CHAPTER 1

INTRODUCTION

Enclosed protected areas are not independent, self-supporting ecosystems and therefore require management. A fundamental principle is that no biotic system is fixed or static. Protected areas are subjected to constant change through the effect of external events on the natural ecosystem (Scholes & Walker 1993), and also the ever-changing influence of modern man. Biotic systems are to a greater or lesser extent dynamic in space and time (Siegfried *et al.* 1982) and continuous review and adaptation of management policies and actions need to be recognised in the management of protected areas.

Determining the nature and direction of change is an important prerequisite to manage a dynamic system. It is also important to assess whether the change that occurred is within the permissible limits of that system, and whether it is conducive to the achievement of ecological management objectives. This can only be ascertained if management objectives have been determined (Coombes & Mentis 1992)

Scientific management involves strategies that are testable and refutable or irrefutable (Mentis 1980). Strategies in applied ecology may be classified as either of the deferred action type, or the adaptive type (Schmidt 1992). The deferred action is that systems cannot be managed until they are understood, therefore least disturbance is allowed until key processes are defined. In contrast, by applying adaptive management, problems are solved by taking a course of action of which the effect is then measured to establish to what extent objectives are achieved. The inherent variability of ecosystems and errors in observing and interpreting them is recognised (Mentis 1980).

Through the process of adaptive management, continuous monitoring improves the manager's knowledge of ecosystems and helps refine management plans (Ringold *et al* 1996). The aim of this process of adaptive management should be the achievement of the reserves' goals and objectives through the effective use of resources. Quantifying goals for the conservation of biological diversity provides a challenge to the manager, as it should be an achievable, testable and auditable target, with specified time and confidence limits (Bestbier *et al.* 1996).

Disturbance is regarded as an important component in many ecosystems, and variations in a disturbance regime can influence the structure and functioning of an ecosystem (Hobbs & Huenneke 1992). Before a desired disturbance regime can be applied to manage for a specific objective, its effect on the system needs to be verified. The Adaptive Management Approach allows management to use current knowledge to model possible effects to predict the outcome of a specific disturbance regime, i.e. herbivory. By interpreting the model it is possible to quantify the desired state of the ecosystem to achieve predetermined objectives. Subsequent monitoring will reveal any progress or regress in the achievement of reserve objectives.

The aims of the study are to investigate and quantify the changes that take place in an ecosystem when subjected to management practises such as herbivory or fire. Changes will be evaluated and interpreted according to degradation gradients to determine the influence on the achievement of reserve objectives. A further objective of this study is to develop a monitoring system to determine the direction and rate of change in each homogenous management unit. The aim of the monitoring system for Rustenburg Nature Reserve is to evaluate the progress or regress in achieving the ecological goals for the reserve, identified through the document "'n Prosedurele bestuursmodel vir provinsiale natuurreservate" (Fourie *et al.* 1993). This document gives an outline of the management process as it should be applied on provincial reserves. It specifically mentioned that the approach to resource management should be at ecosystem level, because of the immense number of species of which the majority is still unknown (Franklin 1993), and that it must be aimed at achieving reserves goals and objectives. It also showed the three requirements pertaining to the development of operational goals for reserve management (Coombes & Mentis 1992):

- realisable - possible to achieve
- measurable - the degree of attainment can be measured
- attainable - the time within which it must be attained is realistic and specified

In this study multivariate processing techniques were used to develop degradation gradients to determine ecological objectives for the reserve, and to interpret monitoring results. To minimize the effect of variation in the gradients in determining ecological goals for Rustenburg Nature Reserve, it was necessary to identify management units based on their homogeneity and practical application. Since plant associations reflect a particular range of uniform environmental variables, the description and classification of homogenous vegetation units form the primary basis for delineating homogenous management units for management and monitoring purposes (Schulze *et al.* 1994), which must be related to environmental factors. A full description of the physical components, i.e. geology, soil, hydrology and climate were therefore needed.

The integrative approach of the ISPD-system was considered essential to attempt to form an understanding of the dynamics of the vegetation in the different management units on Rustenburg Nature Reserve, as well as the responses thereof to disturbances, be it "artificial" (man-made, eg. stocking rate, species composition, controlled burning) or natural. Managing a system according to specific ecological objectives, requires an understanding of the response of the system to various external influences. The ecological management objectives of Rustenburg Nature Reserve are the conservation of the biological diversity associated with that system, as well as the sustained delivery of high quality effluent from this mountain catchment. The objectives of management of the vegetation component are therefore aimed at satisfying these above-mentioned goals.

By constructing a vegetation gradient depicting only the influence of external disturbances (or management actions) on vegetation composition and structure, the constancy or change and the direction of change in a system (Bosch & Kellner 1991) to be revealed by monitoring, can improve knowledge and provide guidance as to the type of management to be applied to most efficiently achieve the reserves' management objectives. This gradient will be interpreted in terms of species composition and appearance or disappearance of species along the gradient. The influence of management actions can then be quantified in terms of the position of a monitoring site along the gradient.

CHAPTER 2

GOALS AND OBJECTIVES OF RUSTENBURG NATURE RESERVE AND THE PRINCIPLES IN THE DESIGN OF A MONITORING SYSTEM

INTRODUCTION

Objectives are central to management, as management is not an end in itself, but only a means of achieving predetermined objectives and goals (Ferrar 1983; Coombes & Mentis 1992). To manage without clear objectives is a contradiction in terms and can be regarded as an aimless exercise (Coombes & Mentis 1992), with consequent inconsistent behaviour (von Gadow 1978). Socio-economic and political influences impacting upon protected areas also require clear objectives and goals and achievement thereof.

A vision is a broad philosophical statement of intent, while an objective is seen as more precise than the vision, but not necessarily achievable (Bestbier *et al.* 1996). The objective must support the vision in that it should expand upon the key elements of the vision and therefore provide a broad base to define the goals (Bestbier *et al.* 1996). A goal expands on the objectives and is considered as an achievable, testable and audible target, with specified time and confidence limits

(Bestbier *et al.* 1996) against which progress can be measured and provides a basis for rational planning (Coombes & Mentis 1992).

Applied ecology involves the accumulation and application of ecological knowledge to achieve predetermined goals in managing ecosystems (Mentis 1980; Schmidt 1992). Objectives range from pure conservation involving minimal management, through conservation for specific purposes requiring specific management activities, to exploitation of wildlife resources involving complete manipulation and control. Managing a reserve according to one or other economic objective, is simple in the sense that the habitat can artificially be altered and manipulated to provide for the specific needs of the animal or the desired vegetational composition to obtain maximum yields and to increase profits. The conservation of dynamic processes within a natural ecosystem is complex in the sense that it is impossible to manage it according to a specific baseline. A fixed baseline will not allow for the dynamic processes in the resource, as management will tend to recover any distortions from the baseline. It will therefore be necessary to determine the permissible change in the system that will not jeopardize ecological objectives and goals.

ECOLOGICAL OBJECTIVES FOR RUSTENBURG NATURE RESERVE

The vision for the Rustenburg Nature Reserve is:

To contribute to the socio-economic well-being of the people of the region through appropriate management of the wetland, its associated catchment and surrounding natural environment and allow for controlled nature-based outdoor activities

The key objectives of the reserve that would form the basis for prioritizing management activities in and around the reserve are:

- to ensure a supply of high quality water
- to maintain the scenic beauty and integrity of this area in the Magaliesberg
- to conserve biological diversity and natural processes and preserve the cultural and archaeological heritage
- to allow public access for
  - environmental education and research
  - outdoor nature-based recreation
- to increase the land area managed under the above objectives
- to more fully integrate the Rustenburg Nature Reserve with the surrounding community and to contribute to the local economy
- to manage the area in a cost-effective way and strive to at least achieve operational sustainability

Management of the natural resources in the reserve will focus on the conservation of biological and genetic diversity and the maintenance of the dynamic processes to ensure environmental sustainability. Parallel to this is the encouragement of sustained utilization of natural resources, which is primarily focussed upon tourism and the creation of opportunities for the public to experience nature.

Biodiversity involves more than species diversity(O'Connell & Noss 1992). According to Risser (1995) it occurs at several hierarchical levels, from genes to individuals, from populations, species, communities and ecosystems to landscapes. At each of these levels there are important relationships between biodiversity and ecosystem processes and between biodiversity and the way the ecosystem responds to disturbance and changing environmental conditions (Risser 1995). These relationships are complex and operate at many spatial and temporal scales.

Franklin (1993) recognizes three attributes of ecosystems:

- Composition
- Structure
- Function

These three attributes constitute the biodiversity of an area (Noss 1990). Composition includes measures of species and genetic diversity. Structure is the physical arrangement of the different elements of a system, and is a measure of the pattern of patches and other elements at a landscape scale. Function contains the ecological and evolutionary processes, and includes processes such gene flow, disturbance and nutritional cycles (Noss 1990).

Analysing the current objectives of the reserve - maintenance of biodiversity and setting limits to preserve soil - can be used as basis for determining ecological goals for Rustenburg Nature Reserve. As the overall statement of intent of the reserve implies the sustained yield of high quality water from the Waterkloofspruit, this parameter is an important indicator of the minimum condition of change that will be allowed in the proportional species composition and structure of the system on the reserve. If accepted, diversity at functional, structural and compositional scale must be maintained to meet the minimum condition requirement to obtain this.

An important fact is that Foran (1976) determined in the Mist Belt, Highland Sourveld and the Moist- and Dry tall grassveld that maximum diversity seems to occur in the mid to upper range of veld condition. Changes in veld condition over a wide range apparently involve mostly a change in proportional species composition. Species are however gained or lost only at the extremes. This is supported by Whyte *et al* (1999), stating that the intermediate hypothesis claims that the highest biodiversity at one point in time, will result from intermediate disturbance regimes, whereas fewer species will be present at extreme levels of disturbance, that is very high disturbance, or no disturbance. This fact provides a motivation to base this study on proportional herbaceous species composition or ß - diversity. Beta (ß) diversity is a measure of how different or similar a range of habitats or samples is in terms of the variety and abundance of species found in them. This is also necessary as the quantitative descriptive nature of this data is of value in the understanding of vegetation patterns.

Small mammals are important biological components of any natural system. They are important for nutrient recycling, habitat modification and soil dynamics, and as herbivores, predators or prey (Armstrong & van Hensbergen 1996). Small mammals have regularly been overlooked in the management strategies of protected areas, largely due to the fact that they are difficult to census. It is therefore important to understand how these animals relate to environmental features (Els & Kerley 1996). Studies have indicated that plant cover and structure (shrub canopy cover) are the most important correlates of small mammal communities and structure (Kerley 1992; Els & Kerley 1996). Fire has a marked effect on the floral and faunal composition of a region (Edwards 1984). The major impact of fire is not so much the killing of any animal (Breytenbach 1987), as the change in the physical environment and the vegetation structure (Els & Kerley 1996). Diurnal species, dependant on cover against predation, disappear from a burn within days (Breytenbach 1987). Studies in the Natal Drakensberg indicated that small mammal numbers peak after the third year, to levels higher than the pre-burn period.

These facts provide the framework for the formulation of broad ecological goals for Rustenburg Nature Reserve:

1. Ensuring the maintenance of a resilient ecosystem inside the reserve, capable of enduring excessive runoff and maximise absorption of water to deliver good quality runoff at a delayed rate
2. Ensuring the maintenance of diversity at all levels of the ecosystem
3. Managing faunal populations within the restrictions of 1 and 2 mentioned above, but ensuring a diverse and viable range of species to meet the objectives of 4
4. Improving the visitors' experience to the reserve by offering a variety and number of ungulates, habitats and landscapes, managed in an ecological sustainable way.
5. Sensitive and responsible development of infrastructure

Monitoring actions derived directly from these ecological goals have to be designed within the ecological limits of the goals, funding and statistical power to show change (Reilly & MacFayden 1992).

MONITORING THE DYNAMICS OF THE VEGETATION

Successful management of large areas of natural vegetation depends on the knowledge of the state of the vegetation and the extent and rate of change in response to herbivory and fire (Walker 1976). By measuring the state of the vegetation on a regular basis, trends and changes can be identified and the effect of management policies can be evaluated.

According to Mentis (1984), the general reason for monitoring is to detect the degree to which the objectives of management are achieved. Monitoring is defined as maintaining regular surveillance to test a null hypothesis of no change in predefined properties of a system that is vulnerable to impacts of which the nature, timing and location are not necessarily known (Mentis 1984). Hinds (1984) defined ecological monitoring as "the purposeful and repeated examination of the state or condition of specifically-defined biotic groups in relation to external stress". While research is conducted to increase our understanding of the ecological components and processes of ecosystems, monitoring measure the direction and rate of these processes (Macdonald & Grimsdell 1983) Macdonald & Grimsdell (1983) mentioned that where management is carried out to maintain a particular component of a system, monitoring should concentrate on the factors that have a direct bearing on that component. Monitoring is geared as an early warning system to detect changes or trends as a result of management or natural events (Coombes & Mentis 1992). Data collection should be sensitive enough to provide feedback to management to maintain that component within acceptable limits. Figure 1 describes the steps that are important in the development of a monitoring programme.

Efficient management cannot be achieved without an effective monitoring programme. For a monitoring programme to be effective and not an aimless activity, the objectives for the monitoring programme must be stated clearly (Aucamp *et al.* 1992). A monitoring programme should be focussed at providing the minimum information required to assess change and to interpret trends. Before a monitoring programme is initiated, the following should be considered:

- identification of important indicators
- objectives with each of these indicators
- determining the most effective monitoring technique and scale of monitoring to measure change and direction of change
- identification of the most appropriate procedures for data analysis and interpretation

Hinds (1984) identified three requirements for a successful monitoring system :

- It must be ecologically relevant
- It must be statistically credible
- It must be cost-effective

After the monitoring programme has been implemented and established, an initial evaluation should be carried out to get confirmation for the following four questions (Macdonald *et al.* 1983):

- Do the data identify any weaknesses that should be researched?
- Have any important components of the system been left out in the initial monitoring?
- Are the procedures adequate and are the accuracy and the precision of the data collected satisfactory?
- Which measurements can be left out in future?

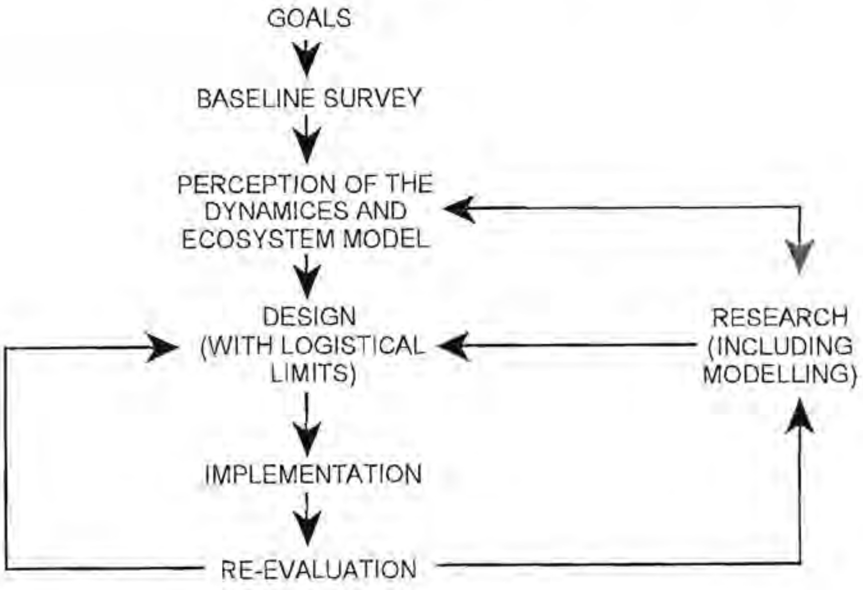

Figure 1: A framework for the development of a monitoring system (Ferrar 1983)

A well-designed monitoring technique becomes important when long-term trends in ecological structure and function have to be researched. The challenge is to develop monitoring techniques that is not only objective, but also more interpretable and quantifiable.

The hierarchy concept as suggested by Noss (1990) requires biodiversity to be monitored at multiple spatial and temporal scales, as the impacts of environmental stresses will be manifested at different levels of the system.

CHAPTER 3

STUDY AREA

PHYSICAL ENVIRONMENT

This study was done in the Rustenburg Nature Reserve, in the North West Province of South Africa. This reserve falls within the boundaries of the Magaliesberg Protected Nature Area and encloses a 17km^2 catchment area. This catchment is the main source of the Waterkloofspruit, a north-flowing perennial stream which flows into the Hex River which in turn feeds the Bospoortdam. Other smaller streams also have their origin in the reserve, a fact that underlines the importance of conserving this area. The reserve accommodates various forms of wildlife and has the potential to be one of the important centres for environmental education in the area.

The Magaliesberg forms a distinct climatic boundary (van Vuuren & van der Schijff 1970) between two major biomes, the savanna and the grassland (Rutherford & Westfall 1994; Low & Rebelo 1996). The mountain range, in which the reserve is situated, is according to Acocks (1988) a transition between the Sour Bushveld (veld type 20) and the Sourish Mixed Bushveld (veld type 19). However, Low and Rebelo (1996) regarded the vegetation type of this region as Mixed Bushveld (Veld type 18). The authors combined the Mixed Bushveld (veld type 18) and Sourish Mixed Bushveld (veld type 19) into one distinctive veld type and discarded the Sour Bushveld (veld type 20) as a separate veld type.

LOCATION

Rustenburg Nature Reserve borders the southern outskirts of Rustenburg, approximately 120 km west of Pretoria (Fig 2) at 25° 41' - 25° 45' South and 27°9' - 27°13' East. The reserve, which covers an area of 4 257 ha, comprises the two original farms Rietvallei 824JQ and Baviaanskrans 308JQ.

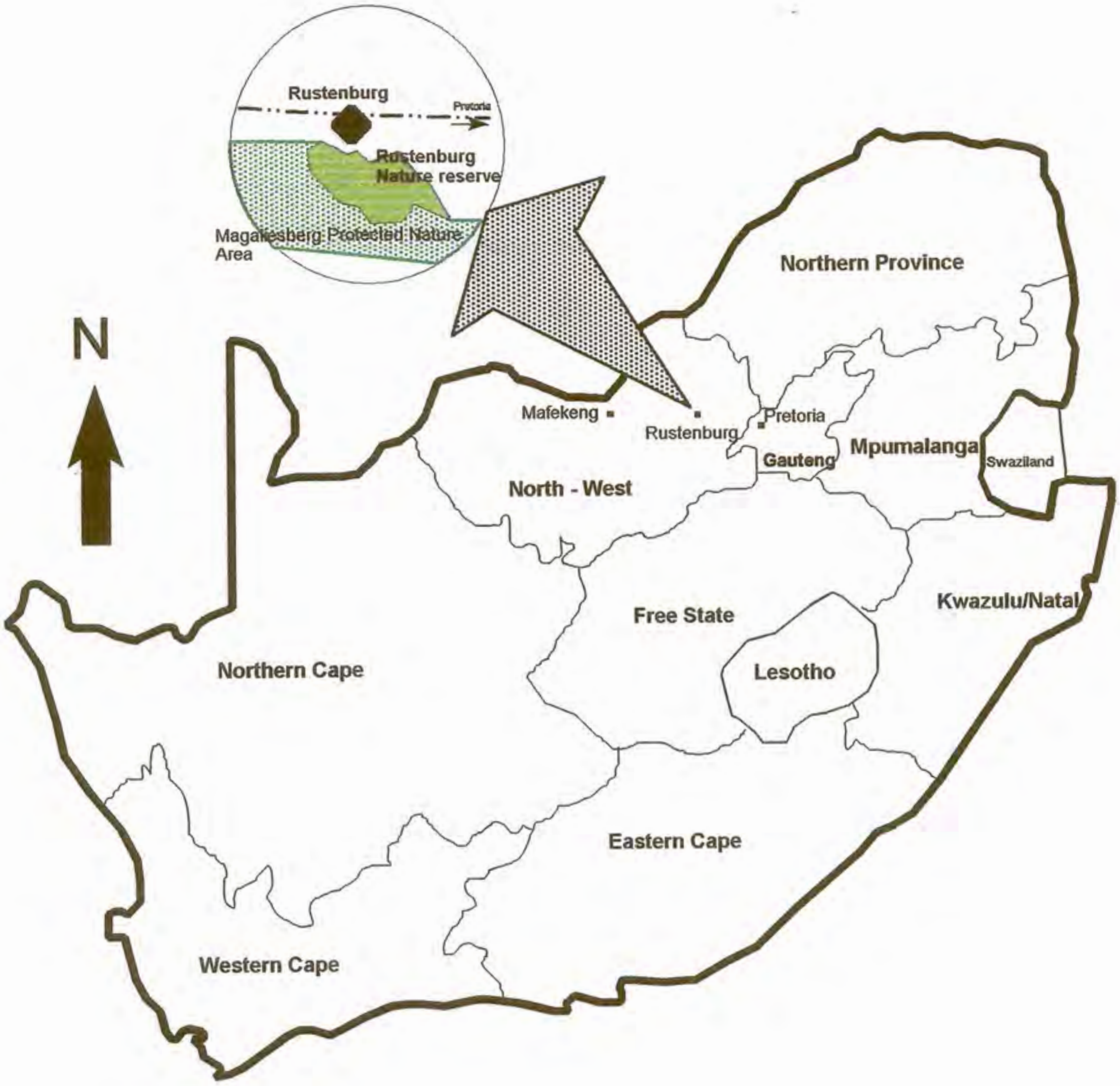

Figure 2: Location map for Rustenburg Nature Reserve

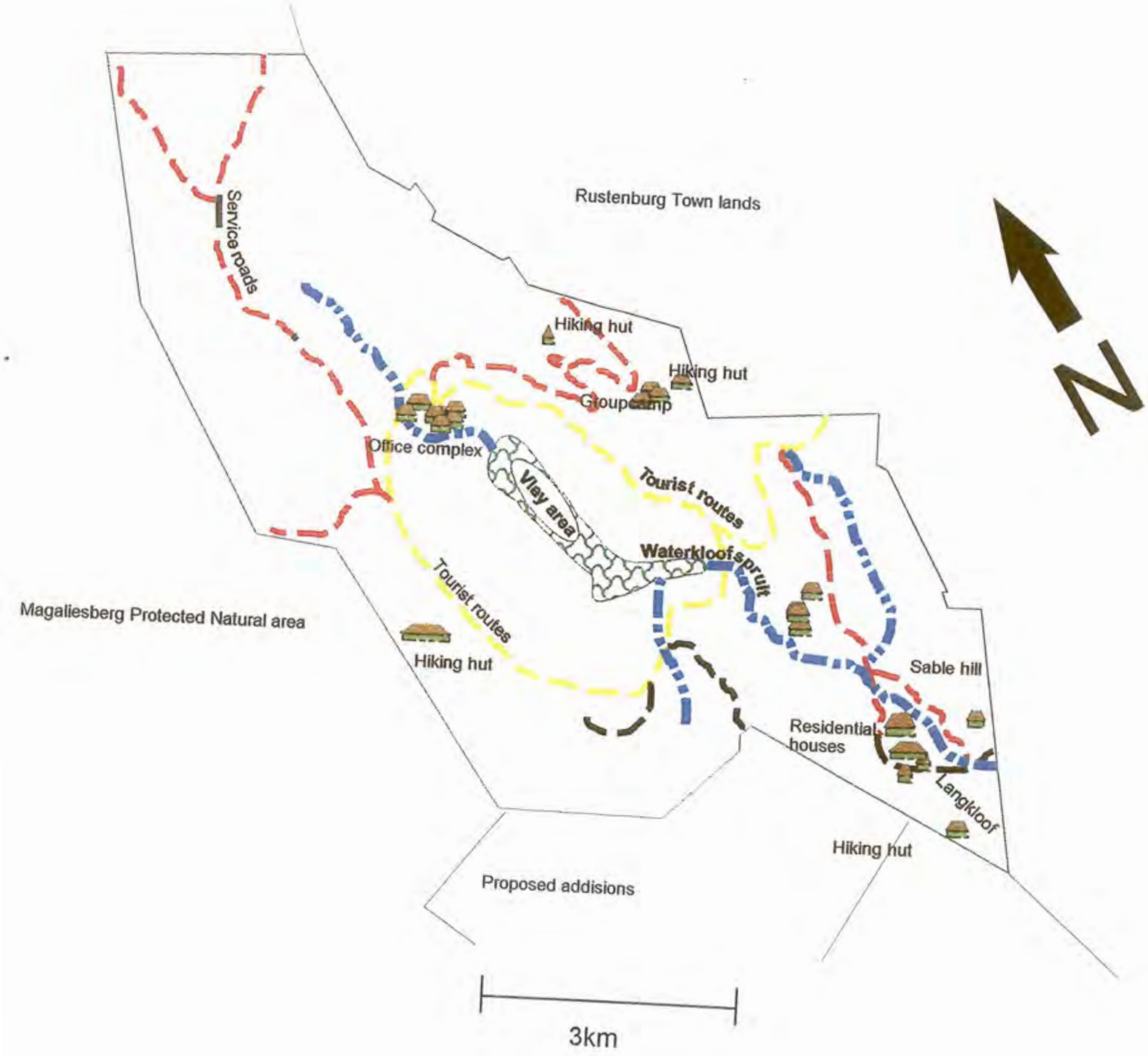

Figure 3: Management map for Rustenburg Nature Reserve

HISTORY

The Rustenburg Nature Reserve was used as grazing for cattle and game since time immemorial by black tribesmen and subsequently white farmers since the middle of the last century.

President Paul Kruger of the Zuid Afrikaansche Republiek owned several farms in the Rustenburg district before the war, among which were Rietvallei, Baviaanskrans and the adjacent Waterkloof (Labuschagne 1983). Kruger had several farming divergences on his properties. According to Coetzee (1975) he used the farm Rietvallei as summer grazing for his horses. Baviaanskrans was used for crops, orchards, and grazing (Juta 1936). These forms of land use were continued by subsequent land owners (Wulfsohn 1993).

The farm Rietvallei later became the property of the Rustenburg Town Council, who leased the area to adjacent farmers for grazing, mainly cattle (Kendall *pers. comm*[1])

In 1966 the town council of Rustenburg donated the farm Rietvallei 824 JQ and a portion of the farm Rustenburg Town and Town lands 272 JQ to the former Transvaal Provincial Administration to be developed as a nature reserve. In 1967 the reserve was formally proclaimed (Du Plessis 1973).

The reserve was fenced and stocked with a large variety of game. Species found mainly in the grasslands of the mountain plateau were springbok *Antidorcas marsupialis* (38), red hartebeest *Alcelaphus buselaphus* (33), blesbuck *Damaliscus dorcas phillipsi* (32), zebra *Equus burchelli* (23), black wildebeest

---

[1] Mr K Kendall, Inhabitant Rustenburg Town

Connachaetus gnou (17), oribi *Ourebia ouribi* (2) and steenbok *Raphicerus campestris* (1). While sable *Hippotragus niger* (21) were found mostly in the woodland on the plateau, kudu *Tragelaphus strepsiceros* (10) were observed in the woodland in the series of valleys. Mountain reedbuck *Redunca fulvorufula* (73+) occurred widespreadly on the slopes. Waterbuck *Kobus ellipsiprymnus* (12) concentrated in the densely wooded areas near the water, while impala *Aepyceros melampus melampus* (114) and common reedbuck *Redunca arundinum* (8) were usually observed in the woodlands.

At the time of proclamation the reserve covered an area of 2 898 ha. In 1981 the farm Baviaanskrans 308 JQ, which included rocky habitats and a waterfall was acquired, adding 1 359 ha to the reserve (Krige 1993).

PHYSIOGRAPHY

Due to drastic geomorphological events in this region of the Magaliesberg, Rustenburg Nature Reserve is very mountainous and altitudes vary from 1 230 m in the low-lying eastern parts of the reserve, to 1 660 m on the high lying western summits. The reserve is situated on the summit, eastern slopes and foothills of the Magaliesberg (Coetzee 1975). Two distinct geomorphological regions can be distinguished on the reserve; the high-lying plateaus and the low-lying valleys. The high-lying plateau contains a flat, convex area of exposed quartzite, at an altitude of 1 500 m - 1 650 m (Coetzee 1975). This high-lying plateau descent southwards into a basin of deep alluvial soil and marsh land which forms the largest natural wetland on the Magaliesberg (Carruthers 1990). The wetland is at altitudes 1 425 m - 1 440 m. The brim emerges at altitudes of 1 440 m in the south and at 1 500 m in the north, east and west (Coetzee 1975).

The second geomorphological region is a northwest to southeast series of valleys, underlain by diabase. These valleys separate the larger part of the summit plateau from a chain of quartzite hills extending from the northern plateau to the south east (Coetzee 1975). Altitudes of the valleys varies between 1 250 m and 1 320 m (Coetzee 1975).

GEOLOGY

From a management perspective, the reserve comprises two opposing geological formations (Fig. 4) *viz.* recrystallized quartzite from the Transvaal System and norite intrusions of the Bushveld Igneous Complex (Dept. Mineral and Energy Affairs 1981)[2].

Transvaal Sequence

The geology of the study area is relatively homogenous. The high-lying summit and slopes are underlain by well-bedded recrystallized quartzite areas with minor hornfels. These are sedimentary rocks of the Transvaal Sequence. The Transvaal Sequence includes all the sedimentary and volcanic rocks deposited in an east-west basin in the south-central part of Transvaal (Walraven 1981). In the North West Province, the Transvaal Sequence is represented as three series *viz.* The Black Reef-, Dolomite- and Pretoria Series. The Pretoria Group comprises four stages, Timeball Hill-, Daspoort-, Magaliesberg- and Smelterskop Stage. Within the Magaliesberg Stage two distinct formations can be distinguished *viz.* Magaliesberg quartzite and Silverton Shale (Kent 1980). Both formations are found on Rustenburg Nature Reserve. The Magaliesberg quartzite consists of considerable coarse quartzite, a feature undoubtedly related to recrystallisation caused by the Bushveld Igneous Complex with which it is often in contact (Walraven 1981). It forms a prominent escarpment along the entire Magaliesberg

---

[2] Dept. Mineral and Energy Affairs, Private Bag , Pretoria

range and conformably overlies the Silverton Shale. These shales are represented as interbedded hornfels in the northwestern region of the reserve (Coetzee 1975).

Bushveld IgneousComplex

The Bushveld Igneous Complex intruded the Transvaal Sequence, which resulted in it subsequently being encircled by the Transvaal Sequence. Three main rock groups have been recognised in the complex: the basic rocks, the granophyres and the granites and these form the basis for the present threefold division of the complex into the Rustenburg Layered Suite, the Rashoop Granophyre Suite and the Lebowa Granite Suite, respectively (Walraven 1981). The Rustenburg Layered Suite, which represents the Bushveld Igneous Complex in the reserve, comprises all the basic layered rocks of the Complex.

According to the stratigraphic nomenclatural system, advocated by the South African Commission for Stratigraphy (SACS), the Rustenburg Layered suite are informally divided into four zones *viz.*; an Upper-, Main-, Critical- and Lower zone. A marginal zone or chill phase of the Bushveld Igneous Complex exists in the western Transvaal (Kent 1980). Rocks of this zone are mostly confined to areas on the northern foothills of the western parts of the Magaliesberg, where they are underlain by a thick succession of Magaliesberg quartzite (Coertze 1974). This marginal zone forms the lowermost part of the Rustenburg Layered Suite and comprises Kolobeng Norite. Quartz is an important constituent in this zone, which suggests that this zone incorporated some of the floor sediments and cooling must have been relatively fast. Local wedging of floor rocks by Kolobeng Norite has taken place (Kent 1980).

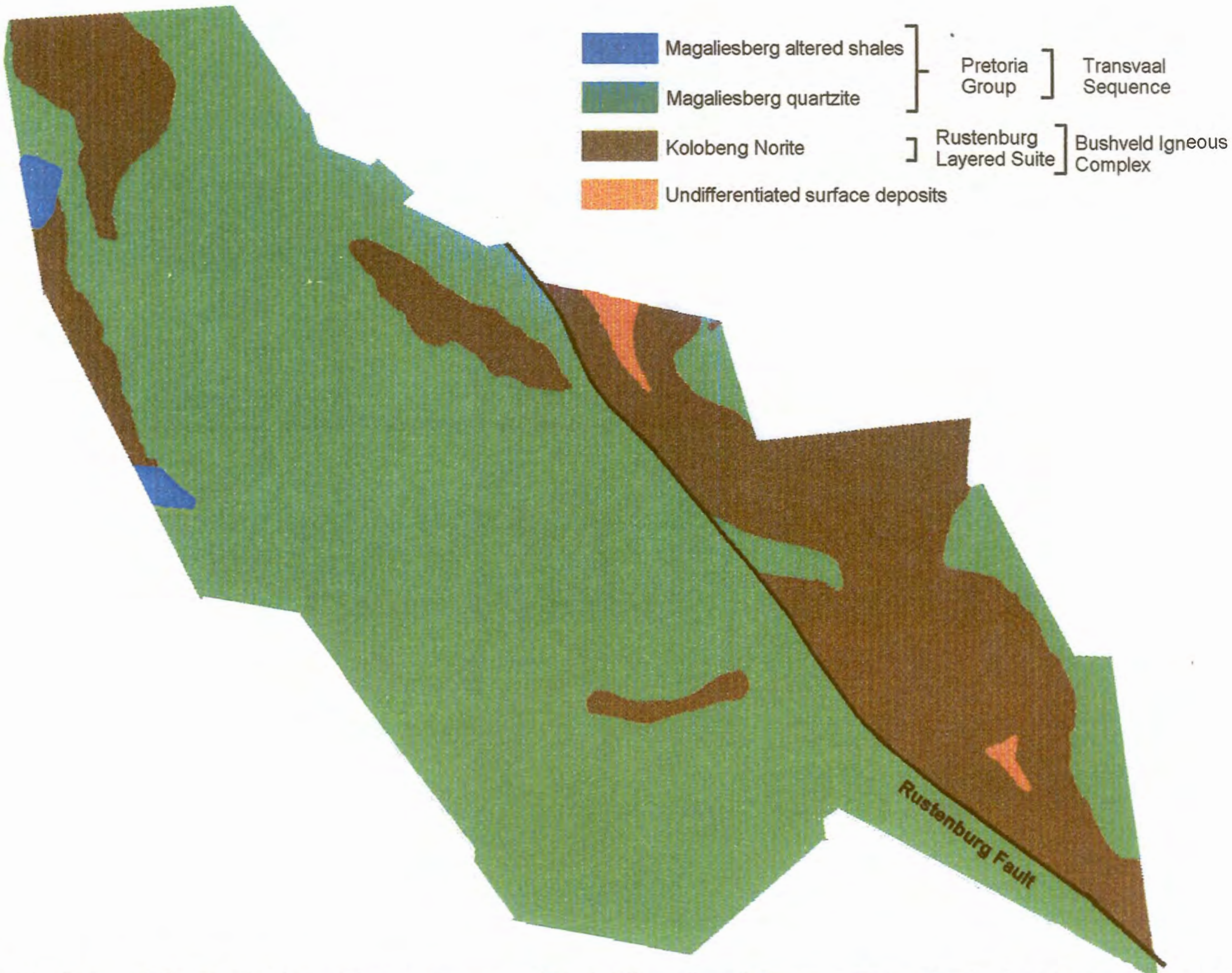

Figure 4: The Geology of the Rustenburg Nature Reserve (Dept. Mineral and Energy Affairs Geological Series 1981; Coetzee, 197
Coertze, 1974)

From a wildlife management perspective, the informal zonal nomenclature as used by Coertze (1974) are more appropriate. Coertze (1974) divided the Rustenburg Layered Suite into eight rock units, on the basis of their field relations. These are the basal norite units, which consist of quartz norite and marginal norite subunits; the harzburgite unit; the pyroxenite unit; the anorthosite unit; the norite unit; porphyritic pyroxenite unit; the gabbro unit and the ferro gabbro-unit. Only the first unit, basal norite and particular the quartz norite subunit is of importance for the geology of the reserve. This subunit occurs where the basal norite unit rests directly on the Magaliesberg which indicates that it was probably formed by the incorporation of quartzite in the basic magma from which the basal norite unit formed (Coertze 1974). The quartz norite subunit merge into the overlying marginal norite subunit by a decrease in the quartz content and an increase in crystal sizes.

The basal norite zone consists of rocks previously described as diabase (Jansen 1977; Coertze 1974). The rocks of this subunit contain, apart from orthopyroxene and plagioclase, abundant clinopyroxene (Kent 1980), amphibole, biotite, quartz, magnetite and in places olivine (Coertze 1974).

Quaternary and Tertiary Deposits

A diminutive quantity of Quaternary and Tertiary deposits are also found on the low-lying areas of the reserve. These deposits formed *in situ* by weathering of underlying rocks, or alluvial deposits along drainage lines and streams (Walraven 1981). An important aspect here is that these surface depositions occurred in successional layers and subsequent layers might differ in structure and texture (Hugo 1979).

SOILS

Soil can be viewed as a mixture of mineral and organic particles of varying size and composition with regards to plant growth (Scholes & Walker 1993). Soil interacts with plants through a combination of chemical exchanges and physical effects and provides it with water, nutrients and oxygen, as well as all essential elements for growth and subsistence. The nutrients in soil primarily influences plant nutrition, while its physical characteristics' plays a crucial role in plant water supply (Scholes & Walker 1993).

Soil is a distinct and important environmental determinant of vegetation structure and distribution (Louw 1970; Bredenkamp & Theron 1976; Fraser *et al.* 1987; Pauw 1988; Prins & van der Jeugd 1992; O'Connor 1992; Smith 1992). Several studies described the influence of local topo-edaphic conditions on the prevailing floristic and structural character of South African savannas (Werger *et al.* 1979; O'Connor 1992). On a global scale, the distribution of savannas is determined by climate, but within this area of broad distribution, however, the occurrence and type of savanna at any given point are strongly influenced by topography and substrate (Scholes & Walker 1993), and there is usually an associated variation in the vegetation. Le Roux (1979) determined that clay and moisture content of soil were the most important components affecting the vegetation in the Etosha National Park. Janse van Rensburg and Bosch (1990) furthermore concluded that the same species of plants often react differently to grazing between sub-habitats of different soil-depth and stoniness in the same topographical unit.

Vegetation often has a modifying effect on soil (Brady 1984; Pauw 1988; Smith 1992). In secondary succession, as well as primary succession, plant growth usually leads to change and often an "improvement" of the soils' properties

(Huston 1994). The autogenic influence of plants adds organic matter to the soil, influencing the physical and chemical properties of soils such as soil carbon and effective soil depth. The most significant contribution of soil organisms to higher plants is organic matter decomposition. Other biologically instigated biochemical reactions are responsible for other effects such as inorganic transformations and nitrogen fixation (Brady 1984).

A study of the vegetation of an area cannot be executed without considering the intrinsic relation between the vegetation and its environment. This relation is a useful aid in the mapping of these resources and a pedological survey is therefore necessary in a study of plant ecology on the reserve.

Methods

By studying 1:15 000 orthophotos and stereo aerial photos of the reserve, the various terrain units and soil/landscape associations were established. Assuming that differences in soil properties result in different vegetation associations and structure (Bredenkamp & Theron 1976; Fraser *et al.* 1987; Pauw 1988; Smith 1992), apparent soil types were demarcated. The correctness of these tentative borders was determined by correlating it with samples taken with a soil auger. In areas where there were no apparent boundaries between different soil types, auger holes along a transect were used to establish the location of the transition.

Soil profiles (78 in total) were studied by means of excavation pits, road cuttings and exposures through erosion, selectively sited within these recognized soil types. Soils were classified according to the binominal classification system of MacVicar *et al.* (1991), correlated with the binomial system of MacVicar *et al.* (1977). This correlation was done to include the soil series which is mainly based on clay content and sand fractions of the soil. The new version system (MacVicar *et al.* 1991) only distinguish soil families . A soil map was compiled, using the orthophotos as base map. The nodal profiles, which represent the dominant soil properties in each mapping unit, were described according to its colour, depth of the different horizons, texture, particle size fractions, structure, consistency and stoniness. Due to cost considerations, certain subjective assessments had to be used to describe the physical character of the different soil types. Particle size fractions and stoniness, consistency and structure classes of selected sites were determined using the limits described by MacVicar *et al.* (1977). The texture classes were determined in the field using a subjective method ("Sausage method")[3] . Soil colour was determined using Standard Soil Colour charts[4]

Thirty-eight samples from the A-horizon of selected sites were taken for further chemical analysis, as well as particle size distribution. Two additional samples were taken as control samples. These samples were chosen to represent the two extremes of soil types on the reserve, *viz.* pure quartzite and black turf. All chemical and physical analysis were conducted by the Climatological and Soil Research Institute[5]. The following chemical and physical analysis were performed:

- Particle size distribution (%)
- Percentage carbon (%)
- Resistance (Ω)
- Exchangeable cations me.100g^{-1} oven dry (100°C) soil
    - K
    - Na
    - Ca
    - Mg
    - S - value
    - T - value (CEC)
- pH (H_2O)
- Electrical conductivity (mS.m^{-1})

---

[3] National Working Group for Vegetation Ecology. Technical Communication No. 3. 1986

[4] Revised Standard Soil Color Charts. Oyama, M & Takehara, H. 1989

[5] Institute for Soil, Climate and Water, Belvedere street Arcadia, Pretoria, South Africa

All analysis was done according to the techniques described in the "Handbook of Standard Soil Testing Techniques for Advisory Purposes" (1990).

Results

The soils on Rustenburg Nature Reserve were studied and interpreted to explain vegetation distribution on the reserve and ultimately assist in the identification of homogenous management units.

Generally the soils on the reserve can be divided into six groups:

1 Shallow soils of the Mispah soil form (Orthic A horizon on hard rock) on the crests and upper slopes

2 Medium-deep stoney soils of the Glenrosa soil form (Orthic A horizon on lithocutanic B horizon) on the foothills

3 Deep and very deep well differentiated soils of the Hutton soil form (Orthic A horizon on red apedal B horizon) in the central basin and northern plateau region

4 Young soils of the Oakleaf (Orthic A horizon on neocutanic B horizon) and Dundee soil forms (Orthic A horizon on stratified alluvial) in the bottom lands of the valleys

5 Deep, sand clay loam soils of the Swartland (Orthic A horizon on pedocutanic B horizon) and Katspruit soil forms (Orthic A horizon on gley)

6 The black clayish soils of the Willowbrook soil form (Melanic A horizon on a G-horizon) , which underlie the *Phragmites australis* reed bed in the central basin area.

by a rocky surface, consisting of norite boulders (>30cm) with little weathering and little topsoil between the boulders.

One family - Myhill (Ms 1100) - of the Mispah soil form can be distinguished on the reserve (MacVicar *et al.* 1991). The A horizon of these soils is not bleached or calcareous and overlie a quartzite substrate. It has a coarse gravel texture (Table 1 & 2), with a low clay content. The colour of the A horizon is a brownish black colour, indicating the presence of decomposed organic matter.

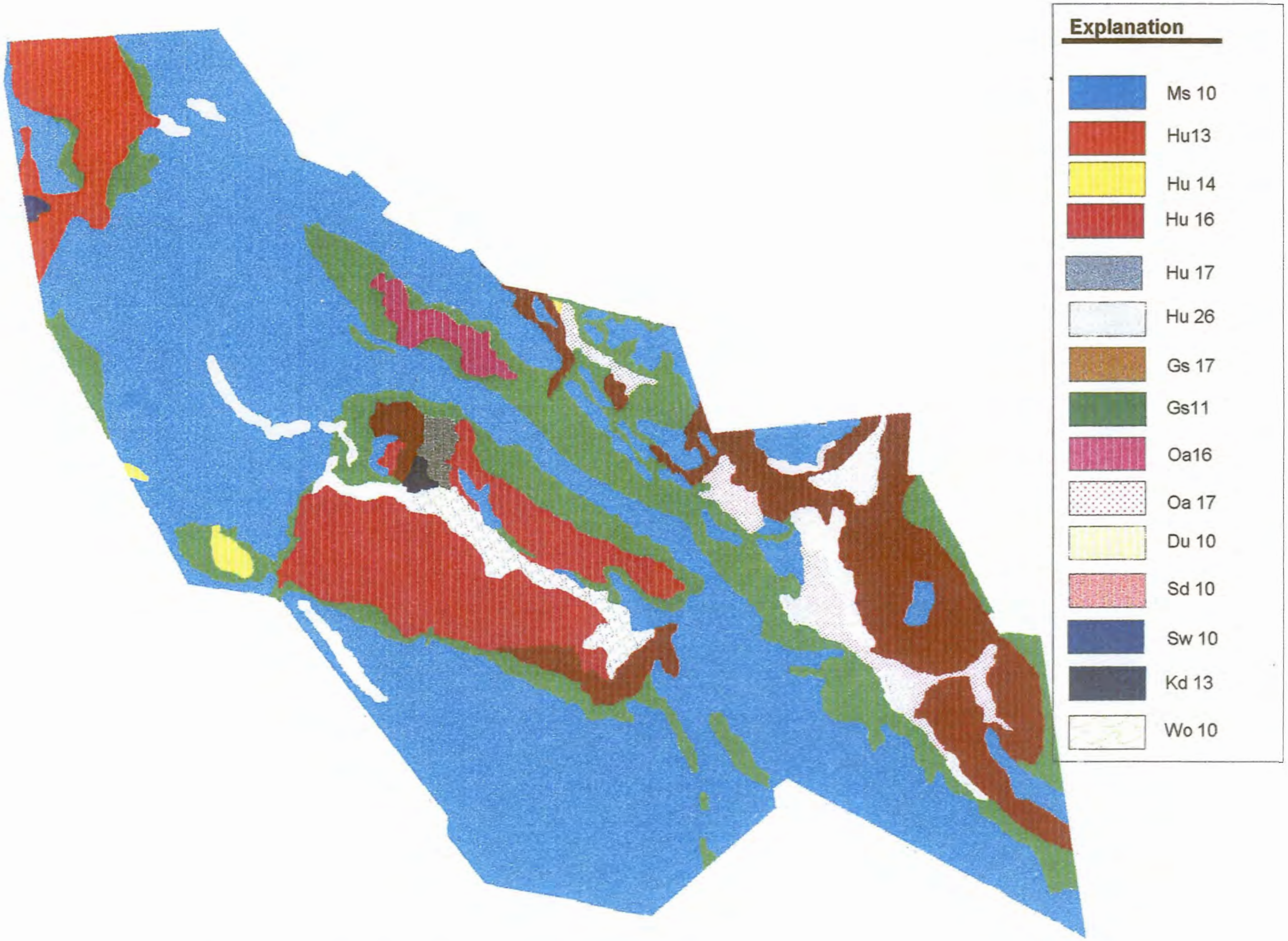

Figure 5 : The soils of the Rustenburg Nature Reserve

2 The medium-deep stoney soils of the Glenrosa soil form on the foothills

The slopes and foothills on the reserve are predominantly covered by shallow to medium deep soils of the Glenrosa soil form. These soils form the transition between the shallow soils of the crests and plateaus and the deeper well-differentiated soils found in the vlei-area and series of valleys to the east of the reserve. On the basis of the hardness of the lithocutanic B horizon, two soil families can be distinguished *viz*.; Dumisa (Gs 1111) and Tsende (Gs 1211) (MacVicar *et al.* 1991). Dumisa contains less than 70% fresh or partly weathered bedrock, while 70% and more of the B horison of the Tsende family consist of hard parent bedrock. Tsende is predominately present on the reserve.

According to the South African Binomial soil classification system (MacVicar *et al.*, 1977) differentiation into series is based upon clay content, sand grade and whether the B horizon is calcareous. Using this classification system, two distinct series in this soil form can be differentiated on the reserve *viz*. Oribi (Gs11) and Trevanian (Gs17). Differentiation between these two series are predominately based on the difference in clay content in the A horizon, which can be relayed to the underlying parent bedrock. The soils on the north western plateau and on the foothills of the central basin, as well as the slopes facing a north eastern direction is underlaid by Magaliesberg quartzite. The reddish brown soils overlying these areas have a low clay-content (10% - 15.6%) (Tables 1 & 2). The sand fraction forms the major constitute of the soils with levels in excess of 75% of the sample.

Table 1: A summary of selected properties of the different soil types on Rustenburg Nature Reserve

Profile no.	Soil form and family	Horizon	Depth (mm)	Colour (Dry)	Structure	Consistence	Stoniness	Texture
Ms 10/11	Ms1100	A - Orthic	150	5Y3/1	1	Loose	Common/medium/angular	Loamy sand
		B - Hard rock(Quartzite)						
	Gs1111	A - Orthic	30	7.5YR 4/6	12	Slightly hard	Common/medium/angular	Sand clay loam
		B - Lithocutanic	30+	5 YR 4/8		Slightly hard	Common/medium/angular	Sand clay
Gs 11/3	Gs1211	A - Orthic	250	5 YR 3/4	13	Loose	Common/medium/angular	Loamy sand
		B - Lithocutanic	250+	2.5 YR 3/4		Slightly hard	Common/medium/angular	Sand clay loam
Gs 17/2		A - Orthic	250	5 YR 4/8	33	Loose	Common/medium/angular	Sand clay loam
		B - Lithocutanic		5 YR 4/8		Slightly hard	Common/medium/angular	Sand clay loam
Hu13/5	Hu1100	A - Orthic	350	2.5 YR 3/4	11	Loose	Few/small/angular	Sand
		B - Red apedal	350+	2.5 YR 4/8		Loose	Few/small/angular	Loamy sand
Hu14/9	Hu1100	A - Orthic	300	2.5 YR 5/4	22	Loose	Few/small/angular	Loamy sand
		B - Red apedal	300+	2.5 YR 5/6		Loose	Common/small/angular	Loamy sand
Hu16/6	Hu1100	A - Orthic	400	5 YR 4/4	11	Loose	Few/small/angular	Sand loam
		B - Red apedal	400+	5 YR 4/6		Loose	Common/small/angular	Sand loam

Profile no.	Soil form and family	Horizon	Depth (mm)	Colour (Dry)	Structure	Consistence	Stoniness	Texture
Hu17/8	Hu2100	A - Orthic	400	5 YR 4/4	31	Soft	Few/small/angular	Sand clay
		B - Red apedal	400+	2.5 YR 4/8		Loose	Few/small/angular	Sand clay
Hu26/7	Hu1100	A - Orthic	350	5 YR 3/4	11	Loose	Many/small/angular	Sand loam
		B - Red apedal	350+	5 YR 4/6		Loose	Few/small/angular	Sand loam
Oa17/12	Oa 1210	A - Orthic	200	7.5 YR 3/4	32	Loose	Few/small/angular	Sand clay loam
		B - Neocutanic	200+	5 YR 4/3		Hard	Few/small/angular	Sand clay
Du 10/4	Du2110	A - Orthic	100	5YR 5/3	11	Loose	Few/small/round	Sand
		Stratified Alluvium	100 - 250	7.5 YR 2/2		Loose	Few/small/round	Sand
Sw10/6	Sw1221	A - Orthic	350	5 YR 3/6	24	Soft	Common/small/angular	Loamy snad
		B - Pedocutanic	350 - 520	2.5 YR 5/6		Hard	Few/small/angular	Sand clay loam
		Saprolite						
Sd 10/15	Sd1120	A - Orthic	100	5 YR 4/4	22	Slightly hard	None	Sand loam
		B - Red structured B	100+	2.5 YR 3/6		Slightly hard	None	Sandt loam
Wo10/3	Wo1000	A - Melanic	200	10 YR6/1	12	Loose	None	Sand clay loam
		B - G-horizon	200+	10 YR 4/6		Very firm (Moist)	None	Sand clay
Kd 14/16	Kd 2000	A - Orthic	280	5YR 3/6	323	Loose	None	Sand loam
		E - horizon	280-530	7.5 YR 4/2		Loose	Few/small/angular	Loamy sand
		B - Gleycutanic	530+	10 YR 4/4		Slightly firm (Moist)	None	Sand clay loam

Explanation:

Structure:	1	Structureless with no observable aggregation or no orderly arrangement of natural lines of weakness
	2	Weakly developed. Peds are indistinct, poorly formed and barely observable
	3	Moderately developed. Peds are well formed and durable but not distinctly seperated from one another in undisturbed soil
	4	Strongly developed. Peds are well formed and durable and distinctly separated from one another in undisturbed soil
Consistency	Dry soil	Loose, soft slightly hard, hard or very hard
	Moist soil	Loose, friable, slightly firm or very firm
	Wet soil	Non-sticky, slightly sticky, sticky or very sticky
Stoniness	Occurence	None, few, common
	Size	Small, medium, large
	Shape	Flat, angular, rounded

In contrast, the soils on the slopes and foothills facing southwestwards, is underlaid by Kolobeng norite of the Bushveld Igneous Complex. These soils have a dark reddish brown colour and a significantly higher clay content (25.1 to 29.5%) than similar soils on the quartzite substrate. (Table 2). The higher clay content of these soils resulted in a significantly higher CEC value than those underlaid by quartzite. The S-value (determined by the amount of leaching Smith (1992) of these soils is also significantly higher than in the quartzite soils. The electrical conductivity values of all the soils in this group indicate no accumulation of soluble salts.

3 The deep, well-differentiated soils of the Hutton soil form

The central basin area, as well as an area on the northwestern plateau (Fig. 4) is predominantly underlaid by deep, well-differentiated soils of the Hutton soil form. This soil form also occurs in certain isolated areas in the valleys in the eastern part of the reserve.

According to the South African Binomial soil classification system (MacVicar *et al.*, 1977) differentiation of the Hutton soil form into series is based upon the clay and sand content in the B21 - horizon. Five series in this soil form can therefore be distinguished on the reserve, *viz.* Wakefield (Hu13), Middelburg (Hu14), Hutton (Hu16), Farningham (Hu17) and Msinga (Hu26). The clay content in these soils varies according to its position in the landscape. The soils with a higher clay content (16,9% - 32.2%) occur on the bottom lands, while those with a high percentage of sand are to be found on the high lying ground, underlaid by quartzite. Farningham (Hu17) is confined to an area in the north of the basin. These soils have a relative high clay content (>35%) compared to the values of other samples taken in the basin.

Table 2: The results of an analysis of selected properties of the A-horizon of the soil on Rustenburg Nature Reserve.

Profile number	Sand %	Clay %	Silt %	Carbon %	P mg.kg^{-1}	Exchange cations cmol (+).kg^{-1} soil					Sum of exchange= ables cations	CEC	Water pH	EC mS.m^{-1}
						Na	K	Ca	Mg	S-value				
The shallow soils of the Mispah soil form on the crests and upper slopes														
3	71.80	6.00	22.20	3.93	11.40	0.00	0.09	0.07	0.10	0.26	4.33	4.60	4.26	20.00
4	72.00	6.00	22.00	3.26	17.80	0.06	0.06	0.14	0.03	0.29	4.83	6.22	4.24	22.00
5	76.40	6.00	17.60	3.21	9.80	0.02	0.06	0.17	0.03	0.28	4.67	5.46	4.46	26.00
26	83.10	7.20	9.70	4.95	13.20	0.01	0.09	0.24	0.10	0.44	6.14	-	4.52	-
37	85.30	6.70	8.00	3.04	13.80	0.01	0.08	0.45	0.08	0.62	9.21	-	4.48	-
Tthe medium-deep stoney soils of the Glenrosa soil form on the foothills,														
9	79.70	10.00	10.30	1.15	1.90	0.02	0.14	0.15	0.06	0.37	3.70	1.88	4.89	37.00
10	78.00	10.00	12.00	1.45	2.70	0.02	0.08	0.04	0.02	0.16	1.60	2.58	5.04	11.00
13	69.50	14.00	16.50	1.95	2.00	0.00	0.28	0.85	0.95	2.08	14.86	5.66	5.96	36.00
14	75.20	10.00	14.80	0.52	1.10	0.06	0.12	0.62	0.78	1.58	15.80	1.73	6.37	14.00
27	80.90	10.90	8.20	1.34	2.80	0.02	0.10	0.88	0.19	1.19	10.88	-	4.04	-

Profile number	Sand %	Clay %	Silt %	Carbon %	P mg.kg^{-1}	Exchange cations cmol (+).kg^{-1} soil					Sum of exchange=ables cations	CEC	Water pH	EC mS.m^{-1}
						Na	K	Ca	Mg	S-value				
33	76.30	11.60	12.10	2.56	3.20	0.01	0.21	0.77	0.10	1.10	9.46	-	4.97	-
36	80.70	8.10	11.20	1.17	12.20	0.01	0.15	0.67	0.25	1.08	13.27	-	5.67	-
17	38.90	36.00	25.10	2.00	1.10	0.00	0.43	2.70	2.51	5.64	15.67	9.51	6.44	27.00
19	38.50	32.00	29.50	2.42	1.20	0.03	0.57	2.97	4.01	7.58	23.69	15.48	6.12	29.00
The deep and very deep well differentiated soils of the Hutton soil form in the central basin and northern plateau region,														
1	81.60	8.00	10.40	1.35	5.20	0.00	0.06	0.13	0.06	0.25	3.13	3.80	4.76	19.00
6	79.40	10.00	10.60	1.25	1.90	0.03	0.02	0.23	0.12	0.40	4.00	2.65	4.69	8.00
8	74.10	14.00	11.90	1.43	1.10	0.00	0.04	0.68	0.66	1.38	9.86	3.73	5.98	14.00
38	69.80	15.60	14.60	2.09	13.20	0.01	0.11	0.09	0.03	0.24	1.52	-	4.54	-
11	79.10	12.00	8.90	1.97	2.00	0.05	0.16	0.62	0.50	1.33	11.08	4.18	5.34	14.00
21	72.70	13.40	13.90	1.48	5.20	0.01	0.08	0.20	0.08	0.36	2.69	-	4.50	-
22	85.01	5.00	9.99	1.47	4.20	0.01	0.09	0.03	0.10	0.24	4.74	-	4.56	-
20	31.80	36.00	32.20	2.61	1.10	0.03	0.77	3.38	3.95	8.13	22.58	11.58	6.34	32.00
35	40.80	37.20	22.00	2.54	2.40	0.01	0.22	0.48	0.21	0.92	2.48	-	5.35	-
28	41.00	42.10	16.90	1.95	2.40	0.02	0.28	0.11	0.03	0.43	1.03	-	5.68	-

Profile number	Sand %	Clay %	Silt %	Carbon %	P mg.kg^{-1}	Exchange cations cmol (+).kg^{-1} soil					Sum of exchangeables cations	CEC	Water pH	EC mS.m^{-1}
						Na	K	Ca	Mg	S-value				
The young soils of the Oakland and Dundee soil forms in the bottomlands of the valleys														
12	60.50	20.00	19.50	1.70	1.30	0.04	0.61	2.37	1.14	4.16	20.80	7.68	5.80	22.00
24	70.00	15.50	14.50	1.29	10.20	0.01	0.16	0.05	0.02	0.23	1.50	-	5.11	-
29	69.70	15.80	14.50	1.37	2.00	0.02	0.13	0.95	0.29	1.39	8.80	-	5.09	-
15	27.30	32.00	40.70	3.02	1.10	0.00	0.48	1.41	2.52	4.41	13.78	10.87	5.40	17.00
16	23.20	36.00	40.80	3.28	1.70	0.03	0.08	1.08	1.21	2.40	6.67	5.28	5.06	14.00
30	42.00	32.30	25.70	5.18	13.60	0.02	0.14	0.81	0.14	1.10	3.42	-	4.67	-
31	66.30	18.50	15.20	1.86	16.20	0.01	0.19	1.78	0.40	2.38	12.84	-	5.51	-
23	24.20	50.90	24.90	2.45	13.40	0.02	0.12	0.06	0.03	0.22	0.44	-	5.43	-
25	62.80	25.00	12.20	2.75	3.20	0.01	0.24	1.31	0.33	1.89	7.56	-	5.18	-
The deep, sand clay loam soils of the Swartland and Shortlands soil forms														
2	68.20	16.00	15.80	2.84	1.80	0.00	0.18	1.00	1.00	2.18	13.63	5.44	5.54	17.00
18	65.80	20.00	14.20	1.21	1.10	0.00	0.32	2.47	0.43	3.22	16.10	5.52	7.26	24.00
The black clayish soils of the Willowbrook and Kroonstad soil form, which underlie the marsh in the central basin area.														
7	10.50	12.00	77.50	12.08	4.80	0.09	0.07	0.35	0.46	0.97	8.08	28.39	5.14	11.00
34	35.10	37.90	27.00	9.80	2.80	0.02	0.22	0.28	0.13	0.65	1.70	-	4.38	-

The soil classification system of MacVicar *et al.* (1991) differentiated between the families in this soil form according to the amount of leaching, as well as the ratio of the clay content between the A horizon and the B1 horizon. According to this classification system only two soil families can be distinguished on the reserve *viz.* Lillieburn (Hu1100) and Hayfield (Hu2100). These soils are non-luvic with no significant difference in clay content between the A horizon and the B1 horizon. The soils are generally dystrophic, except in the bottom lands on the eastern side of the reserve. The S-value of the soils in this area is 8.13 (Table 2), mesotrofic (MacVicar *et al.* 1991) and therefore the need to differentiate between the two families.

Distinct differences in chemical properties occur in the soils of the different landscapes. The cation exchange capacity (CEC) of the soils in the eastern bottomlands is significantly higher than that of the Hutton soils on the plateau and central basin area. As the CEC of soils is affected mainly by the amount of clay and organic matter (Van Rooyen 1984), it can be regarded as an indication of its nutritional status.

The pH-values decrease with altitude between 4.5 and 4.7 on the plateau to 5.6 and 6.3 in the bottom lands. The pH values of the soils in the central basin vary between 5.3 and 5.9. The electrical conductivity values of all the Hutton soils indicate that they are relative free from soluble salts. However, the Hutton soils in the bottom lands (EC = 32 mS.m^{-1}) showed a significantly higher salt content than the other Hutton soils (EC = 14 - 19 mS.m^{-1}).

4 The young soils of the Oakleaf and Dundee soil forms in the bottom lands of the valleys

Tertiaries to recent alluvial soils underlie the valleys in the east of the reserve (Coetzee 1975). Although no distinctive diagnostic horizon can be recognised in these soils, an amount of reorganisation of material did occur and stratifications that were present, have been eradicated. These alluvial deposits developed into young soils of the Oakleaf form. The families in this soil form are distinguished according to colour and clay content of the horizons (MacVicar *et al.* 1991). These soils have a dull reddish brown colour with non-luvic characteristics. Only one family can be distinguished on the reserve *viz.* Caledon (Oa1210). The B horizon of these soils has a high clay content (>15%), and according to the classification system of MacVicar *et al.* (1977) only two soil series can be differentiated *viz.* Leeufontein (Oa16) and Highflats (Oa17). Alluvial soils usually have a variable texture (van Rooyen 1983) as is evident in the soils on the reserve. The clay content of the Oakleaf soil samples in Langkloof is higher than 30%, whereas those of the valley between Witkruiskrans and Sable Hill are below 20%. The soils are deep (>1.5m).

The Oakleaf soils of Langkloof have a relative high carbon content (>3% - 5.18). The exchangeable potassium content is low (<0.04%) and the electrical conductivity indicates no accumulation of soluble salts.

Another group of young undeveloped soils are confined to the drainage lines in the upper regions of the reserve where weathered quartzite pebbles and decomposed organic matter are laid down in alternating layers. Pedogenetic development is minimal and definite layers of a deposition process is evident. Aggregation of soil fragments to form larger units have not yet taken place and the soil conglomerations in the drainage lines are sometimes washed down in a single severe rain storm, even in the presence of a healthy vegetation cover.

The greater part of the stratified alluvium of the Dundee soil form has a brownish black colour, which disqualifies it as a red stratified alluvium. Only one family can be distinguished *viz.* Nonoti (Du 1110) which has a gravelly texture and lateral variability (MacVicar *et al.* 1977). Analysis of these soils was done with samples taken from each recognisable stratified layer which was mixed into one. Only two samples were analysed and, because of the variability of these soils (Table 1 & 2) a representative view of the general characteristics of these soils could not be obtained. These soils are shallow and are found on the slopes, underlain by quartzite parent rock. It also occurs in drainage lines in the central basin area where it is deeper than 2m and overgrown with bracken fern *Pteridium aquilinum.*

5 The deep, sand clay loam soils of the Swartland and Shortlands soil forms

These soils occur in small isolated areas throughout the reserve. The Swartland soil form can be found in a depression on the north western side of the plateau. The hornfels saprolite (Magaliesberg altered shales)(Coetzee 1975) weathered into soils high in clay content and fertility[6]. An unbleached A horizon, underlaid by a red, medium angular B horizon without any calcareous characteristics distinguished only one family, *viz.* Mtini (Sw1221) (MacVicar *et al.* 1991). The soils are ± 500mm deep and although the clay content of the A horizon is relative low , the B horizon has a high clay content. The cation exchange capacity of the soils is also relative low (5.44 - 5.52) and the electrical conductivity indicates no accumulation of soluble salts.

The Shortlands soils occur on the foothills of the eastern hill range, originating from the underlying norite intrusions. One family, Groothoek (Sd1120), can be distinguished. These soils have a mesotrofic character. The pH-value (7,26) of the topsoil is alkaline due to the basic parent rock. No exchangeable potassium is available.

6 The black clayish soils of the Willowbrook and Kroonstad soil form which underlie the marsh in the central basin area.

These soils are confined to the marshy area in the central basin as well as insignificant little areas in the kloofs on the reserve. It is characterised by a high carbon content (>9.50%), responsible for its brownish gray to brownish black colour.

The soils in the marshy area are of the Willowbrook soil form (Melanic A horizon followed by a non-calcereous G horizon). One family, Ottawa (Wo1000), can be

---

[6] National Working Group for Vegetation Ecology Tech. comm. 3 1986

distinguished. The A horizon has a low clay content (12%) and S-value (0.97)(Table 3). The cation exchange capacity is high (28.39), compared with other soils on the reserve (Table 3). The silt content of the soils is high (<75%) and no soluble salts accumulated in these soils. The underlying G horizon has signs of water saturation for long periods and gleying occurs in these soils.

The Kroonstad soil form is limited to an area adjacent to the marsh. This soil form is recognised by the presence of a distinct well-leached E horizon abruptly underlaid by a G horizon. The A horizon has a high clay (>35%) and carbon content (9.80%). These soils lie on a slight slope, which is an important factor in the genesis of the E horizon. The occurrence of a less permeable G horizon causes a temporarily accumulation of water above the B horizon, which is discharged in a lateral direction (MacVicar *et al.* 1991). Soil families are distinguished on the basis of colour of the E horizon and only the Morgendal (Kd1000) family could be differentiated

CLIMATE

Climatic factors mediated through light, heat, and water directly affect biochemical and physiological processes in plants (Tchebakova *et al.* 1993). Botanists and geographers have long been aware that plants are highly responsive to differences in climate. Climate is also considered to be the ultimate determent in savanna distribution (Scholes & Walker 1993), as plant form and vegetation structure are primarily determined by temperature and climatic water balance.

The water regime had a dominant effect at almost all levels. Temperature and light were less important. Heat effects, metabolic rates, water loss and uptake rates are considered to be only important at extreme levels (Rutherford & Westfall 1994). According to Schulze (1965) the following factors are primarily responsible for the existing climatic conditions at a specific locality *viz.* latitude, position relative to distribution of land and sea, height above sea level, general circulation of the atmosphere, influence of ocean currents and position relative to hills or mountains, nature of the underlying surface and vegetation type. This is confirmed by Tyson (1987), although he stated more specifically that the climatic conditions in southern Africa are strongly influenced by the position of the subcontinent in relation to the major circulation features in southern Africa.

The ecological climate diagram provides clear information on the seasonal course of the climate. It contains the most essential climatic data from an ecologists point of view and is comprehensible at a glance (Walter 1979). Climate diagrams not only show the monthly temperature and precipitation values, but also the duration of the relative wet and dry periods and the duration and severity of winter. The climate diagram for Rustenburg Nature Reserve is illustrated in Figure 6. Climatological information had been collected on the reserve since 1980. Initially only rainfall information was recorded using a standard rainfall gauge. In 1989 a small weather station was established using a Stevenson screen as prescribed by the Weather Bureau (Weather bureau 1988). Since 1989 the average minimum and maximum temperatures, absolute minimum and maximum temperature, rainfall and days of frost are recorded each day. Comparisons between the rainfall and temperature data of the reserve and that of the region, obtained from Rustenburg Agricultural Institute (Station 0511523 4, ϕ 25° 43' S, λ 27° 18' E; Ht 1157m) and although no significant differences could be found in the long-term climatic data, some differences were significantly obvious in the short term (Table 3).

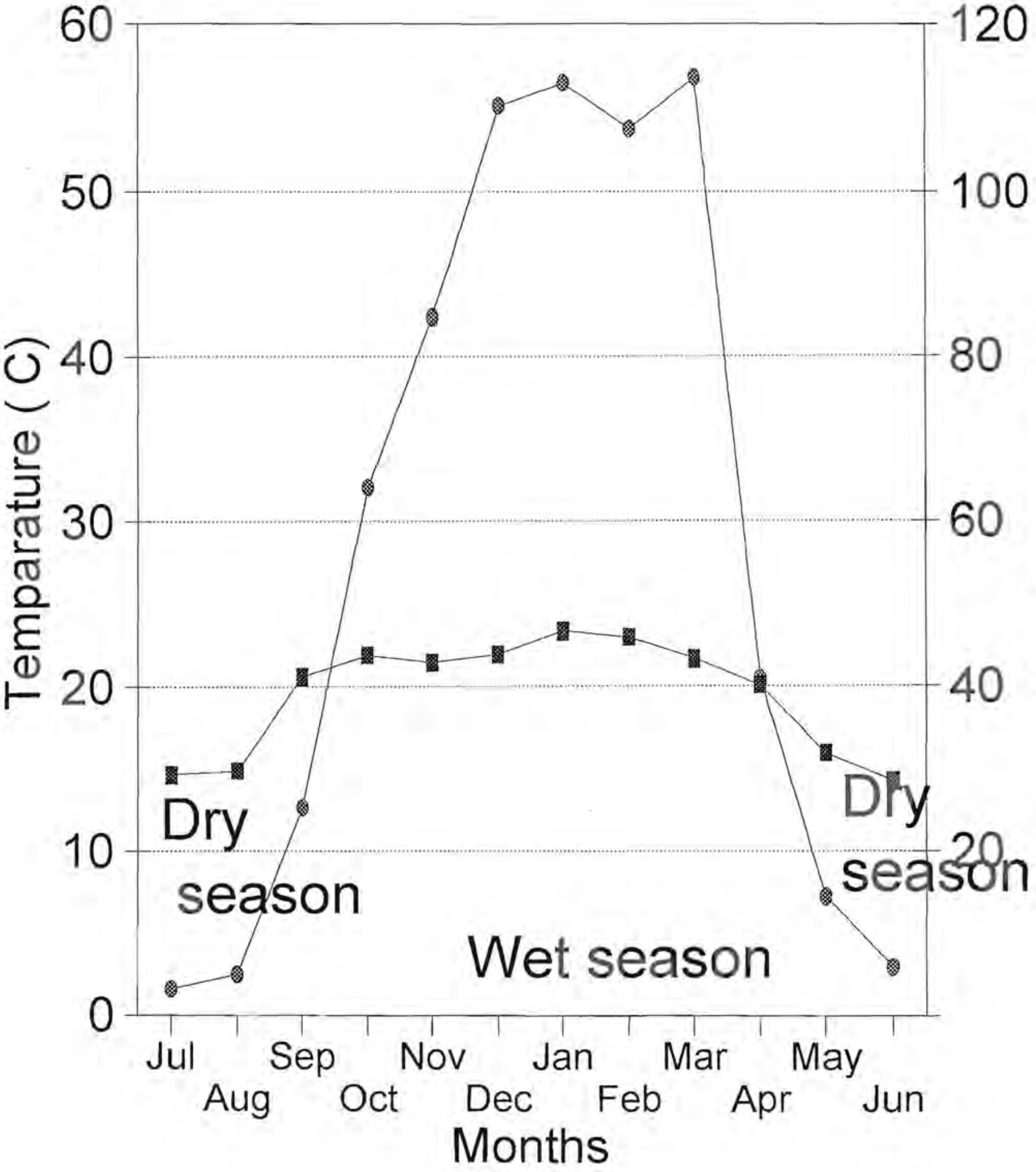

Figure 6: Ecological Climate diagram for Rustenburg Nature Reserve

According to Köppen's classification of the climates of South Africa, Rustenburg Nature Reserve is situated in a transition between two types (Schulze 1947). Firstly, the *Cwa* - type, implying an area where:

C - warm temperate climate with the coldest month 18°C to -3°C
W - winter dry season
a - warmest month over 22°C

and the *Bshw* - type, meaning:

B - an arid climate
S - Steppe (steppe *BS*)
h - Hot and dry mean annual temperature exceeds 18°C Rustenburg mean annual temperature = 18.7°C (Weather Bureau, unpublished)
w - dry season in winter

However, Hugo (1979) classified the climate of Rustenburg as a "Steppe" climate and thus the *Bshw*-subtype of Köppen.

According to the Thornthwaite-classification, which uses the concept of "Precipitation Effectiveness Index" and "Temperature Efficiency Index" as the basis of this system, the reserve is situated in the CB'd - climatic zone, where a sub-humid (C), mesothermal warm temperature (B) prevail, and (d) where moisture is deficient in all seasons (Schulze 1947).

Temperature

The distribution and composition of vegetation communities are largely influenced by extremes of climatic factors (Coombes 1991). Temperatures recorded over the past seven years since 1989 at the station on the reserve give an indication of the temperatures that may be expected. The seasonal trends in air temperature are illustrated in Table 3. The average daily temperature varies from 6.7°C to 21.7°C in the coldest month, June, to 16.8°C to 30°C in the hottest month, January. The mean daily temperature varies from 14.2°C in winter to 23.4°C in summer. Frost is occasional and very light, and occurs during June to August, and is limited to the basin area and high lying plateau. No frost was recorded in the eastern valleys. Frosts may be a limiting factor for the distribution of tropical plant species such as *Rauvolfia caffra, Pittosporum viridiflorum, Ilex mitis, Englerophytum magalismontanum* and *Mimusops zeyheri.*

Table 3: Monthly average temperature and rainfall figures for Rustenburg Nature Reserve from 1980 - 1997

Month	**Average Daily Minimum**	**Average Daily Maximum**	**$\frac{\text{Max + Min}}{2}$**	**Rainfall**
January	16.80	30.00	23.40	113.00
February	16.00	29.90	22.95	107.60
March	15.30	28.00	21.65	113.60
April	12.80	27.30	20.05	40.90
May	8.90	22.90	15.90	14.50
June	6.70	21.70	14.20	5.90
July	6.90	22.40	14.65	3.20
August	7.40	22.40	14.90	4.90
September	12.50	28.70	20.60	25.20
October	13.10	30.60	21.85	64.00
November	14.80	28.10	21.45	84.80
December	15.30	28.50	21.90	110.20
Average/Total	12.21	26.71	19.46	687.80

The average weekly temperatures are on either side of the Magaliesberg higher at the foot slopes than on the crests. The differences between the average maximum temperatures on the foot slopes and the crests on north-facing slopes are 1,82°C and on the southern slopes 4,45°C (van Vuuren & van der Schijff 1970)

Rainfall

The total annual rainfall for the reserve is illustrated in Table 3 and Figure 6. The mean annual rainfall (July to June) for the period 1980 to 1997 is 687.8 mm (± 208.4 mm). The high interannual variability in rainfall is typical of the semi-arid regions (Scholes & Walker 1993). A very distinct aspect of the variability in the annual rainfall is the periods of above and below average rainfall. From 1972-1979 there was a period of above average rainfall, followed by a relative dry period lasting until 1986. Since 1986 there was a decline in rainfall variation, except for 1992, during which only 360.9 mm of rain was recorded, and 1996, during which exceptional high rainfall were recorded (1 222 mm).

The wettest months are December and January with a monthly average of 111.7 mm and 110.2 mm respectively. Although no rainfall data had been recorded for the low lying areas in the east, Van Vuuren and van der Schijff (1970) found that the crests of the north-facing slopes received more rain than the foot slopes, the difference being 113 mm. The difference on the southern slopes was less pronounced and the foot slope only received 26 mm less than the crests.

The rainfall in the region is highly seasonal, as over most of southern Africa (Tyson 1987). Based on data since 1980, it is evident from Table 3 that 95.9% of the annual rainfall falls during September to April, and only 4.1% in the winter months from May to August.

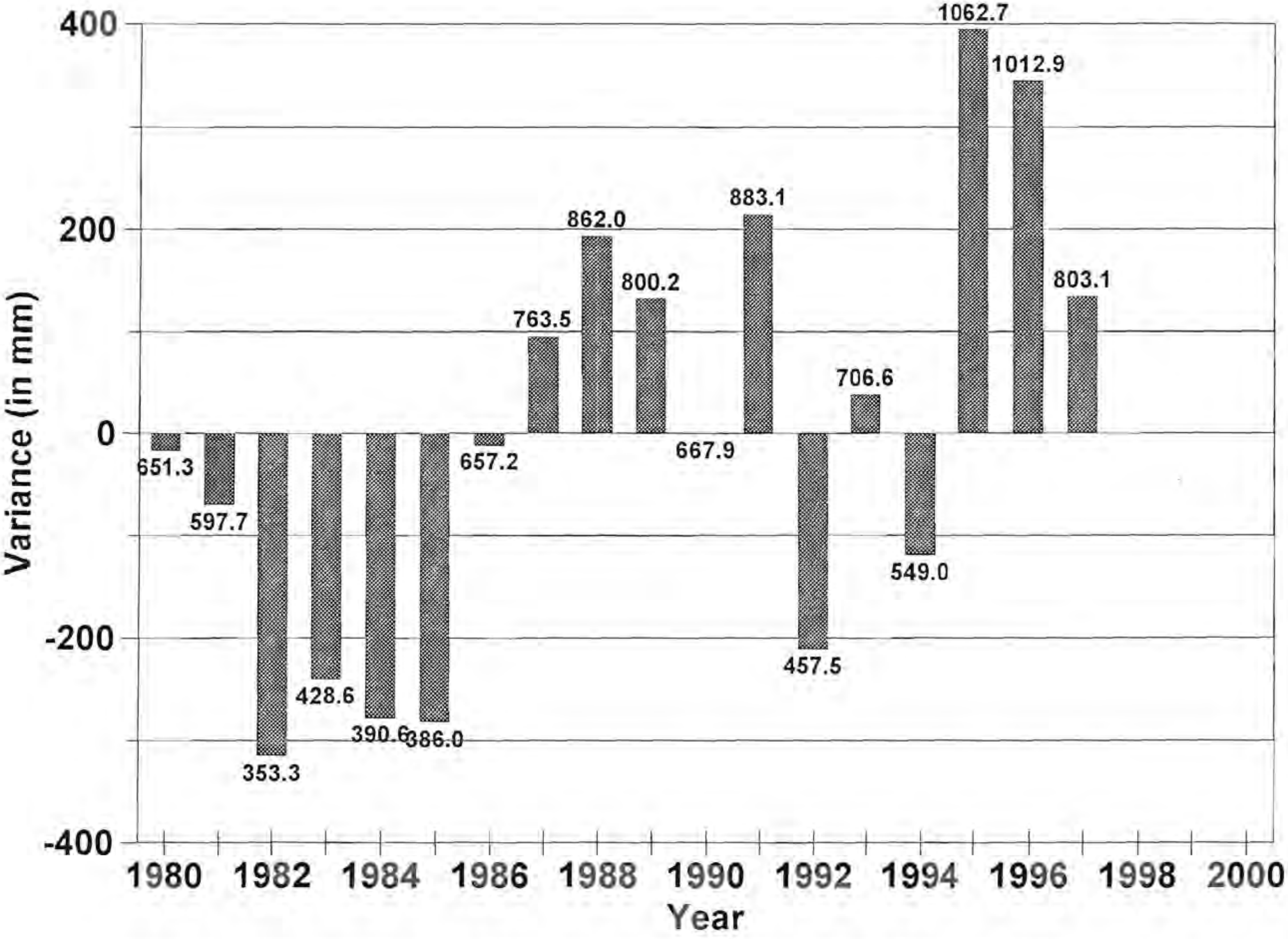

Figure 7 : The variance in the mean annual rainfall for Rustenburg Nature Reserve

HYDROLOGY

The Magaliesberg serves as catchment for numerous little streams (Hugo 1979). The absence of notable vegetation cover on the crest and upper slopes, increases runoff from these surfaces, which flows into cracks and crevices in the underlying rock strata only to emerge through seepage sites further down the northern slopes. Small streams are therefore abundant in the Magaliesberg, especially on the northern slopes (Carruthers 1990). The reserve's boundary includes the upper catchment of the Waterkloofspruit. This catchment comprises a 17 km^2 area on the northern plateau and central basin. The stream flows through a unique *Phragmites australis* reed marsh in the central basin area of the reserve, drops over a 60 m high waterfall and flows further through the farm Baviaanskrans to join the Hex River north of the reserve. Figure 8 illustrates the annual runoff measured at two gauging points in the Waterkloofspruit. A weak correlation (top measure plate: $r^2 = 0.518$; bottom measure plate: $r^2 = 0.465$) exist between rainfall and runoff. This is due to the considerable potential of the underlying substrate to absorb a high percentage of rainfall water, while only floodwater runs down the streams (Hugo 1979).

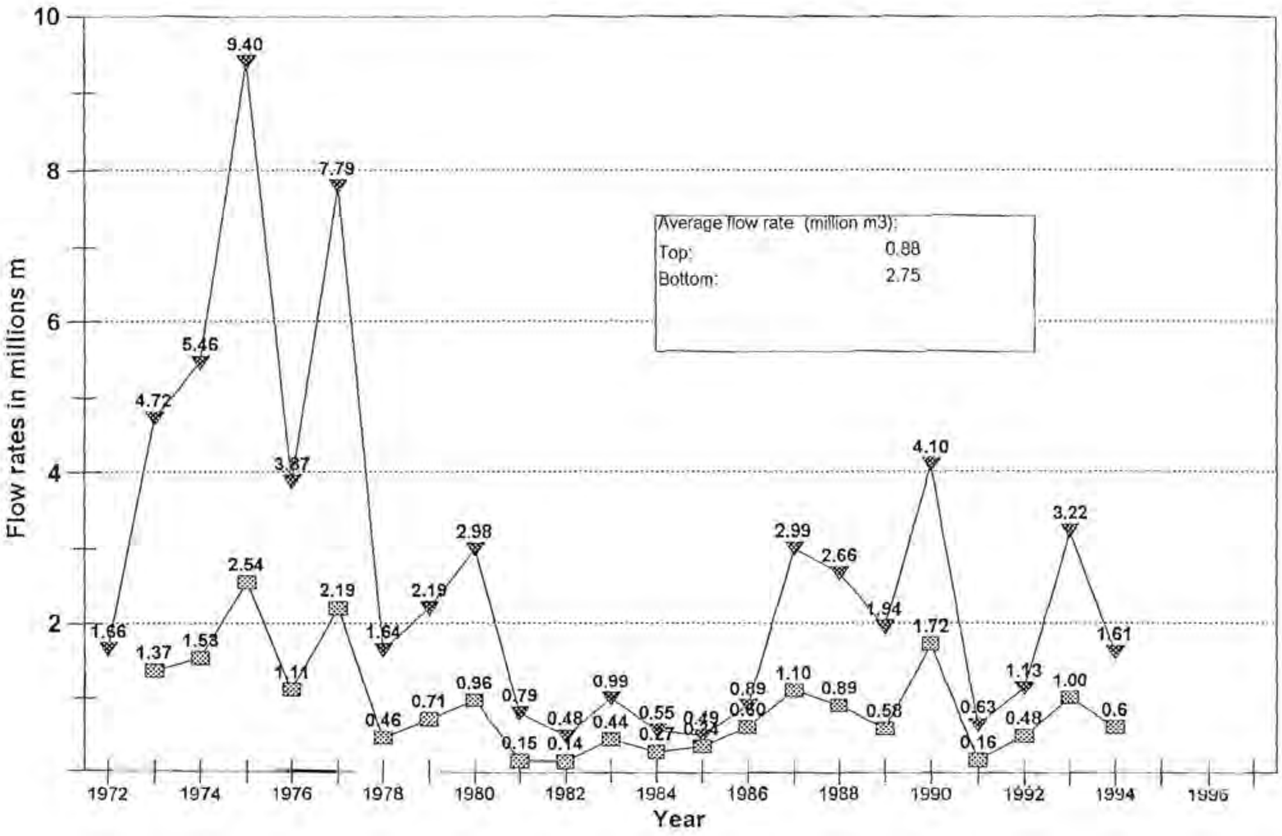

Figure 8: Annual flow rate of the Waterkloofspruit in the Rustenburg Nature Reserve

Several smaller streams also have their origin on the reserve. The rock strata dip to the north and the south-flowing streams are therefore mostly annual while the north-flowing streams are perennial (Hugo 1979; Carruthers 1990). Runoff on the bare northern rock faces is extremely fast and is contained in small spongy areas along the slope. Smaller streams flow from these areas. The Dorpspruit, an important small stream with its source on the northern plateau, flows northwards to join the Hex River north of Rustenburg.