herbaceous vegetation, probably caused, at one extreme, by protection from fire and very low grazing intensity, and, at the other, by high grazing pressure and associated disturbance;

2. successive dry years, allowing ruderal species with low wetness tolerances to invade seasonally wet areas; and

3. high levels of past disturbance.

Several strategies are available for counteracting the alien plant invasions:

1. encourage the establishment and maintenance of a healthy indigenous herbaceous layer through judicious burning, mowing and/or grazing practices;

2. minimize disturbance to reduce the opportunity for continued re-infestation;

3. active eradication, either manually or with herbicides;

4. oversowing; and

5. artificial flooding to favour the indigenous herbaceous wetland vegetation (this would require further investigation before being undertaken).

Strategies 1 and 2, which involve very little capital outlay, should be applied in all areas. However, if the indigenous herbaceous vegetation is in a very poor state of health, Strategies 2, 3, 4 or 5, which tend to involve greater expense, may also be required. Eradication of *S. punicea* and *A. mearnseii* will require active eradication in small localized areas where individual plants are large and/or levels of infestation are very high.

10.7 Dams, weirs and water extraction

Only three dams have been constructed within the wetland, all positioned in the tributary extensions of the wetland (Fig. 9). Dams are potentially harmful (see Appendix 1), and further dam building within the wetland is not recommended.

10.8 Roads and railway lines

Roads or railway lines traverse Boschoffsvlei's tributaries at 6 places (Fig. 9). These crossings are likely to modify local water flow in the wetland. Road causeways dam or drain wetland areas and may concentrate water flow downstream. Clearly, this detracts from the ecological and hydrological values of the wetland. However, from a superficial examination of the tributary road crossings, it appears that although at a very local level they are having a high impact, none has a substantial effect over a wide area of the wetland. If more road crossings are built, they should be carefully planned.

The main body of the wetland is traversed by the R34 in Sector 1a. Had it not been for a weir constructed upstream, this crossing would have had a high impact on the wetland (see Section 10.4).

10.9 Crop production

Examination of the 1935 airphotos shows that wetland cropping was more prevalent then than it is now, particularly at the upstream end of Sector 1a. Limited areas of the wetland, comprising non-wetland/wet grassland mosaics, are cultivated in the upstream ends of Sectors 1a and 2, primarily for maize production.

At present, these limited areas are unlikely to detract substantially from the wetland's functional values. However, considering that cropping in general does detract from a wetland's ecological value and is undesirable from a hydrological and erosion control point of view, the establishment of further croplands is definitely not recommended. Furthermore, consideration should be given to the inclusion of ley cropping or the conversion of cropland to permanent pastures in the wetland areas currently under cropland. This would reduce the environmental impact of current crop production practices in the wetland.

10.10 Building sand excavation

Until 1993, sand was being extracted from the alluvial deposits of the Dorpspruit at its junction with the Wasbankspruit. Begg (1989) states that it is probable that the alluvium deposited on the floodplain of the Dorpspruit constitutes the "keypoint" of the Wasbankspruit portion of the wetland. If this is true, removal of these alluvial deposits is likely to detract from the keypoint function of this alluvial area. Continued extraction could increase the gradient in the flow concentration area thereby increasing the erosive power of the water, promoting the retreat of the channel head into Sector 1b and reducing its degree of wetness. As discussed in Section 10.2.2, this would detract from the functional values of Boschoffsvlei. Thus, from the point of view of the long term well-being of the wetland, it is encouraging that sand excavation has been discontinued. It is recommended that this remain so.

10.11 Ecotourism

Boschoffsvlei has a low tourism potential, with few open water areas and few waterfowl. Nevertheless, it has some interesting biological features and is situated in a very scenic catchment and would certainly be attractive to special interest groups. In addition, Utrecht, the town with which the wetland is associated, is of historical interest.

11. FURTHER INVESTIGATION REQUIRED

From the preceding sections, it is suggested that the following aspects of Boschoffsvlei require investigation:

1. the importance of sand deposits on the banks of the Dorpspruit as a "keypoint" for Sector 1b and the effect of sand extraction at the junction of the Wasbankspruit and Dorpspruit rivers;

2. a more detailed description of the extent of the various land-uses practised in the catchment;

3. a description of the fauna and flora within the vegetation types described in this study, with the most pressing need being for a basic inventory of the wetland fauna; and

4. the effect of different fire regimes on the wetland biota.

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13. GLOSSARY

Animal unit (AU). An animal with a mass of 450 kg and which gains 0.5 kg per day on forage with a digestible energy percentage of 55%. Other types of animals are related to this unit according to the relationship between the three-quarter power of their mass and a similar function of the mass of a 450 kg animal. An animal with a mass *m* constitutes:

$$\frac{m^{0.75}}{450^{0.75}} \text{ of an animal unit}$$

Bioclimatic regions. Phillips (1973) classified the extremely varied natural resources of KwaZulu/Natal into 11 bioclimatic regions based primarily on climatic parameters. These groups provide convenient natural resource classes in terms of which management guidelines can be formulated.

Chroma. This refers to the relative purity of the spectral colour, which decreases with increasing greyness.

Dominant plant species. The dominant plant species are those overstory species that contribute most cover to the area, compared to other overstory species (Barbour, Burk and Pitts, 1984.

Ecological value. This refers to the value of the wetland in maintaining the biotic diversity of the area. Biotic diversity can be measured at many different levels making it almost impossible to prescribe a standard method to describe it. Its assessment may be simplified by determining the degree to which management is affecting biological integrity and populations of valued species.

Flats. Flats refer to a flat areas with slopes of less than 1%, usually situated in a bottomland positions.

Hydric soil. Soil that in its undrained condition is saturated or flooded long enough during the growing season to develop anaerobic conditions favouring the growth and regeneration of hydrophytic vegetation (vegetation adapted to living in anaerobic soils).

Hydrology. Hydrology is the study of water, particularly the factors affecting its movement on land.

Marsh zone. The marsh zone is dominated by tall (usually >1 m) emergent herbaceous vegetation, such as the common reed (*Phragmites australis*). Some marsh zone areas are seasonally wet but most are permanently or semi-permanently wet.

Mottles: soils with variegated colour patterns are described as being mottled, with the most abundant colour referred to as the matrix and the other colour/s as mottles.

***n* Value.** The *n* value refers to the relationship between the percentage of water under field conditions and the percentage of inorganic clay and humus and can be approximated in the field by a simple test of squeezing the soil in the hand. It is helpful in predicting the degree of subsidence that will occur after drainage (Pons and Zonneveld, 1965; Soil Survey Staff, 1990).

Open water zone. The open water zone comprises permanently or semi-permanently flooded areas characterized by few or no emergent plants.

Pans. Pan are natural shallow depressions in the earths surface which have no outlets and are flooded for varying periods in the wet season. They usually dry up seasonally through loss of water by evaporation.

Red data species. Red data species refer to all those species included in the categories of endangered, vulnerable or rare, as defined by the International Union for the Conservation of Nature and Natural Resources (Smithers 1986).

Soil saturation: the soil is considered saturated if the water table or capillary fringe reaches the soil surface (Soil Survey Staff, 1990).

Stocking rate. The stocking rate (SR) refers to the number of AUs per unit of land for a specified period of time. SR may be expressed in terms of number of land units per AU.

Wet grassland zone. The hygrophilous grassland zone is usually temporarily wet and supports a mixture of: 1) plants which are common to non-wetland areas and 2) short (< 1m) hydrophytic plants (predominantly grasses) common to the wet meadow zone.

Wet meadow zone. The wet meadow zone is usually seasonally wet and dominated by short (usually < 1.5 m) hydrophytic sedges and grasses common to temporarily or seasonally wet areas.

Wetland. Land where an excess of water is the dominant factor determining the nature of the soil development and the types of plants and animals living at the soil surface (Cowardin *et al.*, 1976).

Wetland functional values. Where wetland functions (e.g. the trapping of sediment) are of value to society, they are termed functional values. Wetland functions refer to the many physical, chemical and biological processes that take place in wetlands.