The riparian vegetation of the Hottentots Holland Mountains, SW Cape

By

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Promoter: Dr. C. Boucher

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Declaration

I the undersigned, hereby declare that the work in this dissertation is my own original work and has not previously, in its entirety or in part, been submitted at any University for a degree.

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Summary

Riparian vegetation has received a lot of attention in South Africa recently, mainly because of its importance in bank stabilization and its influence on flood regimes and water conservation. The upper reaches have thus far received the least of this attention because of their inaccessibility. This study mainly focuses on these reaches where riparian vegetation is still mostly in a pristine state. The study area chosen for this purpose is the Hottentots Holland Mountains in the Southwestern Cape, the area with the highest rainfall in the Cape Floristic Region, which is very rich in species. Five rivers originate in this area and the vegetation described around them covers a large range of habitats, from high to low altitude, with different geological substrates and different rainfall regimes.

All of these rivers are heavily disturbed in their lower reaches but are still relatively pristine in their upper reaches. All of them are dammed in at least one place, except for the Lourens River. An Interbasin Transfer Scheme connects the Eerste-, Berg- and Riviersonderend Rivers. The water of this scheme is stored mainly in Theewaterskloof Dam. Another big dam for water storage, Skuifraam Dam, will be built on the Berg River near Franschhoek in the nearby future.

In order to study the vegetation around a river, a zonation pattern on the river bank is described and several physical habitats are recognized. A primary distinction is made between a Wet Bank (flooding at least once a year) and a Dry Bank (flooding less than once a year). The Dry Bank is further subdivided into a Lower Dynamic, a Shrub/Tree and a Back Dynamic Zone. In the lower reaches these zones are very distinct, but in the upper reaches of a river they tend to blend into each other and some zones can be absent or very narrow.

Vegetation has been sampled in transects across the riverbed, following the Braun-Blanquet method. Additional vegetation samples have been recorded in the bogs and mires at the sources of the rivers. Vegetation structure and physical habitat has been described to contribute to the description of the vegetation types. In order to understand the environmental processes that determine the vegetation, environmental parameters were recorded in every vegetation sample, such as, slope, aspect, rockiness and soil variables.

The classification of the vegetation samples resulted in the identification and subsequent description of 26 riverine and 11 mire communities. The riverine

communities have been subdivided into ten Community Groups, including a group of Aquatic communities and three groups of Wet Bank communities. The main distinction within the Wet Bank Zone is the importance of erosion or deposition as a driving force of the ecosystem. Three groups of Fynbos communities are identified in the Back Dynamic Zone, with Asteraceous Fynbos occurring on shales and granites, Ericaceous Fynbos occurring on Table Mountain Group sandstones and Transitional Fynbos on a variety of substrates. One community group is characterized by the dominance of *Cliffortia odorata*, which shows affinity with some renosterveld communities known from literature. The two final groups contain the Afromontane Forests and Riparian Scrub communities, respectively.

Discharges are calculated from data recorded at existing gauging weirs. The recurrence intervals, inundation levels and stream power of several flood events are derived from these data and are extrapolated to upstream sites. It appears that most vegetation types in the zonation pattern on the riverbank can be explained by these flood events, except for the Afromontane Forests, which are dependent on other site-specific factors including protection from fire.

Constrained and unconstrained ordinations are used to relate vegetation patterns to the environment. The vegetation is determined by three environmental gradients, operating at different scales. The lateral gradient across the riverbed is mainly determined by inundation frequency and stream power, which are difficult to measure in rocky mountain situations, although variables like distance from the water's edge, elevation above the water level and rockiness are correlated to them. The longitudinal gradient is the gradient along the length of the river, from high to low altitude. This gradient has the least influence on the riparian vegetation. The geographical gradient reflects the large-scale climatic processes across the mountain range. This gradient accounts for the biggest part of the total explained variation. Important variables are especially the ratio between the summer and winter rainfall and the geological substrate. In the Fynbos Biome, where gamma diversity is extremely high, large-scale environmental processes are important in azonal vegetation as well. The most species-rich vegetation associated with the rivers is found furthest from the water's edge at intermediate altitudes.

Knowledge about the vegetation types and environmental processes in Western Cape rivers is essential for monitoring and maintaining these special ecosystems. Specific threats are related to possible abstraction of water from the

Table Mountain Group aquifer and from climate change, which might result in an overall drying of the ecosystem.

Opsomming

Riviere se oewerplantegroei kry die laaste tyd baie aandag in Suid-Afrika, hoofsaaklik vanweë die belang vir die beheer van vloede, stabilisasie van die oewers en die bewaring van drinkwater. Die hoë-liggende dele van die riviere het tot dusver die minste aandag geniet omdat hulle tot ’n groot mate ontoeganklik is weens die onherbergsame terrein waarin hulle geleë is. In hierdie studie is daar veral na bergstrome gekyk waar die plantegroei nog taamlik natuurlik en onversteur is. Die studiegebied wat vir hierdie doel gekies is, is die Hottentots-Holland berge in die Wes-Kaap. Die gebied het die hoogste reënval in die Kaapse Floristiese Ryk en is ook baie ryk aan spesies. Vyf riviere het in hierdie gebied hulle oorsprong. Die plantegroei wat hier voorkom sluit ‘n wye reeks habitatte in: van hoog tot laag in hoogte bo seespieël, verskeie geologiese substrate asook verskillende reënval patrone.

Al die vyf riviere wat ondersoek is, is baie versteur in hul onderlope, maar is nog grotendeels natuurlik in hul hoë-liggende dele. Almal is reeds opgedam deur een of meer damme, behalwe die Lourensrivier. ’n Tussenopvanggebied-oordragskema verbind tans die Eerste-, Berg- en Riviersonderendriviere met mekaar. Die water uit hierdie riviere word tans hoofsaaklik in die Theewaterskloofdam opgegaar. ’n Verdere groot opgaardam, die sogenaamde Skuifraamdam, word binnekort in die Bergrivier te Franschhoek gebou.

Al die riviere se onderlope is tot ’n mindere of meerdere mate vervuil met landbou- en rioolafvoerprodukte. Uitheemse indringerplante, wat die natuurlike oewerplantegroei verdring, skep veral probleme stroomaf van plantasies en dorpe.

Om die plantegroei van die rivieroewers na te vors, te klassifiseer en te beskryf, is variasies in die fisiese omgewing bepaal en korrelasies gesoek om die verspreiding van die plantegroei te verklaar. Die belangrikste verdeling in die oewerplantegroei wat gevind is, is tussen die Nat-oewersone (dit word meer as een keer per jaar oorstroom) en die Droë-oewersone (dit word minder as een keer per jaar oorstroom). Die Droë-oewersone word verder onderverdeel in die Laer-dinamiesesone, die Boom/Struiksone en die Agter-dinamiesesone. In die laer dele van die rivier is hierdie soneringspatrone baie duidelik, maar in die boonste dele van die rivier kan die onderverdelings dikwels nie van mekaar onderskei word nie omdat hulle gemeng is, of kan die sones baie smal wees of selfs heeltemal afwesig wees.

Die plantegroei is gemonster in transekte wat dwarsoor die rivierloop uitgelê is. Die Braun-Blanquet monstertegniek is gevolg. Bykomende monsterpersele is opgemeet in die moerasse in die boonste dele van die berg-opvanggebiede. Om die omgewingsprosesse wat die plantegroei bepaal te verstaan, is ’n aantal omgewingsfaktore in elke monsterperseel aangeteken, wat, onder andere, helling, aspek en bedekking van rotse ingesluit het, terwyl die variasie in samestelling van die bodem ook aangeteken is.

Die klassifikasie van die plantegroei het tot die beskrywing van 26 plantgemeenskappe in die riviere en 11 gemeenskappe in die moerasse gelei. Die struktuur van die plantegroei asook kenmerke van die fisiese habitat is in die beskrywing van die plantegroei-eenhede ingesluit. Die gemeenskappe in die riviere is onderverdeel in tien gemeenskapsgroepe. Daar is een gemeenskapsgroep wat die akwatiese gemeenskappe en drie wat die Nat-oewersone gemeenskappe insluit. Die belangrikste verskille tussen die verskillende Nat-oewersone gemeenskappe word bepaal deur die mate waartoe erosie of deposisie voorkom. Daar is ook drie gemeenskapsgroepe van Fynbos onderskei wat in die Agter-dinamiesesone voorkom. Dit sluit in die Aster-fynbos op die skalies en graniete, die Erica-fynbos op die sandstene en die Oorgangs-fynbos op gemengde substrate. Een gemeenskapsgroep is deur die dominansie van *Cliffortia odorata* gekenmerk. Dit toon verwantskap met renosterveld gemeenskappe wat reeds in die literatuur beskryf is. Die laaste twee groepe sluit die Afromontane woude en Oewerstruikbosse in.

Die waterafloop is bereken deur middel van data verkry vanaf bestaande keerwal meetstasies. Die herhalings-intervalle, oorstromingsdiepte en vloei-sterkte van verskillende vloedtipes word vanaf hierdie data afgelei en stroomop geekstrapoleer. Die meeste plantegroeivariasie op die oewers kan deur die vloede verklaar word, behalwe in die geval van die Afromontane woude, wat deur ander omgewingsfaktore bepaal is.

Beperkte en onbeperkte ordinasie is gebruik om die verband tussen die plantegroeipatrone en die omgewing te bepaal. Die plantegroei se verspreiding is bepaal deur drie omgewingsgradiënte, wat op verskillende skale ‘n uitwerking het. Die laterale gradiënt oor die rivierbedding is hoofsaaklik bepaal deur oorstromingsfrekwensie en stroomvloeisterkte. Hierdie veranderlikes is moeilik bepaalbaar, alhoewel ander soos, afstand vanaf die rivier, hoogte bo watervlak en bedekking van rotse, wat hieraan gekorreleer is, wel meetbaar is. Die lengte gradiënt, dit is die gradiënt wat van oorsprong na einde langs die lengte van die rivier teenwoordig is, het die minste invloed op die plantegroei. Die geografiese gradiënt weerspieel die grootskaalse klimaatsveranderinge oor die bergreeks. Deur hierdie gradiënt word die grootste deel van die totale variasie tussen die monsters verklaar. Die belangrikste veranderlikes is die verhouding van somer- teenoor winter-reënval en die geologiese substraat.

Soortgelyk aan die fynbos in die Fynbosbioom, waar gammadiversiteit buitegewoon hoog is, is die grootskaalse omgewingsprosesse, ook vir asonale oewerplantegroei, baie belangrik. Die spesierykste plantegroei rondom die rivier word die verste van die oewer op gemiddelde hoogtes bo seespieël gevind.

Kennis oor die plantegroei en die omgewingsprosesse in die riviere in die Wes-Kaap is belangrik vir die monitering en effektiewe beheer van hierdie besondere ekosisteem. Spesifieke bedreigings is gekoppel aan die potensiële ontginning van water uit die akwifer in die Tafelberggroep-sedimente asook deur grootskaalse klimaatsveranderinge waartydens die hoeveelheid water, volgens voorspellings, waarskynlik sal afneem in hierdie ekosisteem.

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Erwin Sieben, March 2003.

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The riparian vegetation of the Hottentots Holland Mountains, SW Cape

1. General introduction

Although it is confined to the extreme southwestern tip of South Africa, the flora of the Western Cape Province and its neighbouring regions has the status of a Floral Kingdom (Takhtajan 1969; Good 1974). The Cape Floral Kingdom entails an area of about 90 000 km^2 and its flora is given this high ranking because of its species richness and composition. It contains some 9000 species of vascular plants, of which a large proportion is endemic (68 %), including five endemic families (Goldblatt & Manning (2000). The main families contributing to the vegetation of the Cape Region belong to the families Proteaceae, Ericaceae and Restionaceae, which, in this combination, are not so diverse elsewhere in the world. Because of its uniqueness, the Cape Floral Kingdom should be given the highest priority for conservation in South Africa with support from international nature conservation organisations (World Wildlife Fund - South Africa 2000). South Africa is the only country in the world that contains an entire floral kingdom within its borders so the country has a great international responsibility to study and protect this unique biogeographic feature (Goldblatt 1978).

The best known vegetation type in the Western Cape is fynbos. This is a name for the sclerophyllous shrubland that was first used by Bews (1916). As a result, the Cape Floral Kingdom is often referred to as ‘The Fynbos Biome’ by the general public (Rebelo 1998). This is actually incorrect terminology. The Cape Floral Kingdom or Cape Floristic Region refers to the flora of the whole region of the Western Cape and includes the plant species that occur in vegetation types that are not all fynbos types. The Fynbos Biome refers to the ecosystems and consists basically of two vegetation complexes: Fynbos and Renosterveld. There are other vegetation types that occur within the general borders of the Cape Floristic Region, which do not belong to the Fynbos Biome, like the forests of the Knysna region and the Succulent Karoo near Robertson and Oudtshoorn. The delimitation of the Fynbos Biome has been defined gradually with the contributing works of Bolus (1886, 1905), Marloth (1908), Bews (1916), Pole Evans (1936) and Adamson (1938). This process of delimitation led to the magistral work of Acocks (1953) who subdivided the Fynbos Biome into Macchia (= Fynbos), Coastal Macchia (= Coastal Fynbos) and False Macchia (= False Fynbos) (Acocks 1988).

During the seventies and the eighties the interest in the ecology of fynbos grew considerably by the formation of the National Programme for Ecosystem Research administered by the CSIR (Council for Scientific and Industrial Research). This was set up as an interdisciplinary and multi-organizational programme and inherited a lot from the biome studies of the International Biological Programme (IBP) (Huntley 1992). In 1977 the Fynbos Biome Project (FBP) was established in the Cape. The overall objective of the FBP was ‘to provide sound scientific knowledge of the structure and functioning of constituent ecosystems as a basis for the conservation and management of the Fynbos Biome’ (Kruger 1978a). The FBP was due to run for ten years but the funding continued to 1989 to allow the completion of several studies. Through the project a better understanding of fynbos ecology was obtained and the public interest in fynbos increased a lot (Huntley 1992). Taylor (1978) summarized some of the main distinguishing characteristics of fynbos:

- a great number of species; to date 9000 species of vascular plants have been described from the Cape Floristic Region, of which 68% are endemic to the Region (Rebelo 1998; Goldblatt & Manning 2000);
- the vegetation types are fairly rich in species Taylor (1978) found a maximum of 121 species in a plot of 100 m^2;
- communities are characterized by the presence of three growth forms: the restioid growth form, which are reeds with wiry photosynthetic stems, the ericoid growth form, which are understorey shrubs with sclerophyllous leaves and the proteoid growth form, which are overstorey shrubs with big leaves;
- it is a vegetation type which is adapted to the regular occurrence of fire, with many species that set seed after fires or are able to resprout after fires;
- the soils are extremely infertile.

The occurrence of fynbos is confined to the Western Cape Province with a few outliers that extend into the Eastern and Northern Cape. It is best developed in the winter rainfall climatic area in the extreme Western Cape. The mountain ranges of the Kogelberg, the Hottentots Holland Mountains and the Cape Peninsula are known to be the richest in plant species and many endemics occur here (Cowling *et al*. 1992). Towards the east the climate changes gradually from winter rainfall through year-round rainfall to summer rainfall. This climatic aspect has a big influence on vegetation. The fynbos gradually becomes grassier in the eastern parts near Port Elizabeth. The occurrence of fynbos is mainly concentrated in the Western Cape because of this distinct climatic regime and the substrate of Table Mountain Group sandstone, which is very poor in nutrients (Deacon *et al.* 1992; Figure 1.1).

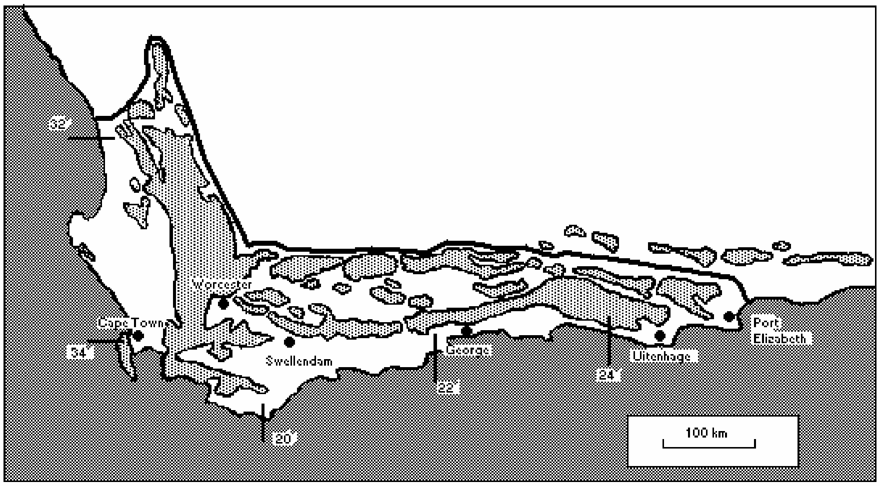

Figure 1.1: Map of the Western Cape with the borders of the Cape Floral Kingdom. The mountain ranges consisting of Table Mountain or Witteberg Group quartzites are shaded.

Ecological research in the fynbos has to cope with several problems: Firstly, much of the fynbos is found in the mountainous areas, which are quite inaccessible. Secondly, new species are still being discovered regularly and the taxonomic status of many taxa is not yet clear as a wide variation occurs within some species. A third problem is that the turnover of species between the different mountain ranges is very high and it is difficult to draw general conclusions (Campbell 1986a).

1.1 Focus on riparian vegetation

Within the Fynbos Biome some types of azonal vegetation occur. Azonal vegetation types are vegetation types that are not dependent on the climatic zone, but are adapted to specific habitat types that can occur across many different climatic regions and are vegetated by specialized plant species (Walter 1973). Some examples are saltmarshes, coastal vegetation, rocky outcrops and aquatic vegetation.

To a lesser extent, riverbanks also belong to this category. Rivers flow through the vegetation of a biome and contain numerous plant species from it, but they also generally support their own specific vegetation. Over the whole course of a river the vegetation around it is influenced by its flood regime. The vegetation associated with a river in Mountain Fynbos will contain a mixture of typical fynbos elements and non-fynbos plants adapted to the specific ecological conditions present around a river. Campbell (1986b) calls this vegetation 'Closed-scrub fynbos', but there are few detailed studies of riverbank vegetation in the Mountain Fynbos to support this structural definition.

Rivers are currently a big issue in South Africa, which is a fairly arid and drought-prone country as they form the country's main source of high quality drinking water. It is expected that in the near future the water resources in South Africa will become limited for an increasing population (Boucher & Marais 1993). The Department of Water Affairs and Forestry endorses a policy that includes sustainable utilization of water, while the river ecosystem itself is also recognised as a water user (O'Keeffe 1986; Davies *et al.* 1993). This principle has subsequently been implemented in the Water Act of 1995. A well-known success story to increase the supply of water from rivers and catchments is the Working for Water Project that also provides low-skill jobs for formerly disadvantaged communities. In this project, alien vegetation is eradicated in order to increase the runoff in the catchment (Boucher & Marais 1995; Anon. 1999).

The riparian vegetation fulfils an important function in the riverine ecosystem. It controls the velocity of floodwater and the erosion of the riverbanks, while it also provides a habitat on its own and adds to the species and habitat diversity of a river ecosystem (Rogers & Van der Zel 1989).

1.2 Aims of this study

A fair number of studies (Boucher 1996; Brown & Day 1995; Brown & Dallas 1998) have addressed the biological composition and functioning of the foothill and lower river reaches, due to the direct interference of human infrastructure with the rivers here. However, very little is known about the upper reaches of the rivers. In order to get a better picture of the riverine ecosystems of the Western Cape, this study will describe, in great detail, the flora and vegetation of the Western Cape mountain streams, focusing on those of the Hottentots Holland Mountains.

This study will benefit the management of the Hottentots Holland Nature Reserve and other comparable reserves in the southwestern Cape, because the management of fynbos reserves has for a long time neglected the role of riparian vegetation. This is not logical when one considers that one of the major functions that the Mountain Reserves fulfil is to serve as catchments for clean drinking water (Davies *et al.* 1993). The riparian vegetation plays a major role in that function. Once more is known about the riparian vegetation and the ecological processes that shape it, it will be feasible to establish sites to monitor change due to management practices. When the natural riparian vegetation is known, it is easy to monitor changes after the natural order has changed due to human interference and when the ecological processes are known it can be found out what practices are necessary to restore the natural situation.

This study differs from the broad-scale all-encompassing surveys of mountain vegetation in that it will concentrate on one habitat complex only. If this approach is followed through the whole biome, then one can achieve the total categorization of each habitat type in a specialist way. In this way, it will be much easier to compare vegetation types across the biome and it will facilitate the classification of the entire biome in the end. In this way the specific ecological processes that play a role in each habitat complex can be highlighted.

Chapters 2 and 3 below serve as an introduction to the study area and the methods used in the study of vegetation. The results of this research project in the Hottentots Holland Mountains are dealt with in chapters 4 to 8. These chapters are formatted for publication in scientific journals, so they are slightly different in their layout than the earlier chapters. Chapter 9 contains a synthesis of the results and highlights the most important conclusions drawn from the study.

2. Description of the study area

2.1 Choice of study area

This study aims at investigating the vegetation of some of the Western Cape mountain streams in detail. The area chosen for this purpose is the Hottentots Holland Mountains in the southwestern Cape. This area was chosen for the following reasons:

- It is situated in the core area of the Fynbos Biome. The highest species diversity occurs here and most probably also the highest diversity in vegetation types (Oliver *et al.* 1983; Cowling *et al.* 1992).
- Five rivers originate in the Hottentots Holland Mountains, two of which have large catchment areas. The rivers flow in different compass directions: north, south, east and west (see Figures 2.1 a & b). It is expected that this will result in strong environmental and climatic gradients.
- Detailed studies have been made on the lower reaches of the rivers that originate in the Hottentots Holland Mountains, because three of them have been dammed already and a fourth will be dammed in the near future. The close proximity to the Cape Metropolitan Area puts a high pressure on the utilization of these rivers to provide drinking water.

The Hottentots Holland Mountain range is situated southeast of Stellenbosch. Most of the area currently falls under the jurisdiction of the Western Cape Nature Conservation Board. The area fulfils different functions. The most important one is the maintenance of catchments with the best quality drinking water. The Steenbras, Kleinplaas and Theewaterskloof Dams are all fed by water from the Hottentots Holland Mountains. They serve as a principle source of water for the Cape Metropolitan Area. For this reason the vast majority of properties at high altitude are now state owned by and subjected to the Mountain Catchment legislation (Cape Nature Conservation 1994).

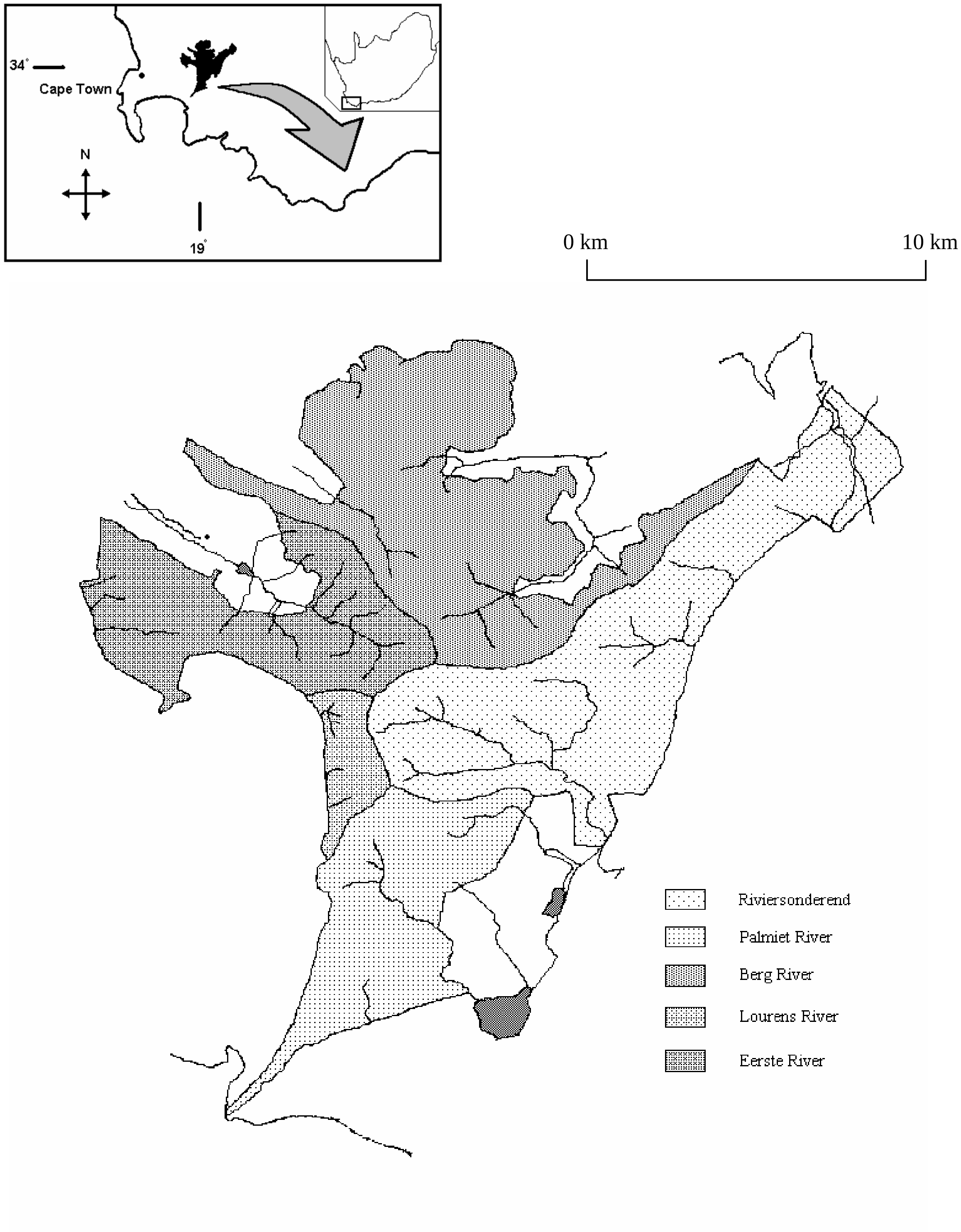

Figure 2.1a: Map of the study area with the five river catchments within the Hottentots Holland Nature Reserve indicated. The inset map shows the location of the study area in the Western Cape.

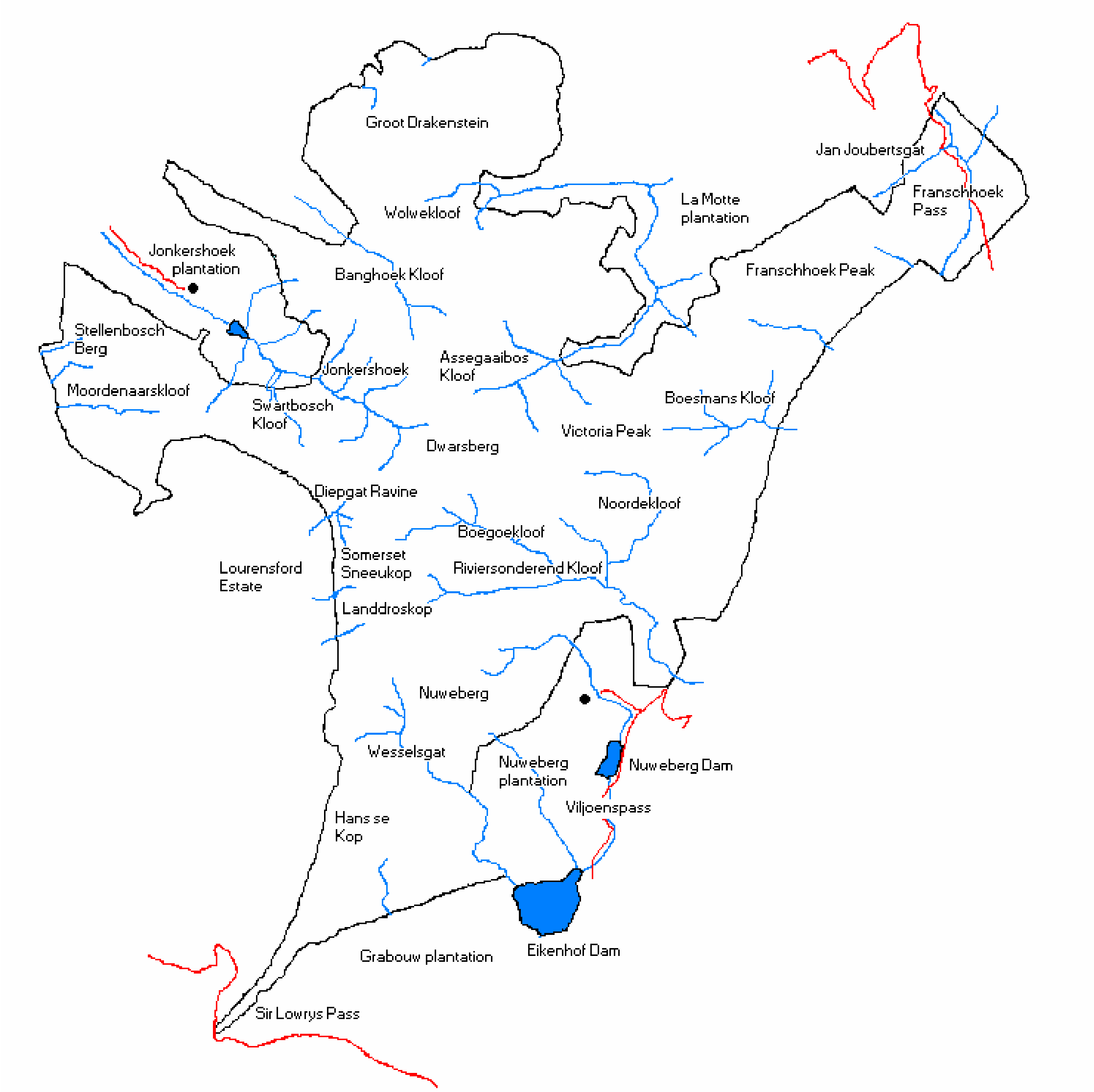

Figure 2.1b: Map of the study area with topographical names commonly used in the text. Scale and orientation are the same as on Figure 2.1a.

Nature conservation is another important function of the area. Together with the Kogelberg Biosphere Reserve, the Hottentots-Holland Mountain range is the centre of plant diversity in the Cape Floral Kingdom so it contains many endemic species and unique vegetation types. In order to manage this biodiversity, the Western Cape Nature Conservation Board has management activities directed to the burning of the fynbos for regeneration approximately every 20 years and the eradication of exotic species such as pines, acacias and hakeas (Cape Nature Conservation 1994).

Another function of the area is recreation. The first section of the Boland Hiking Trail is situated within the nature reserve. Here visitors can experience the botanical diversity of the area on several day hikes. There are four mountain huts within the Nature Reserve where visitors can spend the night: two in Boesmanskloof on the eastern edge of the park and two on Landdroskop in the central part of the park (Cape Nature Conservation 1994).

Around the nature reserve there are big areas utilized for wood production. There are four main Forestry Stations here administered by SAFCOL: Nuweberg in the east, Grabouw in the south, La Motte near Franschhoek in the northeast, and Jonkershoek near Stellenbosch in the northwest. Large private plantations are located in the Lourens River catchment near Somerset West.

There are five major river catchments within the area. Each of these rivers will be discussed in detail in section 2.7.4.

2.2 Climate

The most significant characteristic that distinguishes the climate of the Fynbos Biome from that of the rest of the subcontinent is the season in which most precipitation falls. Within the biome this occurs in winter or year-round, while elsewhere on the subcontinent it occurs mostly in summer. Detailed accounts about the climate of the Western Cape and comparisons to that of the rest of the country are given by Schulze & McGee (1978) and Schulze (1965).

Following the Köppen system (Köppen 1931), the climate in the Westen Cape is classified as Mediterranean with hot dry summers and mild, wet winters. The code symbols given to such a climate in Köppen’s (1931) system is Csb, that means a mesothermal (C) climate with a warm and dry summer with average temperatures above 22° C and relatively wet winters (sb). This is the true Mediterranean Climate and it only occurs in the western part of the Biome, between Saldanha and the Breede River Mouth (Boucher & Moll 1981). Other areas in the world, where this kind of climate is found, are situated around the Mediterranean Basin in Europe and North Africa, in southwestern and southern Australia, in California, and parts of Chile. In the eastern parts of the Western

Cape the climate changes into a steppe climate (Bsk) or a temperate all-year rainfall climate (Cfb). In the north (the Cedarberg) a Csa climate prevails, which has hotter summers (Campbell 1983; Schulze & McGee 1978).

Thornthwaite (1948) developed a climatic classification that takes seasonality into account. He utilizes a climatic water budget and calculates a thermal efficiency index that relates the temperature to the effective precipitation. Poynton (1971) adapted the Thornthwaite classification for use in South Africa. He subdivided Thornthwaite's mesothermal zones according to the minimum temperature of the coldest month. The Western Cape falls into Poynton's warm-temperate and cool-temperate zones, with the coastal zones being warmer (Schulze & McGee 1978).

Emberger (1955) introduced a pluviometric quotient to classify mediterranean climates from hyperarid to hyperhumid. He states that winter rainfall and summer aridity are the two main characteristics of a mediterranean climate. This aridity can be expressed as a quotient of rainfall and temperature. This pluviometric quotient is expressed as follows:

$$Q = \frac{2000R}{M^2 - m^2}$$

in which R is the year-round rainfall, M the mean maximum temperature for summer and m the mean minimum temperature for winter. Small values of the pluviometric quotient represent dry climates while high values represent the wetter climates. The Western Cape supports climates which are both on the arid extreme of this gradient (in the Knersvlakte in southern Namaqualand) and on the hyperhumid extreme of the gradient (the Hottentots Holland Mountains) (Versfeld *et al*. 1992). Emberger (1955) considered the climate to be mediterranean when the ratio of summer rainfall to average mean maximum temperatures for the summer months is less than 7. Lower values signify more pronounced summer droughts. The Swartboschkloof weather station has a ratio of 6.5 which places this area in the mesic extreme of a mediterranean climate. Other parts of the world, that have a similarly high rainfall, have a quite different vegetation cover (Versfeld *et al.* 1992).

Another feature in which the Western Cape's climate differs from that of the rest of the subcontinent is the unpredictability of weather conditions. The high variation and unpredictability of the weather in the area is caused by a combination of coastal mountains which cause windward-leeward patterns and the warm Agulhas current in the south in contrast with the cold Benguela current in the west, which make temperatures highly dependent on wind direction (Deacon *et al*. 1992).

Table 2.1: Average differences between summer and winter in the lowlands of the southwestern Cape (Weather Bureau 1988; Kruger 1974)

	December	**June**
Solar radiation	700-750 cal. cm^{-2} day^{-1}	200-250 cal. cm^{-2} day^{-1}
Temperature range	11-27 ºC	6-19 ºC
Rainfall	10-40 mm	75-175 mm
Relative humidity	65-75%	75-90%
Prevalent wind direction	SE	NW

Schulze (1965) gives a detailed account of the climate in the Western Cape. The atmospheric circulation patterns typical for the latitudes around the Western Cape play a big role in the local climate. In summer, a subtropical high-pressure belt overlies the region and the area is swept by dry easterly winds. In winter, however, this pressure-belt moves three to four degrees to the north, so that the region is then influenced by mid-latitude westerlies, providing orographic rainfall particularly on west-facing slopes. The average total solar radiation is about 450-500 cal. cm^{-2} day^{-1}, which is about 60-70% of the amount entering the atmosphere. The average duration of bright sunshine amounts to 6-8 hours a day, with most clouds occurring in the winter half-year. Table 2.1 indicates the difference between the summer and the winter half-year for the lowlands.

Campbell (1983) mentions four climatic gradients within the biome: west-east, coast-interior, altitude and north-south terrain aspect. The west-east gradient has the following tendencies: towards the east: solar radiation drops by 15%; seasonal and diurnal temperature ranges decrease; evaporation decreases by 30%; and the winter rainfall pattern of the west changes into a bimodal regime (spring-autumn rainfall peaks).

The coast-interior gradient is characterized by a declining humidity with increasing distance from the warm Agulhas Current or the cold Benguela Current. The interior has a more continental climate, with less cloudiness, greater seasonal and daily temperature ranges, less rainfall, higher annual temperatures and more evaporation than the coastal areas. The mountains near the coast have considerable precipitation from mists even in the dry season (Campbell 1983).

In mountainous areas like the Western Cape climatic conditions differ considerably locally and mesoclimate plays a major role in determining the vegetation. Different slopes receive different amounts of sunlight, with northern slopes heating up more than the southern slopes, depending on their steepness and on the season. This results in air currents moving up-slope by day. At night, cold air from near the ground flows down the slopes. This causes a downward movement during the night and an upward movement during the day. With increasing altitude, mean annual temperatures decrease, pan evaporation decreases, rainfall increases and the likelihood for mists and snow increase (Campbell 1983).

2.2.1 Temperature

Fuggle & Ashton (1979) located 120 weather stations in the biome where temperature is recorded, but very few of these are situated in the mountains. Mean annual temperatures throughout the region are close to 17°C. Temperature ranges are bigger inland than near the coast. The highest summer temperatures recorded (higher than 30°C) are from the Great Karoo as well as from the major river basins. These places also experience the coldest winter temperatures. Occasionally high temperatures occur next to the coast associated with certain off-shore winds. Frost is a rare phenomenon near the coast but is common in July and August in the interior (Fuggle & Ashton 1979).

A temperature gradient with altitude for the southwestern Cape was calculated by the South African Weather Bureau. It became apparent that temperatures decrease by 0.5°C per 100 m increase in altitude throughout the year. Temperature lapse rates are more consistent than those for rainfall (A. Chapman, CSIR Stellenbosch, pers. comm.).

High temperatures and arid conditions combined with strong winds are an important cause of extensive veldfires that occur throughout the biome, particularly in late summer and autumn. These play an important role in the life cycle of fynbos plants (Fuggle & Ashton 1979).

There is not much specific temperature data available from the Hottentots Holland Mountains. Versfeld *et al*. (1992) provide some data for Swartboskloof. Temperatures have an average of 16.2°C (range: 0.2°C ∠ 39°C) at the Jonkershoek Weather Station (305 m alt.). Above 600 metres occasional snowfalls occur in winter (Versfeld *et al.* 1992).

2.2.2 Solar radiation

Solar radiation is a fundamental climatic parameter because of its influence on near surface air temperatures, soil temperatures, evaporation and water vapour deficit. It is highly variable in mountainous regions. The intensity is influenced, *inter alia*, by aspect and slope, but also by surrounding geomorphology. Thus narrow valleys are exposed to less direct sun rays than mountain peaks and can lose several hours of sunshine in a day (Kruger 1974). North- and south-facing slopes of less than 30 degrees do not differ that much in their daily receipt of sunshine during summer, but in winter north-facing slopes receive three to five times as much solar radiation as equivalent slopes facing south.

2.2.3 Precipitation and evaporation

Precipitation is mostly in the form of rain with more than 60% falling between April and September. Snow and hail are quite rare and occur mostly at high altitudes. Most mountains in the Western Cape have a rainfall between 1000 and 2000 mm per year, but in the wettest areas (like the Hottentots Holland Mountains) it might exceed 3000 mm (Schulze 1965). Most lowland locations receive much less, up to 750 mm near the coast, and mostly less than 400 mm in the intermontane valleys (Fuggle & Ashton 1979).

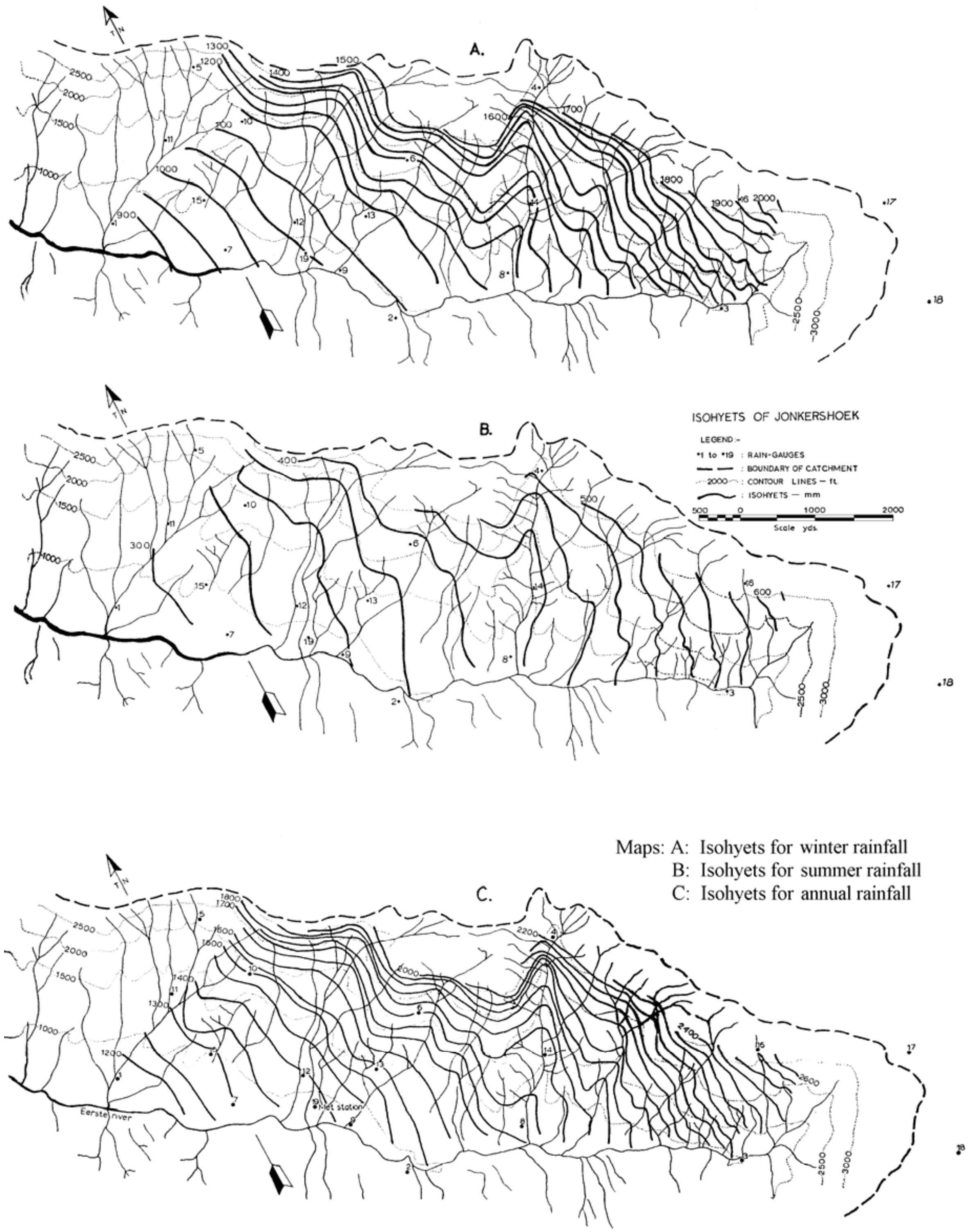

Figure 2.2: Isohyets in the Jonkershoek Valley, determined by intensive raingauging by Wicht *et al.* (1969). The location of this study area is indicated in Figure 2.4b.

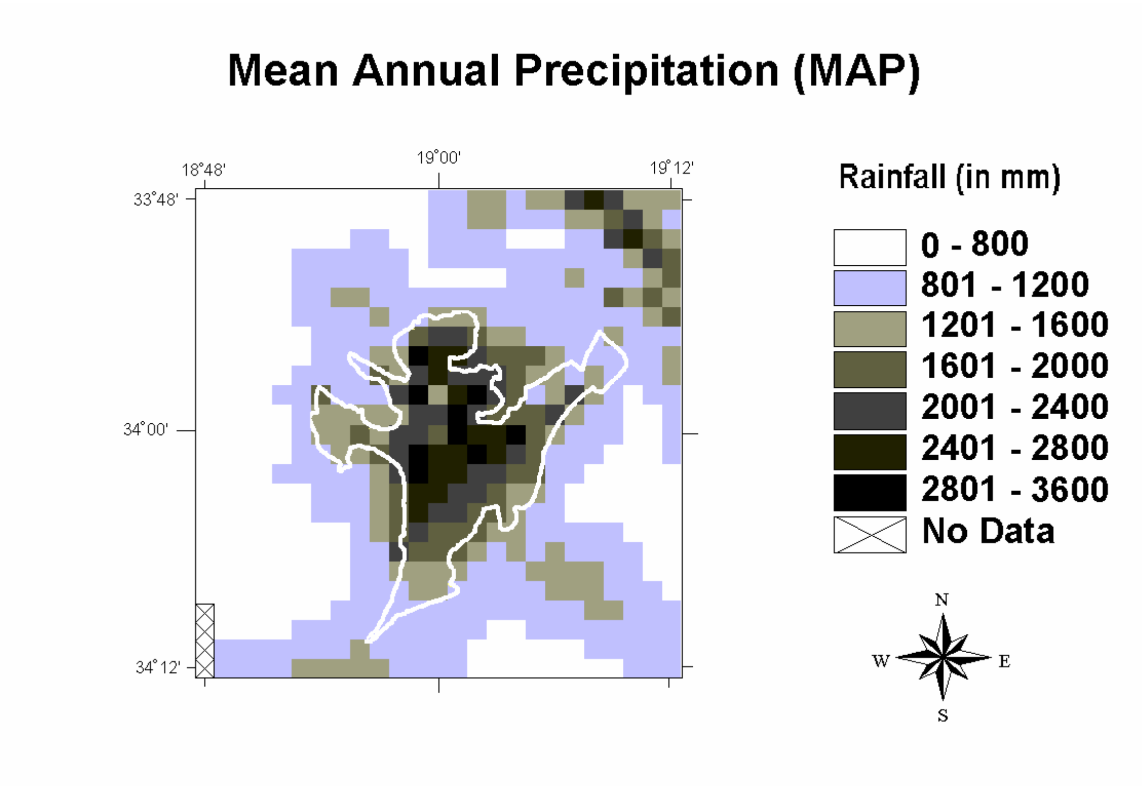

Figure 2.3: Grid with Mean Annual Precipitation in the Hottentots Holland Mountains area (Source: Computing Centre for Water Research, Pietermaritzburg, 2000)

Most precipitation patterns in the Western Cape are determined by cyclonic winter rains. However, the mountains in the Biome play a major role in influencing orographic rainfall. Extremely high regional variation occurs due to the windward-leeward patterns in the mountains and the fact that on the coastal plains winds can sweep unhindered. An example is the Cape Flats area, which is subject to extremely arid conditions in summer. These conditions occur in response to a leeward southeasterly wind descending from the mountain range that extends from the Hottentots Holland Mountains to the Cedarberg range. The Hottentots Holland Mountains, situated only 50 km from the arid conditions on the Cape Flats, enjoy the highest rainfall in the entire Biome. In the south, orographic clouds still form in summer, so the moisture deficit is less here than in the more inland mountains. To the east of the mountains, slightly more arid conditions prevail (Deacon *et al*. 1992).

Schulze (1965) indicates a strong gradient in rainfall with increasing altitude. On an average annual basis he calculates a gradient of 50 mm increase per 300 m increase in altitude. The overall rainfall pattern in the mountains, however, is difficult to predict and very irregular. It is mainly dependent on the exposure of slopes to northwesterly and southwesterly winds. Mountains can also receive a lot of precipitation from mist that is not registered in the rain gauges (Kerfoot 1968; Fuggle & Ashton 1979).

Wicht *et al.* (1969) have done an extensive study of rainfall patterns in the mountains surrounding the Jonkershoek Valley. The maps with isohyets that they produced for the valley are presented in Figure 2.2. From these maps it can be seen that rainfall patterns do not have a very reliable relationship with altitude in the way Schulze (1965) proposed. The data from the many weather stations used in this study and an additional weather station that operated on top of Victoria Peak in the eighties (G.G. Forsyth, CSIR Stellenbosch, pers. comm.) formed the basis for the rainfall grid that was produced by the Computing Centre for Water Research (CCWR) and that is illustrated in Figure 2.3. The methodology to extrapolate rainfall point data to a grid is provided by Dent *et al.* (1987).

In July, orographic rains occur over the west-facing slopes of the Hottentots Holland Mountains. A moisture surplus remains in winter only in the area south of 33°S and west of 20°E (Deacon *et al*. 1992). Southeasterly winds rarely bring rain to the flats, and they generally create arid conditions and föhn-like ‘bergwinds’, after which temperatures increase in Jonkershoek (Wicht *et al.* 1969).

The Jonkershoek Valley shows a very strong orographic gradient. Rainfall increases from 786 mm in Stellenbosch (100 m alt.) to 3625 mm on the Dwarsberg Plateau (1220 m alt.). This is the highest recorded rainfall in the whole of South Africa. The increase in rainfall with altitude is also evident in the Swartboskloof subcatchment in Jonkershoek where it increases from 1523 mm at 305 m altitude to 2815 mm at 910 m altitude. About 75% of this rain falls in the period April-September. The typical pattern of rainfall is one of light to steady rain when frontal air masses arrive from the northwest followed by sharp intermittent showers as the wind swings to the southwest and southeast. Annual evaporation generally exceeds rainfall by 25% (Versfeld *et al*. 1992).

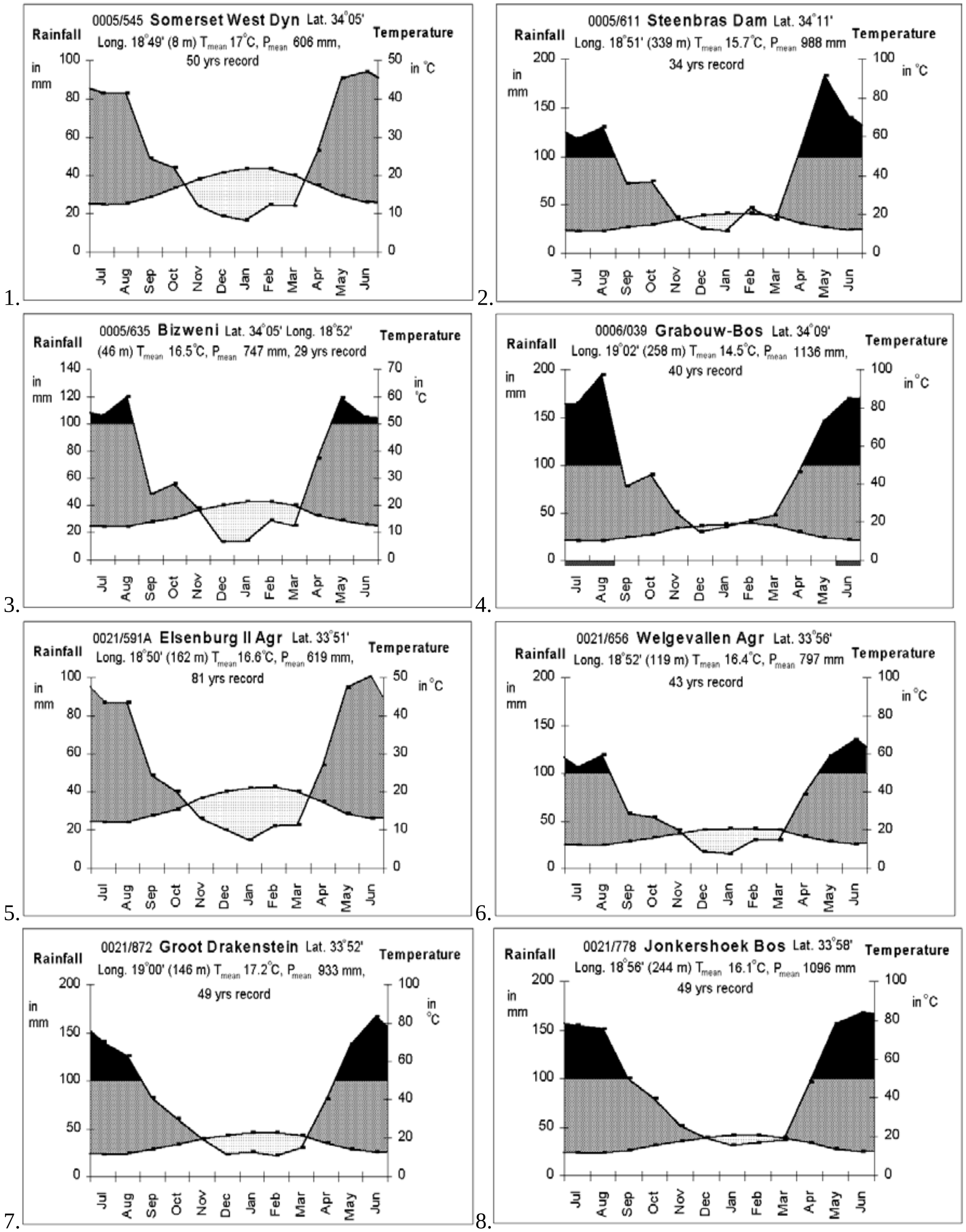

Figure 2.4a: Walter-Leith Diagrams for several weather stations around the Hottentots Holland Mountains (see Fig. 2.4b for their location). Latitude and longitude are indicated with altitude between brackets. Mean temperatures and mean precipitation are also given. Based on data from Weather Bureau (1988).

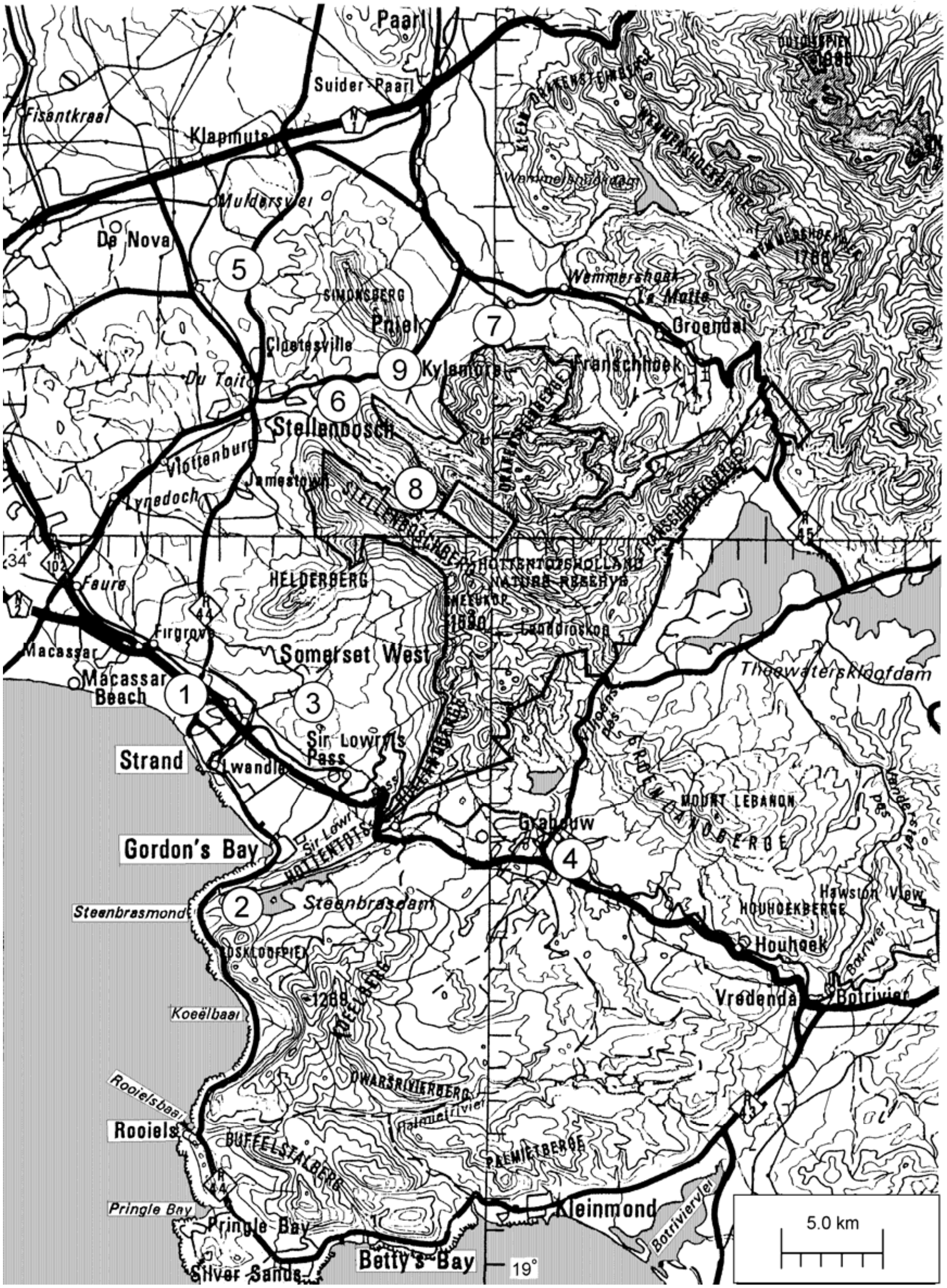

Figure 2.4b: The location of the weather stations of Figure 2.4a. Weather Station 9 cannot be found in the figure, but only in Appendix A. The window in the center indicates the outline of the map illustrated in Figure 2.2.

Evaporation is dependent on many factors. The saturation deficit, which is based on temperature and relative humidity, represents the amount by which atmospheric water-vapour-pressure falls short of saturation and shows the evaporative potential of the atmosphere. Actual evaporation is also dependent on solar energy and on the wind. Values of 2000 mm per year are recorded from the interior valleys and in the southwestern Cape, with about 40% occurring in summer. Towards the east, this value decreases. There is no data available for mountain locations, and it is likely that big differences exist between slopes of different aspect and with different moisture regimes (Fuggle & Ashton 1979). Figure 2.4 illustrates the Walter-Leith diagrams of the weather stations surrounding the Hottentots Holland Mountains. More detailed information about these weather stations can be found in Appendix A.

Tyson (1978) investigated the changes in rainfall patterns in South Africa. He concluded that there are oscillations in rainfall within a 20-year period. There is no progressive trend towards aridification in the Western Cape and historical data on climate can still be useful. Today, however, there might be an effect of global warming on the climate in the Cape, but this still has to be proven (Rutherford *et al.* 1999).

2.2.4 Wind

As shown above, wind plays a major role in determining the weather in the Western Cape. The distribution of precipitation on a mountain depends mainly on the wind. Rain and snow will mainly fall in the wind shadows. Westerly winds blow cold air from the Atlantic Ocean inland, while easterly winds bring warm air overland from the Indian Ocean (Deacon *et al*. 1992).

A ridge of high pressure extends from the South Atlantic anticyclone to the Cape coast. In summer, this ridge lies further to the south, at 37°S, which promotes the dry easterly winds, while in winter the ridge is situated at 32°S and westerly winds dominate. In the latitudes in between an unstable westerly wind gives rise to frontal depressions, ridging anticyclones, coastal lows and cut-off lows which cause highly variable day-to-day conditions of wind, moisture and temperature (Deacon *et al*. 1992).

Extreme wind conditions appear all along the coastal plains, mostly with wind speeds above 30 km/hour. The highest wind velocities occur near Bredasdorp. These high velocities occur here mostly in summer, whereas the mountain tops have a maximum for wind speed in winter (Deacon *et al*. 1992).

Winds mainly blow in directions parallel to the coast, so on the south coast there is polarization along an E-W axis, and on the west coast along a NW-SE axis. Further inland, there are more variations in wind direction (Deacon *et al*. 1992). Figure 2.5 illustrates annual and seasonal windroses for the surroundings of Stellenbosch based on data from the Weather Bureau (1960).

Dominant winds in summer are from the southeast, while in winter they blow from the northwest and carry rain. Warm northeasterly winds (‘bergwinds’) occur especially in late summer. They are characterized by sudden increases in temperature and decreases in humidity. This increases the likelihood of wildfires (Versfeld *et al.* 1992; Kruger 1978b).

2.3 Geology and geomorphology

The distinct climate in the Western Cape is not sufficient to explain the occurrence of unique vegetation types here. The existence of a winter rainfall climate is geologically relatively young, while many taxa that occur in the Fynbos Biome are much older. The mountains and geological formations will also play an important role in explaining why the fynbos only exists in its present refuge (Deacon *et al*. 1992).

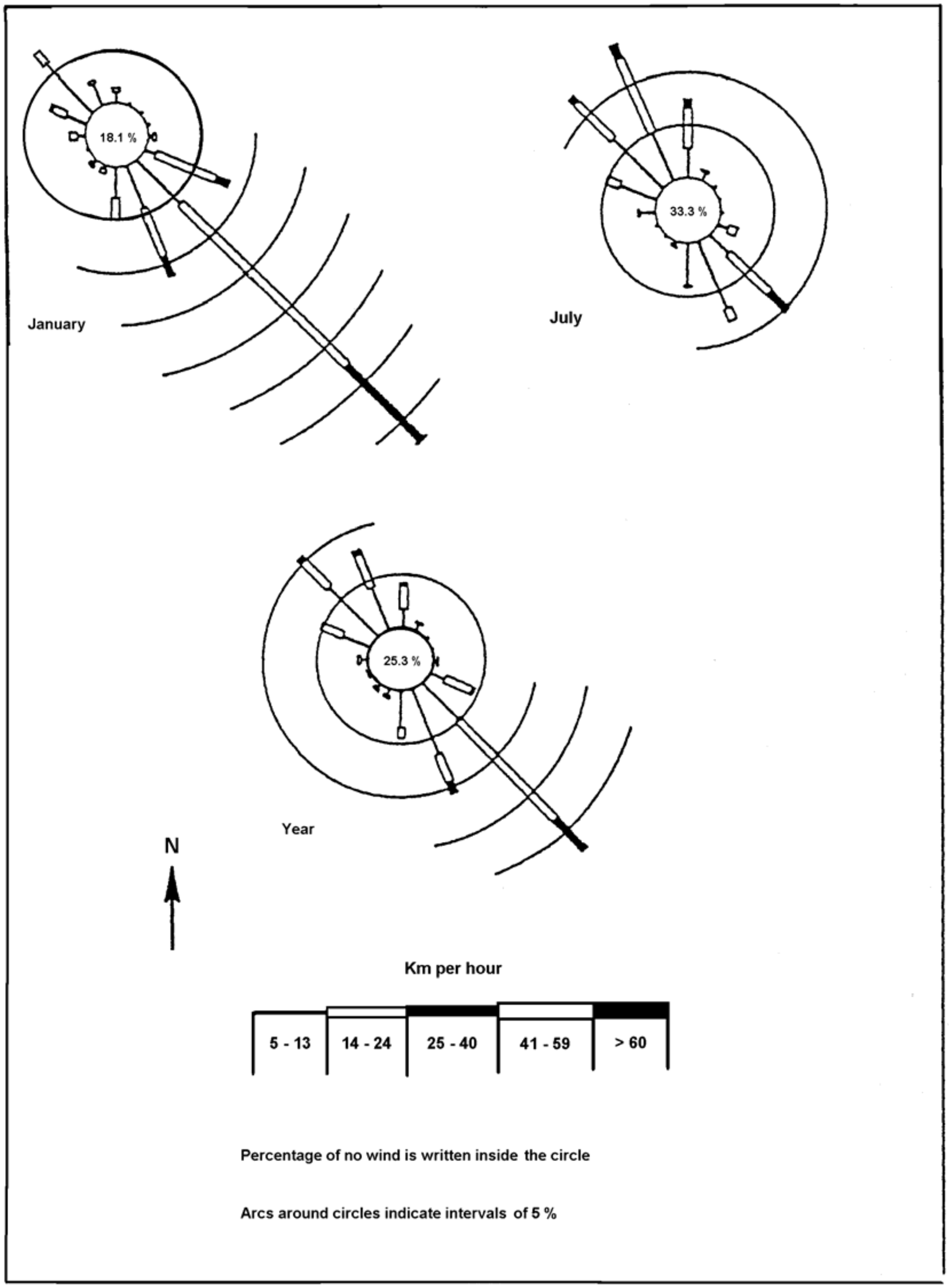

Figure 2.5: Windroses from the vicinity of Stellenbosch, see Figure 2.4b (Weather Bureau 1960).

2.3.1 Geology

The rock formations in the Fynbos Biome have different origins. The oldest ones belong to the Malmesbury, Kango, Kaaimans and Gamtoos Groups. The sediments in these groups were folded during the Late Precambrium, in a period of mountain building that is known as the Saldanian orogeny. Their lithology ranges from clays to conglomerates and they were intruded by granites of the Cape Granite Suite. Erosion reduced these Cape Mountains to a level plain and then they were covered again by sediments of subsequent groups. Of these old sediments, only the Malmesbury Group and the Cape Granites are still found on the surface over large areas. These Precambrian rocks, together with the granites, are different from the later sediments in that they are base rich. On weathering, the predominantly clayey substrates release exchangeable cations, such as calcium, potassium, magnesium and sodium. These are important nutrients for the plants and they play a major role in the formation of soils (Deacon *et al*. 1992).

The newer mountain ranges that were planed over the Precambrian rocks consisted mainly of hard quartzitic rocks belonging to the Cape Supergroup. From old to new these are: the Table Mountain Group, the Bokkeveld Group and the Witteberg Group. The Table Mountain Goup and Witteberg Group are of an arenaceaous (sandstone) origin and are acidic and poor in nutrients. The Bokkeveld Group has an argillaceous (mudstone) facies. Each group can be divided into strata with distinctive lithologies, which are defined as formations. The formations in the Cape Supergroup were formed in the period from the Late Ordovicium until Carboniferous, between 450 and 300 million years ago (Deacon *et al*. 1992).

The Cape Fold Mountains consist of hard quartzitic rocks belonging either to the Table Mountain Group or the Witteberg Group. The synclinal and fault valleys often have other geological units in the substrate such as the highly weatherable slates and phyllites of the Bokkeveld Group, or, as in the case of Jonkershoek, granites of the Cape Granite Suite (Lambrechts 1979).

The Table Mountain Group contains five different formations, some consisting of shale or tillite, others consisting of sandstone. They are listed here from the oldest to the youngest substratum. The Graafwater Formation forms the lower altitude shale-bands. The Peninsula Formation consists of sandstones and is locally more than 1700 metres thick. The Pakhuis Formation consists of tillite of glacial origin. The Cedarberg Formation always accompanies the Pakhuis Formation and consists of a shale-band at high altitude, about 50 metres thick. The Nardouw Formation is formed by the sandstones that occur above these shale-bands and can be 1000 metres thick (De Villiers *et al.* 1964).

The Karoo Formations have a much younger origin. They are presently found only in the more inland areas of South Africa and are not present in the study area. During the deposition of the Dwyka Formation, the oldest of the Karoo Formations, the Karoo and the Cape were folded in an episode of mountain building known as the Cape orogeny. This happened in the Permian and Triassic, between 278 and 215 million years ago. The Cape Fold Mountains rose and formed a source of sediments that were deposited in the Karoo basin. The Dwyka Formation was followed by, respectively, the Ecca, Beaufort and Stormberg Formations and the Karoo sequence was concluded in the Jurassic (about 150 million years ago). After this, Gondwanaland, the big continent of the Southern Hemisphere, started to break up.

Formations from the Cretaceous Period in South Africa are known from near the shore and can be regarded as relicts of the continental breakup. There are alluvial gravels, colluvial screes and coastal deposits that originate from the Cainozoic. These deposits are not particularly thick but they are important ecologically as they form the limestones near Bredasdorp and the coastal sands on the West Coast, both of which have unique vegetation types growing on them (Deacon *et al*. 1992).

In the Hottentots Holland Mountains different geological units are exposed on the eastern versus the western slopes. The distribution of the different strata are illustrated in Figure 2.6. The mountains are mainly formed by sandstones of the Table Mountain Group, which are extremely poor in nutrients.

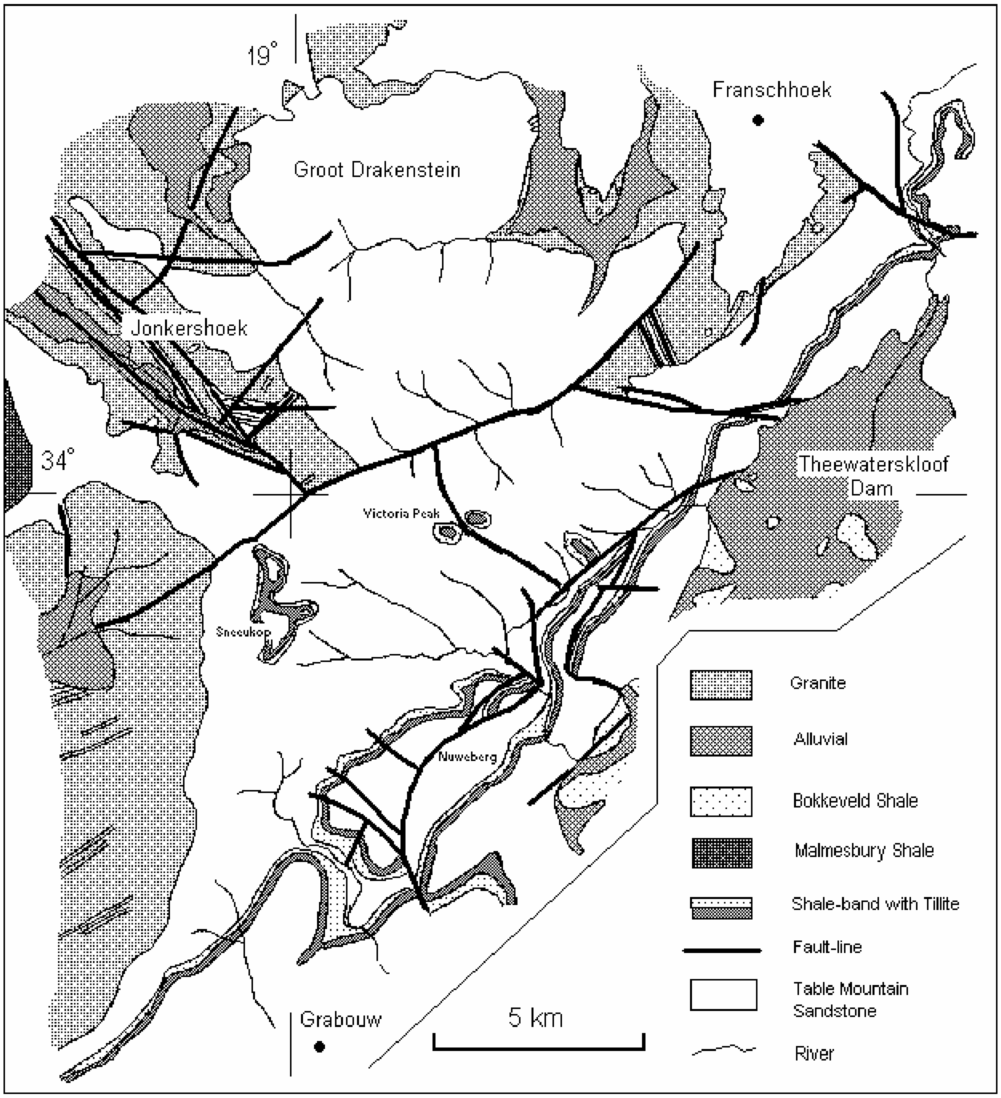

Figure 2.6: Geological units in the Hottentots Holland Mountains (South African Committee for Stratigraphy 1980). See also Figures 2.1 and Figure 2.4b for the locations of catchments and nearby towns.

The main divider between the geological and geomorphological units in the Hottentots Holland Mountains is a fault line that follows the rivers in the Assegaaiboschkloof and Diepgat Ravines and separates the Eerste River catchment from the catchments of the Riviersonderend River and Palmiet Rivers (Figure 2.1b).

On the side of the Eerste and Berg Rivers, granites of the Cape Granite Suite are exposed on the lower valley slopes and alluvial soil deposits occur on the bottom of the valley. In Jonkershoek, many faultlines occur and are accompanied by cataclasite. Small bands of dolerite are also found in the granite. The granite at the head of the valley, towards the Dwarsberg, is of a different structure to the granite found elsewhere. It is an equigranular granite or aplogranite in contrast to the porphyritic granite found towards Stellenbosch. In the Berg River catchment near Franschhoek, other porphyritic granites are found in the area that is covered by the La Motte plantation (South African Committee for Stratigraphy 1980). Rubble from the surrounding sandstone slopes cover part of the valleys, where they overly the granite, which results in a mixed substrate.

The mountains on the side of the Palmiet and Riviersonderend Rivers, on the other side of the dividing faultline, only consist of materials of the Table Mountain Group. These are mainly sandstones; however, thin bands of tillite and shale are exposed over the whole range from Sir Lowry’s Pass to Franschhoek Pass and near the mountain tops of Somerset Sneeukop, Victoria Peak and Emerald Dome. These bands always occur together but their continuity is broken up by several fault lines that cross the area (South African Committee for Stratigraphy 1980). They are also often overlain by sandstone rubble.

2.3.2 Geomorphology

The shape of the earth’s crust is influenced by a series of factors, of which the most important are the geological substrate, the elevation and the climate. Different layers are subject to different rates of chemical and mechanical weathering. The elevation is important because it determines the hydrology of the area compared to the surrounding areas. The climate is all-important because it determines the rate of weathering and the growth of vegetation, which in itself also has an influence on erosion.

The rivers, which form the central part of this study, are also one of the major agents in shaping the landscape. The geological substrate is important as it defines how the river network will develop. On homogeneous substrates this network will develop in a dendritic pattern, in such a strict way that one can simulate its course by computer. However, homogeneous substrates rarely stretch over great distances, so the kind of branching system that develops is dependent on the geology of the area. Harder and softer layers, intrusions and other geological structures all have their influence on the river network.

In the upper reaches of the river erosive forces dominate and here the river cuts deeply into the substrate. The erosive force of water mainly comes from the sediment load. The erosion directly inflicted by the river is called vertical erosion. The slopes of the gorges that come into existence after vertical erosion are subject to colluvial weathering with lateral subsidence into the river. On very hard sandstone rocks, for instance, there is hardly any lateral subsidence into the river, which is why very steep gorges occur in these situations in the Hottentots Holland Mountains.

Eventually, though, in every river, vertical erosion slows down and lateral subsidence becomes the most dominant erosive force. In a mature landscape weathered material from the hillslopes settles down at the foothills to form a pediment. Valleys become broader and flatter and planation takes place until a new geological upliftment takes place. This is called the peniplanation cycle (King 1967).

The African continent in general is characterised by an extreme form of planation that took place after the break-up of Gondwanaland and the deposition of the Karoo sediments. This planation results in the flat landscapes that occur all over the continent. In areas that have a lower elevation this flatness is most obvious, as in the Kalahari Desert. In the Pliocene, however, the interior plateau of the continent was elevated for more than thousand metres while the coastal areas kept their low elevation. This process of cymatogeny resulted in the phenomenon that is now called the Great Escarpment (King 1967, 1978; Partridge 1997). The Great Escarpment is found much further inland than the Cape Mountains which support the fynbos vegetation.

The Western Cape is characterized by the Cape Folded Belt, where a number of mountain ranges occur parallel to the coast. There are two main zones of folding: in the western part there are mountain ranges running north-south concave to the west and in the eastern part there are mountain ranges running east-west, slightly concave to the south. South from Tulbagh the folding takes many directions. This is probably because of the two zones meeting each other here. The present landscape has probably existed since the mid-Cretaceous, after the Cape Orogeny had taken place in Permian and Triassic times and the Cape rivers had excavated the mountain ranges and deposited their sediments in the Karoo (Wellington 1955; King 1962; Lambrechts 1979).

The Table Mountain Group sandstone is a good water-carrier that allows water to penetrate to considerable depths. In several places in the Western Cape, at the junction of the Table Mountain Group sandstone and the Bokkeveld Group shales, warm-water springs can be found, for example at Caledon, Montagu and Citrusdal (Wellington 1955).

Few detailed geomorphological studies have been done to outline the influences of the Western Cape rivers on their landscape. A few studies have been done on the Eerste River in the surroundings of Stellenbosch. Beekhuis *et al.* (1944) give a detailed account of the whole course of this river. They describe some of the alluvial fan-cores that some tributaries in the Jonkershoek Valley have created at the point where they enter the main stream. The fans that have been created at the base of the Swartboskloof and Disa Kloof streams are so thick that they have partially dammed the river, creating a marsh where the current slows down. Above this marsh the river is slow flowing while below it the river flows rapidly and has cut a deep channel.

The alluvial soils around Stellenbosch are the subject of Söhnge's (1981) study. The town of Stellenbosch is built on an alluvial fan with its apex towards the Jonkershoek Valley. Three different periods of deposition have resulted in the formation of three terraces. The oldest deposits are from Mid-Pliocene and probably relate to older tributary courses. During the formation of the two other deposits the Eerste River changed its course.

2.4 Soils and pedogenesis

There is no unified international terminology for soil description. Most versions are variants of the approach presented in United States Department of Agriculture (1951). The classification of the different soil profiles does not have an international standard either, however the United States Department of Agriculture (1975) system is widely applicable. Many regions and nations have their own classification systems (Ball 1986). The South African classification of soil types is outlined by the Soil Classification Working Group (1991). This is the classification followed in this study.

Many of the soils found in the mountains are shallow, weakly developed soils which are termed lithosols. Podzolization is the most important soil-forming process here, although Campbell (1983) argues that its impact is usually overestimated. In the podzolization process substances such as iron, aluminium and organic matter are leached from the A-horizon and accumulate in the podzolic B-horizon which, as a result, becomes darker in colour. The soils are very poor in plant nutrients, particularly in phosphates. Highly variable and localized conditions of soil depth, soil moisture and aspect result in many different microhabitats. In contrast with the soils of the coastal plains, which are base rich, the montane soils favour many specialist species (Deacon *et al*. 1992).

Campbell (1983) found three dominating soil types throughout the mountainous regions of the Cape. These are the Mispah, Glenrosa and Cartref Forms. They are all litholic and represent the shallower soils (less than 0.40 m deep). The soil type is largely determined by the geology (see also Ball 1986). The Cartref type usually occurs at the higher altitudes on the coastal mountains. The Glenrosa and Mispah soils occur in the better drained slopes or at lower altitudes with north aspects. They also dominate the mountain ranges of the interior on the Witteberg Group quartzites. Of these three most common soil types, it is only the Glenrosa Form that also occurs to a reasonable extent on non-quartzite substrates, particularly on shales. The soils on the southerly aspects, the gentler slopes and the lower altitudes throughout the Cape generally have better developed profiles. Here the Clovelly, Hutton and Oakleaf Forms can be found (Campbell 1983).

The main factor that determines the soil type in the mountains is the rainfall. Where rainfall is abundant, soils are leached and poor in iron oxides. Where rainfall is low, the soils are leached to a lesser extent and are rich in iron oxides. The common soil types on mountain slopes in the south of the region, where rainfall is abundant, are the very shallow sandy soils of the Mispah, Houwhoek and Cartref Forms. These soils often contain varying amounts of stone that are coarser than 10 mm in diameter. In the drier areas to the north of the Hottentots Holland Mountains, yellow to yellowish red soils of the Clovelly and Hutton Forms are found. They can also be found at high altitudes with much rainfall, but only locally in iron-rich strata on higher slopes (Lambrechts 1979).

Campbell (1983) discusses the correlation between climate, weathering and pedogenesis within the Fynbos Biome. Because of lower plant cover and higher evaporation on northern slopes one can expect lower rates of chemical weathering, a higher degree of sheet erosion and minimal soil development here (Bond 1981). In the north-western parts of the Biome, plant cover is low and rock and debris accumulations, talus and soil creeps are widespread (Campbell 1983). In the south the debris mantle appears to be stable and is well vegetated.

Kruger (1974) suggests that fertility in quartzites is mainly determined by plant remains in the soil. Campbell (1983) argues that fertility is largely dependent on texture. Many non-quartzite soils have a finer texture and also a higher fertility (Cowling 1984).

Kruger (1974) found the Hutton and Clovelly Forms to be associated with shale-bands. He also found the Dundee Form on young stratified alluvium in drainage channels. Fry (1987) gives a description of different catenas (soil gradients) that occur in Swartboskloof in the Hottentots Holland Mountains. These soil gradients can be extrapolated to the entire mountain range, because both dominant geological substrates (granite and sandstone) are found in Swartboskloof. Soils on granites and shales have a better developed structure and contain more organic carbon in humid places than the soils derived from sandstone. On sandstone, the soil catena from downslope to upslope situations is generally Constantia, Clovelly, Hutton, Glenrosa and Mispah. In lowlands or depressions the catena is formed by a succession of Fernwood (dry phase), Cartref, Houwhoek and Lamotte Forms in places where podzolisation dominates and by Fernwood (wet phase), Avalon, Longlands and Westleigh Forms where hydromorphic processes dominate.

On granite slopes, the catena follows the gradient of Clovelly, Hutton, Glenrosa and Mispah Forms. In specific situations other soil types can occur, such as Swartland and Sterkspruit Form soils occurring in the concave lower slope positions with Estcourt and Kroonstad Forms on the well-drained slopes immediately above. In humid environments the catena tends to be towards the Magwa, Nomanci, Glenrosa and Mispah Forms. In many lower-lying areas a mixture of granite and sandstone parent material occurs as rubble from the erosion of upper slopes.

Table 2.2: Descriptions of some of the most important soil types that can be found in the Hottentots Holland Mountains in riparian zones. The sandstone-derived soils are very acidic (pH lower than 5) and are nutrient-poor (Soil Classification Working Group 1991; B.H.A. Schloms, Department of Geography, University of Stellenbosch, pers. comm.)

Soil Form	**Horizons**	**Lithology**	**Location**
Cartref	A / E / B, shallow	Sandstone	High altitudes of coastal mountains
Champagne	Organic O	Sandstone	Seepages
Dundee	A / alluvium	Alluvial	Lower reaches of rivers
Fernwood	A / E	Sandstone	Edges of seepages, wet places
Glenrosa	A / B, shallow	Sandstone / Granite / Shale	Mainly on granite and shales at lower altitudes
Houwhoek	A / E / B	Sandstone / Granite / Shale	Wet Mountain slopes
Klapmuts	A / E / B	Sandstone / Granite / Shale	Wet Mountain slopes
Mispah	A / bedrock, shallow	Sandstone / Granite / Shale	Mountains
Oakleaf	A / B	Sandstone / Granite / Shale	Forests
Magwa	A / B	Sandstone / Granite / Shale	Forests

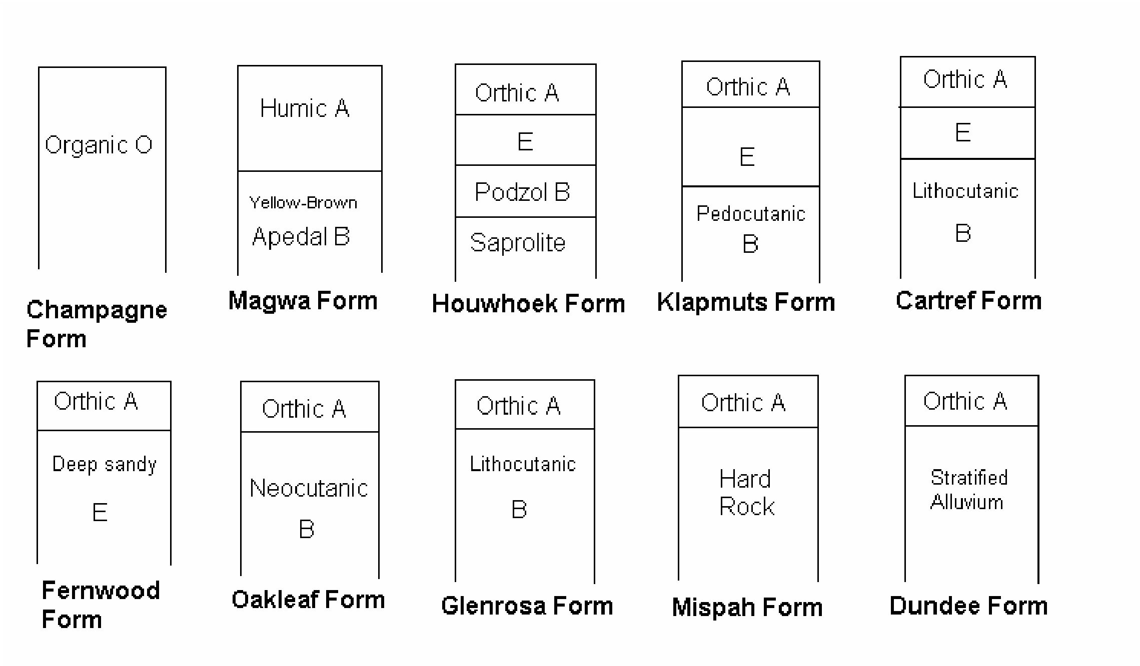

Figure 2.7: Schematic representation of some common soil types in the Hottentots Holland Mountains (Soil Classification Working Group 1991).

The soils found by Fry (1987) in Swartboskloof can be subdivided into four major groups: dark brown humic soils, moderately to well-drained red and yellow soils, moderately to well-drained pale soils and hydromorphic soils.

The dark brown humic soils are mainly found in footslope positions and are very deep. They have an apedal to weak blocky structure and deep root penetration. The red and yellow soils are very diverse. They are derived from quartzites or from a mixture of granite and quartzite. The Glenrosa Form occurs on footslopes and is very shallow. The most important soil form in the group with pale soils is the Fernwood Form of which two phases are recognized: the grey and pale Fernwood Forms. They are both found on footslopes. The hydromorphic soils contain mottling in the B-horizon. The A-horizon is dark brown. Descriptions of some of the different soil types that can be found in the Hottentots Holland Mountains are presented in Table 2.2 and in Figure 2.7.

2.5 Archaeological to recent history

Africa is the continent in which the human species has evolved. The oldest traces of human settlement in the Western Cape are in the form of artefacts, because skulls and bones tend to disintegrate under the acidic conditions which are predominantly found through the biome. There have been few fossil findings, mainly in deeper soil layers that contain calcareous material. There are discontinuities between these and later findings which indicate that the climate has probably not always been favourable for human settlement (Deacon 1992).

2.5.1 The San and Khoikhoi

In the Late Stone Age the people living in the Western Cape were hunter-gatherers and many of the artefacts found from them suggest that their life-style was in many ways similar to that of many San people in modern-day Botswana. The many fossils that have been found from the early Holocene (10 000 years ago) suggest that they lived in territorially organized groups. They probably used fire-stick farming to encourage natural fields of geophytes, and they killed the small antelope in the surrounds of these patches. The population grew steadily until two thousand years ago when a new way of life was established in the Fynbos Biome, namely herding. The first practice of domestication of sheep and cattle originated in the Middle East, from where it quickly spread into North Africa, but took nearly 6000 years for these practices to spread over the entire continent, including the Western Cape. Herding was associated here with the people who spoke

Khoikhoi. In some areas with suitable conditions stock farming was established. When external trade became important, large herds were recorded like one of 20 000 cattle that was driven to Table Bay in 1652. The hunter-gatherer life-style was regularly in conflict with the herding life-style, but in general the two peoples of San and Khoikhoi cultures managed to live together and this is how the first Europeans found the Cape in the 16th century (Deacon 1992).

2.5.2 Early settlers

The first Europeans to arrive at the Cape were Portuguese explorers. Later on, Europeans of different nationalities used the Cape as a stop-over on route to Eastern Asia, and they traded with the Khoikhoi for their supplies. It was the Dutch who took the decision to start a supply station at the Cape in order to control this kind of trade in the face of English and French competition. The Khoikhoi were not united in their resistance to the occupation of their traditional lands and their society was rapidly disrupted. Although Khoikhoi resistance was heavily suppressed by Europeans, the settlers took over several elements of the Khoikhoi culture like nomadism and veld management practices and this facilitated expansion of the colony (Deacon 1992).

The mountains of Hottentots Holland formed the border between the Cape Colony and the vast inland part of South Africa. That is why they were named ‘the mountains of Africa’. In 1663 the land surveyor Hendrik Lacus was the first of the colonists to cross this mountain range and to see the other side of the mountains. He made use of a little track in a gorge near the place where Sir Lowry’s Pass is today. The European colonists called this track the Elandspad. It took many years before others followed. On the lower slopes of the Hottentots Holland Mountains some important outposts of the Cape Colony were established (Heap 1993). In the meanwhile the Khoikhoi crossed the mountains quite often to look for new pastures for their cattle. When the colonists started to trade with the Khoikhoi they started to make use of the Elandspad more often and a tollhouse was established at the beginning of the kloof. Nowadays the traces of the many oxwagons that passed here are still visible and it is a declared National Monument (Cape Nature Conservation 1994).

A second pass over the Hottentots Holland Mountains in the Western Cape was built in 1819. A Franschhoek farmer had built a path through the mountains from Franschhoek to the Viliersdorp side. This path, however, was very dangerous and soon a new track was built by the Cape administration. In 1825 the Franschhoek Pass was opened and this is now recognized as South Africa's oldest mountain pass (Cape Nature Conservation 1994).

2.5.3 Land use

Nowadays the Hottentots Holland Nature Reserve is used mainly as a catchment area for clean potable water, but also as a nature reserve and a recreational area. The surrounding areas are used mainly for agriculture. In the west there are mainly winelands and in the southeastern parts there are orchards with apple trees. Directly on the border of the reserve there are large pine plantations for wood production. This makes the mountain vegetation quite susceptible to alien invaders. A map illustrating basic land use patterns is presented in Figure 2.8.

2.6 Botanical background

In his survey of the general veld types and their potential for agriculture Acocks (1953, 1975) divided the vegetation of the Fynbos Biome into three groups, two of which were dominant in the mountains: Macchia and False Macchia. He changed the word Macchia into Fynbos in a later publication (Acocks 1988). He recognised, however, that this division was quite coarse and preliminary. Azonal vegetation types like riparian vegetation were not described. After the publication of research resulting from the Fynbos Biome Project, the knowledge of the biogeography and ecology of fynbos was deepened.

2.6.1 Origins of the Cape Flora

Different origins for the flora of the Cape are indicated by track analysis. In track analysis, the extra-regional distributions of taxa are examined to determine which areas share a floristic component with the area in question. In this way it can be seen which other floras were previously in contact with the Cape Flora. This can be matched to the knowledge from palaeoclimates and palaeogeography (Stott 1981).

A track is defined by the distribution of a taxon. In European literature, it is also known as a ‘geo-element’ (Walter 1973). If several tracks coincide they form a general track. General tracks can explain the links between several centres of endemism, or between continents. A major part of the taxa in the Cape are endemic at the species level but a closer look at higher taxonomic levels reveals three different tracks. These are the Gondwanan Track, the African Track and the Boreal Track (Adamson 1958; Goldblatt 1978; Linder *et al*. 1992). A track has developed through dispersal along a range of suitable habitats. In many situations, however, a formerly continuous range breaks up (for example through climatic changes or continental drift). This results in discontinuous distribution ranges, as in the Gondwanan and the Boreal Track (Linder *et al.* 1992).

The Gondwanan track consists of 16 supra-generic taxa and some genera like *Gunnera*, *Ehrharta*, *Podocarpus*, *Dietes* and *Bulbinella.* Among the families represented are the Proteaceae, Restionaceae, Haemodoraceae and Cunoniaceae. Their distribution is across all the continents of the Southern Hemisphere: Australasia, South America and Africa. Antarctica only has an extremely poor trachaeophyte flora but would also have been part of this track judging from fossil evidence. Only the Restionaceae and Proteaceae have been studied in detail (Linder 1987; Johnson & Briggs 1975).

The strongest relationship to the Cape Flora is through the African Track. However, the African Track is phytogeographically complex, and several links within the African track can be recognised. Cowling (1984) shows strong relations between the Cape and the Afromontane Floras. This is best shown in genera like *Protea*, *Disa*, *Aristea*, *Cliffortia*, *Anthospermum*, *Mesembryanthemum* and *Pentaschistis*. A study of the genus *Lotononis* reveals that Namaqualand in the north is floristically closest to the Cape Floral Kingdom (Van Wyk 1990). After that the strongest link is with the Afromontane vegetation of the Drakensberg and mountains further north (Linder *et al*. 1992; White 1978).

The Boreal Track, which is represented by genera like *Anemone*, *Ranunculus*, *Viola*, *Festuca* and *Scabiosa*, suggests migration of European species through the East African highlands to the south. Some genera show disjunctions between the Northern and Southern Hemispheres (Linder *et al*. 1992).

Riparian vegetation, which is the main concern of this study, is represented by species of all three tracks. Afromontane elements play an important role in the riparian forests, so here the species of the Boreal Track are most important (examples are: *Olea*, *Ilex*, *Asparagus* and *Blechnum*). However, important species such as *Brabejum stellatifolium* and *Metrosideros angustifolia*, and the family Cunoniaceae, are more closely linked to the Gondwanan Track (Good 1974). The seepage areas at the sources of the rivers are mostly dominated by Restionaceae so here the Gondwanan Track is dominant. The African Track has the least typical riparian elements; the most important riparian species is *Disa tripetaloides*.

2.6.2 Vegetation types in the Fynbos Biome

The vegetation in the Cape Floristic Region does not only consist of fynbos, but also of several other vegetation types. Renosterveld vegetation is one of these vegetation types. It was originally widespread and mainly covered the valleys within the biome. It is characterized by many grass species and many species of Asteraceae of which one, *Elytropappus rhinocerotis*, or renosterbos, is the most common. This species becomes dominant after overgrazing (Boucher & Moll 1981). Because the soil under renosterveld is very fertile, most of it has been ploughed and planted to wheat and nowadays the lowland types of renosterveld are the most threatened vegetation types in the Fynbos Biome. In the mountains, renosterveld occurs in the interior areas with a lower rainfall than the coastal areas. Renosterveld has very specific rainfall limits. In wetter situations it will be replaced by fynbos and in drier situations it will be replaced by succulent karoo (Cowling & Holmes 1992; Cowling *et al*. 1997).

Afromontane forests occur throughout the Biome in small patches in kloofs, on screes and near rivers, except in the coastal area in the eastern part of the biome where they are more extensive and form an own Forest Biome. The boundary between forest and fynbos is often very sharp. It is generally accepted that forest is restricted to fire-protected areas with deeper and moister soils than the adjacent fynbos (Cowling 1984; Campbell 1986b; Manders *et al*. 1992). However, Van Daalen (1981) found afromontane forests on soils identical to those supporting fynbos. Some soil characteristics of forest soils might well be plant-induced, due to differences in nutrient-cycling (Cowling 1984). Forest development is most rapid in permanently moist, fertile and warm sites, most of which occur in the eastern part of the biome where there is more rainfall during the summer (Cowling *et al*. 1997).

Fynbos has been subdivided in different ways over time in botanical history. Acocks (1953) recognized Macchia, False Macchia and Coastal Macchia. The subdivision between Macchia and False Macchia is not very clear and was not recognized by later authors, such as Taylor (1978) and Kruger (1978b). Taylor (1978) described the differences between Mountain Fynbos, Arid Fynbos and Coastal Fynbos (Acocks's Coastal Macchia). Rebelo (1998) offers the latest classification of fynbos types with three lowland (coastal) types (Sand Plain Fynbos, Limestone Fynbos and Laterite Fynbos), Grassy Fynbos (of the eastern mountains) and Mountain Fynbos. Mountain Fynbos remains the biggest group that is difficult to subdivide, although it is extremely diverse.

Taylor (1978) recognized three zones in the Mountain Fynbos: the Proteoid Zone on the valley bottom, the Ericoid-restioid Zone on the higher slopes and the Hygrophilous Fynbos of the riparian habitats. The Hygrophilous Fynbos, that is dealt with in this study, is both floristically and structurally a diverse group. This subdivision is not upheld to any great extent at present, as Campbell (1986b) introduced a new classification of Mountain Fynbos, which is more detailed. Campbell's (1986b) prime subdivision is between the common Mountain Fynbos and the Grassy Fynbos, that only occurs in the eastern parts of the biome. The Mountain Fynbos is further subdivided into Proteoid Fynbos, Ericaceous Fynbos, Restioid Fynbos, Asteraceous Fynbos and Closed-scrub Fynbos. He describes the Closed-scrub Fynbos, together with Afromontane Forest, as a typically riparian type. This subdivision is also extended to the lowland fynbos types and supported by Cowling *et al*. (1997).

Weimarck (1941) first described endemic centres in the Cape Flora (see Section 2.6.3). Oliver *et al.* (1983) reanalyzed and expanded this treatise using modern data and statistical analyses. Rebelo (1998) also uses centres of endemism to subdivide the Mountain Fynbos. Rebelo's (1998) approach to centres of endemism probably does not apply to riparian vegetation, because most typical riparian species have a wide distribution.

In all the above-mentioned classifications, riparian vegetation types received quite some attention because they stand out as being very different in both structural and floristic composition from the other mountain vegetation (Taylor 1978; Campbell 1986b).

2.6.3 Species diversity

One of the most striking features of the Fynbos Biome is its high species diversity and its high degree of endemism (Kruger 1978a & b; Taylor 1978). The climatic and geological explanations of this phenomenon have already been dealt with. What follows is a description of the diversity within the biome, the distribution of species and the degrees of endemicity throughout the biome (Goldblatt 1978; Oliver *et al.* 1983; Cowling *et al*. 1992).

Three levels of diversity are distinguished. Alpha diversity refers to the number of species in a unit area. Beta diversity refers to species turnover across habitats and gamma diversity refers to species turnover between different geographical areas in comparable habitats. Gamma diversity is closely linked to endemicity. Kruger & Taylor (1979) also mention delta diversity which is synonymous with gamma diversity in this sense. Data to quantify these three measures of diversity between different areas within the biome have been collated by Cowling *et al*. (1992).

It appears that alpha diversity does not vary very much within the biome, but alpha diversity of fynbos is significantly richer than that of forest and karroid shrubland. On average, fynbos supports 15 species per m^2 and 65 per 1000 m^2. The variance is small despite the big differences in climate, soil and disturbance regime (Cowling *et al*. 1992).

Beta diversity is difficult to quantify because it depends on the habitat diversity as well. There are difficulties in comparing different ecological gradients with each other. The data that was collated by Cowling *et al*. (1992) is not sufficient to say anything significant about beta diversity throughout the biome.

Gamma diversity can be measured by comparing the species pools of geographically different regions. In most cases this will also include an environmental difference so there will be a beta component as well. Cowling *et al*. (1992) found that gamma diversity in the southwestern part of the biome is greater than in the southeastern part. Especially the high turnover of species of the ‘typical’ fynbos families like Restionaceae and Ericaceae is conspicuous in the southwestern part of the biome.

Endemism varies throughout the biome between the different regions and between different families. Weimarck (1941) distinguished five different centres of endemism within the biome: the Southwestern Centre, the Northwestern Centre, the Karoo Mountain Centre, the Langeberg Centre and the Southeastern Centre. Rebelo (1998) subdivides the biome in more detail and recognizes 24 centres of endemism.

One of the most striking ecological characteristics is the existence of many different ecological responses to fire. Van der Merwe (1966) mentions four fire life-forms, (four ways in which plants can survive fire): (1) fire geophytes: geophytes that regenerate from underground storage organs, (2) fire hemicryptophytes: sprouters that regrow from rootstocks, (3) fire chamaephytes and nanophanerophytes: plants with thick bark that protects dormant stem buds from fire and (4) fire therophytes: woody shrubs and herbs that are killed by fire and regenerate from seed. After every incidence of a fire, a rhythmic succession takes place, ending with the dominance of the fire therophytes after five or six years. The maintenance of a high species diversity is therefore dependent on a suitable fire regime (Taylor 1978; Richardson & Van Wilgen 1992).

2.6.4 Management

Fynbos management is not only important to maintain species diversity but also for the maintainance of catchments with high quality drinking water. Some management aspects receiving attention in fynbos are the control of alien vegetation, maintaining a suitable fire regime, regulations for grazing animals and flower harvesting. The organization that is primarily responsible for the proper management of fynbos is the Western Cape Nature Conservation Board. Management of fynbos reserves depends on the size of the area and of the available finance. In the biggest or most remote areas there might be no management at all except perhaps for the maintenance of fire-breaks (Van Wilgen *et al*. 1992).

The most important questions concerning management of fynbos ecosystems revolve around fire: when to burn the area, how often and at what time of the year. Wild-fires occur mainly in summer and autumn due to the arid conditions at that time of the year in this mediterranean climate zone. Controlled fires are considered to be an effective tool in management but they should be carried out in the season that will secure a good regeneration of the vegetation. This will most often be late summer or autumn (Taylor 1978; Van Wilgen *et al*. 1992; Bond 1997). Different fire intensities influence different plants in different ways. Intense fires stimulate the growth of myrmecochorous species, whereas low-intensity fires stimulate the growth of grasses and small-seeded shrubs. This knowledge can be used by managers to achieve their management goals (Bond 1997; Richardson & Van Wilgen 1992).

Plants in riparian habitats are not always affected by fire. Often they are protected by their physical habitat and many tree species are particularly sensitive to burning. Manders *et al*. (1992) argue that fynbos would eventually turn into forest if it was not for the recurrent fires. Palmiet (*Prionium serratum*), a typical riparian species, is a resprouter after a fire and fire plays an important role in its reproduction (Withers & Boucher 2000). Fire also has a strong marked influence on catchment runoff. Surface runoff increases shortly after a fire, because of decreased interception by the vegetation and because of repellancy of the soils (Scott & Van Wyk 1992).

Another threat to the fynbos that needs proper management are woody invasive exotic species. A few of these are mainly linked to rivers and will be discussed in section 2.7.3. The most important species that invade mature Mountain Fynbos are *Hakea sericea* (a garden ornamental) and *Pinus pinaster* (from plantations). They are mainly removed by manual eradication although insect herbivores have also been introduced successfully to control *H. sericea* (Taylor 1978; Moran *et al.* 1986).

Management aspects of fire regime and the control of alien plants have a big impact on the catchments. Runoff in a catchment increases after a fire. Alien plants take up much water and clearing of alien vegetation can increase the runoff in the catchments (Boucher & Marais 1993).

Conservation areas were established by various regional, national and international bodies in the mountainous areas of the Western Cape to preserve the uniqueness and the species diversity of Mountain Fynbos ecosystems. An overview synthesis of the different vegetation types and their occurrence is necessary to provide an effective conservation strategy for this vegetation. Rebelo (1998) provides a first draft of such an overview and indicates that currently, the Lowland Fynbos and Lowland Renosterveld are among the most threatened vegetation types in the region.

2.6.5 Earlier studies in the Fynbos Biome

Some phytosociological studies done in the Fynbos Biome that are relevant to the present study will be highlighted here. Some of these that have a special significance for this study are summarized in Table 2.3. One of the earliest of these studies was conducted in the Kogelberg Biosphere Reserve.

The Kogelberg Biosphere Reserve is situated about 30 km south of the Hottentots Holland Mountains. It is recognised as one of the most species-rich areas in the Fynbos Biome (Oliver *et al.* 1983). It shares many species and possibly vegetation types with the Hottentots Holland Mountains. Phytosociological research in the Kogelberg was initiated by Boucher (1972). The results of this thesis together with additional data are published in Boucher (1978), which forms a fairly complete overview of the area.

Three different types of riparian vegetation types have been described in the Kogelberg Biosphere Reserve, including the vegetation of the Lower Palmiet River that flows through the area. Although the river flows here in its lower reaches it still has many characteristics of a mountain stream.

Table 2.3: Phytosociological studies in the Fynbos Biome with a special significance for this study. Locations of these studies are given on the map below.

Author	**Locality of study**	**Significance for the present study**
Taylor (1969)	Cape of Good Hope Nature Reserve	first phytosociological study in the fynbos
Werger, Kruger & Taylor (1972)	Jonkershoek	part of study area, many riparian and forest types described
Boucher (1972, 1978)	Kogelberg Biosphere Reserve	proximity to study area, many riparian and forest types described
Kruger (1974)	Jakkals River Catchment	detailed ecological investigations in fire regime, climate and pedogenesis
Campbell & Moll (1977)	Table Mountain, Eastern slopes	many forest types described in detail
McDonald (1983, 1985, 1987)	Swartboskloof	part of study area, includes gradient analysis
Campbell (1986b)	Entire Fynbos Biome	structural description of all types, also of restio marshes and riparian scrub
Boucher (1987)	West Coast	includes riparian vegetation of the lowlands
Rode (1994)	Solva	in close vicinity to the study area, but on a very different substrate

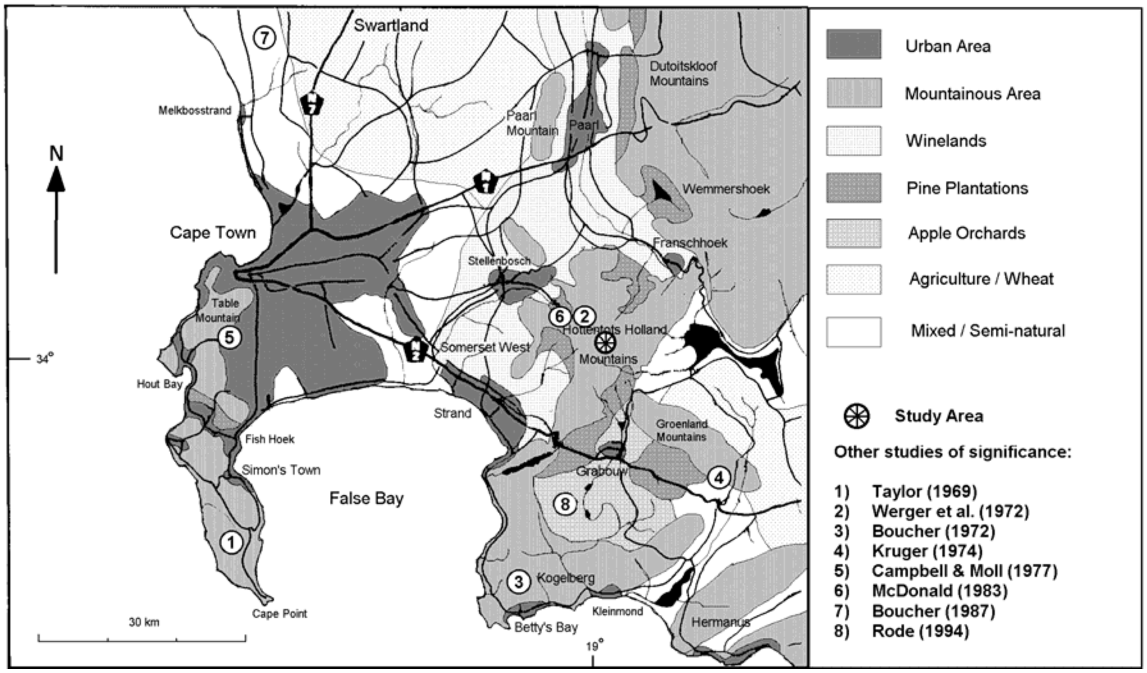

Figure 2.8: Map indicating the locations of previous studies in the fynbos vegetation that are relevant to this study. The major land uses are indicated.

During the seventies a greater number of studies in the Fynbos Biome were completed, especially on Table Mountain (McKenzie *et al*. 1977; Glyphis *et al*. 1978; Laidler *et al*. 1978; Campbell & Moll 1977). Many of these also described forests. Forests border some parts of the rivers in the present study. The study of Kruger (1974) in the Jakkals River catchment provided a very detailed description of the climate, the pedogenesis and the fire regime, which are the major environmental determinants in Mountain Fynbos.

In the eighties, the interest in purely descriptive studies of Mountain Fynbos declined slightly, because of the influential work of Bond (1981) and Campbell (1986a) who both expressed some doubts about the use of floristics for the classification of fynbos vegetation. The studies in this period aimed especially at a general ecological understanding of Mountain Fynbos and at the two major research sites of the Fynbos Biome Project. One of these was situated in the Hottentots Holland Mountains, at Swartboskloof (Kruger 1978; Van Wilgen & McDonald 1992). Four vegetation studies have been undertaken here up to now: Van der Merwe (1966) investigated the fire response of the vegetation. Werger *et al*. (1972) introduced the Braun-Blanquet method to the Fynbos Biome and presented the first phytosociological description of some selected vegetation units. Van Wilgen (1981) mainly investigated the effects of fire while McDonald (1983, 1985) undertook a second, more complete, phytosociological survey of the area. Fry (1987) provided a detailed account of soils found in the valley and related that to the vegetation units described by McDonald (1983). In this period also phytosociological studies that included gradient analysis were carried out (e.g. McDonald 1987).

In the nineties the interest in ‘classical’ descriptive studies according to the Braun-Blanquet method in Mountain Fynbos increased again. Some studies from this period are the ones by McDonald (1993a-c) from the Langeberg and Taylor (1996) from the Cedarberg.

2.7 Riverine ecosystems

With higher water demands for an increasing South African population, the situation has already been reached where nearly every medium-sized river in the country is impounded in at least one place. The ecological consequences of these pressures on the vulnerable riverine ecosystems has received more attention since the end of the eighties (Ferrar *et al.* 1988). The more intensive river research since then is aimed at assessing the amount of water in a river that can be utilized by the human population, while the ecosystem itself is also seen as a ‘competing user’ or later even as the resource base without which sustainable use is not possible (King *et al.* 2000).

Riverine ecosystems are very fragile systems, because they are dependent on the condition of their entire catchment. If there is one point source of pollution somewhere in a river catchment, this will be evident everywhere downstream from that point. And yet, riverine ecosystems have the ability of self-purification and every aquatic disturbance has a downstream recovery distance (Ward & Stanford 1979). With the present population pressure in South Africa, however, it is impossible to conserve rivers entirely in their natural state and some kind of compromise fitting the demands of the people has to be found (Ferrar *et al*. 1988). Nowadays, Environmental Flow Assessments for rivers are conducted in a holistic manner before their water resources are exploited further (King *et al.* 2000).

2.7.1 General river ecology

A river is an essential part of the hydrological cycle. In hydrology one cannot separate a river from its catchment area. The catchment includes a very complicated network of streams, gullies, swamps, seepages and rivers, together with all the bodies of water that move underground. This network of water bodies can only persist in areas where precipitation exceeds evaporation. Water will start flowing superficially when the soil is completely saturated. When the water flows it first collects into little rills. These join together to form gullies. These flow together into the first order rivers that join again to form second order rivers and so on. In this way a branching river system is formed (Hynes 1970).

Along its course a river can be divided into three longitudinal zones: The Mountain Stream Zone, where the erosion exceeds the sediment accumulation, the Foothill Zone where erosion and accumulation are more or less in equilibrium, and the Coastal Plain River Zone where accumulation exceeds erosion (Davies & Day 1998). This longitudinal zonation is merely for descriptive purposes, but in reality a river rarely shows sharp boundaries along its longitudinal gradient (Hynes 1970). In an ‘ideal river’ a graph of the altitude against the distance from the coast would show a perfect concave curve with the mountain river zone showing the steepest angle which will gradually decrease on its course towards the coast. In reality there are alterations in this pattern due to geological heterogeneity (Davies & Day 1998).

The channel morphology is determined by a number of factors and differs along the different reaches. Riffles and pools alternate, riffles in the shallow places and pools in the deeper places. Riffles tend to occur at regular intervals, in places where larger boulders are clustered. They do not occur on sandy riverbeds because they are correlated with a diversity of particle sizes. The deeper part of the river, or the main stream, has a natural tendency to swing from one side to the other thus, especially in the lower reaches, meandering channels are found (Hynes 1970).

Lateral riparian zones form the interface between the riverine ecosystem and the surrounding uplands. They add an extra dimension to the riverine ecosystem and the river receives many nutrients from the soil in the riparian zone (Naiman & Décamps 1997). The river creates many different habitats here during floods and it is one of the most dynamic ecosystems as it also suffers from the upland disturbances. These disturbances result in a high species diversity in riparian zones worldwide. Many authors claim that maximum biodiversity will occur in places that experience an intermediate level of natural disturbances, which applies well to rivers (Ward & Stanford 1983; Gregory *et al.* 1991).

2.7.1.1 Mountain streams

First, the situation in mountain headwater streams will be described. A typical mountain stream is cool, clear and fast flowing. It is the flow of water that dictates what remains in the channel and what is removed. The riverbed is mainly covered by bedrock or boulders, which results in rapid flow and highly oxygenated water. The land that the river drains is usually very rocky with very little loose soil, so the sediment load is low, while the carrying capacity is high. Mountains that consist of hard rocks, that weather slowly, will have water flowing through them that is low in nutrients. This, together with the fast flow, as well as the shading of the edges, will make the mountain stream a harsh climate for plants and animals to live in (Davies & Day 1998).

In the Western Cape, the headwaters of the rivers are oligotrophic which reflects the low level of nutrients in the soil. There is also a low value for Total Dissolved Solids and a low pH (although there are some variations in pH). Altogether, this results in a high potability. Plants that grow in the riverbed extend their roots into the soil with difficulty because of the eroding nature of the stream. They must have strong root systems to withstand high flow rates. The main food supply in mountain streams will be allochtonous plant material: leaves, bark, twigs and fruits of the plants lining the rivers edge. Mountain streams belong to those few ecosystems that rely entirely on an external food source (Hynes 1970). The decomposing bacteria and fungi contribute to the total food resource. This results in the ratio $P:R < 1$, that means that the production (P) is less than the respiration (R). Animals that live in the mountain streams will have to adapt to this food source and can be classified as grazers, collectors, scrapers or shredders, depending on the way they take their food (Davies & Day 1998).

Despite the many difficulties that organisms have to cope with, many different microhabitats can be found in the mountain streams, on the banks as well as in the aquatic environment. Some of these are pools (deep places with low to zero velocity and smooth flow), runs (shallow to deep places with smooth flow and moderate velocities), riffles (high-velocity areas with turbulent flow and broken water surfaces) and cascades (places with free-falling water over bedrock and boulders in step-like arrangements). The microhabitats will change as the water level fluctuates. During a high flood, for example, riffles and pools turn into runs and the cascades can disappear completely (Davies & Day 1998).

During spates or droughts many animals can seek shelter in the hyporheos (the riverbed itself) where they can dig down into the substrate to a depth of up to one meter. This is an often overlooked part of the riverine ecosystem. It plays a major role, though, in the cycling of nutrients in the river ecosystem. It appears that the river itself is only part of a much bigger waterbody that extends underground both laterally and basally (Day *et al.* 1986; Davies & Day 1998).

A distinct feature of many rivers in the Western Cape, especially those on seaward facing slopes and those in the east, is the brown coloration of the water. It must be noted that this brown-ness increases after heavy rains. The darker colour of the water is often correlated to the acidity and King & Day (1979) assume that the cause of it is the presence of ‘humic acids’ in the water. The reason why some waters are browner than others, might be the extensive seepages at the mountain tops (own observation). This will also explain the sudden dark coloration of river water after heavy rains. Another cause of the dark waters that has been suggested is that the detritus of the sclerophyllous ericoid fynbos vegetation is rich in tannins that give the water a dark colour. The litter of sclerophyllous vegetation does not break down as easily as the detritus of forest trees, so the colour of the tannins remains in the water (Stewart & Davies 1990). When the water in the rivers continues its course in the Foothill Zone, the TDS (total dissolved solids) and turbidity will increase, resulting in a better-buffered system that is more alkaline and less brown (King & Day 1979).

2.7.1.2 Lower rivers

Although they do not form part of this study, a short introduction to the lower rivers and the estuaries will be given to provide a more complete scenario of a river ecosystem.

In the Foothill Zone the river size increases as the catchment size increases. The slope here is more gentle so the current speed decreases. As the riverbed widens more sunlight reaches the water, hence water temperatures increase and more algae grow in the river. More soil is washed into the river from the surroundings so that the river carries more suspended material. Both living organisms and the erosion of soil result in water that is less clear than in the headwaters (Davies & Day 1998).

More algae occur in the middle reaches of the river and the production of organic matter in the water increases. The P:R-ratio (Production / Respiration) is greater than 1. The invertebrates that feed on the algae still have the same adaptations to those in the mountain stream, because the stream velocity is still high and the riverbed stony. They tend to be different species, though. They also have a more distinct life-cycle, because temperatures in the middle reaches show more variation throughout the year (Davies & Day 1998).

As the river continues its way through the lowlands it enters the coastal plain where the slope and the stream velocity decrease more. The sediment load of the river is deposited as the slow-moving water cannot carry it any longer. The finer particles are deposited close to the sea where velocities are minimal. The water in the lower reaches is the richest in nutrients as it carries all the nutrients leached from the higher reaches. The riparian environment is ideal for the development of dense stands of emergent plants such as reeds or bulrushes (Davies & Day 1998).

There are many variations to the pattern described here for mountain streams, foothill zones and lower rivers. Some rivers in the Western Cape, such as the Palmiet and Rooiels Rivers, enter the sea directly from the mountains. These rivers do not have a lower river zone at all. In other cases, a river can be ‘rejuvenated’ when it crosses an escarpment, for example like the Orange River at the Augrabies Falls or the Zambezi at Victoria Falls and later at Cahora Bassa (Davies & Day 1998).

2.7.1.3 Estuaries

The estuary of a river is the most vulnerable part of a river ecosystem, because it is influenced by all the anthropogenic activities upstream. Coastal ecosystems benefit a lot from nutrient-rich sediments in the sea and estuaries are often good fishing grounds. Estuaries gain particulate matter from both the river and the sea and are among the most productive ecosystems in the world. Many of the South African estuaries are closed for a part of the tidal cycle. A detailed description of South African estuaries is provided by Day (1981) and by O'Callaghan (1993).

2.7.2 The river catchment

Many processes taking place in a river are catchment-related and these will be discussed in this section. The catchment or subcatchment of a river or section of a river is subject to a specific climate and has a specific geological substrate. All of these characteristics will reflect in the riverine ecosystem, the runoff and the water quality (Boucher & Marais 1993).

Precipitation that falls into a catchment will ∠ if it is not lost through evapotranspiration ∠ flow downhill, either as surface or as ground water. The movement of the subsurface flow is extremely complex and has an important effect on the water chemistry. After a storm many of the subsurface flows might form small rivers and a dense network of small temporary streams is created (Crabtree & Trudgill 1985).

Instead of forming a fixed network of river channels, streamflow is generated in a dynamic, expanding or shrinking source area. This is summarized in the Variable Source Area Concept (Hewlett 1961; Hewlett & Hibbert 1967). After water has infiltrated into the soil, the depth and porosity of the soil help determine whether the water remains in the soil or emerges as streamflow. Some water might be stored in the soil for years, while the rivers only depend on water supply from another nearby source. Wet periods might expand the river network into areas where nutrients have accumulated and cause a spate of nutrients to be released into the riverine ecosystem. This concept is explained in Figure 2.9.

All the features the water seeps through before it reaches the river have their impact on the river water. Geology, geomorphology, pedogenesis and local climate will all have their effect on drainage pattern and water quality of the river. Many of these effects are discussed by Bosch *et al*. (1986).

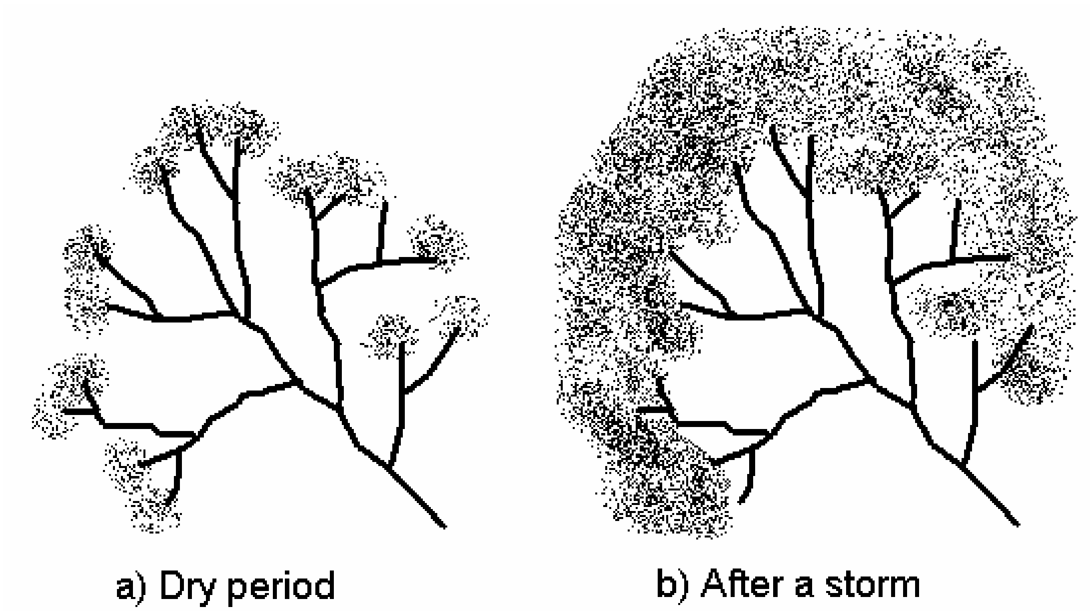

Figure 2.9: River catchment area in a dry period and after a storm: the Variable Source Area Concept (Hewlett 1961). The shaded areas indicate the seepage areas where the river water originates.

In the Fynbos Biome, runoff amounts to 35 – 55 % of the total rainfall. This is considerably higher than that recorded from the surrounding biomes. The high runoff value is mainly because of the low biomass, which results in low levels of interception and transpiration. After fire, water yields increase and level off after about 15 years (Cowling *et al*. 1997).

Figure 2.10 illustrates the main drainage systems in the Western Cape. The Olifants and Berg Rivers mainly drain the inland mountains in the west while the Breede, Gouritz and Gamtoos Rivers are large systems in the south. In areas with coastal mountains such as the Kogelberg and the Knysna area, there are many very short and steep rivers running from the Mountain Stream Zone directly into the sea. The total runoff of all these rivers is 15% of the mean annual runoff of the whole country (King & Day 1979).

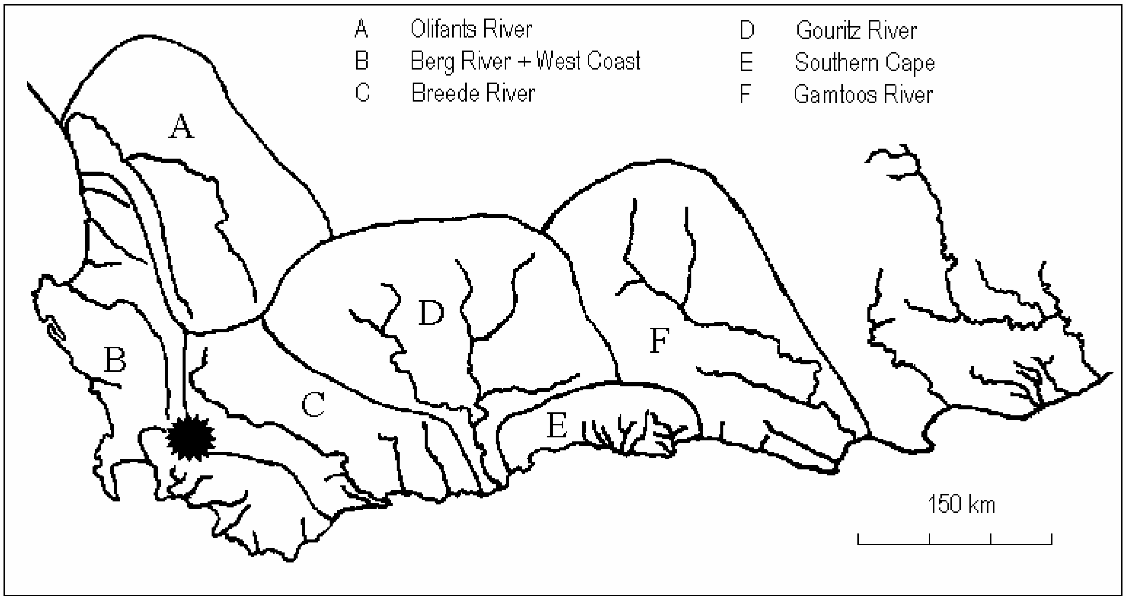

Figure 2.10: Principle river catchment systems in the Western Cape (King & Day 1979). The study area is indicated as a dot.

2.7.3 River health

The river health indicates how much a riverine ecosystem differs from its natural state. The three most important factors that play a role in the river health of South African rivers are dealt with below: water quality, flood regime and the state of the river banks.

2.7.3.1 Water quality

Each river has an intrinsic chemical composition that is dependent on the geographic location of the river. Basically, there are three types of rivers depending on what the key element is that determines their chemical composition (Davies & Day 1998).

- Some geological formations weather readily and many minerals are leached into the water. The mountains of Lesotho with their igneous basalt rocks are a good example. The minerals in the water are dominated by calcium, magnesium and bicarbonate. Their pH is slighly above 7. These waters are said to be ‘rock-dominated’ (Davies & Day, 1998).
- On the other hand, there are rock formations, like sandstones, that consist of old sediments that are highly leached already and release few minerals into the water on weathering. This is the situation in most of the Fynbos Biome. The minerals in water from this type of substrate are dominated by sodium and chloride, which are the dominant elements in rainwater. These waters are said to be ‘rain-dominated’ (Davies & Day, 1998).
- Rain- or rock-dominated rivers can flow through arid areas in their lower reaches. Much water evaporates there and the concentration of salts in the water increases. These waters are said to be ‘evaporation-dominated’ (Davies & Day, 1998).

Human activities in the catchment area can influence the natural chemical composition of the water and affect water quality. Overall water quality can be measured as a set of physical attributes and chemical constituents. A description of some of these is given in Appendix B.

2.7.3.2 The flood regime

The hydrology of a river is important for many of the ecological processes in the river, such as maintenance of the river channel and of the wet biotopes. The ecological flow requirement of a system is defined as ‘that flow which is critical for the maintenance of the essential ecological functioning of the river’ (O’Keeffe *et al*. 1989).

Flow can be regulated and decreased by various human impacts such as impoundment, inter-basin-transfer or water abstraction. All these will affect the natural flow regime of the river. There are two aspects that determine the ecological flow: the base-flow and the flood regime.

The base-flow is the flow that is always present in the river. Base-flows keep hydraulic conditions suitable for the invertebrate life in many biotopes and function as refuges for fish (Davies *et al*. 1993). If base-flows are reduced there will be a change in the environmental conditions of the river. The assumption of Prewitt & Carlson (1980) is that this change is seldom linear, but usually exponential or asymptotic. This means that the river can deal with a slight modification, but as soon as the flow reduction reaches a certain critical level, it will have severe effects. This point is known as the inflection point. If the water level in the river becomes lower, initially it will only mean a slight reduction in the benthic habitat. As soon as the stony bed is reached, the entire benthic habitat is lost and serious changes take place in the riverbed (O'Keeffe *et al*. 1989).

The flood regime or variability in flow is at least as important for the basic ecological functioning of the river as the base-flow. Floods keep the river channel in shape and heavy floods can modify the river channel. They are also important for fish breeding and can flush poor quality water from pools. Rivers in South Africa are characterised by a seasonal flow pattern. The predictable seasonal changes in flow have resulted in specialized aquatic communities, adapted to both very fast flowing and almost stagnant waters. In rivers that experience severe spates, serious droughts or unpredictable floods only an impoverished faunal community will persevere. In the Western Cape big floods will only occur in the winter months, but summer floods (also called freshets) have an equally important role for river functioning (Department of Water Affairs and Forestry 1994).

Hynes (1970) mentioned that floods that almost fill the river channel are the ones that maintain the channel form. This level is called the bankfull discharge and is reached, on average, about every 1.5 years. Bigger floods have longer occurrence intervals and can be expressed as a factor times the bankfull discharge.

The characteristics of individual flood events is best described by the hydrograph shape. The hydrograph is the measured discharge by a water level recorder, plotted over time, starting with the beginning of the rainstorm. The volume of the flood event determines whether there will also be a flood downstream (Bosch *et al*. 1986).

The different habitats on the riverbanks are all affected by the different types of floods. The flood regime creates a diversity of temporary wet habitats on the riverbanks, which are discussed below.

2.7.3.3 The riverbank

A cross-section through a riverbed shows different habitats, which are affected differently by different flow levels. The conditions in these habitats are determined by the frequency of flooding and by the inundation period. The geomorphology determines how wide the lateral riparian zone is. Where slopes are flat and soils have a high water holding capacity a floodplain will develop and create a very wide riparian zone. Usually, the development of the riparian zone becomes more significant in mature rivers of a high stream order. Exceptions are the riparian forests and the source-area seepages, which can also be very wide (Rogers & Van der Zel 1989).

The riparian zone should be distinguished from the phreatic zone, an area recognised by forest hydrologists to describe the area adjacent to watercourses in which trees have constant access to freely available water (Bosch & Versfeld 1982).

The riparian zone is an interface between the terrestrial and the aquatic ecosystem and it has considerable influence on the aquatic ecosystem. Most of the nutrient inputs into the river ecosystem come from the riparian zone (Naiman & Décamps 1997) and the riparian vegetation also serves as an allochtonous food resource for aquatic organisms (King 1981; Stewart & Davies 1990). Riparian ecosystems are extremely complex and are rich in ecological processes. Flooding influences the terrestrial ecosystems while nutrient inputs and subsurface flows have a large impact on the aquatic ecosystems (Gregory *et al*. 1991; Naiman & Décamps 1997).

The first author who described the influence of the river on the vegetation growing on its banks was Illichevsky (1933). Thirty years later, Kopecky (1969) dealt with the vegetation in the riparian zone in detail. He classified European watercourses according to the following criteria:

- the vertical division of the river banks into riparian and subriparian zones.
- the range over which the water level fluctuates.
- the intensity of wave action or speed of flow.

Two fundamental bank types are distinguished by him, based on the amplitude of fluctuations of the water level. The stenosaleutic type is characteristic for small watercourses and for rivers with wide beds and very flat banks. The difference between maximum and minimum yearly water levels does not exceed 0.60 m. In general, riverbanks in the mountain stream zone belong to this type. The eurysaleutic type, in which the water level fluctuates more than one meter, is found more in the lower parts of rivers (Kopecky 1969). The distinction between constricted and unconstricted reaches, as mentioned by Gregory *et al.* (1991), shows much similarities with this subdivision.

The stenosaleutic type of riverbanks can be divided into at most four different ecotopes according to the time spent under water. The submerse ecotope is permanently under water. The demerse ecotope is mostly under water; it is exposed only shortly during the dry season. In smaller rivers this ecotope will barely be recognizable. The semimerse ecotope regularly dries out and is then wetted again during a small flood. This is the lower zone of the riparian zone, which we will later refer to as the Wet Bank. Finally, the emerse ecotope is the area of the riparian zone that will only be inundated during high floods. In every ecotope different vegetation types are recognizable. In the eurysaleutic type, where oscillations of the water level are much higher, the differences are much more distinct. Here the semimerse ecotope can be subdivided into the subsemimerse and the suprasemimerse ecotope (Kopecky 1969).

The riverbanks can be divided into lentic and lotic parts when they are flooded. In the lentic parts the water movement is decreased to a minimum and the silt load will be deposited in these places (Kopecky 1969).

Since Kopecky (1969) many authors have proposed different classifications of riparian habitats. Many kept it very simple, such as Hupp & Osterkamp (1985) and Gregory *et al.* (1991). Different classifications apply to rivers with a different geomorphology, for example the classification by Menges & Waller (1983) applies to rivers with floodplains, while Dixon & Johnson (1999) deal with vegetation on steep river banks. Menges & Waller (1983) base their subdivision on the life strategies of the plants growing in each zone while most other authors base the subdivision on the ecological processes that take place. This is a problem because different reaches are dominated by different processes. In the higher reaches erosion dominates, while in the lower reaches deposition is more important (Davies & Day 1998). There are also the different influences that floods can have on the lateral zones. There are reaches that are mainly affected by the inundation of floodwater (Kopecky 1969; Menges & Waller 1983;

Rogers & Van der Zel 1989), while others are mainly affected by flood power (Bendix 1999).

Mountain streams have banks of the stenosaleutic type (Kopecky 1969). While studying mountain streams the following terminology was developed by Boucher & Tlale (1999) for the rivers of Lesotho (see Figure 2.11): Aquatic Zone for the perennial free water zone, Wet Bank Zone for areas inundated by the wet season flows or intra-annual flows and Dry Bank Zone for the areas inundated only by inter-annual flows.

These lateral zones can be subdivided further. The Aquatic Zone is subdivided into a zone that dries up during the dry season and the zone where there is always water (compare Kopecky's (1969) demerse ecotope). The Wet Bank consists of a Sedge Zone and a Shrub Zone, flooded respectively by the low flow and the high flow during the wet season. The Dry Bank can be subdivided in a Lower Dynamic Zone, Tree/Shrub Zone and a Back Dynamic Zone. The dynamic zones are the areas where erosion and deposition occurs. Both have a lot of disturbance by people, cattle and animals, but they are flooded less than once a year (Boucher & Tlale 1999).

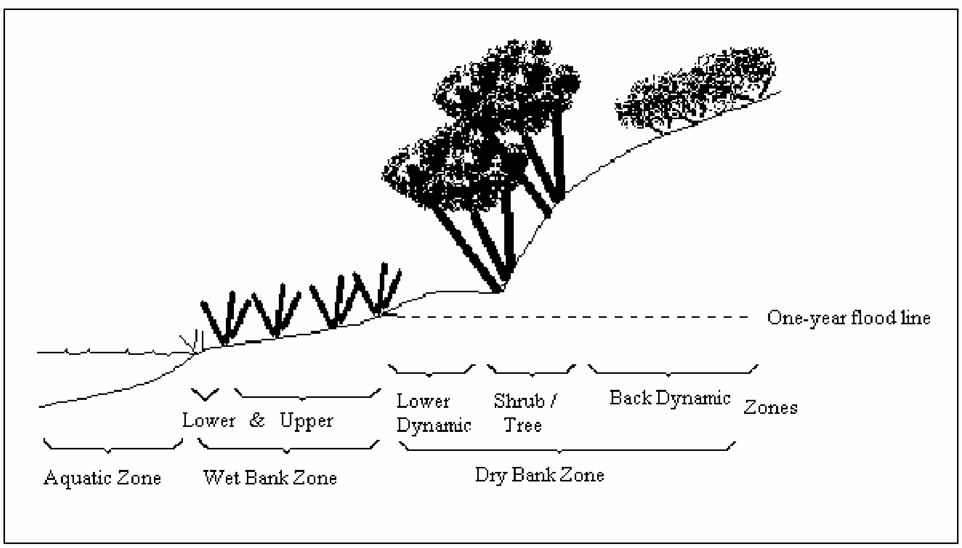

Figure 2.11: Zonation of riparian vegetation in Southern Africa (after Boucher & Tlale 1999).

The current study follows the terminology of Boucher & Tlale (1999), because it uses criteria that can be derived directly from the vegetation as well as the hydrology, so it is quite practical in its use. However, the streams in this study are in higher reaches than the ones studied in Lesotho and fewer zones can be recognized because zones tend to concatenate on each other.

The riparian vegetation has the following functions in a riverine ecosystem:

- control of water velocity, slowing and spreading flood waters;
- control of erosion of riverbeds and banks;
- water retention, thus increasing evapotranspiration and groundwater recharge;
- increased deposition rate of organic and inorganic suspended solids;
- nutrient retention and sink for pollutants;
- enhancement of biotic diversity through heterogeneity of habitats.

For these reasons laws protecting the riparian vegetation against afforestation have been in existence for a long time in South Africa (Rogers & Van der Zel 1989). Nowadays, the importance of the riparian zone for river management is widely recognized and the study of riparian systems is included in many environmental impact assessments for rivers (MacKenzie *et al.* 1999; King *et al.* 2000; Ward & Wiens 2001; Zalewski *et al.* 2001).

It is not only that the flood in the river influences vegetation growth; the opposite is also true. The processes of erosion and accumulation mutually depend on each other and are influenced by the riparian vegetation. During a high flood, the vegetation on the riverbank slows down the current in the river, thereby stimulating the deposition of sediments. However, if the current is slowed down in one part of the river, the current will be accelerated in another part, which would then in turn stimulate the erosion process. In this way riparian vegetation exerts considerable influence on channel morphology and thus on floods. It is also the vegetation that determines where sediments in the stream accumulate; this accumulation will also slow down the current (Kopecky 1963). The density of the riparian vegetation has a big impact on the bed roughness of the river and thus on the flood discharges to be expected in a particular reach (Gordon *et al.* 1992; McKenney *et al.* 1995).

Plants growing next to a river channel have strategies to cope with the differences in depth of the water table and inundation (Menges & Waller 1983). Hydrologically, riverbanks can be divided into two types: the floodplain type and the bank-storage type. In the floodplain type, inundation (permanent or periodic) is the main determinant of structure and functioning of the ecosystem. This type is usually only found in the lower reaches, but it can also occur in high altitude seepages. In the bank-storage type inundation is absent or infrequent and the groundwater level is the major determinant of ecological processes (Rogers & Van der Zel 1989).

Both situations imply stress-factors for the plants. The main stresses that occur in a situation of bank-storage are a result of either anaerobic conditions when the soil is saturated, or water stress that occurs during the dry season or droughts. During floods the stress of extended periods of inundation results in anaerobic conditions in the soil. There might be toxic effects of certain nutrients during anaerobic conditions. There are many different strategies to cope with these stresses (Pezeshki 1994). Turbulent conditions during floods cause destruction by uprooting plants, which results in a decrease in their density. The juvenile stages are especially sensitive, because they do not have extensive root systems. However, this also brings new opportunities for the establishment of seedlings of the same or other species (Rogers & Van der Zel 1989).

2.7.3.4 Anthropogenic influences

Human interference can upset the natural situation described in paragraphs 2.7.3.1 to 2.7.3.3. Water quality is affected by pollution, the flood regime can be altered by dams and weirs and the riparian vegetation can become invaded by exotic species. Methods have been developed to make an assessment of the conservation status of riverine ecosystems in South Africa, but no standardized methods exist. In the Western Cape, the method developed by Kleynhans *et al.* (1988) is applied most often.

Pollution

The word pollution here refers to any alteration of the natural state of the water quality, mostly caused by humans. The most visible forms of pollution, such as cans and bottles near the river, often draw most attention, but this is not always the worst form of pollution. Many toxic substances can be spilt into the river system that are not readily visible but may have disastrous effects. Even many naturally occurring substances can become pollutants, when their concentrations increase until they reach toxic levels. Detailed accounts of pollution are given by Hynes (1963) and Davies & Day (1998).

Dams and weirs

In a country like South Africa, with an unpredictable rainfall and with very few natural lakes, reservoirs are needed to ensure that there is sufficient water available for human consumption and agriculture, even during periods of drought. This is why nearly every major river in South Africa is impounded in at least one place. However, dams are a major threat to the riverine ecosystems. A general account of the influence of dams on water quality downstream, fisheries, floodplains and estuaries can be found in Ward & Davies (1984).

Locally, following construction of an impoundment, the riverine ecosystem changes completely as the river turns into a lake. After a dam is constructed the impounded water enters an unstable phase in which environmental factors fluctuate strongly. In this phase many minerals leach from the inundated soils, some of which may be toxic. They change the water chemistry substantially and many aquatic organisms may become extinct or be replaced by others (Davies & Day 1998).

The flow regime of a river below a dam is influenced considerably by the management of water discharge from the dam. Naturally, river flows can be quite unpredictable. Regulated rivers, though, have few small floods and less extreme events such as big floods or complete droughts, and the variation in flows will become more predictable and less variable. This will have a direct influence on organisms living in the stream and the riparian habitat. Things that might happen when dams are not well managed, are loss of biodiversity, collapse of estuarine fisheries, loss of riparian vegetation and more severe floods (Ward & Davies 1984; Davies *et al*. 1993).

A reservoir, therefore, has two immediate influences on the river downstream: it affects its water quality and its flow regime. Ward & Stanford (1979) deal with both in detail and show that the disturbance caused by a dam will diminish at some point downstream. The reset distance to this point is determined by the level of disturbance and of the reach in which the dam was built. In general, dams in the upper and lower reaches are more favourable than those in the middle reaches because the reset distances are the smallest here (Ward & Stanford 1983; Ward & Davies 1984). Drier conditions due to lower flood levels place the riparian vegetation under stress. This increases the potential for invasion by exotic plants (Macdonald & Richardson 1986).

Exotic plants

The above-mentioned anthropogenic influences will mainly affect the lower reaches of a river. The only disturbance likely to occur in both the upper and lower reaches is the threat of alien invasive vegetation. Few of the herbaceous invasive species have had a serious impact in the mountains; the majority of the troublesome species are woody shrubs (Macdonald & Richardson 1986). This also implies that many of the ecological processes in the vegetation change after it becomes infested with alien species. Species diversity will decrease because understorey shrubs are not adapted to shady conditions and fuel loads of the vegetation will increase (Versfeld & Van Wilgen 1986).

The Fynbos Biome is extremely sensitive to invasion by exotic plants. Many species that have been introduced into the whole of South Africa are only invasive in the Fynbos Biome. Invasive species need an effective dispersal agent, a suitable habitat and a competitive advantage over the indigenous vegetation in order to establish themselves. Even if they can grow vigorously, climatic conditions may prohibit seed setting or dispersal (Kruger *et al.* 1986). Yet, some species like *Pinus pinaster* and *Hakea sericea* are able to invade undisturbed Mountain Fynbos communities. The phenomenon that alien species invade indigenous communities without a disturbance having taken place is very rare throughout the rest of the world (Richardson *et al*. 1992).

Rivers form a specific habitat for the dispersal of another group of invasive exotic plants, the Australian *Acacia* species, that are mainly dispersed by ants, although some species may be dispersed by birds and by water (see below). Riparian habitats are invaded by a number of species, among them *Acacia longifolia*, *A. mearnsii*, *A. saligna*, *Paraserianthus lophantha* and *Sesbania punicea*. The flooding of the riparian zones may scarify the hardcoated seeds of the acacias and stimulate their growth here. They are also very well adapted to the fire regime in the Cape, because their natural habitat in Australia is also very fire-prone (Richardson *et al*. 1992).

Some of the *Acacia* species have established mutualisms with indigenous animals that disperse their seed. This includes dispersal by birds, mammals and ants. Some introduced animals, like the European starling (*Sturnus vulgaris*), also assist in the dispersal of the *Acacia* ssp. Like most species of legumes, *Acacia* spp. have nitrogen-fixing bacteria in their roots that facilitate the species in coping with the low nutrient levels found in the biome. This will also alter the conditions in the soil and the water quality in the streams (Macdonald & Richardson 1986).

2.7.4 Rivers in the study area

The five rivers that have their origin in the study area will now be discussed together with their ecology and the anthropogenic disturbances that were discussed above.

2.7.4.1 Eerste River

The Eerste River rises in the Dwarsberg with a maximum altitude of 1200 m. It flows through the town of Stellenbosch and then bends southwards towards False Bay. Three major longitudinal zones are evident: the Mountain Stream Zone, which flows mainly in the section within the Hottentots Holland Nature Reserve through indigenous fynbos and riparian forest, the Upper River Zone, which flows through the Jonkershoek Valley down to the town of Stellenbosch and the Lower River Zone which flows from Stellenbosch to the sea (Figure 2.12).

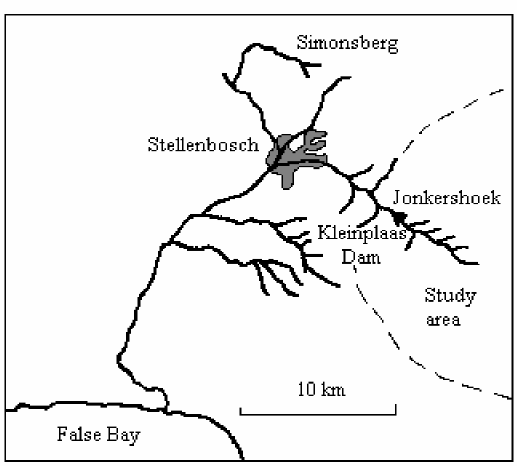

Figure 2.12: The Eerste River catchment area.

Parts of the upper reaches of the river have been studied in some detail, *inter alia* the aquatic animals by King (1981) and vegetation by McDonald (1985) and Van Wilgen & McDonald (1992) This last study was done in the Swartboskloof subcatchment, which was one of the intensive study sites for the Fynbos Biome Project.

The study by King (1982) on the invertebrate fauna of the Eerste River provides some information about the physical environment of the river. Discharge in the river is biggest in winter with major spates in May and July, and lowest between December and March. Water temperature in winter is low in all reaches of the river (between 10°C and 14°C), but shows increase downstream during summer. Variations in pH are small between the different seasons, but water tends to be more alkaline in the lower than in the upper reaches. The amount of nutrients and the buffering capacity increase downstream and are generally higher in summer than in winter.

In the higher reaches of this river, Table Mountain Group sediments are dominant, but lower down in the valleys granites of the Cape Granite Suite and alluvial sediments dominate. Waters draining such areas are naturally pure and have a low buffer capacity.

The Kleinplaas Dam, just below Jonkershoek on the Eerste River (built in 1981) holds water from the Riviersonderend-Berg-Eerste River Government Water Scheme through a series of interconnecting tunnels and an Interbasin Transfer Scheme. The advantage of this system is that water can be released from the Theewaterskloof Dam when water demand exceeds availability in the Eerste River Valley itself. Therefore the Kleinplaas Dam is said to be a balancing and diversion structure. Petitjean (1987) estimates that 48% of the run-off of the river is abstracted to other catchments. The compensation flows from Theewaterskloof Dam are allocated entirely to the water users such as farmers and industries. This results in a water shortage between the Kleinplaas Dam and Stellenbosch during the summer months (Petitjean 1987).

The dam is also used as an experimental trout breeding station administered by the University of Stellenbosch. Investigations are under way to assess the feasibility of building a second dam higher up the river than the Kleinplaas Dam and for a third along the lower Eerste River at Faure (Brown & Dallas 1995).

Downstream from the nature reserve the river flows through agricultural land (mainly vineyards) and is more often accompanied by exotic trees such as oaks (*Quercus robur*), poplars (*Populus canescens*) and gum trees (*Eucalyptus* spp.). The indigenous vegetation that remains, mainly consists of *Metrosideros angustifolia* and *Brabejum stellatifolium* (Brown & Dallas 1995).

In this zone and below, water abstraction takes place to such an extent that parts of the river cease flowing in summer. This has serious consequences for the riverine ecosystem. Firstly, decrease in flow means an alteration of the physical habitat. This has a big influence on the life cycles of the aquatic biota, for example on the passage of fish. Secondly, reduced discharge means that the pollution that enters the river in the lower parts is not diluted (Brown & Dallas 1995).

In the Lower River Zone, the river is heavily polluted, especially downstream from the confluence with the Plankenbrug and Veldwachters Rivers. Petitjean (1987) states that this has already been the case for a fairly long time, ever since the sixties. The two tributaries of the Eerste River in Stellenbosch have a deleterious effect on the river. The Plankenbrug River rises in the Simonsberg and runs through an agricultural area. The Veldwachters River receives effluent from the Stellenbosch Municipality Sewage Works (SMSW). Although the Eerste River is a Special Standards River, the SMSW has been granted a license to release its General Standard effluent into the Veldwachters River. In summer, 95% of the flow in the Veldwachters River is sewage effluent (Petitjean 1987; Brown & Dallas 1995).

The Eerste River has a high conservation status in its upper reaches, and a low conservation status in its lower reaches. This is a pattern that occurs in many of the rivers in the region. The conservation importance of the river is determined by its proximity to the town of Stellenbosch and its recreational use in that area (Brown & Dallas 1995).

2.7.4.2 Berg River

Nearly the whole northern section of the Hottentots Holland Nature Reserve is drained by the Berg River (Figure 2.13), with the exception of the area around the Franschhoek Pass, which is drained by the Riviersonderend River. The catchment consists of three main streams: the Banghoek River, and the streams in Wolwekloof and Assegaaibosch Kloof (see Figure 2.1). These last two rivers join near Franschhoek and from there the Berg River flows in a northerly direction. The Banghoek River flows to the northwest and unites with the Dwars River that joins the main stream near Paarl. With the exception of Banghoekkloof, the Berg River catchment is in the least natural state of all the river catchments in the Hottentots Holland Range. There is a huge pine plantation, managed by SAFCOL at La Motte, in the valley near Franschhoek and many exotic species grow next to the river.

After an extensive feasibility study in 1997, the Minister of Water Affairs gave permission for the construction of a new dam for water supply to the Cape Metropolitan Area in the Franschhoek area. This proposed dam, the Skuifraam Dam, will be part of the Riviersonderend-Berg-Eerste River Government Water Scheme and will be connected to the existing system in Theewaterskloof Dam by a pumping station and a pipeline. At present the Berg River receives water from this scheme during summer.

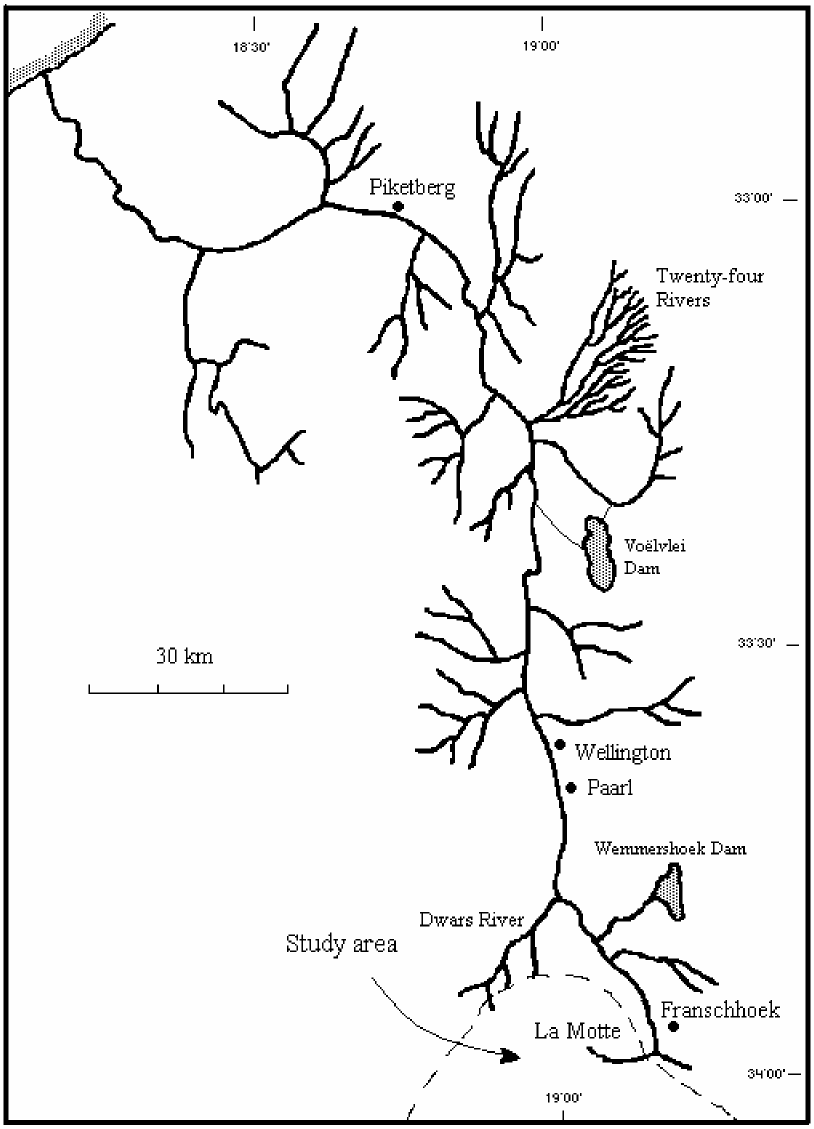

Figure 2.13: The Berg River catchment area.

The feasibility study for the new dam investigated and attempted to define the Instream Flow Requirements for the river. Discharges were calculated for baseflow and the winter and summer high flow events. The summer high flows, also called freshets, were found to be at least three times the baseflow and occurred on average three times a year. Winter floods were usually much bigger. The definition of a flood used in this study is that it needs to scour the top of the riverbed. In this river, a flood of more than 30 m^3/s (average daily flow) is able to clear the channel and move cobbles. Floods bigger than 64 m^3/s control channel forming and floods bigger than 77 m^3/s will change the channel form. This last category occurs in the Berg River once in two years on average. The flood events together with the freshets are important for the conservation of *Barbus andrewii* (Witvis) which has been set as an indicator species for the most natural riverine habitat in this system. If this fish species will benefit from a particular flow regime, other species will also benefit (Department of Water Affairs and Forestry 1994).

Because of these environmental impact assessment studies much is known about the vegetation in this area. Burgers (1992) reports that virtually the whole Berg River between Franschhoek and Paarl has been destabilized, channelized and straightened by bulldozing. This disturbance now extends up to the La Motte plantation. The natural riparian vegetation there is virtually non-existent and is replaced by an exotic plantation. Especially *Acacia longifolia*, *A. mearnsii* and *Eucalyptus camaldulensis* are dominant (Boucher 1996). Burgers (1992) gives some suggestions that should reverse the degradation of the river:

- place a moratorium on channel manipulation and on any disturbance below the maximum flood level,
- introduce a riparian restoration programme with reference to exotic vegetation, reduction of bank erosion and to recreating natural habitats, and
- maintain an adequate flow for the purpose of the basic functioning of the river system.

In this last respect the Skuifraam Dam will be a major disturbance. The frequency and duration of the floods have to be managed very well in order to maintain the vegetation downstream from the dam.

Further downstream, the Berg River contains unique ecosystems in the form of extensive wetlands near its delta. Many disturbances upstream can effect ecosystems downstream, but tributaries downstream can ameliorate the effect of disturbances in the higher reaches. For this reason, the reach between Franschhoek and Paarl is defined as the ‘critical reach’ for the proposed Skuifraam Dam. Three Instream Flow Requirement sites have been sampled here (Department of Water Affairs and Forestry 1994, 1996).

The chemistry of the waters in the Berg River catchment is slightly different from the water in the other rivers in the region. Most conspicuous is that the water is ‘white’, while most of the other catchments have ‘brown’ waters (see section 2.7.1.1). The general rule is that the darker the waters are, the more acidic it is. In this case, the Berg River is an exception, because the water is also acidic (pH 4.3-5.6) (King & Day 1979).

2.7.4.3 Riviersonderend River

The whole northeastern part of the study area is drained by the Riviersonderend River. The main tributaries of this catchment are the Riviersonderend Kloof, Boegoekloof, Noordekloof, Boesmanskloof and Dutoits Rivers (see Figure 2.1). The Riviersonderend River rises at an altitude of approximately 1590 m in Somerset Sneeukop. All the above-mentioned tributaries flow into the Theewaterskloof Dam, which is situated at an altitude of 300 m. Further downstream the Riviersonderend River is joined by tributaries draining the Riviersonderend Mountains. After about 100 kilometres it flows into the Breede River near Swellendam (Figure 2.14; Ractliffe *et al*. 1996).

The Theewaterskloof Dam was built in 1979 but only reached full capacity in 1993. The impoundment acts as the source reservoir for the Riviersonderend-Berg-Eerste River Government Water Scheme. It supplies water to Greater Cape Town, Stellenbosch, Franschhoek and Paarl and to four agricultural areas: the Riviersonderend River Valley, the Eerste River Valley, the Berg River Valley and the Overberg Area (Petitjean 1987). When the dam will receive water from the Skuifraam Dam in the Berg River, the water level might be raised by a maximum of 0.7 m. Since the dam reached its full capacity in 1993, the river downstream from the dam showed a marked departure from its original state, particularly in respect of the flood periods and flood peaks. Delays of up to three months from the first winter floods have been recorded. Now these usually occur in July and August, while they used to be in April and May in the pre-dam period. The period with winter floods is also much shorter now. The decrease in the baseflow is most severe in the periods that are transitional between wet and dry, sometimes endangering the basic living conditions for the aquatic biota. On the other hand, however, releases of water in summer for irrigation have doubled the summer baseflows. The impact of the dam is the greatest immediately downstream from the dam; the runoff from the Riviersonderend Mountains ameliorates the effects of the dam to a certain extent. The absence of large scouring floods downstream of the dam resulted in the encroachment of bankside vegetation, especially aliens, into the riverbed and in the deposition of fine particles in shallow riffle and run areas (Ractliffe *et al.* 1996).

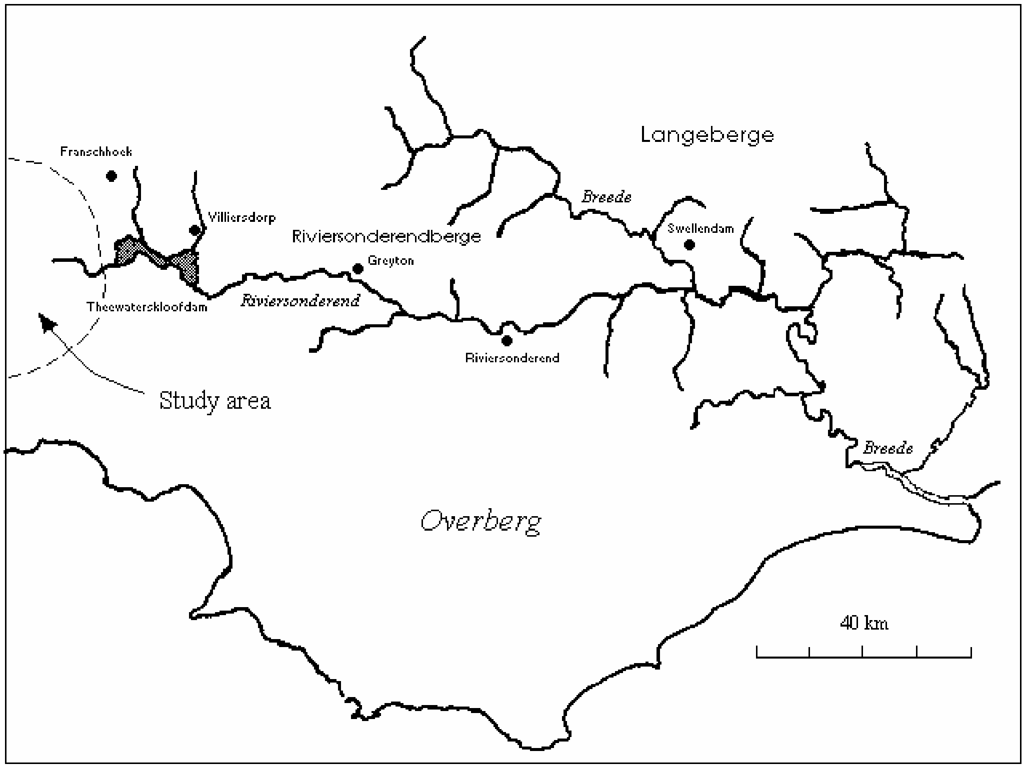

Figure 2.14: The Riviersonderend catchment area. Note that the upper reaches of the Breede River are not on this map.

The geology in the different reaches of the river has its influence on the water quality (see Figure 2.6). The headwaters of the Riviersonderend River are strongly acidic because of the highly leached soils in this area. Acidity fluctuates seasonally with generally lower pH values in winter. The headwaters also have very low concentrations of major ions but these increase downstream of Theewaterskloof Dam. Partially this can be explained by the different geological formations in the lower reaches of the river (Bokkeveld Group shales), but they are also a consequence of agricultural activities (Ractliffe *et al.* 1996).

A conservation status assessment has been conducted for the whole river (Ractliffe *et al.* 1996). The conservation status gives an indication of how much an ecosystem has changed from its natural state due to anthropogenic factors. These factors can be abiotic, such as water abstractions, weirs, dams and pollution, or biotic such as infestation with alien plants or animals. The riparian zonation patterns have also been described at several localities. There is no standard method to determine the conservation status of a river, but the method proposed by Kleynhans *et al.* (1988) has been applied on several other rivers in the Western Cape so that a comparison is possible.

The study by Ractliffe *et al.* (1996) found that the condition of the river upstream from the dam is good except for a limited stretch of pine plantations. Immediately downstream of the dam, at Keeromspoort, the river is also relatively undisturbed, but the dam has had a considerable impact on the flow regime. The lower reaches were assigned low conservation status values; nowhere below the Keeromspoort was the riparian vegetation found to be in a reasonable state. Farmers have extended their fields into the channel or onto instream islands or they have bulldozed secondary channels. Other disturbances include removal of indigenous vegetation, abstraction of water for irrigation purposes, closure of small channels and dumping of litter and rubble (Ractliffe *et al.* 1996).

The river condition is affected especially by the encroachment of riparian vegetation into the river channel, especially by exotic species but also by the indigenous *Prionium serratum*. The floating aquatic weed *Eichhornia crassipes*, an aggressive invasive alien, will invade more of the river as nutrient enrichment follows water abstraction. The indigenous aquatic herbs, such as *Aponogeton distachyos*, will also benefit from the new flood regime with a reduction in current speed (Ractliffe *et al*. 1996).

2.7.4.3 Palmiet River

The Palmiet River rises in Landdroskop at an altitude of 1322 meters. In total, the river is 70 kilometres long and is fed by eleven perennial tributaries with a catchment greater than 4.5 km^2. Three of these are located in the Hottentots Holland Mountains: the Keeroms River, the Wesselsgat River and the main stem of the Palmiet River (see Figures 2.1 and 2.15).

For the first four kilometres, the river flows through Mountain Fynbos before it swings south into the Elgin Valley, where it is first impounded by Nuweberg Dam and then by Eikenhof Dam. After that the river flows through the urban and industrialized area of Grabouw. Below Grabouw the river is impounded a further three times, in respectively the Applethwaite, Kogelberg and Arieskraal Dams. The river between Grabouw and the confluence with the Krom River flows through an intensively cultivated area containing plantations and deciduous fruit orchards. The lower Palmiet River flows through the Kogelberg State Forest, which was declared as South Africa's first Biosphere Reserve under UNESCO in 1999. As such there will be much pressure to keep the lower river in the present state. Because nearly 50% of the water in the upper part of the river is impounded, it becomes clear that the tributaries in the lower parts play a major role in normalising a semblance of a natural water regime in the lower Palmiet River. Below the Arieskraal Dam the Palmiet River is met by the Klein Palmiet, the Dwars- and the Louws Rivers (Brown & Day 1998).

There are five impoundments along the entire length of the river, most of which are used for irrigation supply. Only water from the Kogelberg Dam pumped into Rockview Dam is used to generate electricity as part of the Palmiet Pumped Storage Scheme. The transfer of another 50 million m^3/a of water through this scheme to Cape Town has been approved. This will probably have a severe impact on the lower parts of the river. Except for the in-channel impoundments, there are also numerous farm dams on the Palmiet River and its tributaries the Huis- and Krom Rivers. In some areas water is also abstracted directly from the river for irrigation purposes (Brown & Day 1998). The river used to be known by the Khoisan people as 'Houtema' or Snake River, because of the way it meanders through the Elgin Valley. The modern name is derived from a common plant species lining its banks: *Prionium serratum* or palmiet. However, there is little left of the dense beds of this species found in old times, due to the many impoundments on the river and invasions by exotic tree species. Yet, many of the riparian communities of the Lower Palmiet River are in a very good condition and they are unique for the lower reaches of any river in South Africa (Boucher in Brown & Day 1998).

The geology of the upper and the lower reaches of the Palmiet River is dominated by sandstones of the Table Mountain Group (see Figure 2.6). In the middle reaches more erodable shales and sandstones of the Bokkeveld Group occur. Soils in the latter area are richer in nutrients and this explains, together with the suitable climate, why the Elgin Basin is so intensively cultivated. The water quality of the river is most affected in this area. Runoff from the agricultural lands causes elevated loads of nutrients and silt. Loads of silt result in higher turbidity levels and this again results in less light penetration, low primary production and less food available for organisms higher in the food chain. The accumulation of nutrients causes eutrophication and the increased presence of algae, which may become pests. Fertilisers and biocides are frequently applied on agricultural land and this occasionally leads to runoff of toxins into the river (Brown & Day 1998). Afforestation, which is quite extensive a little upstream from the agricultural area, can cause a lot of erosion and thus a higher silt load, especially during periods when the soil is left exposed before trees are planted (Brown & Day 1998).

In an ecological status assessment conducted in 1998 the worst impacted part of the river appeared to be the area between the N2 and the confluence of the Klein Palmiet River, which is seriously modified, while the upper and the lower reaches are largely natural with few modifications (Brown & Day 1998). The desired state of the river was determined in a sociological study undertaken by Dr. B. Gale in 1998 in which as many interested and affected parties were asked about their needs and wants. The river in the immediate vicinity of Grabouw is mostly used for agricultural, domestic and industrial purposes, while the lower reaches and the estuary are given a high rating for recreation and conservation. People living in the catchment area indicate a strong desire for this part of the river to be maintained or improved (Brown & Day 1998).

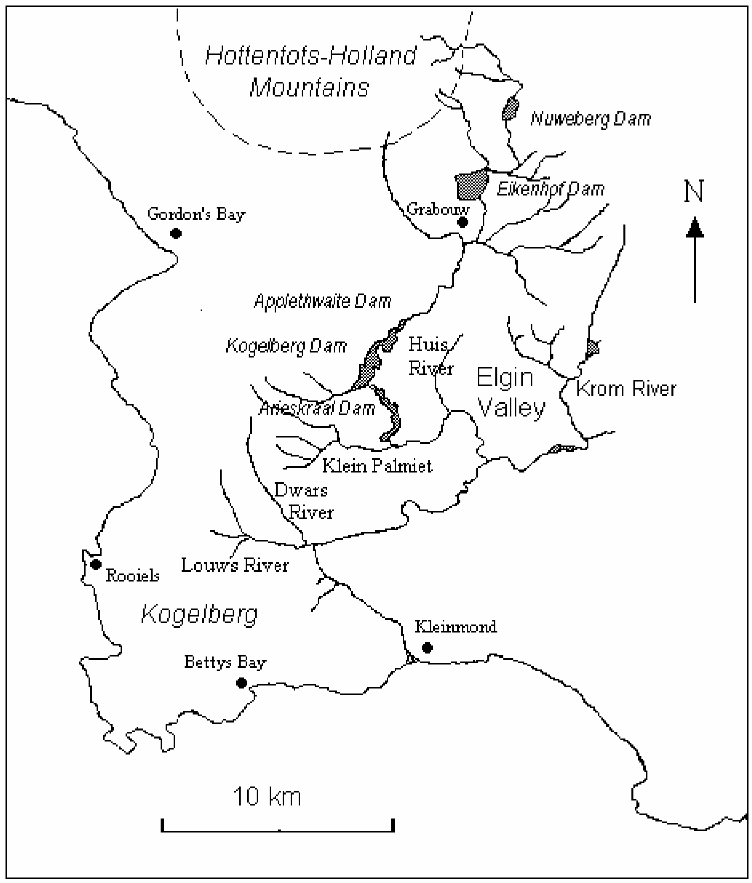

Figure 2.15: Map of the Palmiet River catchment area.

2.7.4.5 Lourens River

The Lourens River was originally called the Tweede River (Heap 1993). It is the shortest of the rivers treated in this study and its catchment area is also the smallest (see Figure 2.1 and 2.16). The lower parts of the river flow through the highly industrialized area of Somerset West. Because the river regularly floods and causes damage in the urban areas an extensive study has been undertaken to plan the stormwater management system and its ecological effects (Tharme *et al*. 1996).

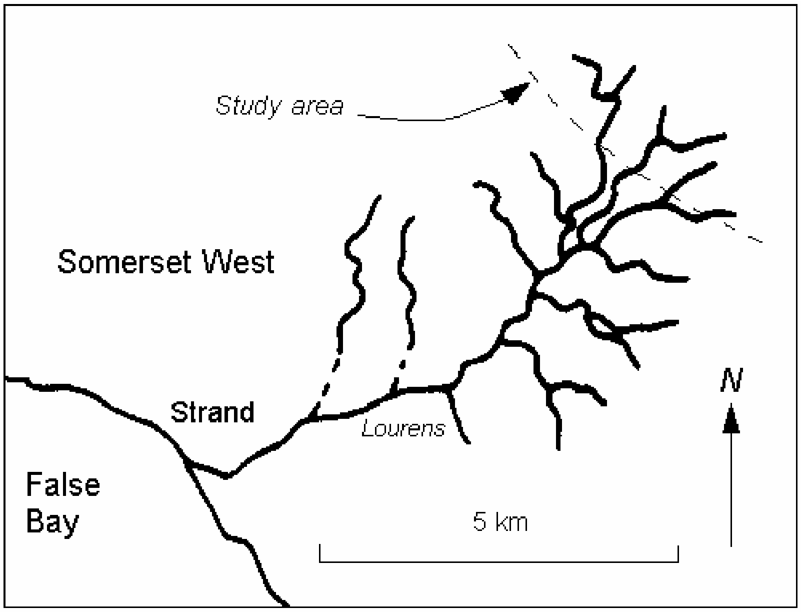

Figure 2.16: Map of the Lourens River and its catchment.

The river is sourced at an altitude of 1080 m in the Diepgat Ravine. It has no major tributaries, but there are some minor ones from Landdroskloof and Sneeukopkloof. In total it drains an area of approximately 140 km^2. Over its length the river is divided into four zones. The first zone is the very steep mountain headwall zone, which is virtually inaccessible. The underlying geology is Table Mountain Group sandstone. The second is the mountain stream zone, which partially flows through pine plantations. This zone is characterised by a heterogenous bed with boulders and cobbles and a great diversity of suitable instream biotopes. Here the river flows through a narrow strip of granites of the Cape Granite Suite. The third is the foothill zone, which mainly flows through agricultural and urban areas. This zone is characterised by a much more homogeneous bed and by more sedimentation of silt and mud. The latter is due to unusually high silt loads because of bank erosion, poor agricultural activities and low summer flows. This zone and the next flow through the coastal plains. The last zone, the lower river zone, is characterized by shallow slow-flowing areas where most of the natural vegetation has been removed (Tharme *et al*. 1996).

The water quality of the river is highly affected in the area just below the Mountain Stream Zone. This zone is subjected to agricultural runoff, afforestation and severe erosion. It has a high impact on the zones downstream of it, although the impact decreases with distance further downstream.

Within the borders of the Hottentots Holland Nature Reserve, the vegetation around the river is still pristine but the number of exotics increases downstream. A special threat is kikuyu grass (*Pennisetum clandestinum*) which forms monospecific stands that suppress the growth of shrubs and herbs usually found next to rivers. There are also the usual exotic trees such as *Acacia longifolia*, *A. saligna* and *Sesbania punicea* (Boucher, in Tharme *et al*. 1996).

A river conservation status assessment has been made for the Lourens River. The conservation status decreases downstream. The most serious problems are:

- removal of indigenous vegetation and infestations of exotics,
- decrease of water quality because of various effluents,
- overabstraction of water,
- dumping of rubbish and litter,
- physical manipulation of the river channel to prevent flooding and erosion, and
- settlement of solids because of erosion.

Due to the efforts of the Lourens River Conservation Society, the river gained the Status of Protected Natural Area in 1997, which offers one of the highest forms of legal protection for a natural ecosystem (Tharme *et al*. 1996).

Because the Lourens River flows through a highly urbanized area it also faces a special problem. The hardening of the surrounding catchment area through the construction of houses, roads and other infrastructure has increased the runoff to the river beyond its natural capacity. This causes more and more serious flooding. One-in-twenty year floodlines become one-in-five year floodlines and areas that are seldom flooded in natural conditions are flooded regularly. A diversion canal for high floods would be ecologically the most responsible way to deal with this problem (Tharme *et al*. 1996).

3. Methods used in this study

3.1 The Braun-Blanquet method

The method of describing and investigating vegetation that is used in this study is the Braun-Blanquet method (Westhoff & Van der Maarel 1973; Werger 1974). This method is the most widely used method of describing and classifying vegetation at the end of the twentieth century and has borrowed concepts from many different and divergent traditions in that century (Whittaker 1962). Most prominent among these are the ‘individualistic concept’ (Gleason 1917, 1926, 1939), which stresses the continuum in vegetation patterns, and the ‘holistic’ concept (Clements 1916, 1928), which stresses the existence of plant communities. For a detailed description of the Braun-Blanquet method and its development see the following references: Braun-Blanquet (1928); Tansley (1939); Whittaker (1962, 1973a); Shimwell (1971); Mueller-Dombois & Ellenberg (1974); Westhoff & Van der Maarel (1973); Kent & Coker (1992); Westhoff & De Smidt (1995) and Mucina (1997).

The most important addition to the ‘classical’ approach of classification is the use of multivariate techniques to expose gradients within the vegetation (Bray & Curtis 1957; Whittaker 1967). These authors regard vegetation as a continuum across the landscape that is determined by environmental gradients. Especially after the introduction of information technology to ecology different types of ordination techniques were developed to expose these environmental gradients (Hill 1973, 1974; Hill & Gauch 1980; Ter Braak 1986, 1987). Some of these techniques make use of linear response curves of plant species to environmental gradients, while others make use of the Weighted Averaging method (Curtis & McIntosh 1951) to apply it to unimodal response curves. The techniques used in this study are mainly Correspondence Analysis or CA (Hill 1974) and Canonical Correspondence Analysis or CCA (Ter Braak 1986, 1987). A detailed description of the different ordination techniques can be found in Gauch (1982), Pielou (1984), Jongman *et al.* (1987), Ter Braak & Prentice (1988) and Legendre & Legendre (1999).

Nowadays, gradient analysis and classification are no longer seen as contradictory approaches to the study of vegetation. In most modern studies, vegetation research or phytosociology uses a combination of both approaches (Whittaker 1972; Westhoff & Van der Maarel 1973; Van der Maarel 1975). Even classification has been aided by multivariate statistics (Goodall 1973). The development of TWINSPAN (Hill 1979) provided an objective manner to classify vegetation types, although manual tabulation still plays an important role as well (Feoli & Orloci 1983).

3.2 A uniform approach ?

Since the Braun-Blanquet approach was introduced to the Fynbos Biome by Werger *et al*. (1972), much discussion has been going on about whether this approach is applicable in the fynbos or in species-rich environments in general.

One of the opponents to the application of the Braun-Blanquet method in the Fynbos Biome is B.M. Campbell. This author argues the identification of hundreds of different species will make classification nearly impossible. On more theoretical grounds his arguments concern the high gamma diversity in the Fynbos Biome. The turnover of species between the different mountain ranges is so high that environmentally and structurally similar communities will have a completely different species composition on different localities. In a flora with a turnover like this a structural-functional classification is more likely to be effective in revealing ecological gradients than a floristic classification (Campbell 1985, 1986a). It is true that in other species-rich areas in the world, the structural approach is often preferred because of taxonomic and practical problems. Shimwell (1971) refers to this as ‘the tropical tradition’. Although Werger & Sprangers (1982) conclude that their floristic and structural classifications of tropical dry forests in India do not differ too much from each other, they also prefer a floristic analysis because it reveals more about the ecological position of the vegetation within the complex of all communities. The decision on whether to choose a floristic or a structural classification is also largely dependent on the aims of the study.

Other counter-arguments are offered by Boucher (1987) and McDonald & Boucher (1999). It is true that there are still a lot of taxonomic problems in the Fynbos

Biome, but these generally concern the rare species while phytosociology is more concerned with general species. Turnover between species also often concerns related species and is especially high on the intraspecific level. Phytosociology does not only use one specific taxonomic level. In some cases, if it is ecologically or biogeographically significant, even an entire genus can be used as a characteristic taxon (Westhoff & Van der Maarel 1973). Turnover itself can only be examined precisely by comparing similar biotopes across the biome. The high gamma diversity also reflects the climatic gradients which are very strong in the Cape. The problem with the identification of species also affects the accuracy of the study. Only proper herbarium specimens are suitable for secure identification by a taxonomist, but most of the specimens encountered during vegetation surveys are in a vegetative state. Therefore, the researcher can best build his collections into a field herbarium of reference specimens, to assist him with the quick identification of vegetative or otherwise imperfect specimens.

Campbell (1985, 1986a, 1986b) developed a classification of the entire mountain vegetation of the Fynbos Biome on structural grounds. This classification is very suitable when a preliminary vegetation survey in a specific area is needed. A phytosociological study, however, is able to explain more detail about the specific area in question and the data can be used for further analysis afterwards (see also Boucher 1987).

The first phytosociological studies in the Fynbos Biome were carried out in the sixties and seventies (see Table 2.3 for references). During the eighties many other studies followed, but the east and the northwest of the biome are still under-represented. Data from the many studies are integrated in the VEGMAP project (McDonald 1997; Mucina *et al.* 2000) in which the classification of the entire Fynbos Biome has been achieved to the level of the vegetation class.

The most notable difficulty with the Braun-Blanquet method in the Fynbos Biome is the characterization of communities by character species, because a character species, *sensu stricto*, is a species that occurs in one community type only and differentiates it from all other community types. Because of the strong ecological gradients occurring in the Fynbos Biome, a species that is a character species for a specific community in one area can be a character species for another in another area, in other words these species are only local character species (Shimwell 1971). Regional character species are only represented by the endemics and these cannot be used when vegetation units of different mountain areas are compared with each other. One can argue that the use of character species was over-emphasized in the European context. In any event, the first priority is to develop a skeleton of syntaxonomic systems for the region, before researchers can realistically discern between character and differential species.

The information value of vegetation classification is increased considerably if the classification is combined with gradient analysis, especially in this biome where gradients abound. After the ecological significance of a species has been revealed through ordination techniques, their role in the classification and the characterization of communities is far more obvious. Autecological studies on dominant or differential species will also increase the understanding of this complex vegetation.

3.3 The sampling method

According to the Braun-Blanquet approach, vegetation samples need to be taken from homogeneous stands of vegetation. Several theories have been developed about how to deal with issues like homogeneity, sample size, sample number, stratification and measurement of abundance. Most of these are summarized by Mueller-Dombois & Ellenberg (1974), Werger (1974), Westhoff & Van der Maarel (1973) and Whittaker (1973a).

3.3.1 Homogeneity

A vegetation sample suitable for analysis using the Braun-Blanquet approach, also called a relevé, has to be homogeneous or uniform. This is the main criterion for the choice of the plots by the researcher. A homogeneous plot contains one vegetation type. There should be no obvious structural boundary in the plot. Differences in floristic composition within the plot are not allowed. It is common practice for a researcher to look for differences in dominant and abundant species in the research area and on this basis to define the different vegetation stands beforehand. Within these stands the contents of a number of homeogeneous sample plots can be recorded (Westhoff & Van der Maarel 1973).

The condition of homogeneity has a very important influence on the choice of sample plots. It has often been commented that the choice of the sample plots is subjective and thus less valid. The American researchers, in contrast, have often favoured a system of randomized plots. However, nearly every empirical science has to deal with the subjective choices of the researcher. Randomization of sample plots seems to have little effect on the results except that many samples have to be discarded because of heterogeneity, which results in a waste of research time (Whittaker 1973a).

3.3.2 Sample size

The size of a sample is largely dependent on the vegetation structure but if the vegetation stand is sufficiently small, it may be sampled entirely in one plot. The size of a sample quadrat in larger stands should be large enough to contain all the species of regular occurrence in that stand. The ideal size for a plot can be determined by successively doubling the surface area of a sample quadrat and counting the number of species in all respective plots. The resulting species-area curve levels off at a certain stage and this area can be taken as the minimal area (Barkman 1989; Kenkel & Podani 1991; Kent & Coker 1992).

Westfall *et al*. (1987) have determined a formula to predict the number of species in a given area in the Waterberg in the Northwest Province of South Africa. With this formula they can calculate the rate at which species numbers increase with increasing surface area. When the increment of species is less than 10%, the optimal sample size is reached.

Van der Maarel (1996) argues that strict application of the minimal area concept may underestimate species capture, due to small-scale dynamics and proposed instead to use a maximum area. Wilson & Chiarucci (2000) have extrapolated the species per unit area to the landscape and regional levels. They made the rigorous conclusion that ‘homogeneous communities’ do not exist and that everything depends on the hierarchical scale at which the study is levelled.

Through the experience of many experts, the optimal sample area for different (physiognomic) vegetation types worldwide has been determined. For equivalent vegetation types that occur within the Fynbos Biome the values are as follows: Hygrophilous (Wet Bank) communities: 1–4 m^2, temperate sclerophyllous shrublands (fynbos): 10–100 m^2, scrub: 25–100 m^2 and temperate deciduous forests: 100–500 m^2 (Westhoff & Van der Maarel 1973, see also Tüxen 1970).

In the case of transects used to sample lateral river gradients, the size of the stand is often limited by topographic features, but the minimal sizes for the different community types fit well within the surface areas obtained in a transect placed across a river with a transect width of 10 metres.

3.3.3 Number of samples

For a good description of the vegetation according to the Braun-Blanquet method it is necessary that there are sufficient samples in every vegetation type under study and no type is under- or over-represented. At the same time, the researcher aims to obtain vegetation samples that from the entire study area to make sure that as many variations as possible are covered. Thus, before or during the sampling process, the researcher already makes some preliminary classifications so that the number of samples of undersampled communities can be supplemented. Unstable or mixed samples have to be removed afterwards (Westhoff & Van der Maarel 1973).

In this study, the number of units that could be sampled was limited by a devastating fire that raged through the study area during April 1999, before all the field work was finished. After this some rare vegetation types could still be sampled in unburnt islands or marginal areas. But the data set still contains some vegetation types that are undersampled, as the fynbos in the Hottentots Holland Mountains will only be in a mature condition, sufficient to identify persistent species, in 5-6 years after being burnt (Van der Merwe 1966). Some additional samples were obtained from neighbouring areas to reduce this shortcoming in the data set.

3.3.4 Stratification

The description of vegetation strata forms an important part of the structural characterization of the vegetation. Early methods of vegetation classification were mainly based on structural data (Shimwell 1971; Mueller-Dombois & Ellenberg 1974). It is often possible to link different floristic vegetation units together into several ‘structural groups’ afterwards. Campbell (1986a) undertook a structural classification of montane vegetation in the Fynbos Biome, and he argues that a detailed, floristic classification in the biome is not feasible, because species turnover between mountain ranges is too high, although he made considerable use of floristic features in his structural classification.

Four different strata are broadly recognized in the present study of riparian vegetation, namely, the tree, shrub, herb and moss layers. Mosses have only been recorded in the Wet Bank Zone (Figure 2.10). The shrub layer has been divided into a higher (2–6 m) and a lower shrub layer (0.5–2 m). Elsewhere in the Fynbos Biome, different layers can be recognised within the tree layer, but none of the tree species occurring in the Hottentots Holland area exceeds 12 metres, so they are all recognised as belonging to the same layer (6–12 m). These vegetation layers are defined in the vegetation database program Turboveg (Hennekens 1996).

3.3.5 Coverage and abundance

In every sample taken in the present study the species are recorded together with the vegetation stratum to which they belong and their projected canopy cover in the Braun-Blanquet or the ordinal scale is estimated. The definition of the ordinal scale compared to the traditional and the extended Braun-Blanquet scale is presented in Table 3.1. There is no real difference between the scales: the ordinal scale was introduced in order to simplify the notation. I recorded vegetation samples using the ordinal scales, which I later converted to the extended Braun-Blanquet scale for analysis and descriptive purposes.

In this study, a herbarium specimen was collected of each of the species encountered to serve as a voucher specimen for identification and for reference purposes. Later records of a species refer to this specimen. The specimens were identified by the staff of the Compton Herbarium, National Botanical Institute at Kirstenbosch or by specialists from the Botany Department at Stellenbosch University. A field herbarium has been made for quick reference to the specimens collected and to be able to compare newly collected specimens with old ones for identification purposes. Nomenclature follows Goldblatt & Manning (2000), but many synonyms from Bond & Goldblatt (1984) are still provided in Appendix C.

Table 3.1: The cover-abundance scale of Braun-Blanquet and subsequent modifications to it. In this study the notations of 2m, 2a and 2b will be abbreviated to m, a and b respectively.

Cover	Number of plants	Braun-Blanquet (1928)	Barkman, Doing & Segal (1964)	Van der Maarel (1979)
<5%	1	r	R	1
<5%	2-10	+	+	2
<5%	11-100	1	1	3
<5%	>100	2	2m (or m)	4
5-12.5%	n.s.	2	2a (or a)	5
12.5-25%	n.s.	2	2b (or b)	6
25-50%	n.s.	3	3	7
50-75%	n.s.	4	4	8
75-100%	n.s.	5	5	9

3.3.6 Vegetation samples in transects

In the highest reaches the vegetation around the rivers forms homogeneous seepage areas, which were sampled in relevés of ten by ten metres. Further downstream the river dynamics play a bigger role and the riparian vegetation is organized in bands or strips parallel to the river, so the vegetation becomes more varied. In this case, vegetation is sampled in transects across the riverbed in order to cover the lateral gradient across the riverbed. The location of the different transects were chosen to cover a range of different altitudes, aspects and communities spread through the different catchment areas. A total of 123 transects have been sampled (see Appendix D). The main limitation is that the locations had to contain natural vegetation and be accessible. Several riparian zones can be recognised, which are described in detail in Section 2.7.2.3. Within each riparian zone, the vegetation should be homogeneous. When sampling a section of a river, a stretch of ten metres along the river is identified and the Aquatic Zone, the Wet Bank, the Lower

Dynamic, the Shrub/Tree and the Back Dynamic Zones are each sampled separately. Glavaç *et al.* (1992) mention an example of riverine floodplains where the vegetation borders are very sharp even though the elevation gradient extends across the whole floodplain. With this example they demonstrate that riverine vegetation perfectly suits the discontinuum theory. The situation in mountain streams is quite different because banks are quite steep, but the vegetation borders are equally sharp.

When sampling takes place along a transect, there are a few considerations to be made. The first one concerns the size of the different samples within the transect. The surface area covered by a particular vegetation unit is dependent on the width of the riparian zone in which it occurs. When a riverbank is steep, zones are narrow and will have a smaller surface area and when banks are flat, the respective zones are wide and the surface areas within the sample are large. In general, however, the same type of vegetation zone will be represented in more or less equally sized samples. Wet Bank Zones are often very narrow, because they only occur in the area where small fluctuations in the water level inundate the substrate. They are often also fragmented and can be broken up by large rocks and boulders. In a stretch of ten metres, a Wet Bank Zone can be quite heterogeneous while the other riparian zones further up the bank are homogeneous. Back Dynamic Zones and Shrub/Tree Zones are represented in wider zones and can be sampled in an area that is large enough for that type of vegetation (see section 3.3.2). The sampling of relevés with different surface areas from the same river zone but in different transects is a problem that is difficult to avoid given the variability in the physiography of the terrain. It is assumed that this does not have a major effect as long as the differences in sample size are not extreme. An attempt was made to stick to comparable sample sizes for each zone.

Another problem that occurs in transects are heterogeneous samples and the definition of the borders. Mostly, the vegetation borders on a riverbank are quite sharp, but where this is not the case an extra sample has to be taken from the 'transition zone'. In these instances there might be different samples representing the same riparian zone. In any event the analysis of the vegetation data is undertaken to include all samples irrespective of their location.

3.3.7 Environmental data

Environmental data were collected at each site. Some features were recorded for each transect as an average or modus over the whole transect (slope, aspect, geology and altitude), while others were recorded for each sample within a transect (e.g., rock and litter cover). In most samples, wherever it was possible, a soil sample was collected and taken to the laboratory for analysis. The environmental data that were collected and their means of measurement are summarized in Table 3.2.

The following classes of boulder size are recognised and their cover percentage is estimated in the field: Bedrock, boulders (> 250 mm Ø), large cobbles (128-250 mm Ø), small cobbles (64-128 mm Ø), pebbles (16-64 mm Ø), and gravel (2-16 mm Ø) (following Boucher & Tlale 1999).

Soil samples were only collected from the topsoil or A-horizon, because it was impossible to take heavier gear into the field for soil sampling. It is also important for the ordination of the data to compare the same ecological characteristics in all relevés. Since the soil samples from the deeper horizons are not present everywhere, they cannot be used to compare samples with each other. Soil samples have only been taken from places where there was a reasonable soil development, so the soil data from the Aquatic Zones and many of the Wet Bank and Lower Dynamic Zones were left out of the analysis.

The particle size distribution of the soils is determined for the fractions finer than 2 mm Ø. After drying and grinding the soil to break up any coagulations, the soils were shaken through a set of sieves. The sieves that were used have raster as follows: 500 µm (to separate coarse sand), 106 µm (to separate medium sand) and 63 µm (to separate fine sand). The fraction that passes through all the sieves is the silt and clay.

Table 3.2: Explanatory variables used in the study. Numerical variables indicated with (N), Nominal Variables (C) and Compositional data (F).

Variable	**DataType**	**Measurement**
PH	N	pH-meter: ORION 420A, measured in H_2O
Organic	N	Percentage calculated by titration using the Walkley-Black method (Walkley 1935)
Slope	N	Angle measured by slope meter in degrees
Geology	C	Geological Map (SACS) and field observation. Classes: Sandstone (San), Tillite (Til), Shale (Sha), Graniet (Gra) and Alluvium (Qua)

Soil type	C	Determined from the literature (Fry 1987, Soil Classification Working Group 1991) and observations on the topsoil layer and the soil depth. Classes (Soil Forms): Mispah, Magwa, Oakleaf, Fernwood, Glenrosa and Champagne
Aspect	C	Measured by compass and classified into quadrants: N, W, S & E
Altitude	N	Determined from orthophotographic maps (scale 1:10 000)
Resis	N	Resistance to an electrical current measured using a YSI model 3200 conductivity meter
Gravel	N	Percentage of coarse material in soil sample
Soildept	N	Depth of soil until bedrock – estimated average expressed in cm
Particle size	F	Percentage of fractions of soil particles. Classes: Coarse Sand (CSAND), Medium Sand (MSAND), Fine Sand (FSAND) and Silt (SILT)
Rock cover	F	Estimate of rock cover percentages. Classes: Bedrock, Boulders (> 25 cm Ø), Large Cobbles (LG_COBB, 13-25 cm Ø), Small Cobbles (SM_COBB, 6-13 cm Ø) and Pebbles (PEBB, 2-6 cm Ø)

Measurement of the clay fraction requires determination through fractionation based on the principle that finer soil fractions take longer to settle than coarse fractions (Ball 1986). In the Western Cape mountains clayey soils are quite rare, although Campbell (1983) found an average of 7% of clay in the soils on Table Mountain Group sandstones. Near the rivers, however, clay is mostly washed out and the only clayey soils in the study area can be expected in the shale bands. These considerations led to leaving out the analysis of the clayey fractions in this study.

Acidity and resistance were measured in water-saturated soils using a pH meter (Orion 420A) and a conductivity meter (YSI 3200). The fraction of organic matter was measured by titration according to the Walkley-Black method (Walkley 1935; Anon. 1990).

3.4 Analysis and synthesis

The vegetation and environmental data were entered into the Turboveg for Windows program (Hennekens 1998) for analysis. A total of 266 vegetation samples have been entered into the program. Different export files are produced by this program and are used for further analysis in other programs as are described below (Hennekens 1998). In Appendix D the location of these samples within the transects is indicated while the location of the transects themselves is indicated in Figure 3.1.

The computer program Megatab (Hennekens 1996) is used for classification. The TWINSPAN procedure in this program is used to classify the samples in a numerical way, but this classification is only used as a first draft, after which modifications are made to the classification order of samples and species based on insight and field experience, using the options in the Megatab Program.

The ordinations are done using the program Canoco 4.0 (Ter Braak & Šmilauer 1998). Before the ordination of the complete dataset is carried out, the correlations between the environmental variables are analysed using Principal Components Analysis (PCA). In this way a choice can be made about the environmental variables suitable for the ordination of the whole dataset. Correspondence Analysis (CA) is used to investigate the dataset for trends and gradients within the vegetation itself (indirect gradient analysis; Hill 1974). After this Canonical Correspondence Analysis (CCA) follows to determine the relation between the vegetation data and the environmental variables (direct gradient analysis; Ter Braak 1986). A Monte Carlo permutation test is undertaken to determine whether the ordination axes have significance (Ter Braak & Šmilauer 1998). The combination of the use of both CA and CCA is necessary to determine how much of the variation in the vegetation data is explained by the environmental variables (McDonald *et al*. 1996; Brown *et al*. 1993; Økland 1996).

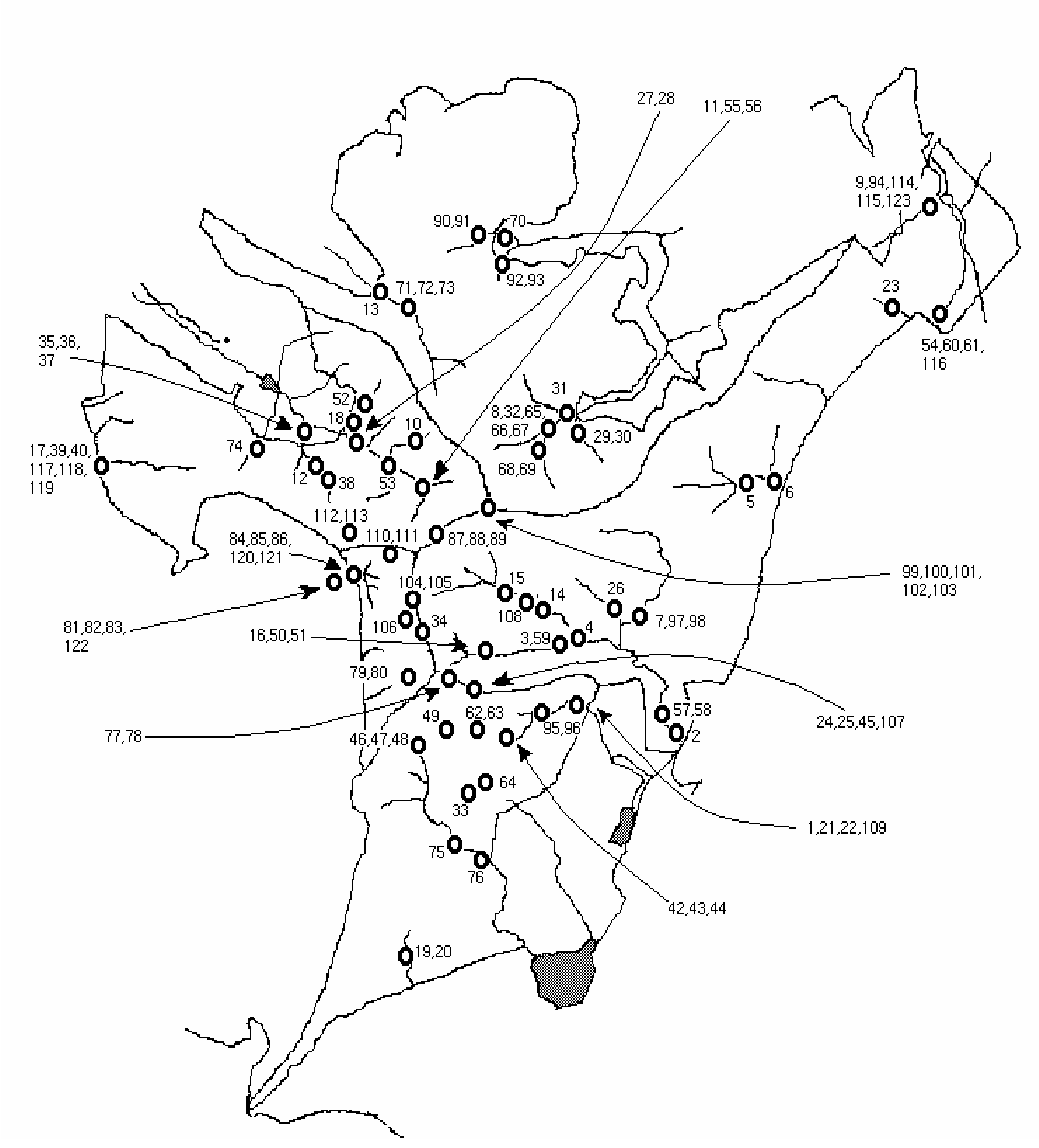

Figure 3.1: The location of the transects in the study area. For the locations of the catchments, compare this map with Figure 2.1.

4. High-altitude fen and mire vegetation of the Hottentots Holland Mountains of the Western Cape, South Africa

4.1 Abstract

A phytosociological survey has been undertaken of the extensive seepage areas occurring in the Hottentots Holland Mountains, Western Cape, South Africa using the Braun-Blanquet method. Nine different communities have been recognized, three of which have been given scientific names following the 3rd edition of the International Code of Phytosociological Nomenclature.

The most important differentiating feature between the mire communities described here is the degree of minerotrophy. The soils in the centre of the mires are very peaty with very little influence from the surrounding sandstone, while the soils on the margin of the mires have a greater admixture of soil originating from sandstone. Most of the mire communities described here are dominated by low growing clonal Restionaceae, such as *Anthochortus crinalis*, although these can occur in a mosaic with the tall restio *Chondropetalum mucronatum*. The mire vegetation in the mountains is vulnerable to climate change and water abstraction and the results of this study can be used as reference types for monitoring.

4.2 Introduction

The Western Cape Mountains are important catchments for high-quality drinking water. A vast quantity of this water is stored after precipitation in the seepage areas before it enters the river systems. The quality of the water is largely determined by the soil conditions that the water encounters on its way to the river, so the seepage areas have a great importance for the river ecosystem (Bosch *et al*. 1986). However, the Variable Source Area Concept of Hewlett (1961) states that the catchment area that drains into a river is variable in size and many seepage areas can be out of touch with the river for a long time. After heavy rains the Source Area of the river expands and much water that was stored in fens for a long time is washed into the river. This explains the brown colour of many of the Cape rivers after heavy rains (King & Day 1979).

‘Seepage area’ is a very general term for the source area of a river. It constitutes all sorts of areas where water moves underground towards the river and includes the majority of wet slopes but also many mires that occur in mountainous regions. The definitions of bogs, fens and mires, as they are used in this text, are given by Gore (1983). Mires are adopted as a general term for wet swampy places, while bogs and fens are more specific types of mires. The term ‘bog’ refers to the strictly ombrotrophic mires found in places with high rainfall, while ‘fens’ are the mires that are fed to a certain extent by water from a minerotrophic origin. Bogs are very rare in the Southern Hemisphere and are probably absent from the Western Cape.

There are three different types of seepages in the Western Cape Mountains that form part of the drainage network of the river system:

(1) The seepages on slopes are better drained than the other two types listed below. They can best be described as Wet Ericaceous Fynbos (Campbell 1986b). The soils here are mostly of the Fernwood Form (Fry 1987). This seepage type can be characterized by the presence of Bruniaceae, although it is highly variable.

(2) In the low-altitude seepages in wet valleys the water is stagnant and peaty Champagne Form soils generally develop here. The vegetation of these habitats in the Kogelberg Biosphere Reserve was described by Boucher (1978) as *Erica-Osmitopsis* Seepage Fynbos. This vegetation type was not found in the Hottentots Holland Mountains. Another type of low-altitude seepage occurs on temporarily wet sandy soils and is dominated by *Elegia filacea* (Taylor 1978).

(3) The high-altitude fens and mires which are situated at the sources of the rivers will be described in this paper.

The high-altitude mires form an important part of the river system but they also form an ecosystem on their own. Rogers (1997) records that the wetland ecosystems in the Cape mountains have received little attention but deserve a closer look. As most African swamps and mires are dominated by grasses and sedges (Thompson & Hamilton 1983; Van Zinderen Bakker & Werger 1974), the mires in the Western Cape are conspicuously different because of the dominance of Restionaceae (Campbell 1986b; Rogers 1997). This study presents a preliminary description of these ecosystems and gives an insight into the ecological processes that drive them.

4.3 Study area

The majority of vegetation samples examined in this paper were recorded from the Hottentots Holland Mountains (between 33º 56' S and 34º 03' S latitude and 18º 57' E and 19º 09' E longitude, see Figure 2.1). This area, situated between the towns of Stellenbosch, Franschhoek, Grabouw and Somerset West, has the highest rainfall of the entire Western Cape. It has many peaks higher than 1000 metres and numerous and extensive mires have developed here.

Most of the mires are part of the Palmiet River catchment, although the Riviersonderend River and the Eerste River catchments also receive water from fairly extensive mire systems. Two other rivers originating in the area, the Berg River and the Lourens River, barely receive water from mires and have their origin on very steep mountain headwalls.

4.4 Climate

The climate at high altitude is very different from the climate in the valleys, because of the gradients in rainfall and temperatures, which vary with changes in altitude (Versfeld *et al*. 1992). Sixty per cent of the precipitation falls in the wettest four months, which is from June to September. This precipitation is mostly in the form of rain but snow can occur in winter on the mountain peaks (Fuggle & Ashton 1979). An unknown amount of precipitation occurs in the form of fog, as few stations are designed to record its occurrence. Although the fog-saturated air definitely has an impact on the physiology of plants, only very few plants, mainly epiphytes, are able to make direct use of water from this resource (Kerfoot 1968). Wind speeds are highest in winter on the mountain tops. This is in contrast with the wind in the lowlands, which are highest in summer. In summer, easterly winds dominate, while the winter brings more westerly winds (Deacon *et al*. 1992).

4.5 Geology and soils

The geology of the Hottentots Holland Mountains is dominated by sandstones and shales of the Table Mountain Group, especially at the higher altitudes. Some of the valleys are underlain by granite, but no mires were found on this substrate in the present study. The sandstones are mainly from the Nardouw Formation. A high altitude shale-band of the Cedarberg Formation accompanied by tillite of the Pakhuis Formation occurs sporadically through the area (De Villiers *et al*. 1964). These bands are situated at higher altitudes than most of the seepage areas and virtually all the vegetation types (with one exception) described in this study are from sandstone.

Soils of the mires are classified as belonging to the Champagne Form (Soil Classification Working Group 1991). The amount of peat is variable and, towards the outer edges of a seepage area, there is a greater proportion of soil originating from sandstones. Here soils of the Fernwood Form will prevail. In this study, soils have been used as a major characteristic to delimit the location of the mires sampled in this study. Vegetation samples have only been taken from the predominantly organic soils of the Champagne Form. There is, however, still much variation in the proportion of organic material in the soils.

4.6 Methods

Vegetation sampling followed the Braun-Blanquet Method (Westhoff & Van der Maarel 1973; Werger 1974). The samples taken from the Hottentots Holland Mountains number 33 in total. An additional four samples have been taken from the Dutoitskloof Mountains to the north of the study area, one from the Groenland Mountains and one from the Akkedisberg, both located southeast of the study area (see Figure 2.4b). These samples were taken to get some indication of the degree of turnover in mire vegetation types across the Cape Mountains. Two of these additional samples fitted in well with the Hottentots Holland data and have been included in the vegetation table (see Appendix E; Table 1).

The vegetation samples from the Hottentots Holland Mountains have been classified using a combination of TWINSPAN and manual tabulation (Hill 1979). During the manual tabulation process, a vegetation scientist assesses the acceptability of the TWINSPAN components and uses his field knowledge and the particular sites involved as a reference (Kent & Coker 1992). The aim of manual reshuffling is to cluster samples, based on the presence and absence of species, as far as possible into blocks (Feoli & Orloci 1985). The programme used for this purpose is Megatab (Hennekens 1996).

Three well-sampled communities have been given names according to the international rules for syntaxomic nomenclature of Weber *et al*. (2000). All communities have been given a local name based on vegetation structure and two important species, useful for local reference purposes, following guidelines proposed by Edwards (1983).

All the environmental variables mentioned in Chapter 3 were collected in the mires. The relationship between the environmental data and the vegetation data was determined using multivariate techniques. Legendre & Legendre (1998) give a good overview of the multivariate techniques currently available. Following Økland (1996), who argues that ordination and constrained ordination complement each other as they provide different information, both a direct and an indirect gradient analysis were undertaken in this study. The package of programs that was used for this analysis is contained in the Canoco 4.0 program suite (Ter Braak & Šmilauer 1998). The compositional data, such as particle size, were log-transformed prior to further analysis, according to the recommendations of Ter Braak & Šmilauer (1998). The technique used for indirect gradient analysis is Correspondence Analysis or CA, which makes use of the Weighted Averaging algorithm, which makes it applicable for unimodal response curves (Hill 1974). The technique for direct gradient analysis used in this study is Canonical Correspondence Analysis or CCA, which constrains the axes found in CA to the explained variation only by comparing axes based on species data with axes based on environmental variables (Ter Braak 1986).

4.7 Results

Table 1 in Appendix E presents the vegetation table for the mires recorded during this study. The communities are described here at the level of association. The higher syntaxonomic levels are not discussed here because they will only become clear after more data from other mountain ranges becomes available. There are only three communities that have received an official syntaxomic name following the Code of Phytosociological Nomenclature (Weber *et al*. 2000). A type relevé, which is a relevé that is typical for the vegetation unit and should at least contain all the differential and name-giving species, is selected for these communities (Weber *et al.* 2000). The differential species, constant companions and the dominant species are identified in each case. A differential species is a species that can be used to differentiate between one community or a group of communities, and the rest at the same syntaxonomic level (Westhoff & Van der Maarel 1973). For this, I used a guideline of a difference in frequency of more than two presence classes (40%). However, a species can also be called differential on the basis of cover. This guideline is not handled strictly in the case of communities with few samples. A constant companion is a species that occurs in more than 60% of all the samples in the community. A dominant species is a species that is constant and has an average cover of more than 25 % (Westhoff & Van der Maarel 1973).

Generally, mires in the Hottentots Holland Mountains can be recognised by a high cover of Restionaceae. Only a few seepage types are dominated by grasses or sedges, such as *Pennisetum macrourum, Carpha glomerata, Isolepis prolifer* or *Epischoenus* spp. More typically, some species of Restionaceae are dominant. The most common species are *Anthochortus crinalis, Chondropetalum mucronatum, Elegia thyrsifera* and *Restio subtilis.* Two graminoids that are common are *Ehrharta setacea* ssp. *setacea* and *Epischoenus villosus.* The Asteraceae are represented by *Senecio crispus* and *Ursinia caledonica.* Montane seepages often contain a narrow drainage channel in which impoverished aquatic or wetbank communities might occur.

Most seepages described here are classified by Campbell (1986b) as Sneeukop Azonal Restioid Fynbos. They occur in general on deep, dark, organic soils with a pH lower than 4. In order to distinguish between the different degrees of minerotrophy in the mires described in this study, I want to introduce the term 'restio marshlands' for the communities on the better-drained sites at the edge of a mire in the Western Cape, in contrast to the 'fens' that are situated in the centre of the mire.

<u>Community Group 1: Fens</u>

Fens form the wettest parts of the seepages and they are poorly drained. The low growing restio *Anthochortus crinalis* is usually dominant and forms dense mats between tussocks of *Epischoenus villosus*. The first two communities described here are unusual because they occur on steep slopes, so they have better drainage despite being very wet.

Community type 1.1: *Protea lacticolor-Hippia pilosa* Tall Shrubland
Number of relevés: 2
Range of species number: 18 – 20

This community, which is found on the impervious shales of the Cedarberg Formation, is characterised by a high cover of *Protea lacticolor*, which is a dominant species. This proteoid forms a dense shrub layer between about two and four metres tall. This structural type is not found in any of the other seepage communities and it is the only form of proteoid fynbos recorded in this study. The herb layer is also very dense and covers more than 80% of the relevé. Tussocks of *Epischoenus villosus* and mats of *Restio perplexus* (a differential species) define the structure of the herb layer. In between, other important species can be found, such as *Senecio umbellatus, Stoebe plumosa*, *Hippia pilosa* and *Oxalis truncatula*. The community occurs on the eastern slopes of Somerset Sneeukop at a very high altitude on the shaleband. It receives an extremely high annual rainfall (more than 3 300 mm). It is also likely to receive snow, which persists longer on the eastern slopes than on the western slopes. Campbell (1986b) refers to this type as Otterford Wet Proteoid Fynbos.

Community type 1.2: *Elegia thyrsifera-Centella eriantha* Short Closed Herbland

Number of relevés: 2

Range of species number: 15 – 16

This community is found near the sources of the Lourens River on the western slopes of Somerset Sneeukop. The tall herb layer is formed by the dominance of *Elegia thyrsifera* and a short herb layer is occupied by a multitude of other species, such as *Senecio umbellatus*, *Hippia pilosa* and *Erica curviflora*. This community, like the *Protea lacticolor-Hippia pilosa* Tall Shrubland, is quite atypical for seepages in the Hottentots Holland Mountains. The differential species, *Carpacoce spermacocea*, *Ursinia eckloniana*, *Centella eriantha* and *Othonna quinquedentata*, are all more common in Ericaceous Fynbos communities (See Chapter 5). It occurs on steep slopes on sandstone. This is the main habitat difference from the former community that occurs on shale. It occurs, as does the former community, at high altitudes and receives a high precipitation.

Community type 1.3: *Anthochortus crinalis-Elegia intermedia* Tall Closed Restioland

Scientific name: *Anthochorto crinalis-Elegietum intermediae* ass. nova hoc loco

Number of relevés: 4

Type relevé: 229 (Appendix E; Table 1)

Average no. of species: 4 (3 – 5)

This is an extremely species-poor seepage community, which is only found in the Berg River catchment on the Dwarsberg. The dominant vegetation stratum is a dense layer of *Elegia intermedia* which grows 1.2 to 1.5 metres tall. This species is the only differential species for this community. Linder (1987) writes in his conspectus of the South African Restionaceae that he casts doubt on the occurrence of this species outside the Cape Peninsula, but Kruger (1978) also mentions that he found this species on the Dwarsberg. In this study, it was recorded in several other locations within the Hottentots Holland Mountains. The lower herb layer of the community is dominated by *Anthochortus crinalis* and is less dense. The Dwarsberg, where this community occurs, receives more than 3000 mm rainfall per annum. The community is only found in the wettest places, surrounded by the *Ficinio argyropae-Epischoenetum villosi* and *Tetrario capillaceae-Restionetum subtilis*.

The species mentioned above are the only species present in the vegetation together with *Senecio crispus*, *Epischoenus villosus* and the moss *Campylopus stenopelma*. The soils are extremely peaty.

Community type 1.4: *Ficinia argyropa-Epischoenus villosus* Short Closed Restioland
Scientific name: *Ficinio argyropae-Epischoenetum villosi* ass. nova hoc loco
Number of relevés: 6
Type relevé: 226 (Appendix E; Table 1).
Average no. of species: 12 (8 – 21)

This is one of the two seepage communities dominated by the restio *Anthochortus crinalis.* This clonal species forms dense mats and is often intertwined with species like *Ehrharta setacea* ssp. *setacea, Senecio crispus* and *Cliffortia tricuspidata*. The vegetation is on average much shorter than the previous communities, and the tallest Restionaceae that is present is *Elegia grandis*, which grows higher than 50 cm together with the tussocks of *Epischoenus villosus*. In the tiny open spaces the short differential species *Ficinia argyropa* and *Anthoxantum tongo* can be found. Another differential species, shared with communities 1.1 and 1.2 is *Senecio grandiflorus*. This community and the next resemble the communities on Table Mountain described by Glyphis *et al.* (1978) as *Erica mollis* Fynbos community and by Laidler *et al*. (1978) as *Restio-Hypolaena* subcommunity (See Table 4.1). It also represents the typical form of what is described by Campbell (1986b) as Sneeukop Azonal Restioid Fynbos. Both communities are associated with peaty soils that are waterlogged for most of the time. In one relevé, a dominance of *Carpha glomerata* was found, which is usually associated with wet habitats at lower altitudes. It is potentially a differential species.

Community type 1.5: *Restio bifurcus-Anthochortus crinalis* Short Closed Restioland
Number of relevés: 4
Average no. of species: 14 (10 – 23)

This is the second seepage type that is dominated by *Anthochortus crinalis*. Floristically and structurally this community resembles the previous one closely and it might be considered a subassociation of *Ficinio argyropae-Epischoenetum villosi*. The main difference is the absence of *Senecio umbellatus* and *Ficinia argyropa*, but this community also has some differential species of its own, namely *Chondropetalum mucronatum* (this species is emergent above the dominant herb layer), *Gladiolus carneus*, *Restio bifurcus*, *R. corneolus* and *Tetraria capillacea*. An unusual differential species in this community is *Prionium serratum*, which is normally found in the Wet Bank Zone of mountain streams (see Chapter 5). A potential differential species that was found only in one relevé is *Anthochortus graminifolius*.

Related communities in the literature are the same as those mentioned in the description of the *Ficinio argyropae-Epischoenetum villosi*, namely, the *Erica mollis* Fynbos community (Glyphis *et al*. 1978) and the *Restio-Hypolaena* subcommunity (Laidler *et al*. 1978). However, when undertaking a TWINSPAN with the combined data of their studies and this study, the resemblance does not go very far. The only species in common are *Anthochortus crinalis*, *Ehrharta setacea* ssp. *setacea* and *Senecio crispus*, while important species such as *Cliffortia tricuspidata* and *Epischoenus villosus* are not present in their data. The comparison can be seen in Table 4.1. These communities are often associated with peaty soils that are waterlogged for most of the time.

Table 4.1: Comparison of mire data with studies of Glyphis *et al.* (1978) and Laidler *et al*. (1978)

	Community 1.4						Commu-nity 1.5				Laidler *et al.* *(1978)*				Glyphis *et al.* *(1978)*			
Ficinia argyropa	1	1	3	1	A	1												
Elegia intermedia	1	a	a															
Senecio umbellatus	a	1	a	r	+													
Gladiolus carneus	+						+	+	+									
Prionium serratum								1	+	+								
Restio bifurcus								1	+	+								
Epischoenus villosus	3	4	3	4	4	m	a	m	4	b								
Stoebe plumosa	1		+			+	r	+	1									
Cliffortia tricuspidata		a	a		+	b			b	4								
Ehrharta setacea	m	1	3	m		b	m	3	b	a	r		r				+	
Anthochortus crinalis	5	m	a	3	3	4	4	3	3	4	1	4	4	3	1	B	b	1
Senecio crispus	a	1	1			1	+	+	a	a		r	r	r	+	1	+	1
Chondropetalum ebracteatum											b	b						
Elegia juncea											1			4				
Berzelia lanuginosa															+	3		b
Restio bifarius															1	1	1	
Tetraria flexuosa															3	1	1	
Erica hispidula											b				b	1	b	1
Penaea mucronata											1				b	+	+	
Elegia thyrsifera														4			b	b

Community Group 2: Restio marshlands

The vegetation types of Community Group 2 are better drained than those in Community Group 1 and have a more minerotrophic origin. They are often found on the edges of the mires and the water drains into the fen types as described above. All but two releves are from the Palmiet catchment, because the most extensive mires were found in this catchment. They are richer in species than the fens. The first two communities described here are transitional because they contain some species that are shared with the fens, such as *Senecio crispus*.

Community type 2.1: *Platycaulos depauperatus* Short Closed Herbland

Number of relevés: 3

Average no. of species: 19 (13 – 20)

This is the only seepage type that is dominated by the restio *Platycaulos depauperatus*, which forms dense green mats and is the most conspicuous differential species of this community. It occurs together with the tussock-forming *Restio subtilis*, which is co-dominant. Together they form the dominant lower herb stratum. One emergent species, *Chondropetalum mucronatum*, 1.5 m tall, forms its own stratum. The species *Elegia neesii*, *Epischoenus villosus* and *Tetraria capillacea* are all significantly lower. In addition to the dominant species, additional differential species of this community are the grass *Pentameris hirtiglumis* and the geophyte *Kniphofia tabularis*, that only flowers after a fire. Although this community is undersampled because of the fire and is described here on the basis of three samples, I can conclude from observations prior to the fire that it is quite common in the Palmiet River catchment. It seems to be intermediate between the *Ficinio argyropae-Epischoenetum villosi* from peaty soils and the *Tetrario capillaceae-Restionetum subtilis* from more minerotrophic soils. It receives less rainfall than other seepage types, with a Mean Annual Precipitation of just over 2000 mm.

Community type 2.2: *Erica autumnalis-Restio purpurascens* Tall Closed Restioland
Number of relevés: 2
Range of species number: 19 – 38

This is one of the two communities described from riparian mires. These communities occur in the highest reaches of the rivers (in this study all were sampled in the Palmiet River catchment) and are a mixture of seepage and riparian elements. Together they make up the most species-rich communities, either in comparison to other seepage types or to the riparian communities. This community has a more prominent tall herb layer than most seepage communities. The dominant species is *Restio purpurascens*, but *Elegia racemosa* and *E. thyrsifera* are also abundant. In the lower stratum *Anthochortus crinalis* is a conspicuous species. Some species such as *Hippia pilosa* and *Senecio crispus* are shared with Community Group 1. This type can best be described as a Restioland, because small and big restio species are the most important constituents of this community. It is difficult to determine the differential species in a situation where relevés are few, but possible differential species are *Aristea bakeri*, *Cliffortia ovalis*, *Elegia racemosa*, *Hippia pilosa* and an unidentified species of Asteraceae. The differential species *Erica autumnalis,* which is used in the provisional name, is endemic to the Hottentots Holland Mountains. The community occurs in the highest reaches of the Wesselsgat River where riverbanks are steep and rocky.

Community type 2.3: *Grubbia rosmarinifolia-Restio* aff. *versatilis* Medium Closed Shrubland
Number of relevés: 3
Average no. of species: 25 (18 – 33)

This is the second type of riparian seepages found along high altitude streams. The main difference from the previous type is the shape of the banks, which are flatter and less rocky in this vegetation. The dominant small restio here is *Restio* aff. *versatilis*, compared to *Anthochortus crinalis* in the previous type.

This community has a more prominent tall herb stratum than most other seepage types and the tall vegetation (between 1 and 1.5 metres) is dominated by the shrubs *Berzelia squarrosa, Brunia alopecuroides* and *Grubbia rosmarinifolia* and the restioids *Restio purpurascens* and *Chondropetalum mucronatum*. The most closely related riparian community is the *Erico-Tetrarietum crassae* (see Chapter 5) which shares many *Erica*-species with the *Grubbia rosmarinifolia-Restio* aff. *versatilis* Closed Shrubland. The most closely related seepage community is the *Tetrario capillaceae-Restionetum subtilis*. *Restio* aff. *versatilis,* a species that is dominant in the ground layer, is shared with this community. The *Grubbia rosmarinifolia-Restio* aff. *versatilis* Community is typical of situations where the riverbanks are not steep and there is a lot of lateral seepage. It can be described as a shrubland because of the high cover of Ericaceae and Bruniaceae. There are numerous differential species in this community, most of which are shared with Ericaceous Fynbos and *Erico-Tetrarietum crassae* in particular. They are, amongst others, *Berzelia squarrosa*, *Brunia alopecuroides*, *Erica fastigiata*, *Grubbia rosmarinifolia* and *Restio bifidus*.

Community type 2.4: *Tetraria capillacea-Restio subtilis* Short to Tall Closed Restioland
Scientific name: *Tetrario capillaceae-Restionetum subtilis* ass. nova hoc loco
Type relevé: 86 (Appendix E; Table 1)
Number of relevés: 9
Average no. of species: 15 (10 – 17)

This is the most common type of seepage in the area, which is characterised by the absence of *Senecio crispus.* The dominant restio is *Restio subtilis*, with *Anthochortus crinalis* and *Restio* aff. *versatilis* as co-dominants. A typical characteristic is the mosaic between the low vegetation formed by the small restios and sedges (*Restio subtilis, R*. aff. *versatilis, Tetraria capillacea* and *Epischoenus villosus*) and the tall vegetation consisting only of *Chondropetalum mucronatum*. This species does not resprout after fires, like many other seepage species, but regenerates from seed. It tends to dominate the community because the old plants form a thick litter layer on the soil beneath it, which seems to prohibit other (aggressively spreading) clonal species from growing there. Differential species of this community are few, because most species are shared with the *Grubbia rosmarinifolia-Restio* aff. *versatilis* Closed Shrubland. Diagnostic features are mostly the dominance of *Restio subtilis* and the occurrence of *Chrysithrix* species. As in the case of the riparian seepage types, this community contains numerous shrub species, such as the differential species *Grubbia rosmarinifolia* and *Berzelia squarrosa*, but they do not grow very tall.

This community occurs on more minerotrophic soils than the former communities. Nevertheless, the soils are very acidic and highly organic. In one case it was found in a riparian zone and it is closely related to the riparian seepage types described above. The community described by Boucher (1978) as *Chondropetalum-Restio* Tussock Marsh seems to be quite similar, but the dominant small *Restio* in the Kogelberg is not *Restio subtilis* but *Restio ambiguus* and many other species are absent in the Kogelberg community.

Figure 4.1: A Restio Marshland, *Tetrario capillaceae-Restionetum subtilis*, at Landdroskop. The tall Restionaceae seen in the picture is *Chondropetalum mucronatum*; the light-coloured shrub is *Grubbia rosmarinifolia* and the yellow flowered shrub in the foreground is *Ursinia caledonica.*

4.8 Ordination

Figure 4.2 displays the ordination diagrams for the relevés of Correspondence Analysis and Canonical Correspondence Analysis. It is conspicuous that the ordination results are very similar. This means that the environmental variables used in the constrained ordination are effective in describing the vegetation patterns. This does not necessarily imply that they are the main environmental factors that determine the vegetation; they might just be correlated to underlying factors that were not recorded. The first axis of the CCA is mainly correlated to the substrate (shale vs. sandstone) and also with altitude and slope. The aberrant communities 1.1 and 1.2 are situated at higher altitudes and have a steeper slope than the other seepages (although the riparian seepages can also have a steep slope; in most seepages however the slope is level or nearly level). The second axis is positively correlated to soil depth and negatively to the soil particle fraction of coarse sand. Especially the communities 2.3 and 2.4, with an average soil fraction of more than 20 % coarse sand represent the real minerotrophic mires. The peaty soils in the centre of the mires are deep soils with a small fraction of coarse sand, while the shallow soils with a high fraction of coarse sand represent the more minerotrophic soils at the edges of the mires. It is also clear that the organic matter contents are correlated to the second axis: deeper soils tend to contain more organic matter than the shallow soils. This correlation is mainly caused by the riparian seepages and the aberrant seepages on slopes (communities 1.1 and 1.2), which contain close to 4 % organic matter instead of the 7 % that is more common in the other seepages. To summarize: the second axis also reflects a gradient in minerotrophy or in waterlogging, which is the most important gradient in mires. In more waterlogged conditions organic matter accumulates and peat formation takes place. There is not much variability in the pH, with values of around 4.0 being the norm. In this ordination the second axis gives more information than the first, because the first axis only splits off some aberrant relevés (the aberrant communities 1.1 and 1.2 on shale bands and slopes at high altitude).

There is also an ‘arch effect’ visible in the CA diagram, which comes into existence due to partial correlation of the second axis with the first axis. There are techniques to remove the arch, known as detrending (Hill & Gauch 1980), but the use of these techniques is highly controversial, because they distort the original data and do not contribute to any real new insight into the data patterns (Minchin 1987). It is better to ‘look through the arch’ for example in this case by comparing the CCA diagram to it.

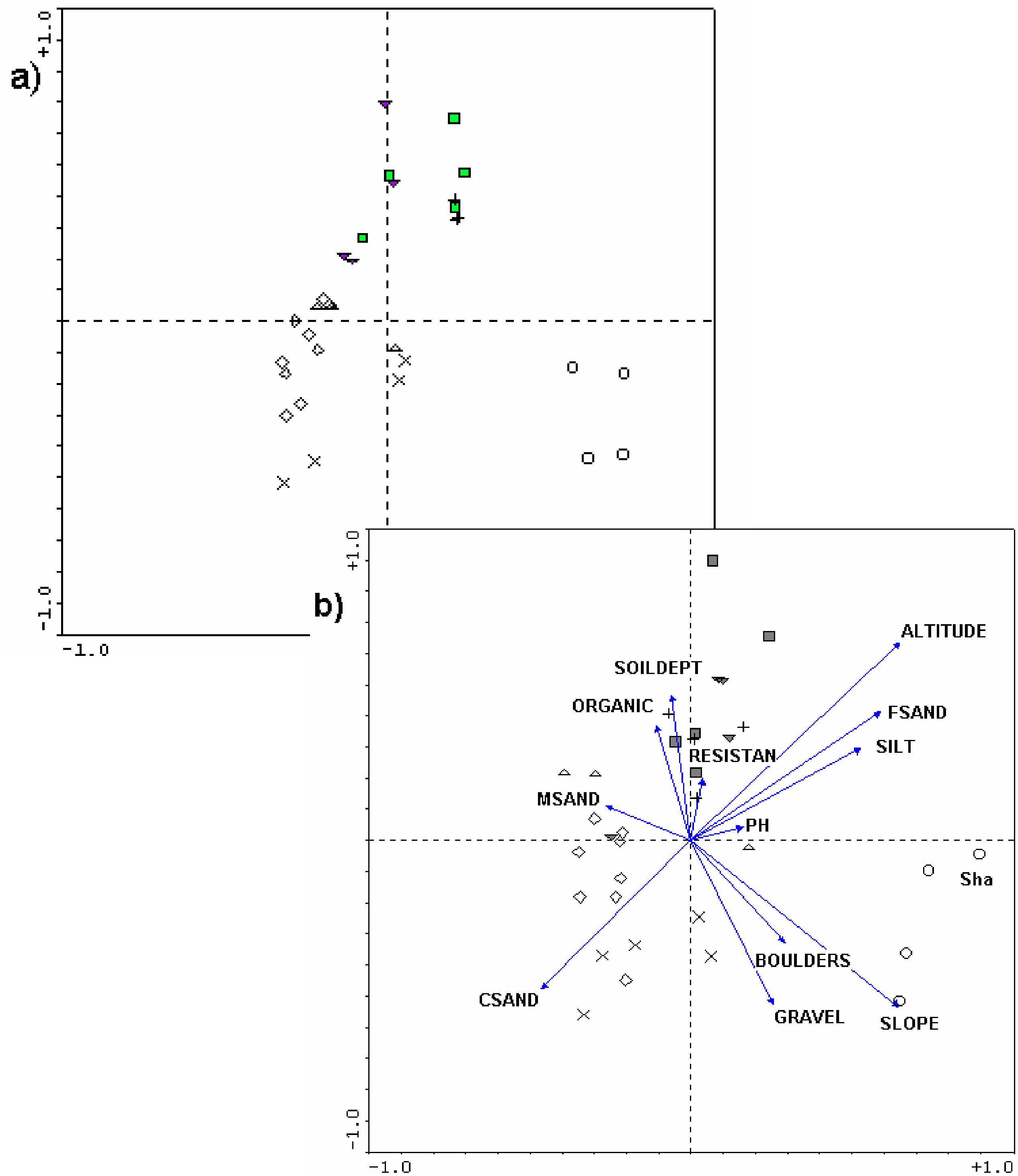

Figure 4.2: Ordination results for the relevés of the mire communities. Ordination (CA) and Constrained ordination (CCA) diagrams for the first two axes. Fig. a) presents the CA diagram and fig. b) presents the CCA diagram.

4.9 Undersampled communities

The fynbos has an extremely high species turnover between mountain ranges (Kruger & Taylor 1979; Cowling *et al.* 1992) and this might be most applicable to the high altitudes because mountain tops have a high insular effect. Campbell (1986b) describes the Sneeukop Azonal Restioid Fynbos specifically for the 'Wet' Mountain Ranges like Table Mountain, the Kogelberg and the Hottentots Holland Mountains. Because of these assumptions, the question arose as to the extent of species turnover in seepage communities is and therefore whether the classification proposed here was also applicable to nearby mountain ranges. For this purpose, six additional seepage relevés were sampled in nearby mountain ranges. These were recorded from the Akkedisberg (16^{th} degree square map 3419 BC), the Dutoitskloof (16^{th} degree square map 3319 CA) and the Groenland Mountains (16^{th} degree square map 3419 AA). Two out of the six additional relevés (both from Dutoitskloof) fitted well into the classification for the Hottentots Holland Mountains: relevé 259 was classified as *Ficinio argyropae-Epischoenetum villosi* and relevé 262 fitted into the *Tetrario capillaceae-Restietum subtilis*, although it is slightly different. The other four relevés emerged as outliers in the classification and ordination for the Hottentots Holland Mountains which shows that there are many vegetation types yet to be described from these habitats. The relevés that did not fit will be described below.

Community type 3.1: *Isolepis prolifer-Bulbinella nutans* Tall Closed Sedgeland

This community was found in the Dutoitskloof Mountains and is completely different from any community in the Hottentots Holland Mountains. It occurs in a very wet habitat: the watertable is exposed above the ground. A similar habitat was not found in the Hottentots Holland Mountains. The species with their respective cover values, arranged according to importance are: *Bulbinella nutans* (5), *Isolepis prolifer* (3), *Elegia thyrsifera* (2b) and *Sphagnum capense* (1).

Community type 3.2: *Anthochortus crinalis-Restio brachiatus* Tall Closed Restioland

This community was found bordering the *Isolepis prolifer-Bulbinella nutans* Sedgeland in the Dutoitskloof Mountains. It forms a very sharp border with this community and occurs on a slightly higher elevation above the watertable. The community is related to the *Ficinio argyropae-Epischoenetum villosi*, but it is much poorer in species. *Restio brachiatus*, the dominant species, does not occur further to the south, so this community will be replaced there, probably by community 1.4 or 1.5, although the *Ficinio argyropae-Epischoenetum villosi* was also found in the Dutoitskloof Mountains. The species with their respective cover values are: *Restio brachiatus* (5), *Anthochortus crinalis* (3), *Cliffortia tricuspidata* (3), *Erica curviflora* (2a), *Erica intervallaris* (2a) and *Laurembergia repens* (+).

Community type 3.3: *Epischoenus quadrangularis-Pennisetum macrourum* Tall Closed Grassland

This is a seepage type that was found at relatively high altitudes in the Groenland Mountains. It is dominated by the grass *Pennisetum macrourum*, so it is classified as a Tall Grassland. The soil is very wet and peaty. Another, relatively species-poor community with a dominance of *Pennisetum macrourum* was found in the Groenland Mountains, but this was not sampled. The *Epischoenus quadrangularis-Pennisetum macrourum* Tall Grassland forms a sharp border with a community that is dominated by *Restio ambiguus*. This is a small restio that was regularly recorded in seepages in the Kogelberg (Boucher 1978). The species with their respective cover values are: *Pennisetum macrourum* (4), *Anthochortus crinalis* (2b), *Elegia thyrsifera* (2b), *Epischoenus quadrangularis* (2b), *Ursinia caledonica* (2a), *Stoebe cinerea* (1), *Erica hispidula* (1), *Polygala nematocaulis* (1), *Chironia decumbens* (+), *Senecio pubigerus* (+), *Stoebe plumosa* (+), *Restio ambiguus* (+) and *Cliffortia graminea* (r).

Community type 3.4: *Carpacoce spermacocea-Elegia thyrsifera* Tall Restioland

This community was found in the Akkedisberg Mountain, where altitudes are relatively low and real high-altitude mires are absent. This community is probably closely related to the low altitude seepage types such as the *Erica-Osmitopsis*-Seepage Fynbos described by Boucher (1978). The dominant species and their respective cover values are: *Elegia thyrsifera* (5), *Carpacoce spermacocea* (4), *Carpha glomerata* (2b), *Cliffortia graminea* (2b), *Berzelia lanigunosa* (2a), *Helichrysum helianthemiifolium* (2a), *Neesenbeckia punctoria* (2a), *Pennisetum macrourum* (2a), *Tetraria cuspidata* (2m), *Cassytha ciliolata* (1), *Erica sessiliflora* (+), *Podalyria species* (+) and *Protea cynaroides* (+).

4.10 Discussion and conclusions

One of the most important questions that is raised from the results of this study is where the high-altitude mires of the Western Cape fit into the worldwide typology of fens and mires. From a phytosociological and physiognomic point of view, the Western Cape mires stand out because of their dominance of Restionaceae. Although they also form the sources of the rivers they are clearly very different from the European spring ecosystems (Zechmeister & Mucina 1994). Swamps and bogs with a high graminoid cover are found extensively in the boreal zone of the Northern Hemisphere (Sjörs 1983) and the vegetation cover of swamps and bogs in Africa is also mostly dominated by graminoids (Thompson & Hamilton 1983).

A more general classification of mire ecosystems makes use of hydrological features. Gore (1983) distinguishes between ombrotrophic and minerotrophic mires, based on the origin of the water. In an ombrotrophic seepage a thick layer of peat has developed and there is no more contact with the mineral substrate. The water originates exclusively from rain, which results in very oligotrophic conditions. The water from minerotrophic mires seeps through the mineral substrate into the mire, so it is richer in nutrients than the ombrotrophic mire. Ombrotrophic mires can only exist in very humid climates such as the blanket bogs of the British Isles and the elevated bogs of Northern Europe; they are quite rare in the Southern Hemisphere. Examples are found in Lesotho (Van Zinderen Bakker & Werger 1974) and New Zealand (McQueen & Wilson 2000).

Actually, the distinction between ombrotrophic and minerotrophic mires is more like a gradient, an idea expressed by Sjörs (1983). Ombrotrophic mires are on the one extreme of this gradient and all mires that do not feed exclusively on rain water make up the rest of this gradient.

Sjörs (1983) also gives a more detailed subdivision of European mires: Topogenous mires (influenced by stagnant water), soligenous mires (influenced by seepage), limnogenous mires (influenced by flood waters) and ombrogenous mires (influenced by rain water). Soligenous and limnogenous mires are both associated with rivers. Soligenous mires form around springs and limnogenous mires occur in the floodplains along the lower reaches of rivers. The mires described in this study are all of the soligenous type. Even though there have been more recent classifications of mires (for example Wheeler & Proctor 2000), these mostly only have local applications, and the original classification of Gore (1983) and Sjörs (1983) is still very topical (Wheeler *et al.* 1995).

The different communities described in this study are situated along a gradient from dry to moist. In the *Ficinio argyropae-Epischoenetum villosi* Association, which occurs in the centre of the mire, water stagnates more because the drainage is slow. On the edges, the *Tetrario capillaceae-Restietum subtilis* Association, which has a faster drainage, will prevail. This gradient is also visible as the second axis in the ordination diagram in Figure 4.2. Further towards the margins, communities dominated by *Chondropetalum deustum* can occur, but these were not recorded during this study. Two communities can occur towards the centre of very wet mires, namely the *Anthochorto crinalis-Elegietum intermediae* Association or the *Isolepis prolifer-Bulbinella nutans* Tall Closed Sedgeland described from the Dutoitskloof Mountains. Both communities are extremely poor in species, because of the specific stresses that occur under water-logged conditions. It is clear that this gradient, from well-drained to poorly drained or from the edge to the centre of the mire, is also very prominent in the ordination diagrams. This gradient was also found by Bragazza & Gerdol (1999) in some mires in the south-eastern Alps. The other distinguishing feature that shows clearly in the ordination diagrams is the importance of the substrate, as can be seen from the *Protea lacticolor-Hippia pilosa* Tall Shrubland from the shale band.

A conspicuous thing about the vegetation of mires in the Western Cape is that they are dominated by the clonal restios *Anthochortus crinalis*, *Platycaulos depauperatus* and *Restio subtilis* (Linder 1985). Because these species tend to cover everything, the vegetation is relatively poor in species. Clonal reproduction is often coupled to environmental plasticity, so the species can tolerate slight differences in the environment. The diversity of microsites is much bigger than the species richness suggests (Price & Marshall 1999). The tall restio *Chondropetalum mucronatum* only regenerates from seed after fires and usually occurs in large, dense monotypic stands when mature. It does not support any vegetation growing underneath it. The dead material from previous generations can form dense accumulations of debris and this creates a very unfavourable substrate for other species.

In marshes elsewhere in the world, clonal sedges and grasses take the place of the clonal Restionaceae recorded in this study. Soukupova (1994) deduces from his investigations on three clonal graminoids that the clonal growth form is often found as an adaptation to waterlogged conditions. After waterlogging there is an increase in clonal modules. Specht (1981) reviews many of the problems that sclerophyllous plants have to overcome in seasonally waterlogged areas.

It has become clear from this study that the mires in South Africa are very different from those on the Northern Hemisphere. There is however very little knowledge about the fens and mires of the Southern Hemisphere. In order to be able to make general statements about mire ecosystems, more attention should be paid to the mire ecosystems in countries like South Africa.

5. Description of the riparian vegetation types of the Hottentots Holland Mountains

5.1 Abstract

This paper presents the results of a Braun-Blanquet phytosociological survey of the riparian vegetation of the mountain streams in the Hottentots Holland Mountains. For the purposes of this study, the riparian vegetation is subdivided into the following zones: the Wet Bank, Lower Dynamic, Shrub/Tree and Back Dynamic Zones. The vegetation is sampled along transects in which each riparian zone is sampled separately. The vegetation data are analysed using a combination of TWINSPAN followed by manual tabulation using the Megatab computer program. Twenty-six riparian plant communities are described which vary structurally from sparse sedgelands and tall fynbos to scrub and forest. The most important factor that explains the vegetation patterns is the inundation frequency, which is, however, difficult to quantify in mountain streams. The investigation of the inundation frequency is described in a separate study (Sieben *et al*., Chapter 6). Each catchment has unique features that are reflected by differences in the vegetation. Communities located on the shales and granites are, for instance, quite distinct from those on the sandstones, while altitude also plays a major role in determining community composition.

5.2 Introduction

Except for the floristic diversity of the fynbos, the mountains of the Western Cape are valued for the high quality drinking water they produce (King & Day 1979). This aspect will continue to play a bigger role as the population of the Cape Metropolitan Area grows and the water demand continues to increase (Davies & Day 1998). The majority of the rivers nowadays are dammed in at least one place and few rivers experience natural flood regimes. It is only in the higher reaches of the rivers where the riparian vegetation still occurs in a more or less natural state (King & Day 1979) and it is this vegetation that forms the subject of this chapter.

Riparian vegetation plays a very important role in the functioning of a riverine ecosystem. It prohibits erosion, slows down turbulent floods, consumes water and adds to species and habitat diversity (Kopecky 1963; Rogers & Van der Zel 1989; Birkhead *et al.* 1996). Anthropogenic threats to riparian vegetation are caused mainly by alien vegetation and modified flood regimes. Many studies have paid attention to the changes in riparian vegetation after the flood regime has been altered (Franz & Bazzaz 1977; Johnson *et al.* 1995; Stevens *et al*. 1995; Marston *et al*. 1995; Tremolières *et al.* 1998). Most of these studies have focussed on the lower reaches of rivers and the upper reaches have generally been ignored, however, in mountain streams there is also an obvious relationship between flooding and vegetation patterns.

Different authors write about the zonation patterns that occur along rivers, but no agreement has been achieved yet on a standard terminology to apply to the zones (Kopecky 1969; Menges & Waller 1983; Hupp & Osterkamp 1985; Bowman & McDonough 1991; Glavaç *et al.* 1992; Dixon & Johnson 1999; Boucher & Tlale 1999). Kopecky (1969) is the first author to subdivide the riparian banks into different ecotopes: the submerse, demerse, semimerse and emerse ecotopes. The criterium used to subdivide the banks is the flood regime. Later on, Menges & Waller (1983) proposed a subdivision based on the life strategies of the plants growing in the zones. It is important to make a distinction between different geomorphic types of riverbanks, such as a floodplain (Menges & Waller 1983) and a steep riverbank (Dixon & Johnson 1999; Boucher & Tlale 1999). Kopecky (1969) also recognized this and treated the eurysaleutic bank type (that of the lower reaches of the rivers, with gentle bank slopes and high floods) differently from the stenosaleutic bank type (that of the higher reaches of the rivers, with steep bank slopes and low floods). His subdivision has an advantage over that of Menges & Waller (1983), in that it is based on fluvial processes so that it can be used as a more generic subdivision and be extrapolated to different biomes.

The subdivision used by Boucher & Tlale (1999) is based partly on the fluvial processes and partly on the structure of the vegetation. This has the advantage that it is easily applied in the field. Their Aquatic Zone is the same as Kopecky's (1969) submerse ecotope, their Wetbank Zone equates to the demerse ecotope, the Lower Dynamic Zone to the semimerse ecotope and the Back Dynamic Zone to the emerse ecotope. Additionally, Boucher & Tlale (1999) recognize a Shrub/Tree Zone between the Lower- and Back Dynamic Zones. This Shrub/Tree zone can be recognized in many riverine ecosystems worldwide and also plays a distinct role in the fluvial processes. It slows down floods, so that deposition of sediments takes place, and is a source of woody debris (Fetherston *et al*. 1995). The subdivisions of Boucher & Tlale (1999) are used in this study because of their applicability.

This study aims at describing the vegetation types of the riparian habitats in the Hottentots Holland Mountains in the Western Cape and the ecological processes that drive them.

5.3 Study area

The area chosen to undertake a detailed study of mountain riparian vegetation of the Western Cape, is the Hottentots Holland Nature Reserve, which is situated between Stellenbosch, Franschhoek, Somerset West and Grabouw. It has the highest rainfall in the entire Western Cape. Five different rivers originate here: 1.) The Berg River, a major river that flows north through the West Coast forelands; 2.) the Riviersonderend River, another major river that flows east through the Overberg Region, and joins the Breede River near Swellendam; 3.) the Palmiet River, an intermediate sized river that flows through the Kogelberg State Forest towards the south; 4.) the Eerste River, a small river that flows west through Stellenbosch towards the False Bay coast and 5.) the Lourens River, a small south-west flowing river that flows directly to the False Bay coast through Somerset West. Out of these five rivers, only the Riviersonderend, through the Breede River, flows into the Indian Ocean. The four other rivers flow into the Atlantic Ocean.

The Hottentots Holland Nature Reserve is situated in the core area of species richness of the Fynbos Biome (Boucher 1978; Cowling *et al*. 1992). Because of the high rainfall, the high diversity of plant species and the high diversity in habitats, the area was considered to be an ideal location for a first detailed study of mountain riparian vegetation in the region, to provide a maximum amount of information about riparian habitats.

5.4 Soils and pedogenesis

The soils adjacent to mountain streams are poorly developed and contain a high proportion of rocks. In many instances the topsoil is completely washed away and the banks consist entirely of bedrock, boulders and large cobbles. The best developed soils are found in the Back Dynamic Zone. The deepest soils that can be found along the rivers are in the forests, the shale-bands and in seepage areas or floodplains. Fry (1987) describes the catenas (soil gradients) that occur on the slopes of Swartboschkloof in the Eerste River catchment. The soils at the bases of these catenas can be found in the Back Dynamic Zones of the rivers. This is mainly the Mispah Form on sandstone or granite substrates. In some places on shale bands and granite substrates, the red apedal soils of the Glenrosa Form can be found in the riparian zone. Under forests, the brown humic soils of the Oakleaf Form can be found. In lowlands and depressions, where small floodplains are formed, the Fernwood Form occurs. This Form belongs to the group of pale soils and it occurs in two phases: the wet form occurs where hydromorphic processes dominate and the dry form where podzolisation dominates. Another soil form that is associated with rivers but that was not found in the present study is the Dundee Form (Kruger 1974).

5.5 River ecology

Rivers are very complex ecosystems that reflect the environmental situation in the entire catchment. The climate and the geological substrate in a subcatchment of a river have an impact on the riverine ecosystem, the runoff and the water quality (Boucher & Marais 1993). Any human activity in the catchment will also affect the river downstream. For example, Dye (1996) has shown that pine plantations in a subcatchment decrease the runoff because a plantation uses more water than indigenous vegetation. However, rivers are resilient systems and the impact of a disturbance decreases with increasing distance downstream (Ward & Stanford 1979).

The catchment is not a fixed network of river channels, but a dynamic expanding or shrinking source area (Hewlett 1961; Hewlett & Hibbert 1967). Some water is stored in the soil while rivers depend on a restricted source area for their water supply. The course that water follows before it enters the river will have a great impact on the water quality in the river. For example, if water percolates through an agricultural area, the water flowing in the river will be enriched in nutrients, while the runoff from an undisturbed area where sandstones dominate, the substrate will be very poor in nutrients (Bosch *et al*. 1986). In the Fynbos Biome, runoff yields between 35 – 55% of the total rainfall. This value is high compared to other biomes in South Africa. After a fire, runoff increases even more and only returns to its original level after about 15 years (Cowling *et al*. 1997).

Mountain streams, which form the subject of this study, have some characteristics that make them different from the lower reaches of rivers. In mountain streams erosion is dominant over deposition. This creates a very unstable substrate both in the riverbed and on the banks. Organisms living in the streams, whether they are plants or animals, are few but are highly adapted (Davies & Day 1998). The riverine ecosystem here stands out because it is entirely dependent on an external food source: the litter from the riparian vegetation. The interaction between shredder populations and the input of allochthonous plant material play a major role in these ecosystems (King 1981; Stewart & Davies 1990; Stewart 1992).

Some reviews of ecological processes taking place in Southern African riverine ecosystems are presented by Davies & Day (1989, 1998) and Day *et al.* (1986).

5.6 Vegetation types

Accounts of Western Cape riverine vegetation types are mainly rather general, such as those by Taylor (1978), Kruger (1978b) and Campbell (1986b), while Werger *et al.* (1972), Campbell & Moll (1977), Boucher (1978) and McDonald (1988) offer detailed vegetation descriptions of specific areas. Kruger (1978b) also gives a detailed account of the different seepage types associated with rivers. The riparian vegetation in the lower reaches of the Western Cape rivers is, in most cases, invaded by alien species. It is described in its natural state mainly by Boucher (1987). A number of studies have been done here to assess the Instream Flow Requirements of the rivers, so the ecology of these vegetation types is relatively well known (e.g. Brown & Day 1998; Burgers 1992).

The ‘typical scrub’ of the riparian sites as described by Taylor (1978) and Campbell (1986b) (‘Closed-scrub Fynbos’) consists mainly of tall shrubs of species such as *Brabejum stellatifolium, Brachylaena neriifolia* and *Metrosideros angustifolia*. This vegetation type is, however, not found everywhere along the rivers and Kruger (1978b) correctly states that the vegetation found along a stream can range from forest to a tall herbland. The zonal variation in riparian mountain vegetation has not been investigated before in mountain streams in the Fynbos Biome.

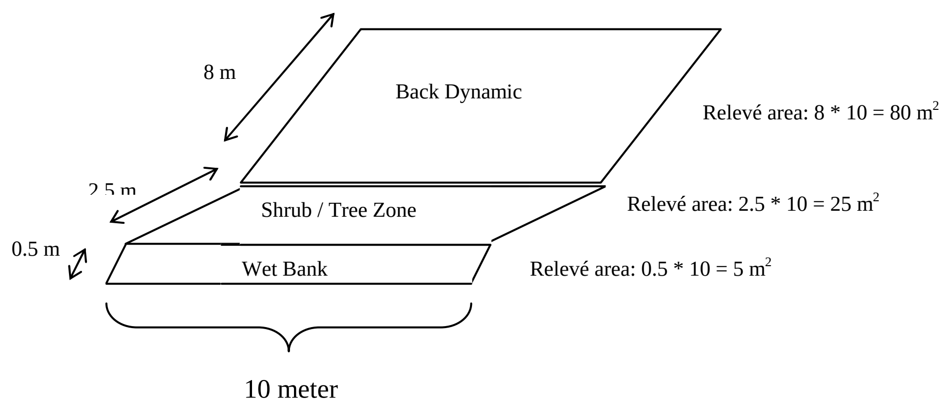

Figure 5.1: The sampling method for riverine transects applied in this study. The relevé area is variable, being dependent on the local width of each riparian zone. The stretch (width) of each transect is consistently 10 metres.

5.7 Methods

Vegetation samples have been taken in transects across the riverbanks. In each transect several vegetation zones could be recognized which were sampled separately. The total length of riverbank in each transect is 10 metres, so the sample size of a vegetation zone depends on the distance each zone extends up the bank (See Figure 5.1). On average, this was 20 m^2 in the Aquatic Zone, 2 m^2 in the Lower Wetbank Zone, 30 m^2 in the Upper Wetbank Zone, 20 m^2 in the Shrub Zone and 100 m^2 in the Back Dynamic Zone or riparian forest. These sample sizes comply well with the sample sizes recommended by Tüxen (1970) for the different structural vegetation types involved (see also Westhoff & Van der Maarel 1973). Vegetation sampling followed the Braun-Blanquet Method (Westhoff & Van der Maarel 1973; Werger 1974). Glavaç *et al*. (1992) pay attention to the nature of vegetation borders along a riparian gradient; they found that even along a continuous gradient several homogeneous vegetation units could be recognized. Vegetation sampling in transects is thus quite feasible, because the different zones are well defined and easily recognizable.

TWINSPAN and manual tabulation (Hill 1979) are used to classify the vegetation samples. When undertaking manual tabulation, the vegetation scientist assesses the acceptability of the TWINSPAN components in groups and uses his knowledge of the vegetation in the field and of the particular sites as a reference. The aim of reshuffling is to cluster the presence and absence of species as far as possible into blocks (Feoli & Orloci 1983). The programme used for this purpose is Megatab (Hennekens 1996). The clusters that are sufficiently sampled have been given scientific names according to the International Code of Syntaxonomic Nomenclature of Weber *et al*. (2000). Community names for local use (for example by managers) are based on the vegetation structure and two names of important species (Edwards 1983). These names have been given to all the communities described. The hierarchical relationships between communities have been examined using the program SYNTAX (Podani 1994).

For the gradient analysis of the vegetation, using multivariate techniques, there are two different methods available, namely, ordination (direct gradient analysis) and constrained ordination (indirect gradient analysis). The program package Canoco 4 is used here for these analyses (Ter Braak & Šmilauer 1998). The compositional data such as particle sizes have been log-transformed prior to further analysis, according to the recommendations of Ter Braak & Šmilauer (1998). The technique used for indirect gradient analysis is Correspondence Analysis (CA), which makes use of the Weighted Averaging algorithm applicable for unimodal response curves (Hill 1974). Økland (1996) argues that CA and Canonical Correspondence Analysis (CCA) should be used complementarily because CCA does not account for the variation that is explained by variables that were not recorded. If the results of CA and CCA are very similar it is clear that all the important environmental variables were included in the study. In this study, only a CA is carried out, while the constrained ordinations are dealt with in more detail in Chapter 7.

5.8 Results

Twenty-six riparian communities have been recognized together with five subcommunities. The dendrogram showing the hierarchical relationships between the different communities resulting from the analysis in SYNTAX, is presented in Figure 5.2. This dendrogram, together with the CA ordination diagram of Figure 5.3, is used to study and interpret the relationships and the transitions between the different vegetation types described in this study. The vegetation units that are closely related can be found near each other in both the dendrogram and the ordination diagram. There is insufficient data from similar communities in other parts of the Fynbos Biome, consequently this study does not present a definitive hierarchical classification of the riparian vegetation types as a whole. Communities are therefore only formally named at the level of the association and below. Instead of a formal hierarchical classification, the vegetation units are clustered into Community Groups, whose exact syntaxonomic status are not yet known. Ten of these Community Groups have been recognized.

The riparian relevé data collected in this study are presented in five syntaxonomic tables (Appendix E; Tables 2 to 6), each presenting one or more Community Groups, and a synoptic table, which summarizes the information in the syntaxonomic tables (Appendix E; Table 7). Thirty-one vegetation units are described. Scientific names are given to 18 associations, eight subassociations and one alliance following Weber *et al*. (2000). No scientific names are given to higher syntaxonomic units, because of a lack of data. In cases where a syntaxonomic name is given, a type relevé is also indicated. The differential species are listed together with the constant companions. These are defined

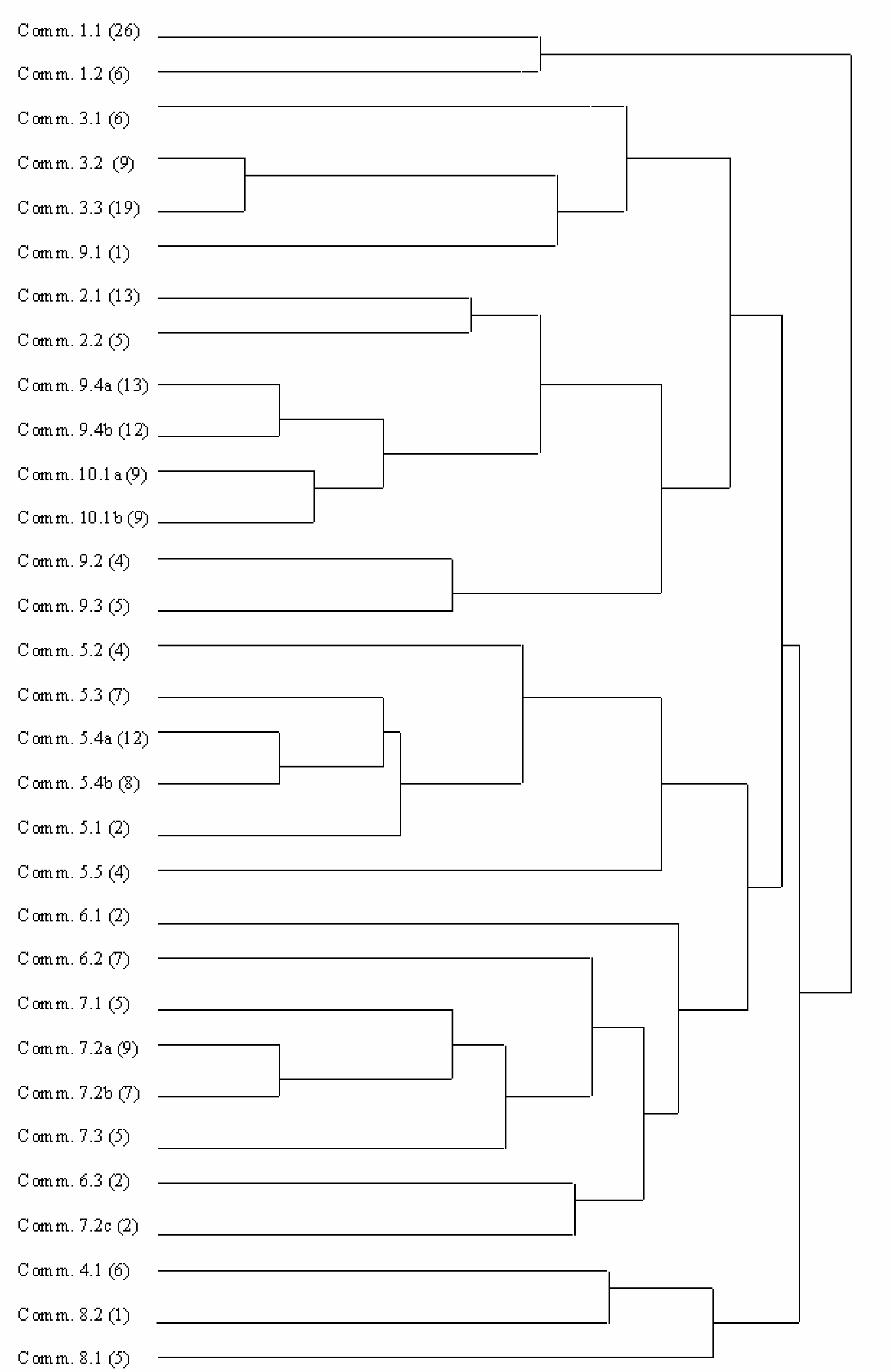

Figure 5.2: Dendrogram indicating the hierarchical relationships between the different vegetation groups. The first number in the community code indicates the Community Group (1 = Aquatic; 2 = Pioneer Wet Bank; 3 = Erosion Wet Bank; 4 = Deposition Wet Bank; 5 = Ericaceous Fynbos; 6 = Transitional Fynbos; 7 = Asteraceous Fynbos; 8 = *Cliffortia odorata* dominated vegetation; 9 = Afromontane Forest; 10 = Riparian scrub; numbers between brackets indicate the number of relevés included)

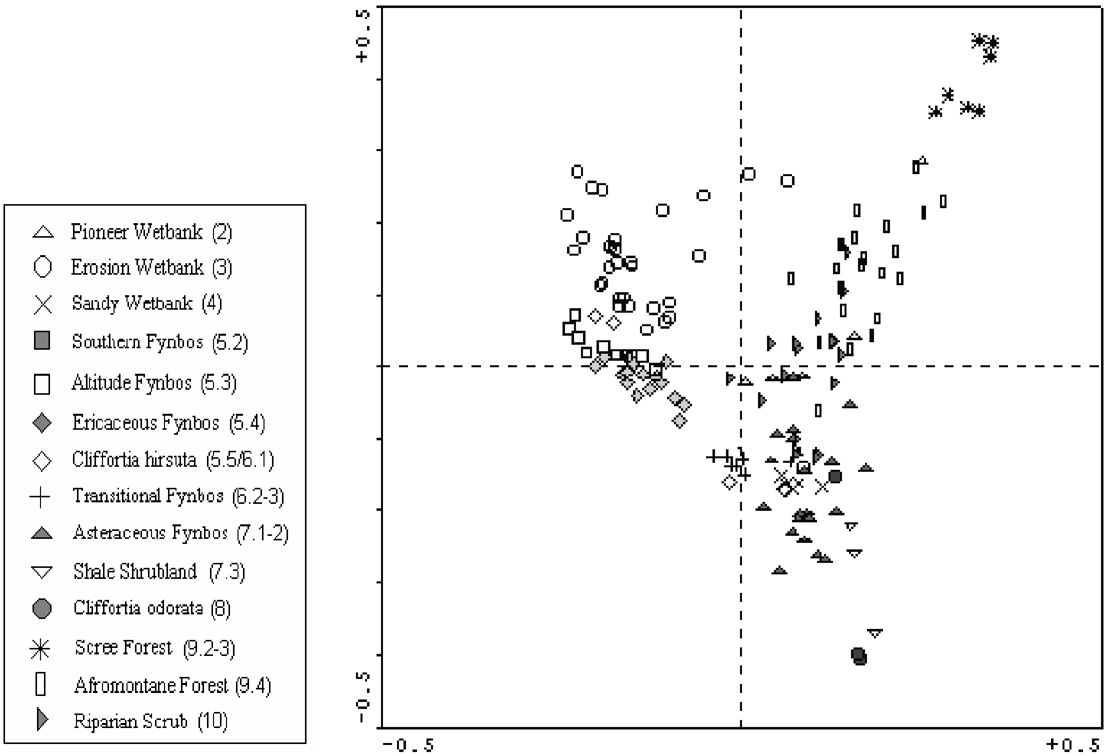

Figure 5.3: First two axes of the ordination of the relevés using Correspondence Analysis.

according to the guidelines given by Westhoff & Van der Maarel (1973). A differential species is a species that occurs in at least 30% or more of the relevés in one community or group of communities than in any of the others. A constant companion is a species that occurs in more than 60% of the relevés in a particular community. In some cases a dominant species is indicated. This is a constant species with an average canopy cover of more than 25%.

In some cases comparisons have been made with data collected by other researchers, which are shown in summarizing syntaxonomic and synoptic tables. These comparisons do not cover the whole biome, however, and they do not result in new classifications or new clusters, because we have chosen to limit these comparisons so as to present the current classification in a broader perspective. When data sets are expanded, however, new ways of ordering the data may arise and new clusters may be recognized. In some of the cases below this might look obvious, but we do not deal with these overall classifications here, as they are also currently undertaken by the VEGMAP project for which published and unpublished data from across the biome is currently being collated (McDonald 1997; McDonald & Boucher 1999).

Aquatic communities (Appendix E; Table 2)

Community Group 1: Aquatic Communities

Aquatic communities in mountain streams must survive the stresses of high stream velocities and dynamic substrates subject to rapid changes. These conditions inhibit the roots, especially of the young seedlings, from taking a strong hold in the substrate. Moreover, the rivers are often shaded by trees while the water is very poor in nutrients, which is not conducive to rapid plant growth. Very few plants are suitably adapted to survive these extreme conditions.

The aquatic communities are differentiated by two species: *Isolepis digitata* and the exotic moss *Fontinalis antipyretica. Isolepis digitata* only occurs in places that receive sufficient light. Where there is open water with a depth of up to one meter and velocities are slow *I. digitata* can occur in high densities. Another aquatic moss, *Wardia hygrometrica,* occurs in these rivers as well, although it was not recorded in the sample sites. It is the only moss species endemic to the Fynbos Biome (King & Day 1979). Two different communities are recognized, both described as associations. The two moss species could be characteristic species, as *Isolepis digitata* occasionally also grows in the Lower Wet Bank Zone. The two associations are combined into an alliance called *Isolepidion digitatae*.

Community type 1.1: *Isolepis digitata-Fontinalis antipyretica* Community

Scientific name: *Fontinali antipyreticae-Isolepidetum digitatae* ass. nova hoc loco

Number of relevés: 26

Type relevé: 56 (Table 2)

Average no. of species: 2 (1 – 2)

This is an aquatic community dominated by *Isolepis digitata* and *Fontinalis antipyretica*. The sedge *Isolepis digitata* covers, on average, 10% of each relevé while the moss

Fontinalis antipyretica covers less than 1% on average. *Isolepis digitata* mostly grows to about 20 cm tall, but in deeper water it can grow taller. It prefers to grow on the downstream side of the rocks where velocities are minimal. It will not grow taller than the rock, so it will be protected when the river is in flood (pers. comm. G.R. Basson). The community occurs is widespread in the mountain streams, with *Isolepis digitata* dominating in places with heavy sunlight and *Fontinalis antipyretica* dominating in the shady areas. The river bottom is covered by boulders between 0.25 m and 1.0 m in size. In the mountain streams where this community occurs, depth is mostly shallow (on average 0.2 m deep). In deeper water (up to 0.8 m) *Isolepis digitata* tends to have a high percentage cover (over 50%).

Community type 1.2: *Isolepis digitata-Pentaschistis pallida* Community
Scientific name: *Pentaschistido pallidae-Isolepidetum digitatae* ass. nova hoc loco
Number of relevés: 6
Type relevé: 204 (Table 2)
Average no. of species: 3 (2 – 12)

This aquatic community occurs in places with shallow water, mostly on bedrock. Except for the two differential species mentioned for the aquatic communities in general, this community can be differentiated by a relatively high percentage cover of the grass *Pentaschistis pallida*. This grass appears to have a broad ecological amplitude, because it can also be found in some places in the Back Dynamic Zone. The dry patches within this community support additional species, such as seedlings of different shrubs, ferns and Wet Bank species such as *Juncus lomatophyllus*. There are also several species of mosses and the liverwort *Symphyogyna podophylla*. Most of these species can be used to differentiate this community from the *Fontinali antipyreticae-Isolepidetum digitatae*. In places where there are many dry patches the community can become relatively species-rich and this type (relevés 167, 204 and 205) is recognized as the ‘typical’ variant of the *Pentaschistido pallidae-Isolepidetum digitatae*. This variant occurs in places with bedrock and in waterfalls and vegetation cover is relatively high here (more than 50%). The sedge *Isolepis digitata* is dominant. It makes up the greater part of the herb layer which is 0.2 – 0.3 m tall. Mosses, of which *Fontinalis antipyretica* is the most important species, also have a high cover. The other relevés (130, 132 and 250) are more depauperate and belong to the ‘inops’-variant. Bedrock is sparser in this type and the vegetation cover is also much lower.

Wet Bank communities (Appendix E; Table 3)

The Wet Bank Zones are the areas around the river that are flooded regularly. In some cases, an Upper and a Lower Wet Bank can be distinguished but this is not always the case.

Three completely different community groups occur in the Wet Bank Zone: Erosion, Deposition and Pioneer Wetbanks. Few species are in common between these vegetation types, except for the seedlings of trees such as, *Brachylaena neriifolia*, *Metrosideros angustifolia* and *Podalyria calyptrata*, and liverworts and mosses, such as *Symphyogyna podophylla* and *Sematophyllum dregei*. This is because these vegetation units come from quite a wide range of environments and probably belong to two different vegetation classes. The main distinction is between Wet Banks where erosion dominates and those where deposition dominates.

Community Group 2: Pioneer Wetbanks

This community group consists of highly unstable pioneer communities. The vegetation types in it occur under the most stressful conditions imaginable in a riparian zone of a mountain stream. Erosion dominates, there is a rocky substrate and it is often flooded. Because of the unstable substrate the community can be completely disrupted after a small flood, which is why this community has a permanent pioneer character. Ferns and shrub seedlings from the Shrub Zone are the only higher plant species occurring here. Differential species for this Community Group are *Blechnum capense*, *Metrosideros angustifolia* and several moss species.

Community type 2.1: *Symphyogyna podophylla-Sematophyllum dregei* Moss Community

Number of relevés: 13

Average no. of species: 8 (3 – 14)

This community occurs in shaded places and is characterized by a high cover of mosses, which are the only species that can persist in this unstable environment. They are typical of shaded conditions because in exposed sites the evaporation is too high.

Because this is a highly unstable and possibly heterogeneous group there are no real constant species. The most important species are the mosses *Fissidens glaucescens* and *Sematophyllum dregei*, the liverwort *Symphyogyna podophylla*, the ferns *Blechnum capense* and *Todea barbara* and the shrub *Metrosideros angustifolia*, mostly occurring in the juvenile stage. These species, except for *Metrosideros angustifolia*, can also be used to differentiate this community from the other Pioneer Wet Bank Community discussed below. Mosses form the vegetation layer with the highest cover (over 10%); the herb layer and eventual sparse shrub layer both have a cover of about 5% on average.

Community type 2.2: *Brachylaena neriifolia-Metrosideros angustifolia* Pioneer Community

Number of relevés: 5

Average no. of species: 6 (3 – 10)

This community occurs in rocky habitats in exposed areas where mosses cannot grow because of the high evaporation. It is very inconsistent and additional sampling of this type should provide useful information. There are only two more or less constant species: the juveniles of *Brachylaena neriifolia* and *Metrosideros angustifolia*. Another conspicuous element in this vegetation type is the presence of juveniles of restios that occur higher up the bank, including *Cannomois virgata*, *Platycaulos callistachyus* and *Restio purpurascens*.

Community Group 3: Erosion Wetbanks

These are well-established Wet Bank vegetation types that occur in those reaches of the mountain streams where erosion dominates. They form the more consistent Wet Bank communities that occur in sheltered places on the riverbanks, where small pockets of soil are protected from washing away. There is often an Upper Wet Bank and a Lower Wet Bank Zone present. The Upper Wet Bank Zone has a different vegetation to the Lower Wet Bank Zone but depressions within the Upper Wet Bank which are constantly wet contain the same species as the Lower Wet Bank, which makes communities sometimes difficult to separate. The distinction between the vegetation of the Lower Wet Bank and the Upper Wet Bank is mainly a matter of scale. The relevés taken from the Lower Wet Bank are small and patchy and similar patches can sometimes be found in the broader Upper Wet Bank Zone or even in other zones where there is seepage. The Lower Wet Bank often has a sandy soil, whereas the Upper Wet Banks will contain many boulders and cobbles. Typical species of the Lower Wet Bank Zone are *Disa tripetaloides, Drosera capensis, Lycopodiella caroliniana, Schizaea tenella* and the mosses *Campylopus stenopelma* and *Sphagnum capense.* These species are differential species for the whole of Community Group 3. In the Upper Wet Bank Zone these species are often found together with taller plants like *Erica lutea, Penaea cneorum, Prionium serratum* and *Pseudobaeckea africana* (see below).

Two Lower Wet Bank and one Upper Wet Bank type are recognized. These three vegetation types show a gradient from low to high exposure, with the Upper Wet Bank having the highest exposure. Acidity probably fluctuates a lot in the water, but the measured pH values are on average slightly higher than 4.

Community type 3.1: *Symphyogyna podophylla-Schizaea tenella* Community
Scientific name: *Symphyogyno podophyllae-Schizietum tenellae* ass. nova hoc loco
Number of relevés: 6
Type relevé: 49 (Table 3)
Average no. of species: 6 (2 – 11)

This community is typically found in shady conditions under riparian forest. Most ‘typical’ Wet Bank species are shade-tolerant only to a certain extent except for *Schizaea tenella*, which is the only species in this community that grows under closed forest. In some cases, however, *Disa tripetaloides* is also found in this habitat. The community is poor in species and the cover of mosses is high. A common moss is *Campylopus stenopelma* and the liverwort *Symphyogyna podophylla* is differential. Other differential species are the juveniles of *Cunonia capensis* and *Erica caffra*, but in general, this community can best be recognized by the absence of many common Wet Bank species. Moss cover can be quite high, often exceeding 50%. It is significantly higher than the cover of the herb layer, which is on average only 8%. The soils in this community are in general darker and contain more organic material than the other Wet Bank types. Soils only occur in localized patches between the rocks and bedrock is common.

Community type 3.2: *Sphagnum capensis-Disa tripetaloides* Community
Scientific name: *Sphagno capensis-Disetum tripetaloidis* ass. nova hoc loco
Number of relevés: 9
Type relevé: 5 (Table 3)
Average no. of species: 10 (5 – 15)

This is the most typical Wet Bank Zone community, with *Schizaea tenella*, *Drosera capensis*, *Lycopodiella caroliniana* and *Disa tripetaloides* as the most important species. It occurs in more exposed places than the *Symphyogyno podophyllae-Schizietum tenellae*, which belongs to the same alliance. It can occur in a mosaic with the next community. Soils are pale and contain a high fraction of coarse sand because regular floods wash the finer materials away. They are permanently wet and covered by mosses; the dominant species is *Sphagnum capense*. The most important vegetation layer is the herb layer (more than 30% cover), which, in some cases, contains *Restio purpurascens* that grows up to 1.0 m tall. Most herbs are much lower, however, being between 0.1 and 0.2 m tall. In cases where a sparse shrub layer is present, it consists solely of *Pseudobaeckea africana*.

Community type 3.3: *Pseudobaeckea africana-Prionium serratum* Closed Short Shrubland

Scientific name: *Pseudobaeckeo africanae-Prionietum serrati* ass. nova hoc loco

Number of relevés: 19

Type relevé: 186 (Table 3)

Average no. of species: 17 (10 – 33)

The typical Upper Wet Bank Zone contains a vegetation type that is more or less transitional between the *Sphagno-Disetum tripetaloidis* and the Ericaceous Fynbos communities discussed below. The most typical element is the dominance of *Prionium serratum*, together with other differential species such as *Erica lutea*, *Grubbia rosmarinifolia* (which grows tall here), *Penaea cneorum* and *Pseudobaeckea africana*. The generalist riparian shrub *Brachylaena neriifolia* typically grows in the lower shrub stratum. The shrub layer is more prevalent here and covers on average nearly 20% of the sample. Most of the shrubs grow to a height of only 1.0 – 1.5 metres, although species like *Podalyria calyptrata* can form a taller shrub stratum in places. The herb layer is the dominant stratum and is formed by a mosaic of *Prionium serratum* (up to 0.5 m tall), some Restionaceae, such as *Restio purpurascens* and *Askidiosperma esterhuyseniae* (up to 1.0 meter tall) and species from the former community (about 0.2 m tall). The *Pseudobaeckeo africanae-Prionietum serrati* often forms a mosaic with the *Sphagno-Disetum tripetaloidis*, which makes it difficult to separate them. Mosses are sparser in the *Pseudobaeckeo africanae-Prionietum serrati* than in the Lower Wet Banks. Soils are similar to the soils of the Lower Wet Bank Zone but are not permanently wet. The *Pseudobaeckeo africanae-Prionietum serrati* occurs on stony riverbeds in exposed positions. In the Hottentots Holland Nature Reserve this community mostly occurs in the eastern catchments. In the Eerste River *Prionium serratum* occurs in impoverished monospecific stands in the lower reaches on sandstone, a substrate which it prefers to granite (Du Toit 1998). Another reason why this community might not be well developed in the Eerste River is because of the abundance of riparian forest here. These forests, which shade the northern riverbanks in particular (Du Toit 1998), suppress the growth of stands of *Prionium serratum*.

Figure 5.4: Palmiet-dominated Wet Bank vegetation *Pseudobaeckeo africanae-Prionietum serrati* in the foreground. In the background a very shrubby form of the *Cliffortio atratae-Restionetum purpurascenti* can be seen.

Boucher (1978) describes a *Prionium-Wachendorfia* Swamp Community, which is the only reference in the literature to a comparable community. However, no relevés were recorded by him in this swamp community. This community occurs in the lower reaches of the Palmiet River and also along the border of the Hottentots Holland Nature Reserve in the Viljoens Pass. In the swamp community *Prionium serratum* generally grows much taller than in the *Pseudobaeckeo africanae-Prionietum serrati* mountain stream community. In the reaches where the latter community occurs, sediment deposition takes place rather than erosion. This makes it a completely different ecological system. Taylor (1978) categorizes both types of *Prionium* communities as Hygrophilous Fynbos, but this is not a consistent floristic unit.

Community Group 4: Deposition Wetbanks

This Community Group contains only one community in the area. It is found in the lower reaches where sediment loads are deposited in the Foothill Zone. It is very exposed and the vegetation is sparse. It can occur in both the Upper and the Lower Wet Bank Zones.

Community type 4.1: *Wimmerella bifida-Juncus lomatophyllus* Open Sedgeland
Scientific name*: Wimmerello bifidae-Juncetum lomatophylli* ass. nova hoc loco
Number of relevés: 6
Type relevé: 146 (Table 3)
Average no. of species: 18 (9 – 30)

This community is found on open beaches where sand accumulates in the reaches where the river enters the Foothill Zone. The vegetation mainly consists of sedges, with some Restionaceae and grasses. The soils are sandy and contain many cobbles. Most samples of this type have been found where the Riviersonderend River leaves the mountains and enters the plains near Theewaterskloof Dam. Here the community is very well developed. An additional sample from the Lourens River shows that this community can also occur in higher reaches, but in a depauperate form.

The community occurs in its optimal form on open sandy beaches. Here a slight zonation pattern occurs, but it is not distinct enough to be illustrated by the data available in this study. Further research might show that this association contains a number of subassociations. Because the banks formed by sandy beaches are often very flat, very small fluctuations in water level reflect marked differences in the horizontal distribution of species. *Isolepis prolifer* grows closest to the water where it binds the accumulating sand so that *Juncus lomatophyllus* can then colonize the sand at elevations of just a few centimetres higher than the *Isolepis prolifer* Zone. *Juncus lomatophyllus* forms the dominant species in this vegetation type. Higher up the bank *Calopsis paniculata*, *Pennisetum macrourum* and *Pentameris thuarii* can be found. These species, together with several juveniles of shrubs such as *Brachylaena neriifolia* and *Morella serrata*, form a vegetation belt that holds the sand firmly. Two other differential species found in this zone and the next one are *Wimmerella bifida* and *Juncus capensis.*

If the beach is wide enough there is also a zone higher up the beach where the sand is very dry and subject to wind erosion. Barely any plants grow here, because of the unstable environment. This shows clearly that the structure of this vegetation type is highly variable. In the *Isolepis prolifer* Zone the vegetation is low and dense; in the *Pennisetum macrourum* Zone the vegetation is tall and dense and higher up the beach the vegetation is low and sparse.

Ericaceous and Transitional Fynbos communities (Appendix E; Table 4)

The communities in Table 4 are found in the Lower and Upper Dynamic Zones of the rivers and consist of two Community Groups. Community Group 5 consists of communities that fit Campbell's (1986b) description of Ericaceous Fynbos. However, this author might have classified some of the relevés as Proteoid Fynbos when the proteoid *Leucadendron xanthoconus* has a high cover in the relevé. This example shows that structurally different types can be closely related floristically in the Fynbos Biome. This was also concluded by Werger *et al*. (1972) in Waboomveld (*Protea nitida* vegetation). The structural classification of Campbell (1986b) does not provide much information in these situations. Community Group 6 consists of some unrelated communities that are somehow transitional between Community Group 5 and Community Group 7 (shown in Appendix C; Table 5).

<u>Community Group 5: Ericaceous Fynbos</u>

The following group of communities is very diverse and contains the most species-rich vegetation samples found in this study. Vegetation can be below half a meter tall and only consist of dwarf shrubs, or it can be taller than three metres. The total vegetation cover is always more than 70 %. One species that all these communities have in common is *Erica hispidula*; however, this species also occurs in the Asteraceous Fynbos and in the Upper Wet Bank Zones. The following differential species are shared with the *Pseudobaeckeo africanae-Prionietum serrati* described above, namely: *Penaea cneorum, Erica lutea*, *Berzelia squarrosa* and *Restio purpurascens.* There are three differential species that are not shared with any other Community Group, namely: *Erica equisetifolia*, *Erica longifolia* and *Capeobolus brevicaulis*. The shrubs *Leucadendron xanthoconus* and *Brunia alopecuroides* are only shared with Community Group 6.

Related communities in the literature are the *Erica viridescens-Hypodiscus aristatus* Community (Bond 1981), the *Tetraria thermalis-Hypodiscus aristatus* Community (Kruger 1974), bergpalmietveld (Taylor 1978), the *Leptocarpus membranaceus-Hypodiscus aristatus* Community (McKenzie *et al*. 1977) and the *Penaea-Erica* Fynbos Community subcommunities B and C (Glyphis *et al.* 1978). The species that are in common between these communities are: *Aristea major, Capeobolus brevicaulis, Chrysithrix capensis, Cliffortia atrata, Erica hispidula, E. plukenetii, Helichrysum felinum, Hypodiscus aristatus, Leucadendron xanthoconus, Penaea cneorum, Restio bifarius, Tetraria cuspidata, T. thermalis* and *Widdringtonia nodiflora.*

Campbell (1986b) classifies all these types as belonging to his Nuweberg Mesic Ericaceous Fynbos. The communities described below all occur on shallow acid soils that consist mainly of medium textured sands derived from Table Mountain Group sandstones.

Community type 5.1: *Ischyrolepis triflora-Protea grandiceps* Closed Tall Shrubland
Number of relevés: 2
Range of species number: 45 – 46

A very distinct vegetation type, which is only represented here by two relevés, occurs in the highest reaches of the Lourens River catchment. It occurs on sandstone and can be described as a seepage area on a steep slope dominated by *Berzelia squarrosa*. Soils are relatively deep and acidic and the drainage is quite good. There is a high cover of rocks, which line the gullies draining the slopes. The western slopes of Somerset Sneeukop that are drained by the Lourens River belong to the steepest altitudinal and climatic gradients found in the region and mist is probably quite common. The vegetation occurs in two strata: a herb stratum, which is the dominant stratum and a low shrub stratum 1.5 – 2.0 m tall, which covers 20% of the relevé. This is one of the most species-rich vegetation types found in riparian habitats in the area. It contains many species that are absent or rare in the other types, such as *Cliffortia integerrima, Galium tomentosum, Protea grandiceps, Psoralea asarina*, *Struthiola martiana* and *Willdenowia sulcata.*

Community type 5.2: *Nebelia fragarioides-Staberoha cernua* Closed Short Shrubland
Number of relevés: 4
Average no. of species: 19 (8 – 28)

This is a very low vegetation type (generally below 0.5 m) on sandstone that occurs in the extreme south of the study area in the Palmiet River catchment. It is dominated by *Brunia alopecuroides* and *Erica intervallaris*. Structurally, it resembles a transition between a restio marsh and a riverbank, because the vegetation is very low (mostly lower than 0.5 m). It is a vegetation type that contains many southern elements and similar communities were found in the Kogelberg Biosphere Reserve (Boucher 1978; compare Table 5.8). These communities probably belong to the same alliance. Differential species that are typical are *Chironia jasminoides, Nebelia fragarioides, Nevillea obtusissima, Staberoha cernua* and *Tetraria capillacea*.

Table 5.8: Comparison of the *Nebelia fragarioides-Staberoha cernua* Short Shrubland with the Kogelberg study by Boucher (1978). Many of the species presented here have a southern distribution from the Kogelberg to Bredasdorp and belong to the Kogelberg centre of endemicity (Rebelo 1998).

	Comm. 5.2				Chondropetalum-Berzelia Hygric Fynbos from Boucher (1978)																						
Restio purpurascens	m	+	a	1	3			+								+											
Tetraria capillacea	m	m	m	a			r		1																		
Carpacoce spermacocea		b	+																		r						
Cassytha ciliolata	1		1	+																							
Staberoha cernua	a		1																				r		+		
Erica hispidula	1	m	1		r			r		3	+	+	a	a	1	+	4	+	1	a	r	+	+	1	+	r	+
Nebelia fragarioides	+	+	+						+	+	+	1		+	+	r	+			3		+				r	
Restio occultus	1		1	+			r			+	+	+				+				+		1	r	+	+	1	r
Leucadendron xanthoconus	1	+	+	1					a										+				a	a	a	a	
Nevillea obtusissima	3	a			a	a		+	+	+	+	+		+	1			4	+	+	+	r	r	r	+		+
Restio bifidus	m		a		+	3	1	4	3			+	+		1	1	+	a	3	r			+				
Brunia alopecuroides	+	3	4	4	a	+	r	+					+			a	+	+	+		a		1	+	+		
Chondropetalum mucronatum	+	b	m	3		a	a	r	+				3						+	1	r						
Erica intervallaris	a	b	3	3	r	3		r	+																	r	r
Elegia spathacea	a		1				r	+				1				+			+	r		+	r	r	+	1	
Restio dispar						1				1			+	+	1	+		+									
Erica thomae										+	+	+	a			+			+								
Tetraria flexuosa										+	+	+	+	+		+	1	1	1		r						
Erica pulchella										+				+	+	+	+	+	+								
Restio distichus														+	+	+		+	+								
Erica pulchella																						r	+	+	+	a	
Pseudopentameris macrantha																						+	r	r	+	+	1
Erica sitiens																							r	+	+		+
Pentaschistis eriostoma																				r			+	r	r		
Thamnochortus gracilis																				r			r	r	+		
Thamnochortus pulcher										+	1	1	+	+	+	+								r		a	
Elegia persistens										1				1	1	+	a			+	r		+	+			
Chondropetalum ebracteatum							1	r		+	+		a	1	3	1	3	4	3	+	1	1	+	+	+	+	1
Leucadendron gandogeri			r			+				3			1	3	a	a	3				1			r			1
Alciope lanata										+			+	+	+		+		+			r	r	r	+		
Bobartia gladiata										+	+	+	r	+					r		r	r	r		+		r
Erica fastigiata								r		+	1	+	+		1		1		1	r	+		1	+			+
Saltera sarcocolla										+			+	+		+	+					r		r	a	r	+
Tetraria fimbriolata										+	+					+	+		+	r	r		+		1	+	
Schizaea pectinata										+			+				+			r	r		r	+	r		r
Penaea mucronata										1			+				1		1	r	+	+	+			+	+
Sympieza labialis										1	+	1				+						+	+	+	1	+	r
Tetraria thermalis										1				+		+	1		+	r		r	r	r	+	+	
Erica massonii					+					+	+	+				+	+				+	a	+	+	+		+
Chondropetalum deustum			m					+	a	a	1	a	+	1		1	+			+		+	r	r	a	a	+
Tetraria fasciata					+	1	+	r	1	+		+			+	1		1	+	a	a	+	+	+	1	+	+
Tetraria cuspidata			1		r	1	r	r	+	+	+	+	+	+	+	+		+		r	r	r		R		+	1

The soil is quite acidic here with pH lower than 4 and the substrate is less rocky than the other Ericaceous Fynbos types. The organic matter contents are low close to the river but higher in the Back Dynamic Zone.

Community type 5.3: *Erica longifolia-Tetraria crassa* Closed Short Shrubland.
Scientific name: *Erico longifoliae-Tetrarietum crassae* ass. nova hoc loco
Number of relevés: 7
Type relevé: 216 (Table 4)
Average no. of species: 41 (27 – 55)

This is one of the most species-rich riparian communities found in this study. It sometimes supports more than 70 species on a surface area of 30 m^2. It is found at higher altitudes in the Palmiet and Riviersonderend River catchments. One relevé (no. 263) was collected outside the actual study area in the Groenland Mountains. The community occurs in places that receive more rainfall than any of the other Ericaceous Fynbos types and mist is quite common. The community occurs on shallow soils of the Mispah Form with many boulders. It contains typical seepage species (see Chapter 4), like *Restio subtilis* and *R*. aff. *versatilis*, which indicates that this community grows in a wet habitat.

Half of the relevés have a shrub layer, 2.0 – 3.0 m tall, covering 20% of the relevé and consisting of species such as *Brachylaena neriifolia* and *Podalyria* aff. *montana*. The herb layer, which is dominant, is relatively low (mostly shorter than 0.5 m).

Especially Ericaceae (*Erica fastigiata, E. longifolia, E. lutea, E. plukenetii* and *E. sessiliflora*) and Restionaceae (*Chondropetalum deustum, Elegia neesii, E. spathacea Restio bifidus, R. burchelli, R. corneolus, R. subtilis, R.* aff. *versatilis* and *Staberoha vaginata*) have a large number of species and a high cover in these communities. Less conspicuous, but also important constituents of this vegetation type are the sedges, especially *Tetraria* spp. (*T. bromoides, T. crassa,* and *T. pillansii*).

Community type 5.4: *Cliffortia atrata-Restio purpurascens* Closed Tall Shrubland
Scientific name: *Cliffortio atratae-Restionetum purpurascentis* ass. nova hoc loco
Number of relevés: 20
Type relevé: 225 (Table 4)
Average no. of species: 25 (11 – 38)

This is the most common of the Ericaceous Fynbos types. It is subdivided into two subassociations, of which one occurs in mesic habitats and the other in xeric habitats. They are found in the eastern half of the mountains on sandstone in the Back Dynamic Zones of the rivers. The vegetation consists of a shrub layer 2.0 – 4.0 m tall, covering 20% or more of the community and a dominant herb layer 0.5 – 1.0 m tall. The tallest constituents of the herb layer are the Restionaceae, especially the common species *Restio purpurascens*. This vegetation type is quite similar to the surrounding fynbos in the uplands, except for the presence of *Restio purpurascens* and occasional plants of *Brachylaena neriifolia, Penaea cneorum*, and a number of Bruniaceae species, that grow in the wetter conditions near the river. Higher up the slope, *Tetraria thermalis* usually becomes more dominant and occurs in patches. This is the vegetation type that Taylor (1978) refers to as 'bergpalmietveld', referring to the common name for *Tetraria thermalis*. The community has few differential species at the association level (*Askidiosperma esterhuyseniae, Chrysithrix capensis, Cliffortia atrata* and *Coleonema juniperum*). Most of the differential species will be discussed at the subassociation level.

Subassociation 5.4a: *Cliffortio atratae-Restionetum purpurascentis typicum* subass. nova hoc loco
Number of relevés: 12
Type relevé: 225 (Table 3)
Average no. of species: 23 (13 – 30)
This is the nutrient-poor form of the community that occurs on the drier mineral soils with a higher pH. The soils are also rockier than in the mesic subassociation. Differential species are *Ceratocaryum argenteum, Pentameris macrocalycina* and *Pseudobaeckea africana*. Some additional differential species at the subassociation level are shared with

the *Erico longifoliae-Tetrarietum crassae*, namely, *Erica lutea*, *Restio bifarius* and *R. burchelli*.

Subassociation 5.4b: *Cliffortio atratae-Restionetum purpurascentis centelletosum erianthae* subass. nova hoc loco

Number of relevés: 8

Type relevé: 91

Average no. of species: 27 (11 – 38)

Figure 5.5: Riparian fynbos along a mountain stream: *Cliffortio atratae-Restionetum purpurascentis*. *Restio purpurascens* is the dominant emergent Restionaceae. The yellowish shrub is *Leucadendron xanthoconus*.

This is the mesic form that occurs on soils with higher organic content and a lower pH than the subassociation *typicum*. A mat of *Centella eriantha* and *Carpacoce spermacocea* (both differential species) covers the ground layer locally underneath the ericoid shrubs, sometimes in association with small restios such as *Restio intermedius* and *R. perplexus.* There is also a higher occurrence of *Ficinia filiformis*, which can be used as a differential species of this subassociation. The vegetation is dominated by *Restio purpurascens* and *Erica hispidula*.

Community type 5.5: *Restio purpurascens-Cliffortia hirsuta* Closed Tall Shrubland
Scientific name: *Restio purpurascenti-Cliffortietum hirsutae* ass. nova hoc loco
Number of relevés: 4
Type relevé: 223 (Table 4)
Average no. of species: 26 (22 – 37)

This is a very shrubby community, which is related to the *Elegia capensis-Cliffortia hirsuta* Closed Tall Shrubland of Community Group 6 (see below; Community 6.1). It occurs in places where there is seepage from the slopes into the river. Because of the wet conditions, some typical Wet Bank species such as *Drosera capensis* or *Schizaea tenella* can occur in the lower strata. A shrub stratum, 1.5 – 2.5 m tall, is present in all but one of the relevés and generally covers more than 50% of the sample plot. The herb layer consists of two different height classes, the tallest (1.0 – 1.5 m), formed by *Cliffortia hirsuta*, being dominant. The low herbs are about 0.5 m tall. Differential species are *Cliffortia hirsuta* and possibly also *Erica curviflora*, *Elegia thyrsifera* and *Neesenbeckia punctoria*, which are shared with *Cliffortio atratae-Restionetum purpurascentis*.

Some samples have been taken on a shale substrate, but the pH is relatively low (around pH 4), probably because of mixing with sandstone rubble originating from the immediate environment. The lowest parts of the Palmiet River and a significant part of Noordekloof belong to this vegetation type. Additional data from this community would be useful although it is quite characteristic, hence a formal scientific name was given to it here.

Boucher (1978) mentions the occurrence of *Cliffortia hirsuta* and *Neesenbeckia punctoria* together in his *Erica-Osmitopsis* Seepage Fynbos. Floristically and ecologically these communities have the seepage aspect in common, although they are clearly different communities.

Community Group 6: Transitional Fynbos

These are three different communities that are transitional between the Ericaceous Fynbos of Community Group 5 and the Asteraceous Fynbos of Community Group 7. They do not seem to be closely related amongst each other however, so they are treated separately.

Community type 6.1: *Elegia capensis-Cliffortia hirsuta* Closed Tall Shrubland
Number of relevés: 2
Range of species number: 10 – 19

This community seems to be an extreme form of the *Restio purpurascenti-Cliffortietum hirsutae*, in which *Cliffortia hirsuta* dominates and the typical species of the Ericaceous Fynbos communities, such as *Erica hispidula*, *Leucadendron xanthoconus* and *Restio purpurascens* are absent. Only two transects having this community were sampled: one in Boesmanskloof, where it seems to be quite extensive, and one in Wolwekloof. It is a very species-poor community completely dominated by dense stands of *Cliffortia hirsuta*. The other species that are differential for this community are *Elegia capensis*, *Ficinia trichodes* and the peculiar species *Psoralea fleta*. This is a very tall and slender shrub (up to 5.0 metres tall) that offers a very sparse overstorey. The understorey of *Cliffortia hirsuta* and *Elegia capensis* is mostly about 1.5 – 2.0 m tall and covers the entire relevé. The community occurs on dark sandy soils with a pH of 4.

Community type 6.2: *Muraltia heisteria-Erica pinea* Closed Tall Shrubland

Scientific name: *Muraltio heisteriae-Ericetum pineae* ass. nova hoc loco

Number of relevés: 7

Type relevé: 248 (Table 4)

Average no. of species: 28 (19 – 39).

This community is transitional between the Ericaceous Fynbos communities and the Riparian Scrub communities. It is structurally similar to the *Helichryso-Myrsinietum africanae* of Community Group 7 and to the *Brabejum stellatifolium* Community of Werger *et al.* (1972), but it contains many elements of the Ericaceous Fynbos group. Campbell (1986b) would classify this community as Witrivier Closed-Scrub Fynbos together with the scrubland communities of the *Ischyrolepido-Metrosiderotetum angustifoliae* (see Appendix E; Table 6), but the main difference from the other Closed-Scrub Fynbos types is the extensive cover of the herb layer (more than 70% cover), which is very weakly developed in the *Ischyrolepido-Metrosiderotetum angustifoliae*. Taylor (1978) would call this community type, and the other Closed-Scrub Fynbos communities, Hygrophilous Fynbos. Except for the herb layer, there is a shrub layer present in which *Brabejum stellatifolium* (differential), *Leucadendron xanthoconus* (dominant), *Metrosideros angustifolia* and *Podalyria calyptrata* are the most important species. Some of the lower shrubs that are present are *Diospyros glabra, Muraltia heisteria*, *Cliffortia grandifolia* and *Liparia capitata*. The last two are differential species, together with the herbs *Erica nudiflora, E. pinea* and *Elegia asperiflora*. The exotic shrub, *Hakea sericea,* is often present. The shrub layer covers about 30% of a relevé and ranges in height between 1.5 and 3.0 metres. The herb layer also contains some tall species, especially Restionaceae, like *Cannomois virgata*, *Restio dispar* and *Platycaulos callistachyus*, which grow to 1.5 m tall. The most common species in the herb layer is *Pteridium aquilinum.*

In the Hottentots Holland Mountains this community is only found in the extreme north, at Jan Joubertsgat. The Mean Annual Precipitation is low (less than 1000 mm) and the difference in rainfall between January and July is high, with July having more than ten times the amount falling in January. This means that there is likely to be water-stress in summer, although the riparian communities will not suffer too much from that. The community occurs on relatively deep mineral soils with a relatively high pH between 4.5 and 5.0. The boundary between this community and the stony Wet Bank is very sharp. There seems to be a subdivision between samples with and without *Brabejum stellatifolium* and *Erica pinea*. Not much attention has been paid to this possible distinction because the relevés were all taken from the same locality and the number of relevés is not very high.

Community type 6.3: *Euryops abrotanifolius-Haplocarpha lanata* Closed Tall Shrubland
Number of relevés: 2
Range of species number: 29 – 39

This community represents the vegetation of the Back Dynamic Zone in Assegaaiboschkloof. It is a mixture of riverine elements and the vegetation from the slopes of Assegaaiboschkloof, which is a form of Talus Asteraceous Fynbos (Campbell 1986b). Because the Riverine Shrub Zone is often very wide in this area and there is a lot of riparian forest, this fynbos vegetation rarely penetrates into the riparian zone. This explains why only two relevés were recorded in this type. The vegetation is mostly herbaceous with only a very sparse shrub layer (10% cover, consisting of species such as *Cassine schinoides* and *Metrosideros angustifolia*). Some of the differential species in this herbaceous layer are *Cliffortia ruscifolia, Gibbaria ilicifolia, Haplocarpha lanata, Helichrysum cymosum* and *Othonna quinquedentata.* The soils are shallow and very stony for a Back Dynamic Zone. They are slightly acidic (pH 4.5).

Asteraceous Fynbos and Renosterveld communities (Appendix E; Table 5)

The communities in this table are taken from the Back Dynamic Zones of the western and northern slopes of the Hottentots Holland Mountains, mainly in the Berg and Eerste River Catchments. There are relevés located on shale, granite and sandstone substrates, but only the communities on shale stand out as separate entities. These are sampled in the Moordenaarskloof of the Stellenbosch Mountains, where shales from the Malmesbury

Group are exposed (See Fig. 2.6 and South African Committee for Stratigraphy 1980). One of these is related to the Asteraceous Fynbos communities found on granite or sandstone in Jonkershoek and the other is completely different, namely a monospecific community of *Cliffortia odorata*. The communities dominated by this species are clustered in Community Group 8.

Community Group 7: Asteraceous Fynbos

This Community group consists of Asteraceous Fynbos, in which the 'typical' fynbos elements like ericas, restios and proteas are less pronounced (The only differential *Erica*-species is *Erica hirta*. However it contains many species of Asteraceae, ferns and sedges (especially *Ficinia* spp.; *Ficinia trichodes* is a differential species). It also has a more distinct shrubby element and grows taller than most Ericaceous Fynbos types. Some other differential species are *Cliffortia cuneata*, *Myrsine africana* and *Oxalis livida.*

The communities in this group occur on the yellow plinthic soils found on granites or shale, which occur mostly on the western side of the mountain range. In Assegaaibosch Kloof they are also found on sandstone. Campbell (1986b) did not mention these vegetation types, which are typically riparian, but the Talus Asteraceous Fynbos or Waboomveld is very similar to it.

This community group shares many species with forest and scrub, namely: *Asparagus scandens, Blechnum punctulatum, Halleria elliptica, Ischyrolepis gaudichaudiana*, *Myrsine africana* and *Pteridium aquilinum*. The only tree that typically occurs outside of the forest, *Maytenus oleoides*, is regularly found in these communities. Another tree species, *Cassine schinoides*, is in these communities restricted to the lower shrub stratum and does not grow any taller.

Community type 7.1: *Wahlenbergia parvifolia-Pentameris thuarii* Closed Tall Grassland
Scientific name: *Wahlenbergio parvifoliae-Pentameritetum thuarii* ass. nova hoc loco
Number of relevés: 5
Type relevé: 196 (Table 5)
Average no. of species: 28 (20 – 38)

This community would not have been recognized as fynbos by Campbell (1986b) because of the high cover of grasses and it is best described as a Tall Grassland (Edwards 1983). However, from a floristical point of view, it is closely related to the *Helichryso cymosi-Myrsinietum africanae* that is clearly fynbos. The marked dominance of the grass *Pentameris thuarii* makes this community distinct, even from a considerable distance, as it appears as yellowish patches in the seepage zones around riparian forests in Swartboschkloof and Diepgat Ravine. It is also found in the riverbeds of seasonal rivers. In many instances it can extend for a long distance away from the rivers themselves. The vegetation consists of two herb layers, the tallest of which is dominated by the tall graminoids *Pentameris thuarii* and *Pennisetum macrourum* (both differential species). This layer is 1.0 – 1.5 m tall and covers the entire plot. Some shrubs and tall herbs also grow in this layer but rarely become emergent to form an own shrub layer, such as *Othonna quinquedentata*, *Psoralea pinnata* and *Rhus angustifolia*. The lower herb layer is about 0.5 m tall and is found sparsely distributed between the grass. The most important species in this layer are: *Pteridium aquilinum* (dominant), *Cullumia setosa*, *Helichrysum helianthemifolium*, *H. foetidum*, *Phylica pubescens* (juv.), *Pseudoselago serrata* and *Wahlenbergia parvifolia*. The last four species are also differential.

It is peculiar that this community was not recorded by McDonald (1988) in his vegetation survey of Swartboschkloof in 1983. It is also not visible on a clear picture of the valley from 1973 shown in Van Wilgen & McDonald (1992). Because the last fire in Swartboschkloof prior to 1973 was in 1958 (Van Wilgen & McDonald 1992; McDonald 1988) it seems likely that this vegetation type will be replaced by another later in the successional stage. *Pentameris thuarii* is a pioneer species after fire and it was found throughout the area after the fire of April 1999. It is interesting to note that in some places the species manages to persist for a much longer time and grows into a tough woody grass. In Swartboschkloof it has persisted for 12 years since the fire in 1987. The differences might be caused by a different fire intensity or fire season. A better understanding of this vegetation type can be obtained by studying the autecology and fire response of this species. The soils on which this tall grassland type occurs are shallow mineral soils on granite with a pH of around 4.5.

Community type 7.2: *Helichrysum cymosum-Myrsine africana* Closed Short to Tall Shrubland

Scientific name: *Helichryso cymosi-Myrsinietum africanae* ass. nova hoc loco

Number of relevés: 18

Type relevé: 175 (Table 5)

Average no. of species: 25 (14 – 42)

This association is quite variable and there are two subassociations described together with one undersampled subcommunity. The two subassociations differ mainly in their structure, one is low and fynbos-like and the other is in succession to a scrub-community, and is poorer in species. The undersampled subcommunity is also poor in species and is found in the higher reaches of the Eerste River. The most important differential species are *Agathosma crenulata, Metalasia cephalotes* and *Stoebe cinerea.* Within Community Group 7, *Erica hispidula* is also differential for this community. Both subassociations occur typically in the Back Dynamic Zone on sandstone or granite. It is found in Jonkershoek and the lower reaches of the Berg River catchment. Campbell (1986b) would describe it as a riverine form of Talus Asteraceous Fynbos. Werger *et al*. (1972), described it as *Brabejum stellatifolium* Community, which suggests that they only found the subassociation *inops*. McDonald (1988) mentions this type as *Halleria elliptica-Cliffortia cuneata* High Closed Shrubland, which is a good description for the subassociation *ficinietosum acuminati* described here.

The comparison with the McDonald (1988) and Werger *et al.* (1972) studies is shown in Table 5.9. This table shows that there is actually a gradient from Waboomveld to *Brabejum* Scrub and the *Helichryso-Myrsinietum africanae* is situated between them. The *Brabejum* Scrub was not clearly identified in this study. It is most common on talus slopes in Swartboschkloof. The soils are brown or yellowish and shallow, while the pH is around 4.5. McDonald (1988) mentions the following soils occurring in association with this community: Hutton, Fernwood, Magwa and Oakleaf Forms (see also Fry 1987).

The new classification of the data that can be seen in Table 5.9 results in some shifts of relevés from one cluster to another; that is why the names of the vegetation types are only stated in general terms. The exact classification of all data will become clear during the VEGMAP project (McDonald 1997; McDonald & Boucher 1999).

Subassociation 7.2a: *Helichryso cymosi-Myrsinietum africanae ficinietosum acuminatae* subass. nova hoc loco

Number of relevés: 9

Type relevé: 175 (Table 5)

Average no. of species: 26 (14 – 42)

This is the structurally shorter herbaceous form of the association, which is richer in species than the taller shrubby form, because there is more diversity in the niches within it. Shrubs do occur but cover on average only 20% of each relevé. Herbs shape the dominant stratum and the most common species, *Ischyrolepis subverticillata*, is a 1.5 m tall Restionaceae. Differential species are the shrub *Otholobium obliquum*, the two inconspicuous sedges *Ficinia acuminata* and *F. nigrescens* and the vine *Dipogon lignosus*.

Subassociation 7.2b: *Helichryso cymosi-Myrsinietum africanae inops* subass. nova hoc loco

Number of relevés: 7

Type relevé: 180 (Table 5)

Average no. of species: 25 (19 – 29)

Table 5.9: Comparison between the Communities 7.1, 7.2a, 7.2b and 7.3c (respectively in columns 4, 5, 6 and 7) with two other studies in Jonkershoek (Werger *et al*. 1972 and McDonald 1988). A gradient from Waboomveld to Riparian Scrub is clearly illustrated in this table. The first three columns represent several types of Waboomveld or Talus Asteraceous Fynbos (including relevé 99 from the present study in column

3). Columns 8 and 9 represent two types of *Brabejum stellatifolium* Scrub, which are mostly riverine. Column 9 also includes relevé 113 from the present work. Column 7 (Community type 7.3c) is an outlier in this comparison. Values in the table indicate percentages of occurrence.

Vegetation type	1	2	3	4	5	6	7	8	9
Number of relevés	5	6	22	5	8	6	2	3	11
Agapanthus africanus	100		9						
Arctotis flaccida	80	17							
Pelargonium tabulare	100	17							
Olea europaea subsp. africana		67	5	20					18
Rapanea melanophloeos		83		20				33	9
Oxalis versicolor			50						
Erica totta			46						
Leucadendron salicifolium			46					33	
Montinia caryophyllacea		50	77						
Clutia alaternoides	100		77						
Protea neriifolia	20	67	77						9
Watsonia borbonica	80	17	32		13				
Oxalis bifida	80	50	18						
Protea nitida	60	100	50	20				33	9
Restio triticeus	80	67	23						
Cymbopogon marginatus	80	17	91						
Otholobium obliquum	80	17	18	20	25				
Aspalathus commutata	80	100	5						18
Anthospermum aethiopica	100	100	73					100	
Psoralea pinnata	40	33		80	13				
Wahlenbergia parvifolia				60					
Pseudoselago serrata	40			80					
Pentameris thuarii	20			100	25				36
Ficinia acuminata			5	20	75				
Ischyrolepis subverticillata				40	75	67			9
Helichrysum helianthemifolium				60	13	50			
Berzelia lanuginosa	20		5		13	17		100	9
Cliffortia polygonifolia			5		25		100		
Cullumia setosa		33		40		17	100		
Maytenus oleoides	40	83	82	20	63	33			46
Cliffortia cuneata	100	100	73	40	38	17	100		27
Ischyrolepis gaudichaudiana	20		82	20	50	33		33	27
Aristea major	100	67	82	60	75	83	50	33	27
Stoebe plumosa	60	17	18	20	38	17		33	9
Pteridium aquilinum	100	100	86	80	63	67		67	82
Rhus angustifolia	80	83	91	40	50	50	50	100	82
Diospyros glabra	80	100	91	60	88	83	50	100	82
Halleria elliptica	20	33	77	40	38			100	82
Helichrysum cymosum	20		9	40	38	33	100	33	
Myrsine africana	100	100	50	20	63	83		33	73
Brabejum stellatifolium			23	40	63	67		33	82

This is the shrubby form of the association, which can occur in the Shrub Zone or in the Back Dynamic Zone. It forms a relatively open scrub vegetation, which is poor in species.

In two of the relevés there is a tree stratum 4.0 – 6.0 m tall, which covers more than 70% of the plot. A shrub stratum of 2.0 – 4.0 m is more common and covers about 40% of the relevé. The dominant shrub is *Brabejum stellatifolium*, but *Cassine schinoides* is also common. The herb layer is in most cases sparse; it only covers about 50% or less of each relevé.

Subcommunity 7.2c: *Cliffortia polygonifolia-Cullumia setosa* Variant

Number of relevés: 2

Range of species number: 20 – 25

This subcommunity was sampled twice at high altitude in Jonkershoek in a river reach where the Back Dynamic Zone was not well developed. It is best characterized by the absence of some typical *Helichryso-Myrsinietum africanae* species such as *Halleria elliptica* and *Myrsine africana.* The vegetation here is very dense with a shrub layer that covers about 60% and a herb layer that covers nearly the whole plot. The Shrub layer is dominated by *Podalyria calyptrata* and *Cliffortia cuneata,* while some of the typical species in the herb layer are *Cullumia setosa, Cliffortia polygonifolia* and *Pelargonium hermanniifolium*. This community occurs in similar environmental conditions as the other *Helichryso-Myrsinietum africanae* communities, but at a higher altitude. Also, one of the two samples occurs on a soil that is richer in organic material than in the other *Helichryso-Myrsinietum africanae* subcommunities.

Community type 7.3: *Pelargonium tomentosum-Chasmanthe aethiopica* Closed Tall Shrubland

Scientific name: *Pelargonio tomentosi-Chasmanthetum aethiopicae* ass. nova hoc loco

Number of relevés: 5.

Type relevé: 67 (Table 5)

Average no. of species: 33 (24 – 40)

Figure 5.6: Asteraceous Fynbos growing on shale: *Pelargonio tomentosi-Chasmanthetum aethiopicae*. The dominance of bracken (*Pteridium aquilinum*) is the most obvious characteristic of this community. The restio on the left is *Calopsis paniculata.*

This community occurs on shale in the western part of the mountains. It is only found in Moordenaarskloof where it forms a mosaic with *Pteridio aquilini-Cliffortietum odoratae*. It is a dense community with a high species diversity. The dominant species is *Pteridium aquilinum*, with *Rhus angustifolia* often occurring in the shrub-stratum. This shrub-stratum covers on average about 30% of the relevé and is relatively low: between 1 and 2 metres tall. The herb layer covers nearly 90% of the vegetation plot and contains many differential species, among which there are only a few from the 'typical' fynbos taxa. These are: *Chasmanthe aethiopica, Clutia alaternoides, Cyperus denudatus, Pelargonium tomentosum, Rubus pinnatus, Salvia chamelaeagnea, Stachys aethiopica, Zantedeschia aethiopica* and several others. The soils are deep, with fine particles dominating and a pH of about 5.5, which is typical for a shale substrate. The community occurs in the Back Dynamic Zone, which starts very close to the river. The communities occupy a small floodplain on the valley bottom. Because the river cuts very deeply through the easily erodable shale, the river channel is quite narrow with steep edges. Rode (1994) collected data from fynbos on Bokkeveld Group shales in Solva, but no similarities with this vegetation type could be found. This is mainly because the area in Solva receives much more rainfall, which makes the local situation there very unique.

The shales of the Bokkeveld Group are also different from those in the Malmesbury Group because the former are freshwater deposits while the latter are marine deposits (South African Committee for Stratigraphy 1980).

Community group 8: *Cliffortia odorata* Shrublands

These are communities that are nearly monospecific with a dominance of *Cliffortia odorata*. This is a tall herb that can grow up to 2.0 m tall to form a dense bush while the lower leaves die off. The only other plants that are found in these communities are strong competitors such as *Pteridium aquilinum* and *Rhus angustifolia*.

Previously, the communities dominated by *Cliffortia odorata* were categorized as Renosterveld, because they are also common in the lower reaches of the rivers, where the rivers are surrounded by Renosterveld (Boucher 1987; Nel 1995). However, as these communities do not have any floristic relationships with Renosterveld, their syntaxonomic relationships need to be revised. Their ‘twin’-community from shale-bands in the Table Mountain Group, with a dominance of *Cliffortia hirsuta* (a very similar species), is typical fynbos, with a relatively high proportion of Restionaceae (see Community type 6.1).

Two communities occur in this group, one of which is only represented by one relevé. Their relationship with the lowland communities of the *Polygonum salicifolium-Cliffortia odorata* Riverine Shrubland Community recorded by Nel (1995) is shown in Table 5.10. They belong to the same alliance for which I propose the name *Cliffortion odoratae*. Boucher (1987) suggests that they belong to his alliance *Polygono-Salicion mucronatae*, but he bases this on only three relevés taken from lowland habitats.

Table 5.10: Comparison of the *Cliffortia odorata* dominated communities. Nel’s (1995) data is from the lowlands; the rest are from the Hottentots Holland Mountains.

	Community 8.2					Relevé 160	Nel’s (1995) Polygonum-Cliffortia Riverine Shrubland					
Cliffortia odorata	3	3	5	a	5	4	5	5	5	5	5	5
Pteridium aquilinum	+	4	a	+	a	+			+		+	

Blechnum capense	a			b		+						
Calopsis paniculata	1				1	b						
Cyperus denudatus	+			+								
Rhus angustifolia	+	3										
Brabejum stellatifolium				4		+						
Metrosideros angustifolius	+			a	+	+						
Rubus rigidus						3						
Berzelia lanuginosa	r					a						
Ficinia ramosissima						m						
Juncus capensis						m						
Panicum maximum						a						
Platycaulos callistachyus						a						
Wachendorfia thyrsiflora						a						
Carpha glomerata	1					1					1	
Typha capensis							r	3		1		r
Zantedeschia aethiopica							+	m	r	1	m	1

Community type 8.1: *Pteridium aquilinum-Cliffortia odorata* Closed Tall Shrubland

Scientific name: *Pteridio aquilini-Cliffortietum odoratae* ass. nova hoc loco

Number of relevés: 5

Type relevé: 122 (Table 5)

Average no. of species: 6 (3 – 10)

Within the shale community of the *Pelargonio tomentosi-Chasmanthetum aethiopicae* there are some patches that are entirely dominated by *Cliffortia odorata*. This species is even more successful than its sister species *Cliffortia hirsuta* when it comes to overwhelming all other species and it often creates a monospecific community, about 1.5 m tall. Only some occasional shrubs grow taller and can tower up to 3.0 m above the rest of the vegetation. The soils under this community tend to be deeper than in *Pelargonio tomentosi-Chasmanthetum aethiopicae.*

Community type 8.2: *Rubus rigidus-Cliffortia odorata* Closed Tall Shrubland

Number of relevés: 1

Number of species: 35

Relevé 160 is the only *Cliffortia odorata* dominated relevé from the eastern slopes of the mountains and it is much richer in species than the relevés from the western slopes. It occurs in a very different habitat, namely on steep alluvial banks with a sandy soil. The community is structurally more diverse than the previous community. Some of the species present are: *Calopsis paniculata*, *Carpha glomerata*, *Diospyros glabra*, *Helichrysum helianthemifolium*, *Panicum maximum*, *Rubus rigidus*, *Stoebe plumosa* and *Wachendorfia thyrsiflora*.

Forest and Scrub communities (Appendix E; Table 6)

Forest and scrub communities have many species in common, yet they are different in their syntaxonomic relationships. Scrub communities are typically riparian and the most dominant species are restricted to the Fynbos Biome. Forests can occur in several habitats, like screes or kloofs, and in some cases they can even cover entire mountain slopes, as in the case of Table Mountain or the forests around Knysna. The forests in the Fynbos Biome are of an Afromontane origin. This is the reason why the forest and scrub communities are presented here as two separate entities in two different Community groups. However, most scrub species can occur in riparian forest as well.

<u>Community group 9</u>

Forests in the Fynbos Biome are mainly restricted to kloofs, screes and riparian zones (Campbell 1986b; Cowling *et al*. 1992; Manders *et al*. 1992). Many studies have been done on forests in the Fynbos Biome (Campbell & Moll 1977; McKenzie *et al.* 1977; Geldenhuys 1997). These forests are of an Afromontane origin and are most extensive in the area around Knysna on the South Coast. Most species have an Afromontane distribution and occur through the Drakensberg, Chimanimani Mountains to Mlanje in Malawi. Some of the species, like *Apodytes dimidiata*, *Ilex mitis*, *Podocarpus latifolius* and *Rapanea melanophloeos*, occur as far north as Ethiopia (White 1978).

In riparian forests some elements of riparian scrub occur together with the Afromontane vegetation. Some of these species, such as *Brabejum stellatifolium* and *Metrosideros angustifolia*, do not occur east of the Gouritz River (see Figure 2.12; Campbell 1986b). In their study of the extensive forest communities of Table Mountain, Campbell & Moll (1977) recognized a few forest communities that are typically riparian. The single species that distinguishes riparian forest from other forest types is *Cunonia capensis* (rooiels) and in some cases *Platylophus trifoliatus* (witels). These forests typically occur on deeper soils and are most extensive in gorges that seldom burn. The pH of the soil ranges between 4.5 and 5.0.

In this study, riparian forest was found in all the river catchments and, with the exception of the communities typical for the Lourens River, there are not many differences between the forests of the respective catchments. In most cases, forests occur at low altitudes at the bottoms of the valleys, while structurally lower vegetation types dominate at the higher altitudes. In Wesselsgat, in the Palmiet River catchment, this situation is reversed, and one relevé in forest has been sampled here from above 800 m. In the Riviersonderend and Boegoe Kloofs there are also some forest patches at high altitudes. These gorges are very steep and probably receive a lot of rainfall. Protection from fire and the moist climate will be the main reasons why the forests occur here. Differential species of the Afromontane Forest in the tree layer are *Apodytes dimidiata, Cunonia capensis, Ilex mitis, Maytenus acuminata* and *Rapanea melanophloeos,* while the herb layer is dominated by *Asparagus scandens, Hymenopeltatum peltatum* and *Schoenoxiphium lanceum.*

Community type 9.1: *Platylophus trifoliatus-Cunonia capensis* Forest
Number of relevés: 1
Number of species: 14

One relevé from Boesmanskloof is aberrant because it contains both *Cunonia capensis* and *Platylophus trifoliatus*. In this locality not many samples have been taken, because it is not an easily accessible area. The other dominant tree species is *Brabejum stellatifolium*. The tree layer is the most important layer, but some large ferns of *Todea barbara* occupy the herb layer. The community occurs in the Wet Bank Zone and some typical Wet Bank species such as *Pseudobaeckea africana* occur in an open patch.

Community type 9.2: *Platylophus trifoliatus* Forest

Scientific name: *Platylophietum trifoliati* ass. novo hoc loco

Number of relevés: 4

Type relevé: 255 (Table 6)

Average no. of species: 9 (5 – 11)

This community occurs in the riparian belt of the Lourens River. The tree layer consists of only one species: *Platylophus trifoliatus*. It grows on shallow mineral soils on a stony bottom. The tree layer covers 80% of each sample, on average and grows to about 5 m tall, while the herb layer is very sparse. Further up the bank it borders on a scree forest. The only other community in which *Platylophus trifoliatus* dominates is the *Platylophus trifoliatus-Cunonia capensis* Forest described above. This species also occurs sporadically in Jonkershoek, but it does not form an extensive community there.

Community type 9.3: *Curtisia dentata-Diospyros whyteana* Scree Forest

Scientific name: *Curtisio dentatae-Diospyretum whyteanae* ass. nova hoc loco

Number of relevés: 5

Type relevé: 200 (Table 6)

Average no. of species: 15 (10 – 18)

This community occurs in the Back Dynamic Zone of the Lourens River. The tree layer is the dominant stratum and it grows taller than in the former community, namely, up to 8 m tall. Common species are *Ilex mitis, Kiggelaria africana, Maytenus acuminata*, *Olea capensis* and *Rapanea melanophloeos* while *Curtisia dentata, Diospyros whyteana, Podocarpus latifolius* and possibly *Olinia ventosa* are differential. The herb layer is also more extensive, but only covers about 20% of the sample area. A common grass species in this layer is *Ehrharta erecta*, which is absent from most of the other forest types. This is a typical scree forest and the only riparian characteristic is the occurrence of *Cunonia capensis*. It might be that a scree forest is quite insensitive to flooding because the water drains readily during a flood. That could explain why this vegetation type does not differ much from the (non-riparian) scree forest types described by Campbell & Moll (1977) as the *Olea capensis-Curtisia dentata* Variant. When the data from this study is compared with the data of Campbell & Moll (1977), it appears that the *Curtisio dentatae-Diospyretum whyteanae* is exactly the same as their community and it also matches a community that was described by Boucher (1978). It appears to be that this is one of the very few vegetation types in the Fynbos Biome that is widely distributed and that has been well sampled. The community occurs on wet screes with shallow soils, intermediate in organic matter.

McDonald (1988) describes another scree community from dry screes with *Heeria argentea* and *Rapanea melanophloeos* as the dominant tree species.

Community type 9.4: *Todea barbara-Cunonia capensis* Forest
Scientific name: *Todeo barbarae-Cunonietum capensis* ass. nova hoc loco
Number of relevés: 25
Type relevé: 46 (Table 6)
Average no. of species: 17 (6 – 29)

This vegetation type forms the typical riparian forest found in the Western Cape Province. Afromontane Forests, as the name implies, are not restricted to rivers and an extensive study has been made of the forest types of Table Mountain by Campbell & Moll (1977). In the Hottentots Holland Mountains, however, it is mainly restricted to riparian habitats and wet kloofs. Only the forest vegetation of screes is a really distinct riparian forest type (see the description of *Curtisio dentatae-Diospyretum whyteanae*). In the *Todeo barbarae-Cunonietum capensis* there is much variation, which is best described by subdividing the association into two subassociations. There are still some unusual relevés, however, namely the relevés 18, 108, 112, 170, 209 and 211. Relevé 18 represents riparian scrub with one specimen of *Ilex mitis* in between, so it might be called heterogeneous. Relevé 108 is located in a Wet Bank Zone that is forested. Relevé 112 is dominated by young shrubs of *Brabejum stellatifolium* and it is transition between *Helichryso-Myrsinietum africanae inops* and *Todeo barbarae-Cunonietum capensis*. Relevé 170 is located on a steep riverbank and mostly contains low trees and shrubs. Relevés 209 and 211 are very poor in species because they are sampled around a very small and steep gully.

If these unusual relevés are left out, the tree layer covers on average 80% of the sample area and the shrub layer about 20%. The herb layer differs between the two subassociations. Trees are significantly lower than in the scree forest, between four and six metres tall, and the shrub layer ranges between two and four metres tall. Differential species occurring in these two strata are *Cunonia capensis, Metrosideros angustifolia* and *Podalyria calyptrata.* The most important species in the herb layer are the fern *Todea barbara* and the restio *Ischyrolepis subverticillata*.

Table 5.11 compares the relevés of this community in the present study with those of several other studies that included Afromontane Forest. It appears that the riparian type of Afromontane Forest is distinct from the types that cover entire mountain slopes, as on Table Mountain or in the Langeberg.

Subassociation 9.4a: *Todeo barbarae-Cunonietum capensis typicum* subass. nova hoc loco

Number of relevés: 13

Type relevé: 46 (Table 6)

Average no. of species: 19 (6 – 29)

Table 5.11: Comparison of Forest communities with other studies. Community 9.4a in column 2 contains one relevé from McDonald (1988). Columns 3 & 4 each contain one relevés from Boucher (1978). The data from Table Mountain originates from Campbell & Moll (1977) and McKenzie *et al.* (1977). The large numbers indicate the frequency in % of a species. The small numbers indicate average Braun Blanquet cover values in the ordinal scale.

	Comm. 9.4a +McDonald (1988)		Comm. 9.4a		Comm. 9.4b		Table Mountain		Langeberg (McDonald 1995)
Olea europaea subsp. africana	56	3					18	6	
Oxalis cf. dentata	56	4	8	3					
Knowltonia vesicatoria	67	3			15	2			
Hymenophyllum peltatum	11	4	15	4	39	7			
Pteridium aquilinum			54	6	8	2			
Diospyros glabra	22	3	62	3	39	3			
Metrosideros angustifolius			54	7	62	7			
Podalyria calyptrata	11	3	46	6	46	5			

Ischyrolepis subverticillata			62	7	54	5				
Brachylaena neriifolia	22	5	62	6	46	6				
Aristea major			46	3	62	3				
Blechnum punctulatum	56	3	46	4	15	3			40	3
Brabejum stellatifolium	44	7	69	7	8	2				
Todea barbara	44	4	39	5	77	6	18	3	40	2
Maytenus acuminata	89	6	39	2	8	2	73	5	60	7
Ilex mitis	56	8	31	7	8	7	52	5	40	5
Schoenoxiphium lanceum	100	6	39	4	31	3	82	6	100	6
Apodytes dimidiata			15	5	31	6	67	5		
Cunonia capensis	89	8	39	8	69	7	91	7	100	9
Asparagus scandens	89	5	77	3	39	3	82	3	60	6
Cassine schinoides	67	7	46	6	31	6	39	5	40	7
Kiggelaria africana	78	5	15	2			76	4	20	3
Olinia ventosa	56	3					46	5	20	3
Blechnum australe	67	5	8	6			61	3		
Rapanea melanophloeos	78	6	15	5	23	2	67	6	100	7
Canthium inerme							52	3		
Diospyros whyteana	11	3					70	5	20	3
Knowltonia capensis							73	2		
Curtisia dentata							67	5		
Olea capensis			8	2	8	2	82	6		
Podocarpus latifolius							70	5	40	7
Cyathea capensis							24	6	100	7
Ocotea bullata							27	3	80	8
Platylophus trifoliatus							6	7	80	9
Pterocelastrus rostratus			8	5	8	1			100	8

The soil in this subassociation is drier than that of the next one and is poorer in moss species. The herb layer is also much poorer than in the other subassociation. A few differential species occur in the herb layer: *Asparagus scandens, Asplenium aethiopicum, Chasmanthe aethiopica* and *Oxalis dentata.* The tree layer tends to be denser than in the other subassociation and the occurrence of *Brabejum stellatifolium, Ilex mitis, Maytenus acuminata* and *Rapanea melanophloeos,* can be used to distinguish it. *Cunonia capensis* is a dominant tree.

All but one of the relevés come from the Eerste River and Berg River catchments. This subassociation has been described before by McKenzie *et al.* (1977) as the *Cunonia capensis-Ilex mitis-Rapanea melanophloeos* subassociation. They also recognize a related community without *Rapanea melanophloeos* that was also recognized by Campbell & Moll (1977). This *Cunonia capensis-Ilex mitis* Community will occur in drier situations than the former. In the Hottentots Holland Mountains this community was not distinguished. Boucher (1978) found the *Cunonia-Alsophila* Kloof Forest, which is definitely different from the type described here.

In this study it was found that the forests in Jonkershoek are often co-dominated (except for one aberrant sample where it is the dominant species) by *Brabejum stellatifolium*. Werger *et al*. (1972) described this community as *Rapanea melanophloeos* Community. This is the same as McDonald's (1988) *Rapanea melanophloeos-Cunonia capensis* High Forest. It is found on mineral soils that contain many boulders. The substrate can be either granite or sandstone.

Subassociation 9.4b: *Todeo barbarae-Cunonietum capensis hymenophylletosum peltatae* subass. nova hoc loco

Number of relevés: 12

Type relevé: 64 (Table 6)

Average no. of species: 18 (6 – 29)

This subassociation is poorer in species than the first one, but has a higher cover of the herb layer. The soils are wetter and they support more mosses and the fern *Hymenophyllum peltatum*, which grows in the moss layer. This species attains a high cover on wet, vertical slopes. The herb layer covers 40% on average and the moss layer 30%. Differential species in the herb layer are *Aristea major, Elaphoglossum angustatum* and *Hymenophyllum peltatum*. Many of the relevés were sampled from steep slopes in ravines. The subassociation appears to be a transition between Afromontane Forest and the riverine Scrub communities of Community Group 10 because it also contains typical species from that group, such as *Brachylaena neriifolia* and *Metrosideros angustifolia*. The ground layer is dominated by *Todea barbara* and *Ischyrolepis subverticillata*. Compared with the subassociation *typicum*, it will be closer to Boucher's (1978) *Cunonia-Alsophila* Kloof Forest. However, the tree fern *Cyathea capensis*, an important species in his community, was only found in one sample in the Hottentots Holland area.

While the *Todeo barbarae-Cunonietum capensis typicum* mostly occurs on the western slopes on granite, this community prevails on the sandstones of the eastern slopes.

Community Group 10

This Community Group forms the typical riparian scrub that was described by Campbell (1986) as Closed-Scrub Fynbos. In the study area it consists of only one association with two subassociations.

Community type 10.1: *Ischyrolepis subverticillata-Metrosideros angustifolia* Low Thicket

Scientific name: *Ischyrolepido subverticillatae-Metrosiderotetum angustifoliae* ass. nova hoc loco

Number of relevés: 18

Type relevé: 30 (Table 6)

Average no. of species: 14 (3 – 28)

This is the community that Campbell (1986b) refers to as Witrivier Closed-Scrub Fynbos. Its most conspicuous characteristic is a scrub layer, which is a high shrub layer of between two and four metres tall. This layer covers about 45% of the relevé. Sometimes a sparse tree layer is present which is slightly higher than the prevalent scrub layer. Two scrub species that characterize the association are *Erica caffra* and *Metrosideros angustifolia*. There are two subassociations: one with *Metrosideros angustifolia* dominant and the other one with *Brachylaena neriifolia* and *Metrosideros angustifolia* co-dominant. Scrub communities occur in the riverine zones downstream of riparian forests. They are poor in species and most species are very widely distributed in riverine habitats. This makes scrub a very widespread community and it has been described previously (Boucher 1978; Taylor 1996).

Figure 5.7: Riparian Scrub Community: *Ischyrolepido subverticillatae-Metrosiderotetum angustifoliae typicum*, growing on an extremely poor substrate.

Subassociation 10.1a: *Ischyrolepido subverticillatae-Metrosiderotetum angustifoliae podalyrietosum calyptratae* subass. nova hoc loco

Number of relevés: 9

Type relevé: 94 (Table 6)

Average no. of species: 15 (8 – 28)

This community occurs in those places where there is some, albeit poor, soil development and where there are few boulders present. Because of the soil development, herb species are more common here and cover more than 40% of the sample area. Species such as *Blechnum capense, Cassytha ciliolata* and *Centella laevis* are differential while *Ischyrolepis subverticillata* is dominant. The shrub layer also contains some species that differentiate it from the subassociation *typicum*, namely, *Podalyria calyptrata* and *Brachylaena neriifolia*. This community is intermediate between Werger *et al*.'s (1972) *Brabejum stellatifolium* Community / *Helichryso-Myrsinietum africanae inops* and the *Ischyrolepido-Metrosiderotetum angustifoliae typicum*. This subassocation is common in Jonkershoek.

Subassociation 10.1b: *Ischyrolepido subverticillatae-Metrosiderotetum angustifoliae typicum* subass. nova hoc loco

Number of relevés: 9

Type relevé: 30 (Table 6)

Average no. of species: 11 (3 – 19)

This community grows in those situations where the riverbed is very stony and soil development is extremely poor. Stream power is likely to be very strong during a flood. Only very few species survive in this habitat and *Metrosideros angustifolia* is the most successful among them, which results in a dominance by this species. The herb layer is mostly occupied by *Todea barbara* and *Ischyrolepis subverticillata*, but does not reach a high cover. This subassociation is particularly common in Assegaaibosch Kloof.

5.9 Discussion

The proposed classification of riverine vegetation is summarized in Table 5.12. Each of the Community Groups has its own diagnostic species, which have been presented above in all the descriptions of the Community Groups. There are however also very common species that occur across the Community Groups. Many of these are typically riparian, others are just very common Fynbos elements. They can be seen in the last rows

Table 5.12: Proposed classification of riverine vegetation of the Hottentots Holland Mountains. Syntaxa that are recognized as associations or subassociations are indicated with respectively 'Ass.' or 'Subass.'. The communities of which the hierarchical status was not recognized are indicated with 'Comm.' or 'Subcomm.'.

Community Group 1: Aquatic communities
Ass. 1.1: Fontinali antipyreticae-Isolepidetum digitatae
Ass. 1.2: Pentaschistido pallidae-Isolepidetum digiatatae
Community Group 2: Pioneer Wet Banks
Comm. 2.1: Symphyogyna podophylla-Sematophyllum dregei Moss Community
Comm. 2.2: Brachylaena neriifolia-Metrosideros angustifolia Pioneer Community
Community Group 3: Erosion Wet Banks
Ass. 3.1: Symphyogyno podophyllae-Schizietum tenellae
Ass. 3.2: Sphagno capensis-Disetum tripetaloidis
Ass. 3.3: Pseudobaeckeo africanae-Prionietum serrati
Community Group 4: Deposition Wet Banks
Ass. 4.1: Wimmerello bifidae-Juncetum lomatophylli
Community Group 5: Ericaceous Fynbos
Comm. 5.1: Ischyrolepis triflora-Protea grandiceps Closed Shrubland
Comm. 5.2: Nebelia fragarioides-Staberoha cernua Short Closed Shrubland
Ass. 5.3: Erico longifoliae-Tetrarietum crassae
Ass. 5.4: Cliffortio atratae-Restionetum purpurascentis
Subass. 5.4a: typicum
Subass. 5.4b: centelletosum erianthae
Ass. 5.5: Restio purpurascenti-Cliffortietum hirsutae
Community Group 6: Transitional Fynbos
Comm. 6.1: Elegia capensis-Cliffortia hirsuta Tall Closed Shrubland
Ass. 6.2: Muraltio heisteriae-Ericetum pineae
Comm. 6.3: Haplocarpha lanata-Euryops abrotanifolius Closed Shrubland
Community Group 7: Asteraceous Fynbos
Ass. 7.1: Wahlenbergio parvifoliae-Pentameritetum thuarii
Ass. 7.2: Helichryso cymosi-Myrsinietum africanae
Subass. 7.2a: ficinietosum acuminatae
Subass. 7.2b: inops
Subcomm. 7.2c: Cullumia setosia Variant
Ass. 7.3: Pelargonio tomentosi-Chasmanthetum aethiopicae
Community Group 8: Cliffortia odorata dominated Shrublands
Ass. 8.1: Pteridio aquilini-Cliffortietum odoratae
Comm. 8.2: Rubus rigidus-Cliffortia odorata Shrubland
Community Group 9: Afromontane Forests
Comm. 9.1: Platylophus trifoliatus-Cunonia capensis Forest
Ass. 9.2: Platylophietum trifoliati
Ass. 9.3: Curtisio dentatae-Diospyretum whyteanae
Ass. 9.4: Todeo barbarae-Cunonietum capensis
Subass. 9.4a: typicum
Subass. 9.4b: hymenophylletosum peltatae
Community Group 10: Riparian Scrub
Ass. 10.1: Ischyrolepido subverticillatae-Metrosiderotetum angustifoliae
Subass. 10.1a: podalyrietosum calyptratae
Subass. 10.1b: typicum

of the synoptic table (Appendix E; Table 7) and by looking at these species one can obtain a picture of the broader relationships of the different Community Groups.

There are many species in common between the Ericaceous Fynbos (Community Group 5) and seepages of Chapter 4. These are for example *Elegia neesii*, *Restio* aff. *versatilis*, *R. corneolus* and *Tetraria capillacea*. Also conspicuous are the species in common between the Upper Wet Banks of Assocation 3.3 and the Ericaceous Fynbos communities, like *Penaea cneorum*, *Erica lutea* and *Tetraria cuspidata*. Species that occur in all these three groups (seepages, Upper Wet Banks and Ericaceous Fynbos) are species that prefer organic wet soils with little rocks. Among these are especially the species of the typical fynbos families Bruniaceae and Grubbiaceae as well as *Chondropetalum mucronatum*, *Erica intervallaris* and *Restio purpurascens*. Species that can occur in all three Fynbos Community Groups are *Agathosma crenulata*, *Metalasia cephalotes* and *Struthiola myrsinites*. These species seem to be quite indifferent between the substrates sandstone and granite.

On the other hand there are the species in a more shrubby habitat that are in common between Asteraceous Fynbos, Afromontane Forest and Riparian Scrub. These are for example *Blechnum punctulatum*, *Brabejum stellatifolium*, *Cassine schinoides* and *Pteridium aquilinum*.

The last category are species that occur in virtually all riparian habitats. Some of these species are species that are also very common in the upland fynbos vegetation like *Ehrharta rehmannii* and *Erica hispidula*. Others are preferring the shady conditions that often occur in riparian zones but can also occur elsewhere where vegetation is tall: these are for example *Aristea major* and *Cassytha ciliolata*. Other species are obligate riparians: *Erica caffra* and *Ischyrolepis subverticillata*. Many tree and shrub species have a very wide distribution across the different communities but occur in the Wet Banks and in the Fynbos Communities only as seedlings or very small shrubs. These are for example *Brachylaena neriifolia*, *Cassine schinoides* and *Cunonia capensis*.

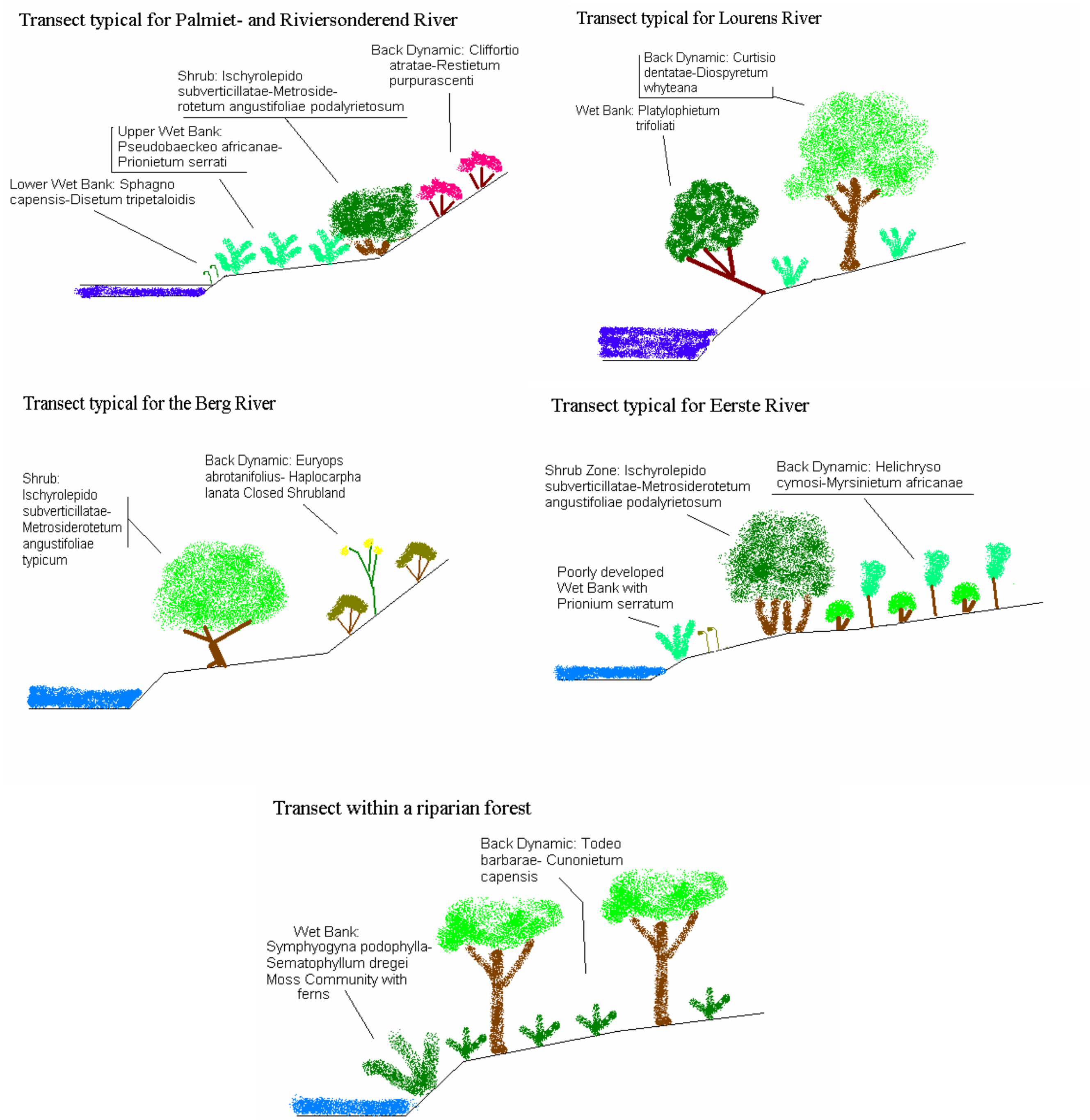

Figure 5.8: Some typical riparian transects in the study area

On a riverbank, typically, a combination of one or more of the Wet Bank communities of Community Groups 2, 3 and 4 and one or more of the Dry Bank communities of Community Groups 5 to 10 is found. Not all combinations are however likely to occur. Except for a classification of vegetation types, a classification of riverbanks is possible if one looks at the combination of vegetation types. The river banks illustrated in Figure 5.9 are the most important of these, but there are many variations on these and there are also less common types like the river banks on Malmesbury shale (with communities 7.3 and 8.2 in the Dry Bank and poorly developed Wet Banks), river banks with seepage from the slopes (with communities 5.5 and 6.1 in the Dry Bank and communities of Community Group 3 in the Wet Banks) or river banks where deposition dominates and sand beaches develop (with community 4.1 in the Wet Bank and community 10.1a in the Dry Bank).

The TWINSPAN analysis, the Correspondence Analysis and the hierarchical clustering using SYNTAX all showed similar results about the basic clustering of the data on riparian vegetation collected in this study. It is only when vegetation types are compared with other studies in the Fynbos Biome that clusters become differently defined. This is mainly because some aberrant samples fit in better with the other studies. The best way to improve the present classification is to collect more data, especially from other areas in the biome. The use of the Community Groups is sufficient at this stage.

In the comparison with the other types it also has become clear which vegetation types were under- or oversampled. The only well sampled vegetation type in the study has been the *Curtisio dentatae-Diospyretum whyteana*, since detailed vegetation data on this type has already been collected by Campbell & Moll (1977) and by Boucher (1978). Vegetation sampling in forests is easier than in fynbos, because the species are more widespread and easily identified. The different Wet Bank types in this study have also been well sampled and the sufficient amount of data has helped to define them adequately. From what I have seen outside Hottentots Holland, I do not expect a high regional variation in these vegetation types either. The vegetation types that need to be sampled further are the Fynbos communities. These communities have a high regional diversity and show a completely different species composition in other mountain ranges. Although there is one Riparian Fynbos type in the Hottentots Holland Mountains that is clearly dominant (*Cliffortio atratae-Restionetum purpurascentis*), there are still some types with narrow distribution ranges (but not necessarily so in other mountain ranges) that are undersampled.

More data from other river catchments within the biome should be collected before attention should be directed to a comprehensive hierarchical classification. The distribution of the different riparian vegetation types through the Fynbos Biome must be determined before any conclusions can be drawn about rarity and uniqueness of the vegetation types. Some rare vegetation types recorded in the Hottentots Holland Mountains might be more common in other places in the Fynbos Biome. However, because the Hottentots Holland Mountain Range is the wettest area of the Biome and perennial rivers become scarcer further to the north and to the east, this is not very likely to be the case for most vegetation types. Dominant species in the present study like *Restio purpurascens* only have a limited distribution outside the study area. It is quite probable that rare vegetation types within this study are also rare vegetation types throughout the Fynbos Biome, such as, for example, the *Cliffortia hirsuta* dominated shrublands or the *Muraltio heisteriae-Ericetum pineae*. Perhaps the most unique vegetation types found in this study are those from the granites and shales, because these substrates are relatively rare in the mountains of the Fynbos Biome. The *Pelargonio tomentosi-Chasmathetum aethiopicae* was only found in one locality and it is quite improbable that a similar vegetation type will be found elsewhere, because it is entirely restricted to the unusual occurrence of shales from the Malmesbury Group in the mountains.

The vegetation types that are found in this study can be used to identify the river zonation. All the types are characteristic for a specific zone on the riverbank and vegetation types can be used to determine the hydrological regime. This also means that changes will occur in the vegetation after changes occur in the flood regime. This implies that changes in the flood regime can be assessed by monitoring riparian vegetation types. The following chapter will deal in detail with the links between vegetation and channel hydraulics.

The collection of data in the mountains is always more difficult than in the lowlands because of access difficulties. However, in a river ecosystem, the ecological processes in the mountain reaches are intricately correlated with those in the lowlands, because the entire river catchment can be seen as one ecosystem. Riparian vegetation should be monitored in all the reaches, because only then a complete overview of the state of the river can be achieved. With this survey of twenty-six communities and five subcommunities of which eighteen were recognized as an association, a contribution towards this aim has been achieved.

6. The influence of floods on the vegetation zonation along mountain streams in the Western Cape

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Keywords: Hydrology, hydraulics, riparian vegetation, mountain streams, floods, stream power, Manning's *n*.

6.1 Abstract

In this paper we aim to describe zonation patterns of riparian vegetation in mountain streams using hydraulic and hydrological parameters. Flow data is not available at the sites used in the study, because all sites are situated upstream from the existing weirs. The discharge data at the weirs is extrapolated to the sites upstream by multiplication with a correction factor that is dependent on the size of the subcatchment. In this way, recurrence intervals for floods in mountain streams are derived. Discharges at sites are also calculated using bed roughness or Manning's *n* in straight sections with uniform flow conditions. Stream power is derived from the discharges calculated in this manner. The combination of stream power and recurrence intervals explains the occurrence of most vegetation types occurring on the banks, except for one type: Afromontane Forest. This type is more dependent on other factors, such as protection from fire and the depth of the groundwater table.

6.2 Introduction

Riparian plants are highly influenced by the fluctuations in the water level of the river and especially by large flood events (Menges & Waller 1983; Hupp 1988). While small annual floods are important to keep a narrow vegetation zone next to the river wet and to determine small-scale processes such as germination and seedling survival, larger floods, that occur less than once a year, have a major impact on the riparian zones higher up the riverbank. They can uproot trees and shrubs and move boulders in the riverbed and create large habitat structures such as oxbow lakes. Flood events occur in a continuum from low-power, high frequency floods to high-power, low frequency floods. Inundation frequency and stream power are often assumed to be inversely proportional (Brinson 1990; Naiman & Décamps 1997). A detailed study of stream power by Bendix (1999) shows that this assumption is not necessarily correct and that stream power has its own influence independent of inundation frequency. This impact varies between different catchments because the effect of stream power is dependent on local geomorphology. In steep gorges, stream power is generally greater than in wide valleys.

The impact of large floods on vegetation can be seen best by the impact of impoundments on the downstream riparian vegetation. In the case of impoundment, large flood events are retarded or reduced and riparian vegetation on floodplains and higher riverbanks starts to change (Stevens *et al*. 1995; Trémolières *et al*. 1998; Dixon & Johnson 1999). The impact of large dams on downstream biota is best described by Ward & Stanford (1979).

In South Africa, where nearly every river is impounded in at least one place, and water shortage is a realistic threat (Davies & Day 1998), a methodology has been developed to calculate the minimum requirements for environmental flows (King *et al*. 2000). This is called the Building Block Methodology and it has been successfully applied, for example, in studies in Lesotho (Metsi Consultants 1999) and on the Palmiet River in the Western Cape (Brown & Day 1998). For the calculation of the Instream Flow Requirements of these rivers information about the correlation between flood regimes and riparian vegetation is fundamental, and to this end the lower reaches of these rivers have been studied in some detail. A problem arises when studying mountain streams upstream of the dams because few flow data are available in these reaches. The flood regime here is still in its original state but the vegetation is different from that found in the lower reaches of the respective rivers. For a full understanding of the riverine ecosystem these reaches need further study.

Riverbanks in the higher reaches of rivers are of the stenosaleutic type (Kopecky 1969). This means that the banks are steep, bank zonation is compressed and annual flood level fluctuations are typically less than one meter. The heights of upstream floods are correlated to the height of the downstream floods, but it is not known with what factor they are correlated. This depends on the size of the catchment, the rainfall within the catchment and the runoff from the catchment.

6.3 Aim of study

In this study we aim to describe riparian vegetation patterns by using hydraulic and hydrological parameters in ungauged mountain catchments. The riparian vegetation in these mountain streams shows clear zonation patterns and flood influences are clearly visible in the vegetation. Hydraulic data consists of zone heights above the riverbed, longitudinal slopes of the river and total input stream power. These data are compared with the data available from the hydrological approach, which consists of an extrapolation upstream of the flow discharges, and the frequencies of floods that are measured at a weir downstream.

6.4 Study area

Two mountain catchments in the Western Cape were chosen to survey the flood events in riparian vegetation of mountain streams. Both are situated in the Hottentots Holland Nature Reserve but they have different exposures and different geological substrates. The data from the weirs in the catchment was kindly placed at our disposal by the Department of Water Affairs (Department of Water Affairs and Forestry, unpublished data).

The Eerste River Catchment is found in the western section of the Hottentots Holland Mountain range. The bottom of the valley is underlain by granite, while the highest reaches of the rivers start on Table Mountain Group sandstone. The weir *G2H008* is located immediately upstream of the Kleinplaas Dam and has a 40 year flow record, from 1961 to 2000. The area of the catchment above this weir is about 25 km^2 (Department of Water Affairs and Forestry, unpublished data).

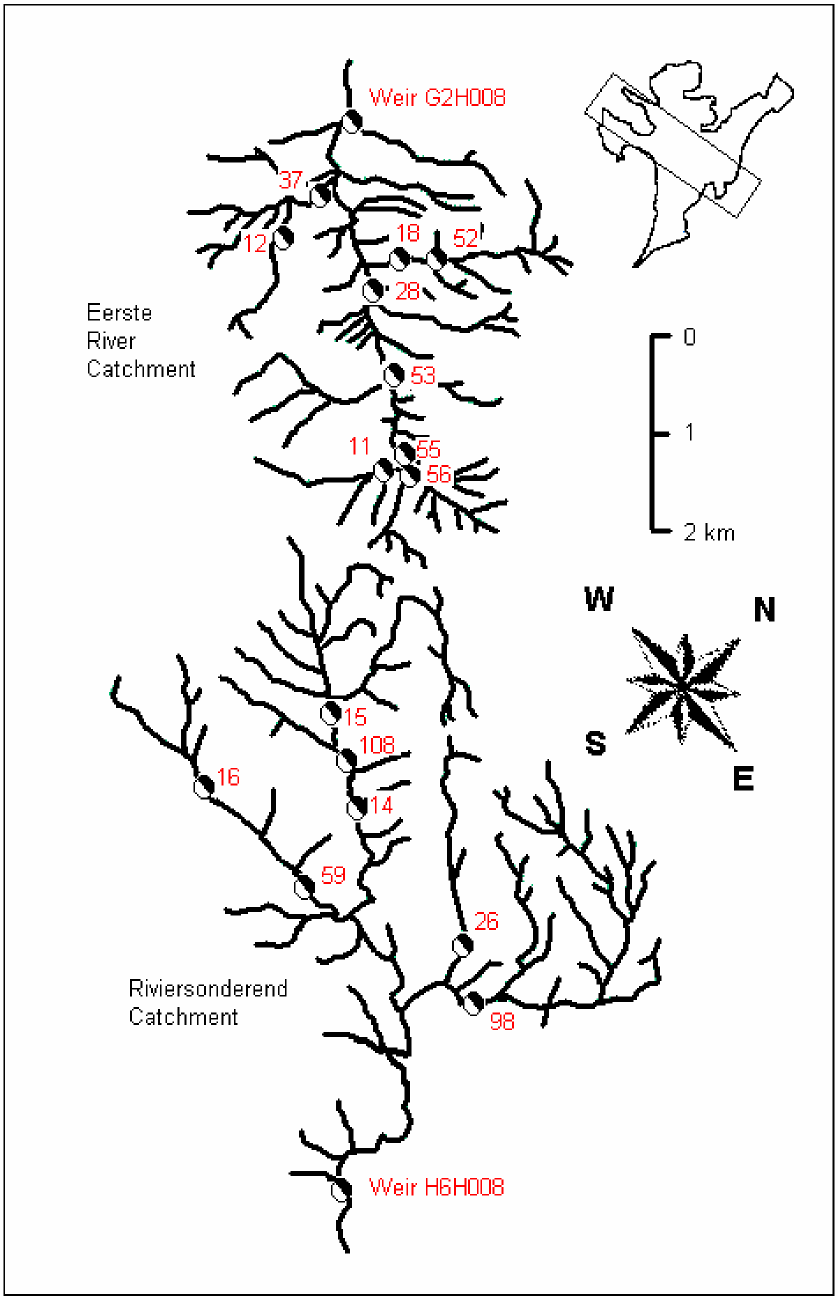


Figure 6.1: The location of the transects examined in this study. Transect no. 12 was discarded because of the complexity of its channel.

The Riviersonderend Catchment is situated in the eastern section of the Hottentots Holland Mountain range and is entirely underlain by Table Mountain Group sandstones, with some local shale bands. The weir *H6H008* is situated at the bottom of the

Riviersonderend Kloof, just before the Riviersonderend River enters the Theewaterskloof Dam. The weir has a flow record of 29 years, from 1963 to 1992. Above the weir the river drains an area of about 38 km^2 (Department of Water Affairs and Forestry, unpublished data).

6.5 Methods

Seventeen transects were chosen in both catchments: Two at the weirs *H6H008* and *G2H008*, eight dispersed through the Eerste River Catchment above the weir and seven in the Riviersonderend Catchment above the weir. Figure 6.1 indicates the location of the transects within the catchments.

In every transect a profile through the riverbed was measured using a Vertex Forestor hypsometer. Vegetation on one bank was sampled (in the transects near the weirs both banks were sampled) and characterized using the Braun-Blanquet method (Westhoff & Van der Maarel 1973; Werger 1974). Flood heights that are required to submerge specific vegetation zones can be derived from these profiles and are then translated into discharges. This is possible using a discharge table. Only three observed points are needed in such a discharge table (Gordon *et al*. 1992) and other data can be derived through interpolation. The discharges at these points can be calculated in two different ways (see below).

The realistic flood levels and their frequencies are derived from the flow records at the downstream weir. Although rainfall is not equally distributed over the whole catchment, it is assumed that the magnitude of a flood at a certain point is directly correlated to the square root of the size of the subcatchment that it drains. The magnitudes of the interannual floods are derived from the record of yearly peak flows at the weir. In the table below the sizes of the peak flows for the two weirs are shown.

6.6 Analysis

The method of calculating the discharge at a particular transect in the catchment from the flow depth depends on the local situation. The flows in mountain streams are generally subcritical flows which means that they are controlled by a critical point such as a cascade immediately downstream. This means that at the critical point the flow goes through a critical depth, which changes the flow to supercritical. Sub- and supercritical flows simply represent the two different states of flow possible for a certain net energy level: subcritical representing the lower velocity, deeper flow state, and supercritical representing a higher velocity, shallower flow state. If this critical point or cascade is nearby and forms a simple channel (as in a weir), it can be used as a control section. The discharge can be calculated from the control section because the discharge here will be the same as in the original section. Certain unique characteristics are found at the control section making it possible to calculate the discharge there if the critical depth is known. This method of deriving the discharge has been used in four transects: Transect 11 and 28 in the Eerste River and Transect 15 and 26 in the Riviersonderend River. However, it appeared that this method is quite sensitive to certain variables that had to be estimated and it was abandoned at a later stage.

At the critical point of a cascade the following equation is valid:

$$\frac{Q^2 \cdot B_{top}}{g \cdot A_c{}^3} = 1 \qquad (1)$$

In which Q is the discharge, B_{top} is the top width of the river at a certain water depth, g is the acceleration of gravity and A_c is the cross-sectional area of the water (Featherstone & Nalluri 1995). From this equation the discharge can be calculated if A_c is known. To relate this to the water depth at the point of sampling slightly upstream, the equal-energy equation can be used, assuming that the discharge is equal at both points:

$$z_c + y_c + \frac{Q^2}{2 \cdot g \cdot A_c^2} = z_2 + y_2 + \frac{Q^2}{2 \cdot g \cdot A_2^2} \qquad (2)$$

where z is the elevation of the riverbed in relation to a fixed level and y the depth of the water at both points. Equations (1) and (2) can be solved simultaneously through repeated iteration to determine the two unknown variables, discharge Q and water depth y_2 (Featherstone & Nalluri 1995). The problem with this method is that the value of z_2 has to be determined very accurately. The hypsometer did not allow this precision so the value had to be estimated, which left many insecurities in the results. The method was abandoned at a later stage.

After the first method was abandoned, the second method was applied to all transects. In this method, the discharge has to be calculated directly from the flow depth related to a vegetation zone at the spot. One factor complicating this calculation is the hydraulic roughness of the streambed. The hydraulic roughness of the streambed is dependent on the shape of the bed sediments that cause resistance to the flow. If streamflow is low and many boulders stick above the water surface, the flow will have a lot of resistance and relative roughness will increase as flows get smaller. On the other hand, if flows get so large that the riparian vegetation is completely submerged, hydraulic roughness increases as well. In mountain streams, hydraulic roughness is generally much greater than in the lower reaches because of the coarse bed material, steep slopes and dense riparian vegetation containing a large woody component. This makes accurate flow calculations difficult, as most of the available formulae are not scientifically sound under low-flow or high roughness conditions.

In a situation with relatively straight sections with uniform flow conditions the discharge Q can be calculated using the Manning's friction equation:

$$Q = \frac{A \cdot R^{2/3} \cdot \sqrt{S}}{n} \qquad (3)$$

In which R is the hydraulic radius (Area / wetted perimeter), S is the slope and n is Manning's n value expressing the hydraulic roughness of the riverbed (Featherstone & Nalluri 1995). Roughness is a difficult value to determine (Gordon *et al*. 1992). In this study the following formula has been used:

$$\frac{1}{n} = \left\{1.11 \cdot \sqrt{g} \cdot \left(\frac{R}{d_{84}}\right)^{0.46} \cdot \left(\frac{d_{84}}{d_{50}}\right)^{-0.85} \cdot s^{-0.39}\right\} \Big/ R^{1/6} \qquad (4)$$

in which d_{50} is the average boulder size in the river bed and d_{84} the 84 percentile boulder size (Simons & Senturk 1992). The roughness is calculated separately for the riverbed and the banks, because the riparian vegetation has a high impact on the roughness. For this purpose the river profile has been subdivided into three sections, in which the two bank sections have a maximum roughness. Application of this formula to the mountainous reaches of the Eerste and Riviersonderend Rivers shows that Manning's *n* varies between values of 0.15 and 0.25. These are problematic values because they mean extreme roughness and many of the flow equations do not apply in this situation.

Flood levels at the weirs

The discharge data for the weirs *G2H008* and *H6H008* were supplied by the Department of Water Affairs and Forestry. The peak discharges at *H6H008* were all above the maximum of the weir discharge capacity, which is only designed to register small flood events. These discharges were then calculated from the peak flood levels (h) by extrapolation of the discharge tables. The equation used for this extrapolation was:

$$Q = A \cdot (h + D)^{B} \qquad (5)$$

in which A was calibrated as 46.8427, B as 0.41448 and D as -1.12.

From the annual peak discharges of the two rivers the discharges for several recurrence intervals at the weir can be calculated. For this purpose the program STFLOOD (Alexander 1991) was used. The results of this analysis are shown in Table 6.1.

Table 6.1: Floods at the different recurrence intervals at the weirs

Recurrence Interval (year)	Eerste River *G2H008*	Riviersonderend *H6H008*
1 yr	30 m^3/s	44 m^3/s
2 yr	37.5 m^3/s	50 m^3/s
5 yr	50 m^3/s	54 m^3/s
10 yr	56.5 m^3/s	56 m^3/s
20 yr	64 m^3/s	58 m^3/s
50 yr	73 m^3/s	60 m^3/s

The discharges of these recurrence intervals occurring at the transects in the higher reaches are correlated to the discharges at the weir through the proportion of the catchment that they drain. To calculate the discharges for these same recurrence intervals at the transects this area-effect can be accounted for by the following formula:

$$Q_{transect} = \sqrt{\frac{A_1}{A}} \cdot Q_{weir} \qquad (6)$$

where A_1 represents the surface area of the subcatchment drained by the transect and A the surface area of the entire catchment (Alexander 1991).

Surface areas of the subcatchments were calculated with the help of the WaterShed command of the Geographic Information System IDRISI (Eastman 1997) and a Digital Elevation Model of the area, which was supplied by the Western Cape Nature Conservation Board.

Transect 26		
s	0.070	
d_{84}	1.000	
d_{50}	0.400	
n	0.350	
	R	Q
Normal	0.212	0.223
Wet Bank	0.350	0.751
Forest	0.603	2.990
Shrubland	1.017	15.007

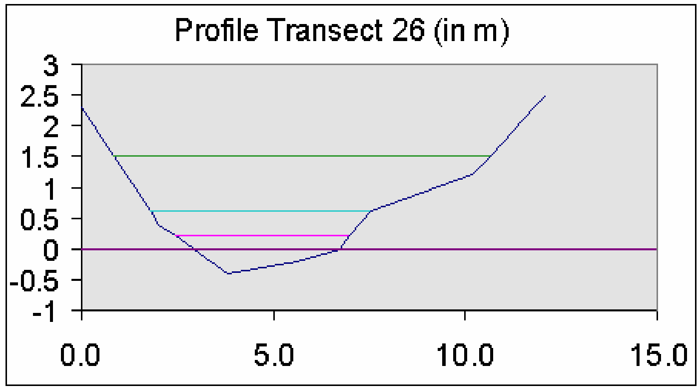


Figure 6.2: Example of calculations for Transect 26, showing the profile and the most important floodlevels. S indicates slope, R hydraulic radius and Q discharge.

Table 6.2: Explanation of the vegetation categories used in this study. More detailed information is available in Chapter 5.

Wet Bank	Thin band of sparse vegetation closest to the water's edge. Dominated by mosses and a few herbs. Typical species: *Disa tripetaloides*.
Palmiet	Sparse vegetation band on a stony bottom. Dominated by palmiet and low shrubs of about 1 m tall. Typical species: *Prionium serratum*.
Scrub	Low trees and shrubs of between 2 – 4 m tall. Sparse ground layer and stony bottom. Typical species: *Metrosideros angustifolia*.
Forest	High trees with thick stems between 4 – 8 m tall. Ground layer dominated by ferns and sedges. Typical species: *Cunonia capensis*.
Shrubland	Fynbos vegetation similar to the vegetation higher up the slope, although typical riparian species are present. Typical species: *Erica hispidula*.

Table 6.3: Catchment areas and the indices calculated using Equation (6).

Jonkershoek			Nuweberg		
Transect	Area	SQRT(A/A_1)	Transect	Area	SQRT(A/A_1)
11	2.82	0.33	14	11.03	0.53
12	2.11	0.29	15	8.96	0.48
18	3.08	0.35	16	4.13	0.32
28	13.15	0.72	26	2.74	0.26
37	2.90	0.34	59	6.98	0.42
52	2.73	0.33	98	8.33	0.46
53	9.01	0.60	108	9.58	0.49
55	5.36	0.46			
56	3.17	0.35			

6.7 Results

The vegetation classification is simplified by using the categories Forest, Scrub, Wet Bank, Palmiet and Shrubland/Fynbos. These are broad vegetation units that describe the structure of the vegetation well, but each consists of several floristic units, which are not dealt with in detail here (see Chapter 5 for a detailed description). A description of these five vegetation categories is given in Table 6.2.

The flood events taking place in the transects are calculated from the profiles. An example is shown in Figure 6.2 for Transect 26 in the Riviersonderend River. The values for slope, roughness and discharge for each flood event are indicated in the table that accompanies the figure.

Table 6.3 presents for every transect the area of the catchment that it drains and the coefficient with which the discharge at the weir should be multiplied to obtain the local discharge (see Equation 6). The discharges for the different return periods can be compared to the discharges calculated at the transect, to determine the return periods of the floods at the transect. Most of the floods calculated appear to be intra-annual floods and the accuracy of this method does not allow one to make any clear distinctions within this category. In contrast, the distinction between interannual and intra-annual floods is quite sharp.

Figure 6.3 illustrates the graph of the discharges in the transects (Q) against the slope of the river (s). Two transects (18 and 52) are left out because their slopes are too steep. Since $\rho * g * Q * s$ equals the stream power, the diagonal lines displayed in the graph represent lines of equal stream power (Yang 1973). Figure 6.3a presents all the relevés with their transect number; Figure 6.3b indicates the hydraulic radius for every sample, which is a good index for stream power and Figure 6.3c shows the approximate recurrence interval of the respective floods.

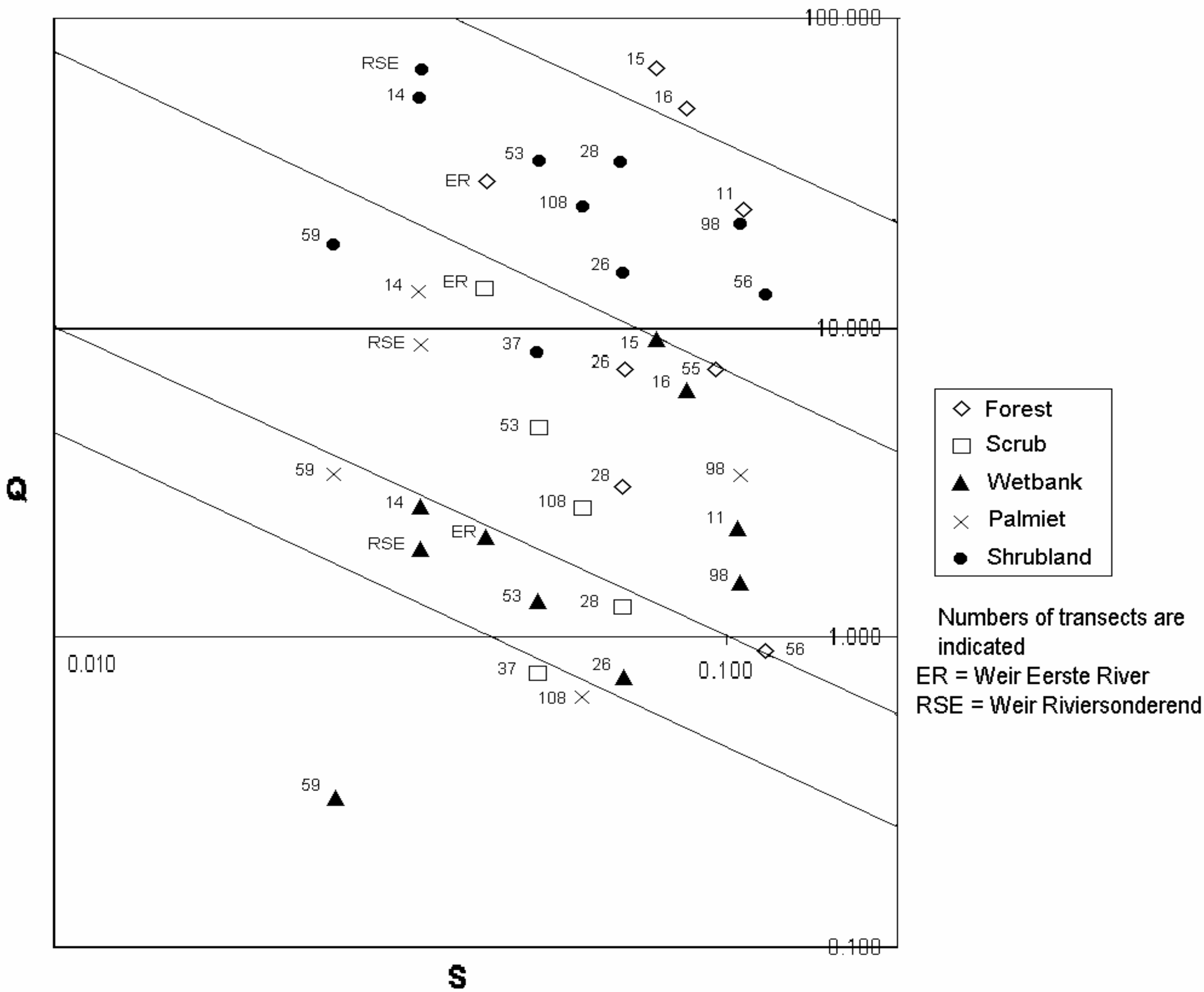


Figure 6.3a: This figure gives an indication of the transect numbers of the respective records. The diagonal zones indicate zones with equal stream power. The scale is logarithmic on both axes.

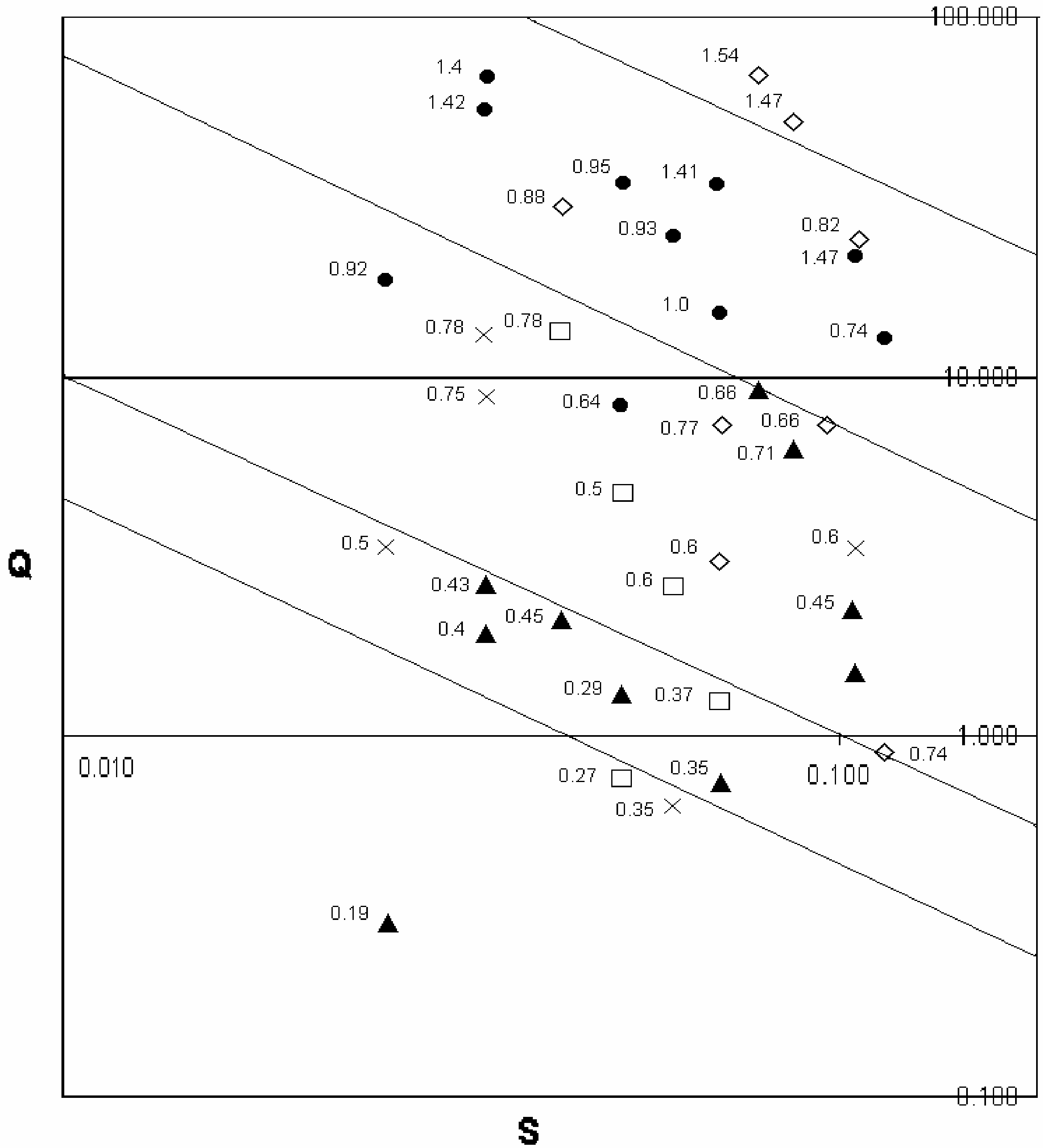


Figure 6.3b: This figure gives an indication of the hydraulic radius within the same graph as Figure 6.3a. Note that a high hydraulic radius co-occurs with a high stream power. This makes the hydraulic radius a good index. The scales on both axes are logarithmic. See Figure 6.3a for the identification of the symbols.

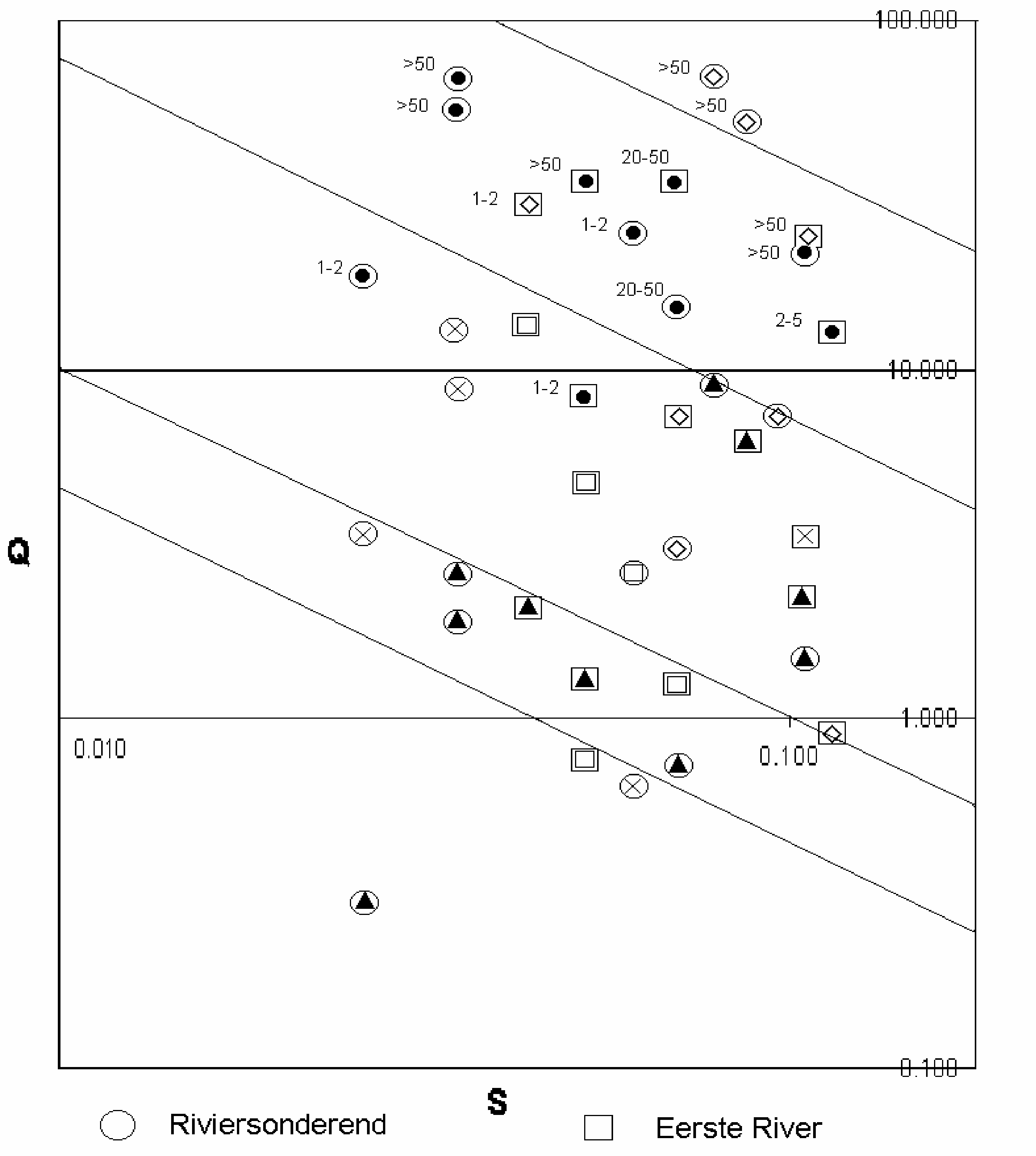


Figure 6.3c: This graph indicates the approximate return period for the inter-annual floods. The samples without any number indicated are intra-annual floods and more detailed information about their inundation frequencies is not available. The scale is logarithmic on both axes. See Figure 6.3a for the identity of the symbols.

At first sight these results might not seem very satisfactory. Most of the floods in the graph are intra-annual floods for which the extrapolation method of Equation (6) does not apply (Alexander 1991). The pattern of the interannual floods is confused. There is no clear distinction in different bands between the one in two year floods and the one in fifty year floods. The stream power, however, gives a much clearer picture. There are well-defined bands for the Fynbos and for the Wet Bank vegetation while the Scrub Zone and the Palmiet Zone occupy the same band. The only riparian zone that does not form a clear band in the graph is Forest, which is found scattered over the entire graph. Note that there are two outliers of Fynbos with lower stream power than the other samples of Fynbos. Although the stream power is lower, the recurrence intervals of these two samples are quite similar to those of other fynbos samples.

6.8 Discussion

Vegetation patterns

The vegetation patterns next to a river in the mountains are determined by two factors: stream power and inundation frequency. It seems that the Wet Bank vegetation and the Palmiet and Scrub Zone can be distinguished clearly from the stream power of the floods running over them. Palmiet and Scrub do not occur together and seem to be interchangable. The Palmiet Zone is mostly found in the Riviersonderend River and the Scrub Zone mostly in the Eerste River. We assume that Scrub is mostly found in rivers with steep banks where small floods coincide with large stream power, while Palmiet thrives on the gentler banks where less damage is done to the vegetation during regular floods.

Fynbos is found on the outer edges of the riparian zone and structurally it is similar to the vegetation in the adjacent non-riparian uplands. The riparian fynbos types are able to withstand high stream powers, but they are flooded only rarely. The mechanical disturbance of the flood might well be so severe that a certain part of the vegetation has to regenerate after a high flood, especially in cases of the one in fifty year floods, where whole lifespans of fynbos plants take place in between floods. Riparian

Fynbos only occurs in zones that are flooded inter-annually, but there is no clear distinction between the floods with recurrence intervals of only a few years and those with very large recurrence intervals. This aspect will be discussed further below.

Forest is scattered all over the diagram which suggests that this vegetation type is indifferent when it comes to flooding. Most of the tree species are indeed shared with other habitats like wet kloofs and screes and are thus not obligate riparian species. The trees grow close to the river because their deep rooting systems can reach the seepage water in the hyporheos, but they can still grow quite high up the bank as well. Flooding does not affect them very much because their stems are physically strong and they break down the stream power so that smaller shrubs will be spared from flood damage as well. The herbaceous layer probably regenerates rapidly after a flood.

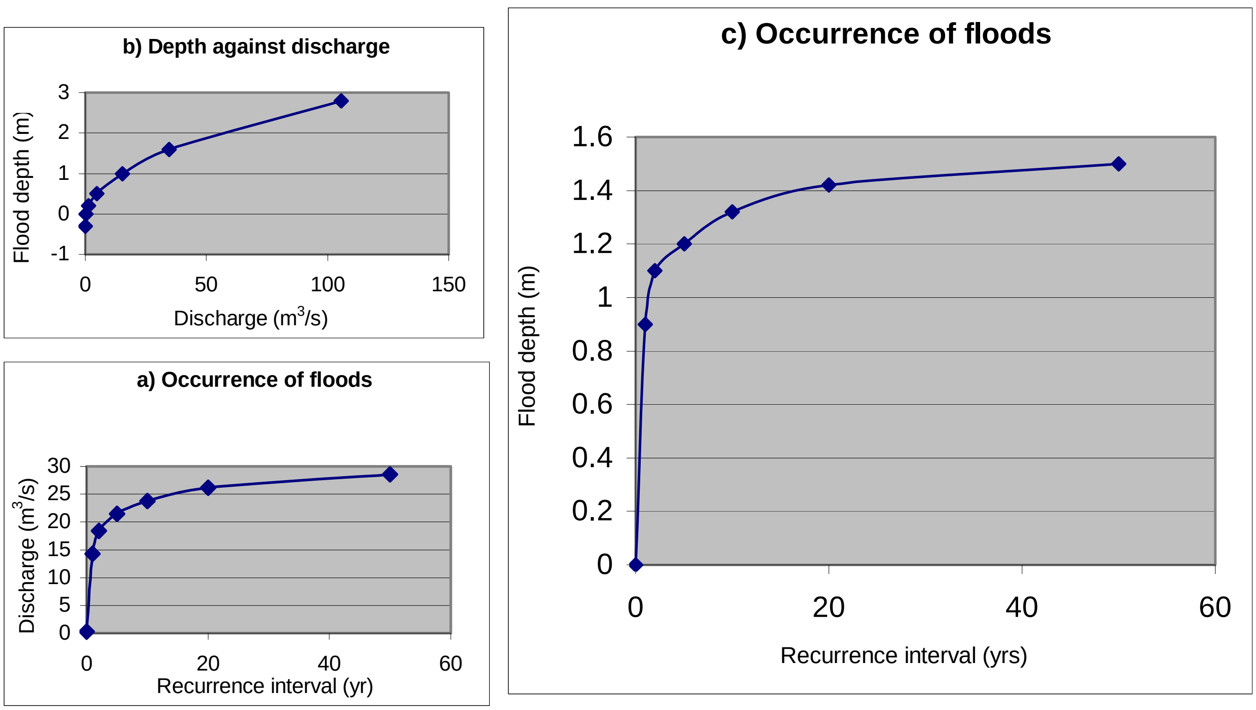


Figure 6.4: An example of the derivation of the Flood height / Recurrence interval-Graph for Transect 53 in the Eerste River Catchment. Graph 6.4c is derived from the two other graphs 6.4a and 6.4b.

<u>Flood levels</u>

The main distinction between the floods is between the intra-annual and the inter-annual floods. In Figures 6.3a to 6.3c the zones affected by the intra-annual floods are further subdivided into zones affected by different stream power, but there is no clear subdivision within the zones affected by inter-annual floods, or at least, that has not become clear with the methods used in this study.

But the methodology need not be the limiting factor. Slight elevations in the water level coincide with huge additional discharges, especially in the higher zones up the banks. The difference in the discharges of the one in two year floods and the one in fifty year floods is relatively small, so the difference in the water level will not be as substantial as one would expect. Figure 6.4 illustrates an example of the Flood height / Recurrence Interval-Graph derived from two discharge graphs. The example shows a transect in the Eerste River. It is clear that the difference in water level is negligible in the larger recurrence intervals. Since banks are often relatively steep, vegetation bands reflecting, for example, a one in ten year flood would be very narrow, whereas in the lower reaches these vegetation patterns would be clear because of the greater bank widths. In the Riviersonderend the situation is even more extreme, because differences in discharge are smaller here than in the Eerste River (see Table 6.1). This might be due to the extrapolation using Equation 5, but it could also be that the Riviersonderend has a different seasonal water regime.

Methods used

The methodology used in this study can be applied in general to mountain streams where discharges measured at weirs need to be extrapolated further upstream. This is a positive outcome, because the more precise measurement of discharges in mountain streams would involve measurement of rainfall intensity, which is only very rarely available. There are however a few critical factors in the equations that deserve some further attention:

Slope: slope needs to be measured very precisely, because a slight difference in slope can cause a huge difference in discharge. In this study two measurements of slope were used: one was measured directly in the field with a slope meter and one was derived from orthographic maps. The first measurement, which is the slope on a small scale, produced the best results, which were used in the rest of the study. When slopes are too steep (> 10%) Equation (4) does not apply any more.

Boulder sizes: The roughness equations require the median and 84% percentile of the boulder size. Equation (4) is quite sensitive to the values chosen for these percentiles so it is important to make a good estimate. If there is a large spread in boulder size, in other words, a large difference between d_{50} and d_{84}, it results in large values for roughness and lower discharges. In this respect the situation in the mountain streams in the Western Cape often poses a problem, because there is indeed a large spread in boulder sizes. There are mostly two size classes, a class of big rocks with a diameter of about 1 to 1.5 metres and a class of small boulders with a diameter of about 0.2 to 0.4 metres. The calibration of Equation (4) in the literature (Simons & Senturk 1992) is derived from situations where d_{50}/d_{84} is on average 2.18 and maximally 6.0. The boulder sizes in this study still fall within this range, but high values for d_{50}/d_{84} often produce extremely high values for Manning's n. We suggest that it might be best to estimate d_{50} and d_{84} separately for each of the size classes. This will however require further investigation. In this study only the small rocks have been used, but it would probably be prudent to concentrate on the bigger rocks when calculating big floods and to use the smaller rocks when calculating small floods. In a small flood, the big rocks do not have a large influence on the roughness because they mainly stick out of the water, while in a large flood the roughness is mainly determined by the large rocks and the influence of the small ones is negligible.

6.9 Conclusion

The main questions concerning the hydraulics of rivers upstream from the highest weirs are about understanding the natural ecosystem. The methods used in this study are reasonably efficient in achieving this aim, and a correlation between the vegetation zonation patterns and the hydraulics of the channel could be shown in graphs such as Figure 6.3.

However, in comparison to the standards of accuracy attainable in the lower reaches of the rivers, the methods used are not accurate at all and the calculated recurrence intervals in particular might easily be out of range by more than 25%.

The only way to get more accurate data is to use weirs or other expensive instruments in the highest reaches to collect exact measurements at several locations in a mountain catchment. Since there is no direct need from society’s point of view, it is quite unlikely that this will happen soon. In the meantime, the methodology described here provides a cheap and reasonably efficient technique.

7. Scaling of environmental factors structuring riparian vegetation in the species-rich Fynbos Biome

Keywords: Riparian vegetation, Fynbos Biome, Gradient analysis, Hierarchical scaling, Canonical Correspondence Analysis, Variation Partitioning, South Africa.

Nomenclature: Goldblatt & Manning (2000)

7.1 Abstract

A combination of hierarchical scaling and variation partitioning is used to describe patterns of riparian vegetation in mountain catchments in the Hottentots Holland Mountains, Western Cape, South Africa. Three different gradients are defined in order to describe the complex vegetation patterns found here. The geographical gradient describes the climatic and topographical changes across the entire mountain range. The longitudinal gradient describes the changes along the different river reaches. The lateral gradient describes the processes along the profile of the riverbed. The three gradients operate on three different hierarchical scales. Partial Canonical Correspondence Analysis is used to determine the amount of variation that is explained on each of the hierarchical scales. The geographical gradient accounts for the highest fraction (more than 50%) of the TVE (total variation explained). This reflects the high gamma diversity in the Fynbos Biome. The spatial variation that is not explained by the geographical gradient is a very small fraction, which suggests that the variables used for description of the geographical gradient are acceptable. The most important among these are geology and the fraction of annual precipitation that falls in the driest months. The second most important gradient is the lateral gradient, which reflects stream power and inundation frequencies of the river. This gradient represents about one third of the explained variation. The longitudinal gradient is the least important of the gradients and reflects considerable overlap with the geographical gradient, because climatic changes also occur within the catchment. This gradient mainly explains the amount of erosion or deposition that takes place in a particular river reach. This is reflected best in the Wet Banks, the riparian zones that are inundated on an annual basis.

Abbreviations used in this chapter: CCA = Canonical Correspondence Analysis, CA = Correspondence Analysis, TVE = Total Variation Explained (by all explanatory variables); TI = Total Inertia.

7.2 Introduction

Riverine ecosystems belong to the most complex ecosystems in the world. Day *et al.* (1986) describe them as having four dimensions: the longitudinal axis of the river, the profile of the riverbed, the elevation of the water level and the time-scale. The riparian zones next to the river are very dynamic ecosystems, because they are subjected to both the disturbances coming from the river and to those from the surrounding uplands, such as fire, herbivory and disease. This creates a very heterogeneous environment where many different species find their own niche (Gregory *et al*. 1991). Furthermore, the river and the riparian zone reflect much of the environmental heterogeneity in the catchment, because many of the nutrients occurring in the substrate of the catchment find their way into the river (Rogers & Van der Zel 1989; Naiman & Décamps 1997) and the vegetation in the riparian zone is dependent on the underlying substrate. From their side, riparian habitats influence the instream biota by shading and nutrient inputs (King 1981; Stewart & Davies 1990; Stewart 1992).

Rivers themselves also create heterogeneity on their banks, for example by depositing sediment on the inner bend of a meander (Gregory *et al.* 1991). This makes riparian ecosystems a good showcase for the hierarchical patch dynamics theory of Wu & Loucks (1996). Van Coller *et al*. (2000) suggested, in their study of the Sabie River in South Africa, that riparian ecosystems can best be studied by a combination of patch dynamics and gradient analysis. The different scales at which environmental influences operate on riparian vegetation are also shown by Jean & Bouchard (1993), Malanson (1993), Ward & Wiens (2001) and Decocq (2002).

This study aims to propose a different view on riparian ecosystems by focusing on the mountain streams in the Fynbos Biome in the Western Cape. Except for the habitat diversity normally encountered in riparian habitats, this area has an extremely high species diversity (Taylor 1978; Kruger & Taylor 1979; Cowling *et al*. 1992), due to a complex evolutionary history (Goldblatt 1978; Linder *et al.* 1992) and to sharp ecological gradients (Campbell 1983; Cowling *et al*. 1992; McDonald *et al*. 1996). The complex vegetation patterns that are a result of these two superimposed ecosystems will be revealed by an approach that theoretically resembles the hierarchical scaling used by Van Coller *et al.* (2000) and methodologically makes use of variation partitioning described by Borcard *et al*. (1992) and Økland & Eilertsen (1994).

The study area that is chosen to reveal these vegetation patterns is the Hottentots Holland Mountain range in the southwestern Cape, South Africa.

7.3 Study area

The Hottentots Holland Mountains are situated between the towns of Stellenbosch, Franschhoek and Grabouw in the Southwestern Cape. A map of the study area is presented in Chapter 2, Figure 2.1. Five different rivers originate in this extremely wet environment: the Berg River (a major river that flows north through the coastal forelands to the Atlantic Ocean), the Riviersonderend River (another major river that flows east through the Overberg Region to join the Breede River near Swellendam), the Palmiet River (an intermediate sized river that flows south to the Atlantic Ocean), the Eerste River (a small river that flows west through Stellenbosch towards the False Bay coast) and the Lourens River (a small river that flows into False Bay near Somerset West). Oliver *et al.* (1983) and Cowling *et al*. (1992) identify this area, together with the Kogelberg located immediately south of the Hottentots Holland Mountains, as the core area of the Fynbos Biome. The species and habitat diversity in this area are very high (Campbell 1983; Deacon *et al.* 1992) which makes the area an attractive subject for gradient analysis.

7.4 Climate

The Hottentots Holland Mountains enjoy a climate classified as Csb in the Köppen (1931) system, which is a mediterranean climate with hot dry summers and mild wet winters. The climate at high altitudes is slightly different from the climate in the valleys, because rainfall increases and temperature decreases with altitude (Versfeld *et al*. 1992). Sixty per cent of the precipitation falls in the wettest four months - from June to September. This precipitation is mostly in the form of rain but snow can also occur on the mountain peaks in winter (Fuggle & Ashton 1979). Schulze (1965) mentions a total precipitation on the tops of the Hottentots Holland Mountains in excess of 3000 mm per annum. The high precipitation in the mountains is caused by orographic rain precipitating during both winter and summer months (Deacon *et al*. 1992). Rainfall patterns in the mountains are extremely complex and the only detailed study in the area, so far, is by Wicht *et al.* (1969). Solar radiation on the mountaintops is high, but temperatures drop 0.5° C for every 100 metres. Temperature records from the higher altitudes are sparse to non-existent in many areas (Fuggle & Ashton 1979).

7.5 Geology and pedogenesis

Sandstones of the Table Mountain Group dominate the geology of the Hottentots Holland Mountains. Within the sandstones there are two shale bands that can be accompanied by tillite, one at high altitude and one at low altitude (De Villiers *et al*. 1964). On the western slopes much older deposits of the Cape Granite Suite cover the valley bottoms, most extensively in Jonkershoek, but also in Banghoek Kloof and at Lourensford. In Assegaaibosch Kloof granite is also found at the edge of the Hottentots Holland Nature Reserve. The Jonkershoek Valley has many faultlines along the axis of the valley. In a small area on the southwestern slopes of Stellenbosch Mountain shales of the Malmesbury Group are found (South African Committee for Stratigraphy 1980).

Most soils developing on quartzite are very shallow and poorly developed. Podzolization is the most important soil-forming process (Fry 1987; Deacon *et al.* 1992). Next to the river, soils are even more poorly developed because the finer particles and the nutrients are washed away regularly. The substrates in riparian habitats mainly consist of rocks but further away from the river deeper soils can be encountered. The soils under riparian forest are mainly of the Magwa and the Oakleaf Forms, and on granites and shales the Glenrosa Form can be encountered (Soil Classification Working Group 1991). In mires at high altitudes the Champagne Form is most common while the Fernwood Form is found on the edges of the mires (see Chapter 4).

7.6 Environmental gradients

Mountain streams have even higher habitat diversity than the lower reaches of these rivers. Pools and riffles, cascades, waterfalls, large boulders and fallen logs all create a complicated mosaic of different microhabitats. The patch hierarchy described by Van Coller *et al*. (2000) for riparian ecosystems also applies to mountain streams, but because the channels are in general much narrower, it is not a very suitable way to observe mountain streams. Instead, longitudinal gradients are much steeper in mountain streams, and consequently an approach of composite gradients was chosen.

Vegetation in the riparian zones in the study area is subject to very complex environmental patterns, due to the many gradients that are found there. To unravel this pattern we take a closer look at each of these gradients and the individual scales at which each operates, separately. A direct gradient analysis is undertaken at each of these scales (Whittaker 1967, 1973b). Therefore we start at the largest scale:

1. On the first hierarchical scale there is a climatic gradient across the mountains. The Western Cape contains very sharp climatic gradients from the mesic climate on the coast to the arid climate in the interior (Campbell 1983; Deacon *et al*. 1992). The amount and the seasonality of the rainfall can change across a single mountain range. As a result, gamma diversity is extremely high (Kruger & Taylor 1979; Cowling *et al.* 1992), even for azonal vegetation types like riparian habitats (see Chapter 8). Each river catchment experiences its own climatic regime. This gradient is referred to as the geographical gradient and is described in detail by Campbell (1983), Deacon *et al.* (1992), Malanson (1993) and McDonald *et al*. (1996). The gradient is very dependent on the topography and on the locality of the sampling site. For this reason, Borcard *et al.* (1992) suggest that all the geographical coordinates of each relevé and its quadratic and cubic products should be recorded.

2. On the second hierarchical scale there is the gradient along the longitudinal axis of the river. Here, not only the altitude changes, but also the nature of the river reach. Altitude has a major impact on the climate and zonal vegetation also changes with altitude (Campbell 1983). In general, rainfall is higher at high altitudes while temperatures are lower. Because the gradient of the river decreases, river reaches at lower altitudes have less erosive power than those at higher altitudes. This gradient is referred to as the longitudinal gradient and is described by Vannote *et al*. (1980), Minshall *et al.* (1983), Day *et al*. (1986), Fetherston *et al*. (1995) and Davies & Day (1998).

3. On the third hierarchical scale, a very clear gradient occurs across the riverbed, representing zones of different inundation frequency. This gradient is most obvious in a floodplain, as was described by Illichevsky (1933) for rivers in Eastern Europe. The study by Glavaç *et al.* (1992) confirms that vegetation units are very conspicuous and vegetation borders are generally very sharp in riparian zones. In a mountain stream the vegetation zones are more compressed than in the lower reaches but differences in vegetation are just as conspicuous. Close to the river, inundation frequency is high, erosive power is large and stream power is low. Further away, inundation is less frequent, deposition is more common and stream power can be very high. The gradient described here is referred to as the lateral gradient and is described by Kopecky (1969), Menges & Waller (1983), Hupp & Osterkamp (1985), Gregory *et al.* (1991), Glavaç *et al*. (1992), Dixon & Johnson (1999), Boucher & Tlale (1999) and Bendix (1999).

Superimposed on these gradients are environmental characteristics of a ‘patchy’ nature. These operate mainly at a larger scale, like geology and soil types. These variables are recorded as nominal variables. Some other soil variables, which are not nominal, are dependent on the substrate and the climatic conditions and are also included in the geographical gradient, like contents of organic material and pH.

This description clearly demonstrates that there are three hierarchical scales in which an environmental gradient can be described. These gradients are referred to as nested environmental gradients. In the study area, vegetation surveys have been done in five different catchments, which are subject to a climatic gradient. Within each catchment there is an altitudinal gradient and at every sample site there is a gradient in inundation frequency. On top of these three ‘nested environmental gradients’ there are different geological substrates that also have a profound influence on the riparian vegetation. A schematic review of these three gradients is illustrated in Figure 7.1.

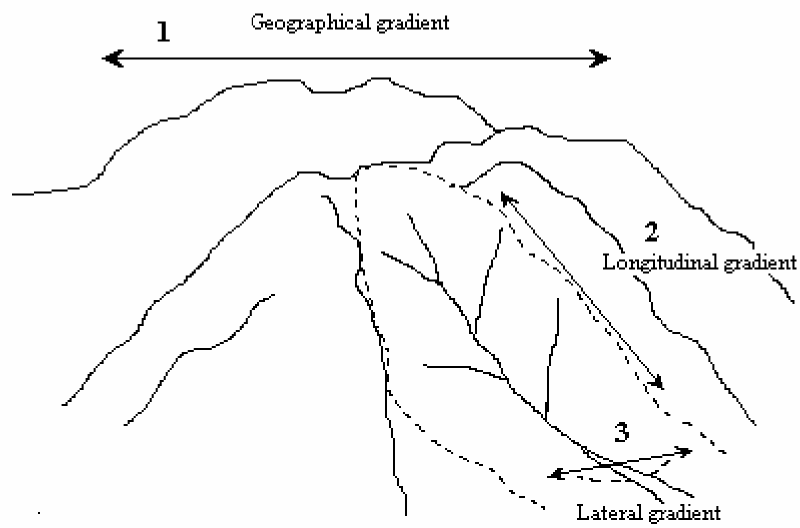


Figure 7.1: Schematic presentation of the three environmental gradients and their hierarchical scales presented in this study.

7.7 Methods

Data collection

In the study area 249 vegetation samples were collected according to the Braun-Blanquet field sampling protocol (Westhoff & Van der Maarel 1973; Werger 1974). Thirty-three of these were collected in high altitude seepages and mires. These were sampled in quadrats of 100 m^2. The rest were collected in transects on the riverbanks in the valleys within the area. The transects were 10 metres wide and occupied the entire zone that was influenced by the river, that is, up to the highest flood marks if these were present. Vegetation relevés were sampled in optically homogeneous plots that consisted of a single lateral riparian zone in each transect. Using this methodology, sample sizes are not always the same, because lateral riparian zones can have different widths. This is not a serious problem in vegetation studies as long as the sample size is suitable to represent the specific vegetation type. For example, a forest requires a larger plot than a sedgeland (Westhoff & Van der Maarel 1973). The thin bands in the riparian zones (these are the samples with the smallest sample sizes) are those closest to the water's edge and these mainly consist of sedge vegetation. They are sampled in areas of about 2 to 5 m^2. The vegetation further from the water's edge consists of forest, scrub or fynbos and these are sampled in areas of about 50 to 100 m^2.

The vegetation types present in the plots are classified into 26 vegetation units at the association-level (see Chapter 5).

Environmental variables describing the lateral, longitudinal and geographical gradients have been determined for the majority of these relevés. The relevés from which the environmental data is incomplete (mainly the aquatic vegetation) or that were outliers, have been left out of further analysis, leaving a data set of 182 relevés with 182 species (the species with less than five occurrences were left out). In the majority of analyses the seepages were left out because they were the cause of considerable heterogeneity in the data set. This resulted in a data set of 150 relevés and 161 species. It must be noted, however, that in the highest reaches of the rivers many vegetation elements of the seepages occur in the riparian zone, making the distinction between the two ecosystems somewhat fuzzy (see Chapter 4).

Environmental variables

The environmental variables recorded along each transect included slope, aspect, geology and the gradient of the river reach at the site (coded as GRAD1, Tab. 1). Other variables were recorded in every sample within each transect; these included rockiness and several soil variables. Electrical resistance and pH were recorded for the soil samples and the organic matter contents were determined using the Walkley-Black method (Walkley 1935). Particle size distribution was determined by sieving (sieve sizes 2 mm, 250 μm, 106 μm, 63 μm) to separate Coarse sand, Medium sand, Fine sand and Silt respectively. Soil types were determined using the limited data that were available, namely soil depth, texture, organic matter contents, pH, habitat and the colour of the topsoil. Soils were compared with the soils found in Fry's (1987) study of fynbos soils in Swartboschkloof, Jonkershoek, and then soil types were attributed on the grounds of this comparison.

However, most riparian soils are very poorly developed because of the dynamic environment near rivers: soils are often washed away during floods and it is mainly the boulders that remain. Distance and elevation from the water's edge were recorded for every riparian zone and their product was also recorded as an environmental variable. These variables are an indication of inundation frequency and stream power, although Bendix (1999) points out that they are in fact imprecise and do not provide information about the exact ecological processes that take place during a flood. These indices are however in most cases the best that can be obtained, especially in mountain streams, where calculation of exact flood levels can be very costly and labour-intensive (Bendix 1999; Sieben *et al.* this thesis, Chapter 6).

Data about altitude and the gradient of each river reach (indicated as GRAD2) were determined from orthophotographic maps (scale 1:10 000). Other indices (Rjan_jul, Rsummer, Rjan, Rjuly and MAP) were available through climatic data obtained from the Computing Centre for Water Research (CCWR). Rainfall data was obtained from several Weather Stations in the vicinity (Weather Bureau 1984), from an extensive rainfall investigation in the Jonkershoek Valley, involving 18 rain gauges (Wicht *et al.* 1969) and from an automatic Weather Station on top of Victoria Peak (pers. comm. G.G. Forsyth, CSIR Stellenbosch). All these rainfall data were compiled by CCWR and transformed into a grid according to the model of Dent *et al*. (1984). The grid size of the rainfall data is quite coarse (about one square minute) and gradients increase sharply with increasing altitude, consequently the rainfall data might not be accurate enough for the requirements of this study. The ratio between summer and winter rainfall can be determined more precisely, however, because the potential error from the grid size is cancelled out by dividing one precipitation value by the other. Two climatic indices are calculated: (1) the ratio between the rainfall in July and the rainfall in January (Rjan_jul) and (2) the inverse of the fraction of rainfall that falls in the four driest months, from January to March (indicated as Rsummer). These variables show a less sharp gradient than the original values as is indicated on the rainfall maps in Figure 7.2. The values of Rjan, Rjuly and Mean Annual Precipitation are also employed as explanatory variables in numerical analysis although their accuracy is likely to be much less. The environmental variables have been divided into three groups, representing the three hierarchical scales mentioned above. A list of the explanatory variables and the environmental gradients they represent is presented in Table 7.1.

Table 7.1: Explanatory variables used in the study. Gradients indicated as scale: (1) Geographical gradient, (2) Longitudinal gradient and (3) Lateral gradient. Numerical variables indicated by (N), Nominal Variables by (C) and Compositional data by (F). Compositional data consists of several numerical variables that together total 100%.

Scale	Variable	Type	Measurement
1	Rsummer	N	Inverse of the fraction of the yearly precipitation that falls in the four driest months: December, January, February and March (Source: Computing Centre for Water Research).
1	Rjan_jul	N	Ratio between the rainfall of July and the rainfall in January (Source: CCWR).
1	PH	N	pH-meter: ORION 420A, measured in H_2O.
1	Organic	N	Percentage calculated by titration of Walkley-Black method.
1	Slope	N	Angle of deviation from horizontal, measured using a slope meter in degrees.
1	Geology	C	Geological Map (South African Committee for Stratigraphy, 1:250 000) and field observation. Classes: Sandstone (San), Tillite (Til), Shale (Sha), Graniet (Gra) and Alluvial (Qua).
1	Soil type	C	Determined from the literature (Fry 1987, Soil Classification Working Group 1991), and by personal observations on the topsoil layer and soil depth. Classes identified: Mispah, Magwa, Oakleaf, Fernwood, Glenrosa and Champagne.
1	Aspect	C	Measured using a compass and classified as: N, W, S and E.
2	Altitude	N	Read from orthophotographic maps (scale 1:10 000).
2	MAP	N	Mean Annual Precipitation: from CCWR.
2	Rjan	N	Rainfall in January, from CCWR.
2	Rjuly	N	Rainfall in July, from CCWR.
2	GRAD1	N	Estimate of the fall in a ten meter section of a river.
2	GRAD2	N	Tangent of the gradient of a longer section of a river stretch, read from an orthophotographic map (1:10 000).
3	Distance	N	Distance of the upper edge of the vegetation zone from the edge of the water in a river.
3	Elev	N	Elevation of the upper edge of the vegetation above the water level.
3	Distelev	N	Distance and Elevation multiplied.
3	Resis	N	Resistance to an electrical current measured with YSI model 3200 in Ohms.
3	Gravel	N	Percentage of coarse material in soil sample (from 2 mm to 2 cm).
3	Soildept	N	Depth of soil estimated in cm.
3	Particle size	F	Percentage of several fractions of soil particles. Classes: Coarse Sand (CSAND), Medium Sand (MSAND), Fine Sand (FSAND) and Silt (SILT).
3	Rock cover	F	Estimate of rock cover percentages. Classes: Bedrock, Boulders (> 24 cm), Large Cobbles (LG_COBB, 10-24 cm), Small Cobbles (SM_COBB, 5-10 cm) and Pebbles (PEBB, 2-5 cm).

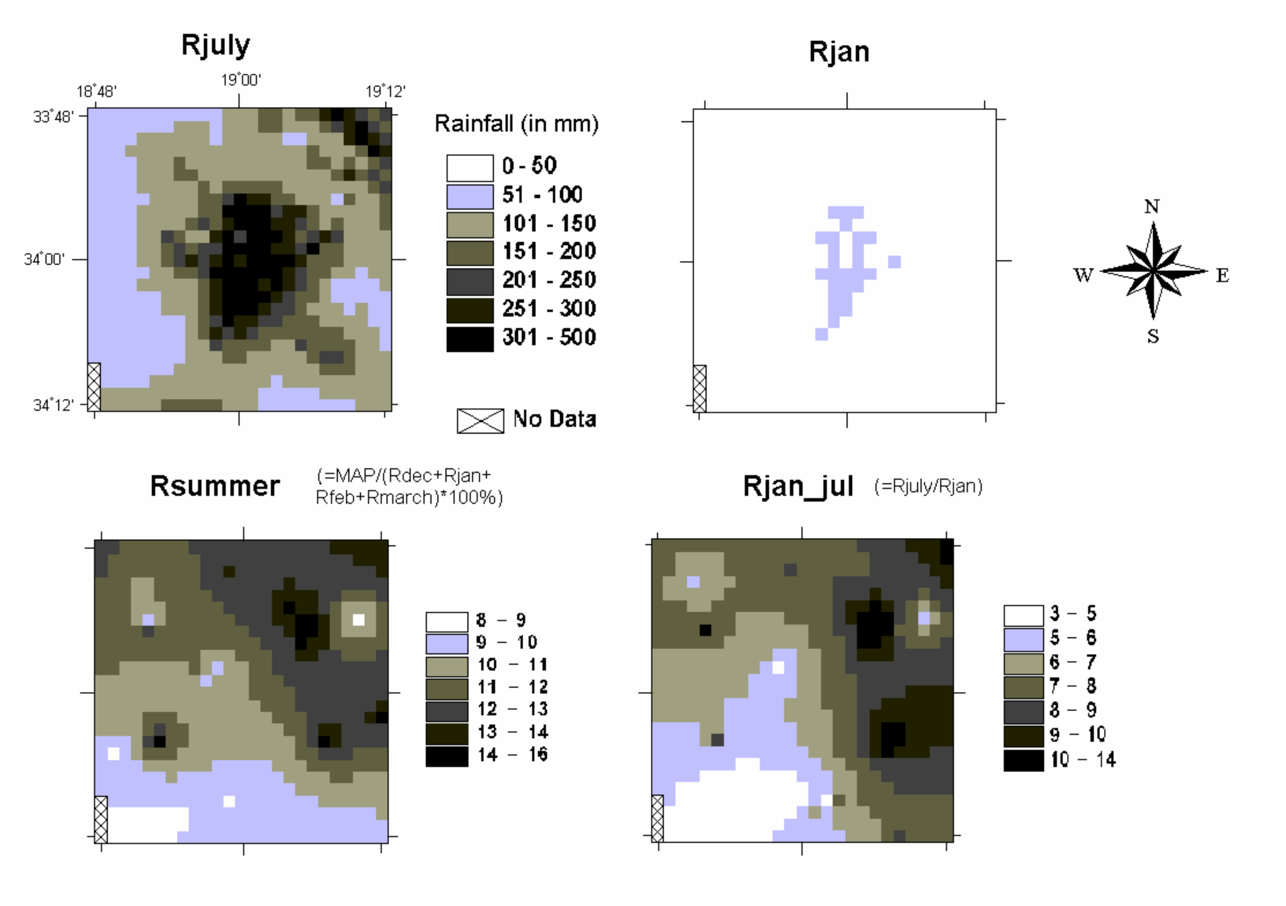


Figure 7.2: Derivation of the climatic indices for rainfall seasonality. Note that the gradients in the graphs below are less sharp than those of Rjuly. For an outline of the study area compare with Figure 2.3.

<u>Ordination techniques</u>

Canonical Correspondence Analysis is a multivariate technique that is very suitable to relate vegetation data to the environment (Ter Braak 1986, 1987). It is an extension of Correspondence Analysis (Hill 1974) and makes use of the Weighted Averaging algorithm (Curtis & McIntosh 1951), which makes it applicable to unimodal reponse curves. The assumption of unimodal response curves has received much criticism but there is no alternative statistical method that takes into account skewed or bimodal response curves (Austin 1987; Austin & Smith 1989; Austin & Gaywood 1994; Austin *et al*. 1994). An overview of the available ordination techniques shows clearly that CCA is the most suitable method for direct gradient analysis that is currently available (Jongman *et al*. 1987; Legendre & Legendre 1999).

The Canonical Correspondence Analysis technique correlates the variation found in the vegetation data to explanatory variables, which are supplied by the researcher. In this way, it divides the variance into an explained and an unexplained part. The sum of all the unconstrained eigenvalues, that is the result of a Correspondence Analysis, is a measure of the total variation found in the data set and is referred to as the total inertia (TI). The sum of the canonical eigenvalues (TVE) gives an indication of the fraction of the variation that can be explained by the explanatory variables supplied (Økland 1994). The unexplained part of the variation can be split into several portions, which are clarified by Økland (1999). A part of it is 'potentially explainable', but for the greatest part it consists of stochastic variation due to noise in the data set and to lack of fit to the unimodal model. There is also a part of the unexplained variation that is due to the choice of the explanatory variables. The best explanatory variables to use are those that quantify directly the physiological processes that influence plant life, but these data are often very difficult to obtain and so the methodology of data collection also has an impact on the fraction of variation that is explained (Austin *et al*. 1984). To give an example relevant to this study: if the inundation frequency of a river bank and the field capacity of the soils are known, it would be a good quantification of the physiological stresses that riparian plants experience, namely, anaerobic conditions in the root zone, followed by quicker or slower drainage resulting in more arid conditions (Hewlett 1982). However, hydrological data in the mountains is often lacking and it is impossible to collect undisturbed soil samples from areas that are only accessible by foot. Explanatory variables that can be used as an alternative are the distance from and the elevation to the water's edge, and the particle size distribution of the soils, which are easier to determine. These variables are correlated to the 'direct physiological' variables, but are less accurate and will leave a part of the variance unexplained.

In order to subdivide the explained variation further into several categories, Ter Braak (1988) proposed an extension to CCA: Partial Canonical Correspondence Analysis. With this method, the canonical axes of variance can be found after the variance explained by certain variables (called covariables) has been removed. The forward selection procedure in Canoco 4 (Ter Braak & Šmilauer 1998) is also based on this principle. By running a Partial Canonical Correspondence Analysis a few times with different sets of explanatory variables and covariables, the contribution of each set of variables to the total explained variation can be clarified. Borcard *et al.* (1992) applied this principle mainly to separate the spatial component from the rest of the variation, but it can also be useful when looking at influences operating at different scales (Økland & Eilertsen 1994).

The three sets of explanatory variables collected with this set are discussed above. The compositional variables were log-transformed following the recommendations of Ter Braak & Šmilauer (1998). A CCA and a CA were carried out on the complete data set with and without the seepages. In all the other analyses the seepages were left out. Data partitioning was used to partial out the spatial component. This component plays a major role in the Fynbos Biome, because of the high species turnover. For this reason, all cubic and quadratic products of longitude and latitude were included as explanatory variables (Borcard *et al.* 1992). Forward selection only retained X^2Y, Y^3 and Y, where X is latitude and Y is longitude. Further variation partitioning took place with the variation explained by the environmental variables according to the three scales discussed above. A schematic view of these ordinations is shown in Figure 7.3.

The three sets of environmental variables are interchanged as variables and covariables in a series of Partial Canonical Correspondence Analyses. This provides the following information for each environmental gradient, considering three sets of explanatory variables, P, Q and R:

1) The amount of variation explained exclusively by a specific environmental gradient (of which the explanatory variables are in variable set P) is obtained by a CCA in which the variables of the two remaining hierarchical levels are taken as covariables. In this case, the variables of set P are taken as explanatory variables and variable sets Q and R are taken as covariables.

2) The amount of variation explained by the overlay of the two other environmental gradients excluding the variation of the variable set P is obtained by the reverse situation where Q and R are taken as explanatory variables and variables from set P are taken as covariables.

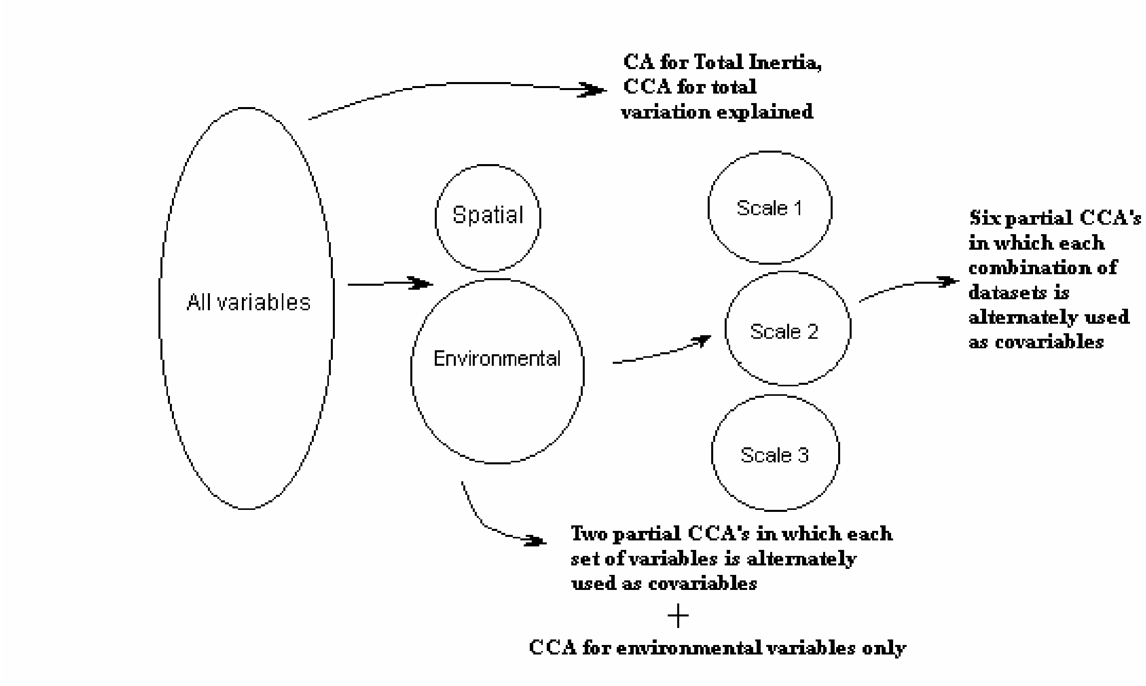


Figure 7.3: Schedule with the ordinations done in this study to achieve variation partitioning for three environmental gradients at three different scales.

In order to illustrate the variation on each hierarchical scale in detail, three other Canonical Correspondence Analyses were carried out without variation partitioning (These are not illustrated in Figure 7.3). They deal with one hierarchical scale at a time and indicate which explanatory variables are most important at that specific scale. The results of these ordinations are then illustrated in ordination diagrams showing the first two canonical axes.

For the ordination of the first hierarchical scale (the geographic gradient), the complete data set was used, but for the two other hierarchical scales the data set was split into two. The actual purpose was to do the ordination on the second hierarchical scale (the longitudinal gradient) within a single catchment, but then the data set would have to be split into five, which would result in a very restricted data set. Instead, it was decided to divide the data set into two groups of two similar catchments and to leave the fifth, the Lourens River catchment out of further analyses, because of its aberrant vegetation types (mainly Scree Forests, see Figure 7.5). After this split, the species occurring in less than four relevés were left out. The Eerste and Berg Rivers are taken together to create a data set of 74 relevés and 88 species. These catchments are similar in their total species composition (see also Chapter 8), their geology (granite and shales in the valley bottoms and sandstones at the higher altitudes), exposure (western and northern slopes) and geomorphology (rivers originating on steep mountain headwalls). Data collected from the Riviersonderend and Palmiet Rivers, combined together, result in a database of 91 relevés and 119 species. They can be grouped for the same reasons as the Eerste and Berg Rivers, both being situated on the eastern and southern slopes, which are gentler and underlain by sandstones and occasional shale bands. The resulting data sets are used for Canonical Correspondence Analysis on the longitudinal and lateral gradients.

7.8 Results

The classification of the vegetation samples resulted in 26 clusters of riparian vegetation and nine clusters of seepages. These vegetation units are described in detail in Chapters 4 and 5. In order to illustrate these clusters in ordination diagrams the 26 original clusters of riparian vegetation are combined to form 14 larger clusters, while the bogs and mire types are regarded as one category. This subdivision is presented below together with the most typical species that occur in them. The abbreviations of species used in the ordination diagrams are indicated in brackets after the scientific names.

Wet Banks: These are the vegetation types found closest to the river’s edge. They are subdivided into Pioneer Wet Banks (with mosses and juveniles of trees and shrubs, forming Community Group 2), Erosion Wet Banks (with species like *Schizaea tenella* (Schitene), *Disa tripetaloides* (Disatrip), *Drosera capensis* (Droscape) and *Prionium serratum* (Prioserr), forming Community Group 3) and Deposition Wet Banks (with species like *Juncus lomatophyllus* (Juncloma) and *Isolepis prolifer*, forming Community Group 4).

Ericaceous Fynbos: These are the most common fynbos types of the eastern slopes. The most important species are *Restio purpurascens* (Restpurp), *Erica hispidula* (Erichisp), *Berzelia squarrosa* (Berzsqua) and *Leucadendron* *xanthoconus*. Five categories are recognized in the ordination diagrams. The common type (Comm. 5.1 and 5.4) contains species like *Carpacoce spermacocea* (Carpsper) and *Restio burchelli*. The high altitude type (Comm. 5.3) also contains these species in combination with *Restio bifidus* (Restbifi) and *Tetraria crassa*. A southern type (Comm. 5.2) contains species like *Tetraria capillacea* (Tetrcapi) and *Erica intervallaris* (Ericinte). There is one type (Comm. 5.5 and 6.1) with seepage that is dominated by *Cliffortia hirsuta* (Clifhirs). The final type (Comm. 6.2 and 6.3) is transitional to Asteraceous Fynbos and is characterized by species like *Muraltia heisteria* and *Stoebe cinerea.*

Asteraceous Fynbos: These fynbos types are typical of the fine-grained soils on the western slopes of the mountains. The most important species are *Myrsine africana* (Myrsafri), *Pteridium aquilinum* (Pteraqui), *Helichrysum cymosum* (Helicymo) and *Cliffortia cuneata* (Clifcune). Three categories are recognized here. The common type (Comm. 7.1 and 7.2) contains the shrub *Brabejum stellatifolium* (Brabstel) and the sedge *Ficinia acuminata* (Ficiacum). The type found on shale (Comm. 7.3) is characterized by *Chasmanthe aethiopica* (Chasaeth) and *Calopsis paniculata* (Calopani). Then there is one type (Community Group 8) that is dominated by *Cliffortia odorata* (Clifodor).

Forest and Scrub: These are the tallest non-fynbos riparian vegetation types. They are subdivided into three categories. Afromontane Forest (Comm. 9.4) contains species like *Cunonia capensis* (Cunocape), *Maytenus acuminata* (Maytacum) and *Todea barbara*. Scree Forest (Comm. 9.2 and 9.3) contains these species together with *Platylophus trifoliatus* (Plattrif) and *Diospyros whyteana* (Dioswhyt). Riparian Scrub (Community Group 10) is very poor in species. The most important species are *Metrosideros angustifolia* (Metrangu), *Brachylaena neriifolia* (Bracneri) and *Ischyrolepis subverticillata* (Ischsubv).

Seepage Fynbos: Seepage Fynbos occurs at the sources of the rivers at high altitudes but is left out of most analyses here because it is very different from the riparian vegetation types (See Chapter 4). The most important species are *Restio subtilis*, *Anthochortus crinalis*, *Senecio crispus* and *Epischoenus villosus* (Episvill).

Most of the 40 species mentioned in the text are shown in the ordination diagrams of Figure 7.4. A good distinction can be made between the Ericaceous and Asteraceous Fynbos Types. Species of Ericaceous Fynbos show more affinity with the species of the Erosion Wet Banks and the seepages, while the species of Asteraceous Fynbos show more affinities with the Forest species. The species occurring in Scrub are in the center of the diagram because these species are common in nearly all of the riparian habitats.

Variation on the first hierarchical scale

The results of the Canonical Correspondence Analysis are shown in Figure 7.5. The explanatory variables in these diagrams are of the first hierarchical level. The diagram becomes clearer after the seepages are left out. The most important explanatory variable in the diagram with seepages is the organic matter content, which is extremely high in the seepages. Organic matter is highest in soils of the Champagne Form, which does not occur often in riparian habitats. After seepages are left out the differences between the riparian vegetation types becomes more obvious. The variation on the first axis is mainly explained by the nominal variables, especially geology. The nominal variable ‘aspect’ is not reliable because the variation inflation factor is too high (> 20). The second axis is mainly correlated with the climatic gradient from south to north, expressed in the variables Rjan_jul and Rsummer. The correlation coefficient between these variables is 0.84, but Rjan_jul has a more pronounced west-east gradient and Rsummer a more pronounced north-south gradient. The topographic distribution of seasonal rainfall is shown in Figure 7.2. The northern part of the study area has a more pronounced winter

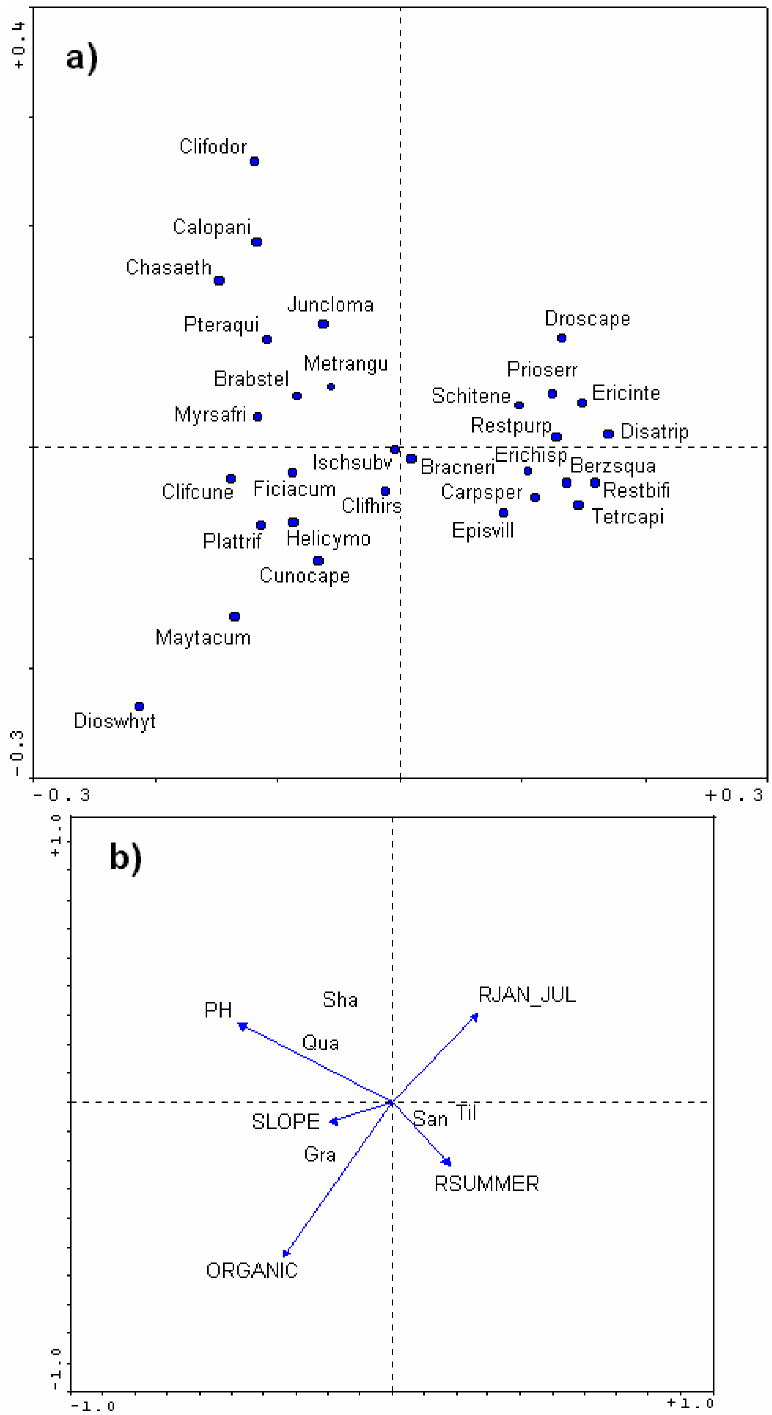


Figure 7.4: Ordination diagram (a) presents an ordination of an arbitrary selection of important species found in the riparian zones in the study area. The environmental variables of the first hierarchical scale are shown in the second diagram (b). The abbreviations are defined in Table 7.1. Note that the scales of the two diagrams are different.

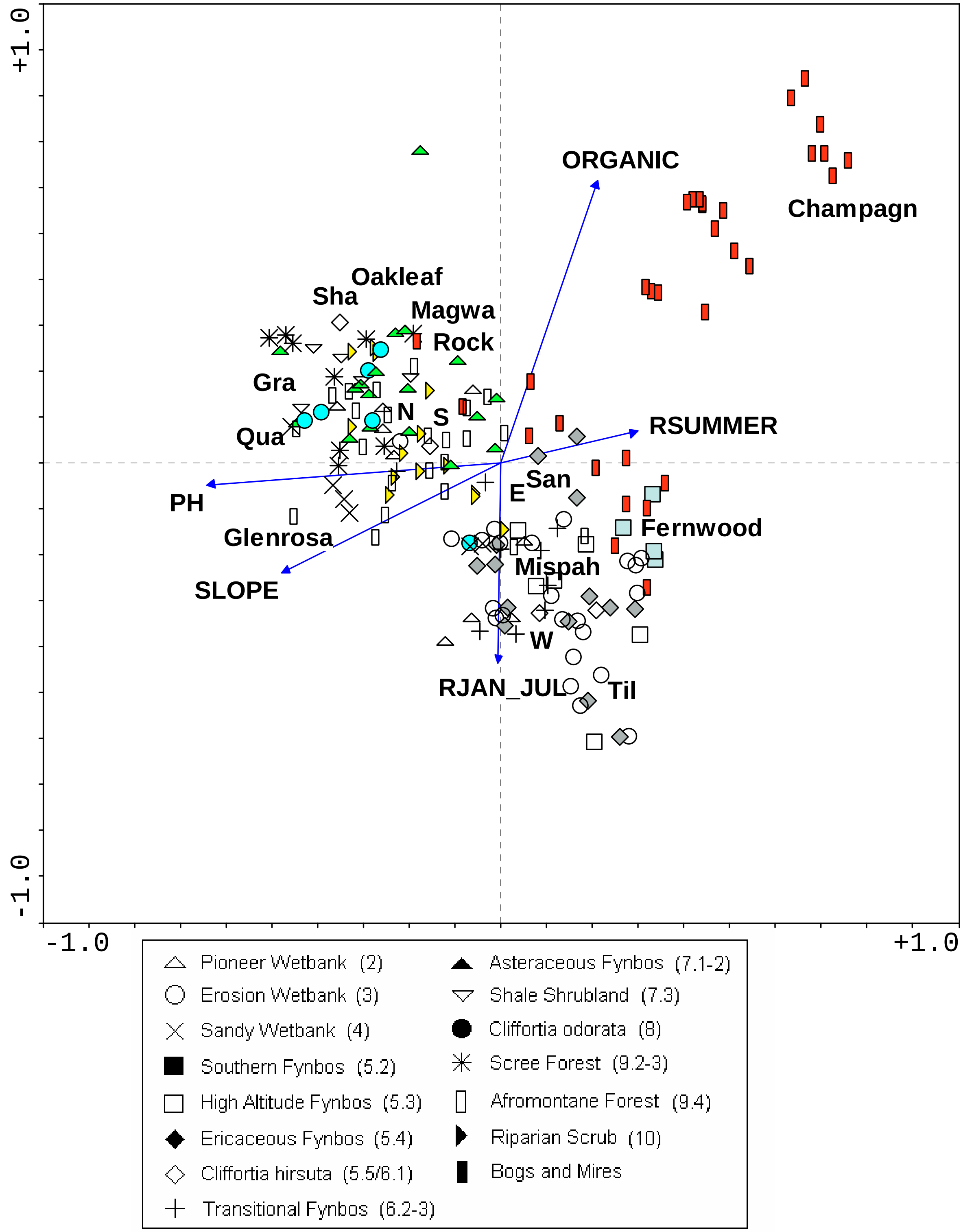


Figure 7.5a: CCA ordination diagram of the relevés on the first hierarchical scale. This diagram includes relevés from the Restio Marshes (182 relevés, 182 species). See Table 7.1 for the abbreviations of the environmental variables.

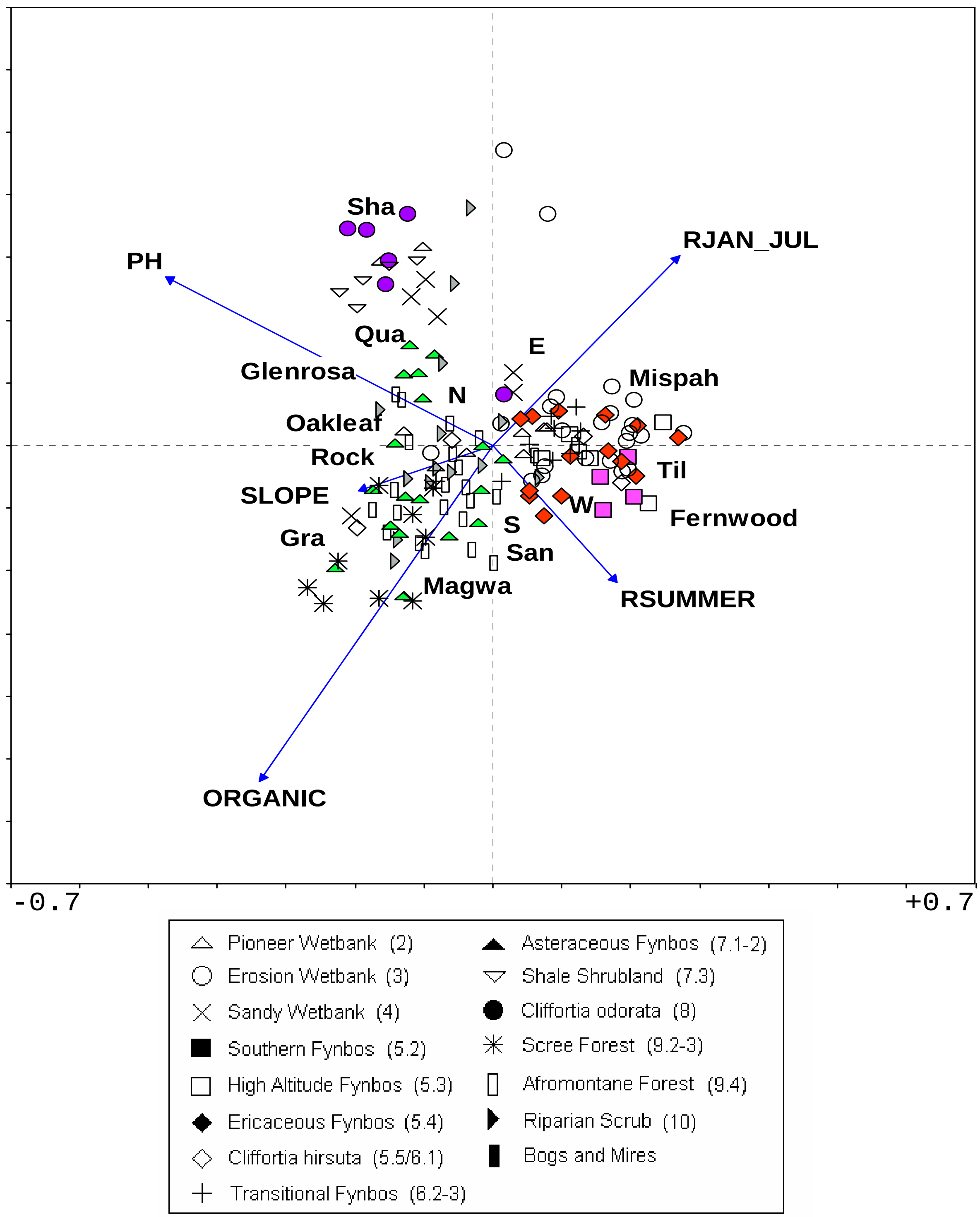
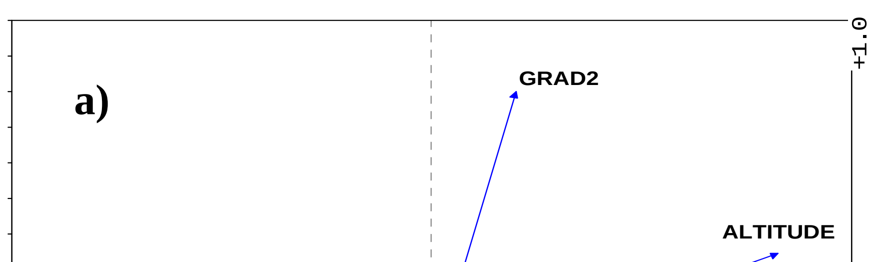


Figure 7.5b: CCA ordination diagram of the relevés on the first hierarchical scale. This diagram is obtained after the relevés from the Restio Marshes are excluded (150 relevés, 161 species).



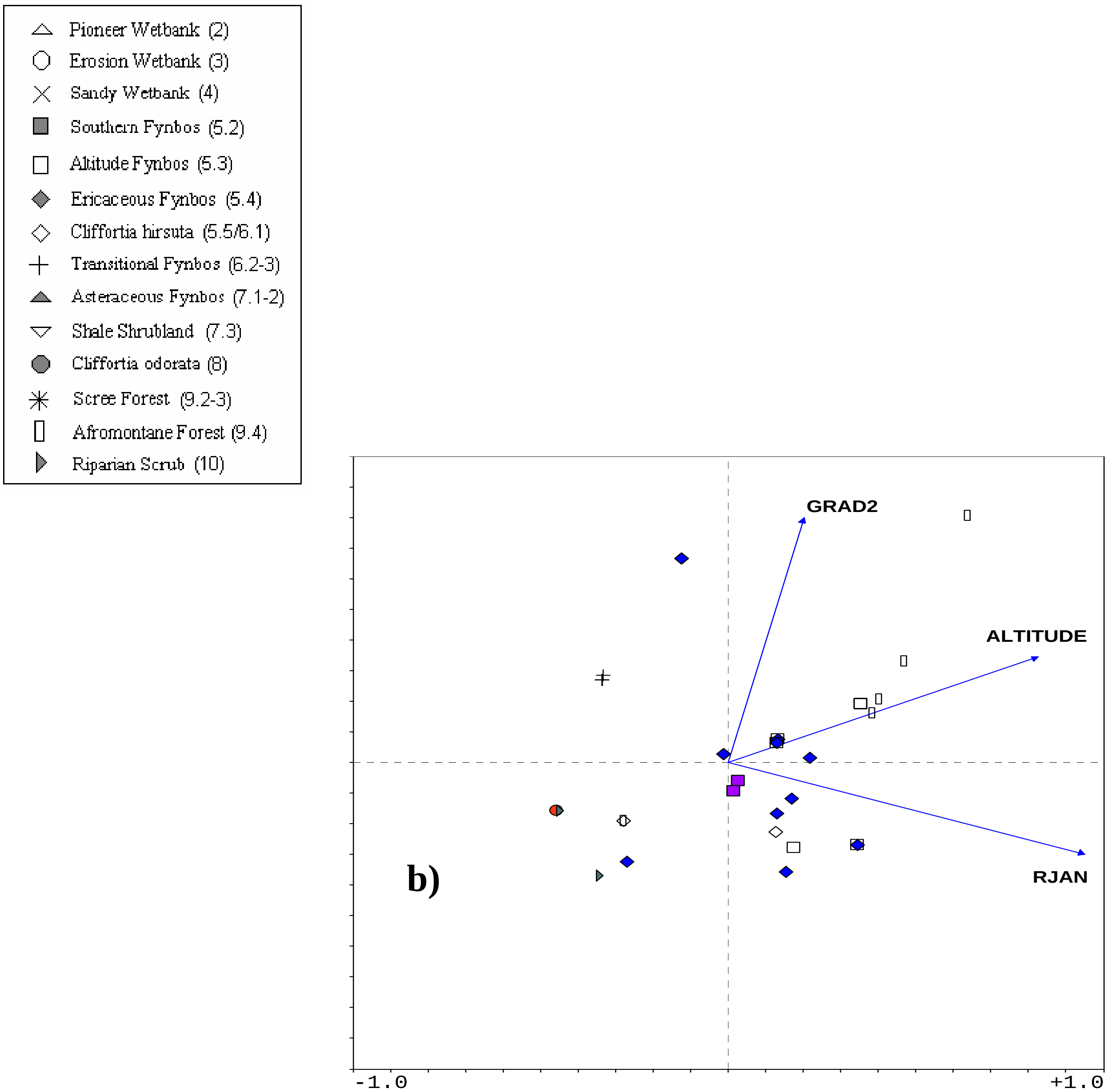
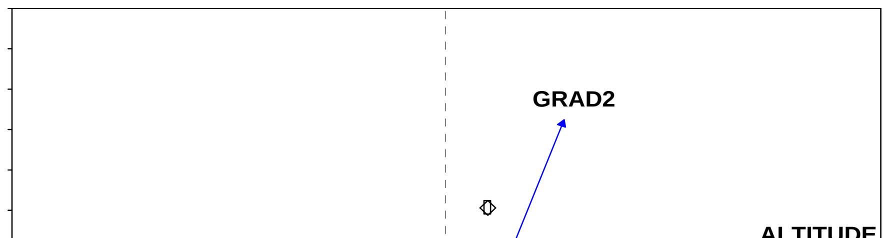


Figure 7.6a & b: Ordination diagrams of the second hierarchical scale in the Riviersonderend and Palmiet River Catchments (91 relevés, 119 species). Diagram a) illustrates the Wet Banks and Diagram b) the Dry Banks. Rjan is correlated with MAP and Rjuly and GRAD2 is correlated with GRAD1.



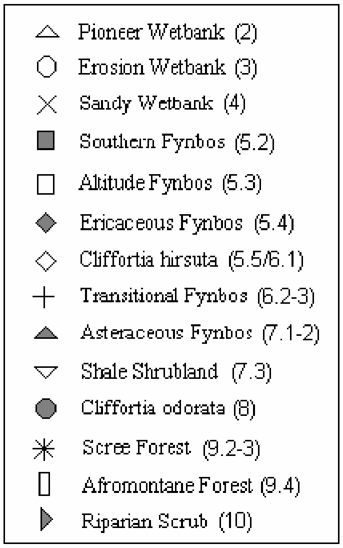
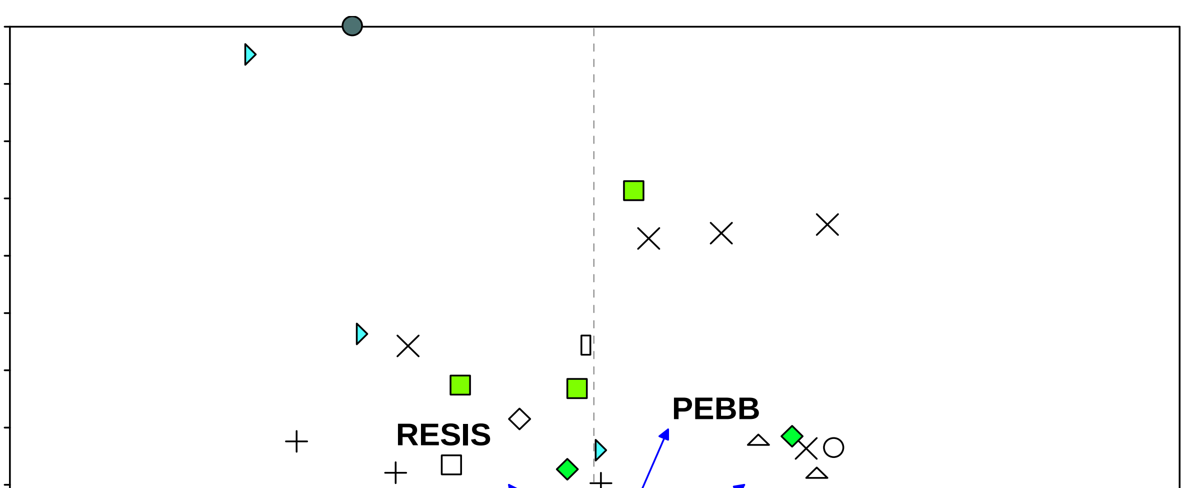


Figure 7.6c: Ordination diagram of the second hierarchical scale from the Dry Banks of the Berg and Eerste River Catchments (74 relevés, 88 species). The Wet Banks of these catchments are not illustrated because they are all of the same type. Rjan is correlated with MAP and Rjuly and GRAD2 is correlated with GRAD1.



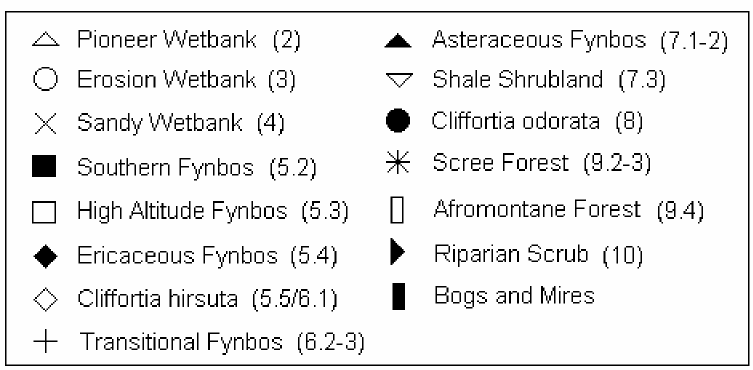
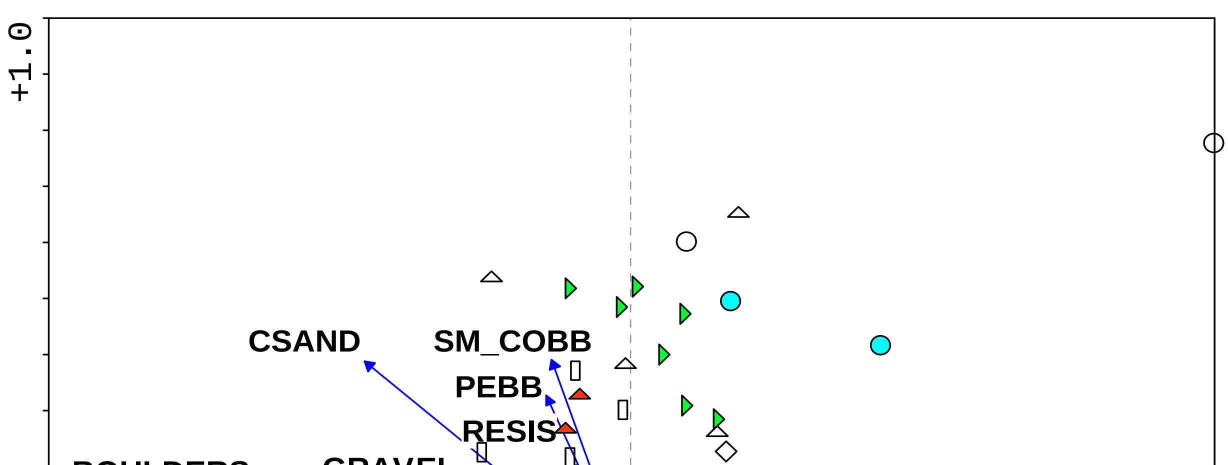


Figure 7.7a: Ordination diagram of the third hierarchical scale in the Riviersonderend and Palmiet River Systems (91 relevés, 119 species).



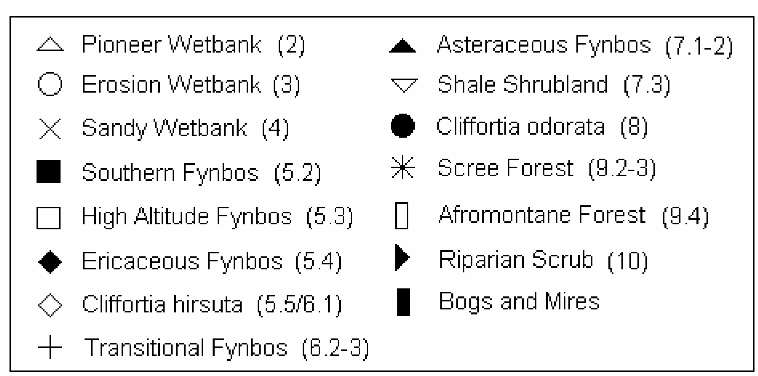


Figure 7.7b: Ordination diagram of the third hierarchical scale in the Eerste and Berg River Systems (74 relevés, 88 species).

rainfall aspect than the southern part. This means that water stress in summer is more likely in the northern areas.

Variation on the second hierarchical scale

The variation within the catchment is determined strongly by altitude. Altitude has a direct influence on temperature, which is collinear with altitude (Versfeld *et al*. 1992). The lapse rate is calculated by the South African Weather Bureau and is about 0.5°C per 100 metres. Ordination diagrams of the two catchments are shown in Figure 7.6. In both catchments, the amount of rainfall is the most important determinant of within-catchment variation. The river gradient that is correlated to the second axis only plays a major role in the Riviersonderend / Palmiet catchment, because a wider array of Wet Bank types were sampled here (see next paragraph). The river gradient seems only to have an impact on the Wet Bank vegetation, while Shrub and Back Dynamic vegetation is determined by local climate. The Deposition Wet Banks occur where gradients are very low while Pioneer Wet Banks, associated with scouring, are found at places where gradients are very steep. Altitude has in both cases a higher correlation with the first axis than rainfall. Rainfall is correlated with altitude but the correlation coefficient is only 0.39. The higher correlation coefficient for altitude is probably because the rainfall data is not very precise and because altitude also has an impact on other environmental factors. Among these, temperature, hours of sunshine and the occurrence of mist probably play a major role. There is, however, no direct data available for these factors.

Variation on the third hierarchical scale

The variation on the third hierarchical gradient is illustrated in Figure 7.7. Explanatory variables at this level have the same effect on vegetation throughout the entire area, although the vegetation types furthest from the river can differ greatly from catchment to catchment. Forest and scrub is less common in the Riviersonderend / Palmiet River catchment and well-developed Wet Banks are less common in the Eerste / Berg River catchment. The most important explanatory variable on the first axis is DISTELEV, which is distance times elevation and provides an estimate of a measure of inundation frequency. The most important explanatory variable on the second axis is ‘Boulders’. The scarcity of well-developed Wet Banks in the Eerste / Berg River catchments is striking. It can best be explained by the influence of stream power (Bendix 1999). In steep rivers, flowing in steep gorges, stream power for relatively small floods is much higher than in more gentle rivers such as the Palmiet and Riviersonderend Rivers. Wet Banks simply cannot develop because they are washed away too frequently. The combination of inundation frequency and stream power would be the best measure to describe the lateral gradient.

Variation partitioning

The total inertia for the complete data set without seepages is 10.042. The sum of all canonical eigenvalues in a CCA including all environmental and spatial variables is 4.211. This means that 42.1% of the total variance is explained by the explanatory variables that are available. The rest is unexplained variation. Økland (1999) mentions that the terms explained and unexplained variation should rather be abandoned and focus should be directed on the proportions of the explained variation by different sets of environmental variables. Normally the unexplained variation falls in the range of 50-70% of the total inertia.

In this study only 2.2% of the variance can be explained exclusively by the spatial variables. This means that the major proportion of the spatial variation is also covered by the explanatory variables. Borcard *et al*. (1992) refer to these variables as 'spatially-induced environmental variables'. The most important of these in the current study are Rsummer and Rjan_jul, which express the strong climatic gradient across the area. The proportion of spatial and environmental variation is illustrated in Figure 7.8.

Of the variation explained by the environmental variables, 56.2% is explained by the first hierarchical scale (most important variables: Rsummer, Rjan_jul, Slope, Geology, Organic), 30.4% is explained by the second hierarchical scale (most important variables: Altitude, Rjan) and 38.2% is explained by the third hierarchical scale (most important variables: Distelev, Gravel, Boulders, Bedrock). The sum of these fractions is higher than 100%, which suggests that there is considerable overlap between the different hierarchical levels. Most of this overlap is between the first and the second hierarchical scale, as can be seen in Figure 7.9. This is mainly because climatic gradients across the area also show a lot of variation within the catchments, especially in the case of large catchments such as that of the Riviersonderend River.

Table 7.2 gives a list of the variables with their correlation coefficients, their importance in the forward selection and the significance levels of the Monte Carlo permutation tests. The information in this table is a useful supplement to the information provided by Variation Partitioning. It can be seen, for example, that the most important explanatory variable (the one on top of the table) is Altitude, even though this variable belongs to the apparently least important hierarchical scale. This is possible because the first and third hierarchical scales include many environmental variables that, as individual variables, do not explain as much variation as Altitude. The variables Rsummer and Rjan_jul, which are important explanatory variables on the first hierarchical scale (see Figure 7.5), are located fairly low down in the table. This is mainly because there is a correlation between them and the spatial variables on top of the table. Forward selection lists them only on the criterion of the 'remnant variation', that is, the variation that is left after the variation explained by the previous variables is removed.

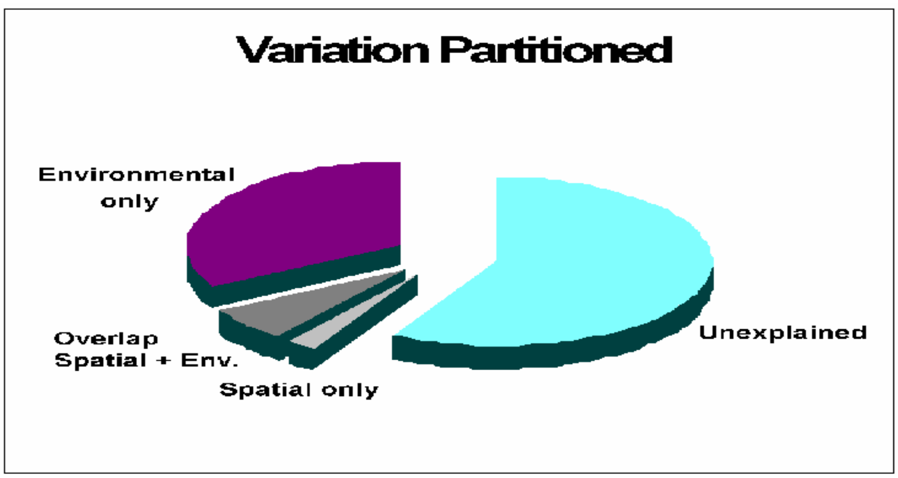


Figure 7.8: Total Inertia partitioned into spatial and environmental variables.

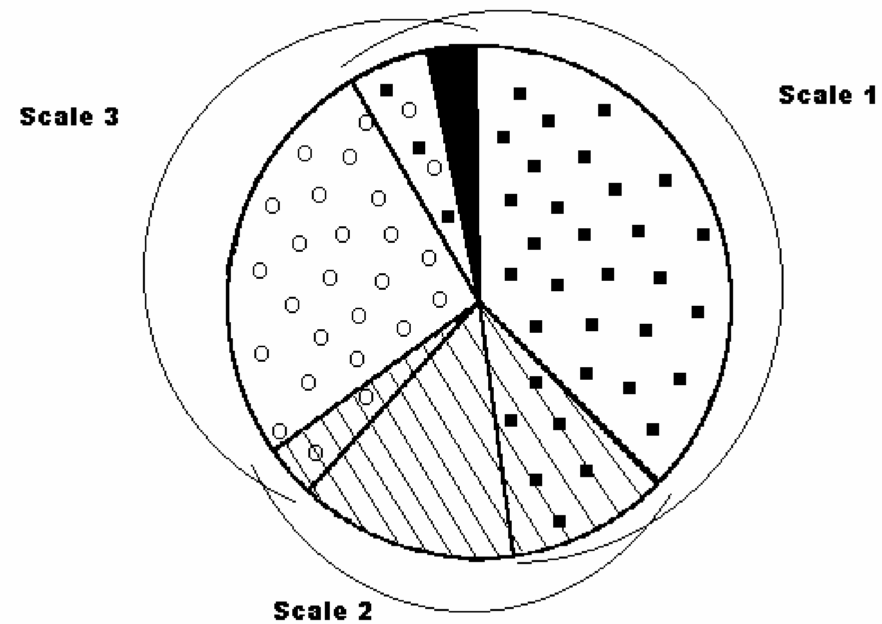


Figure 7.9: Sections of explained variation divided into the three hierarchical scales. The black section signifies the variation that is explained by all hierarchical scales. Note that scales 1 and 2 have a considerable overlap.

Table 7.2: The results of Forward Selection on the explanatory variables. 'Expl.' indicates the variation explained and 'cumul.' the cumulative variation explained. The P-Value indicates the significance level of the Monte Carlo permutation test. This test is only performed for the residual variance explained by the explanatory variable, in other words, the variance that is not yet explained by all variables that preceeded it. The correlation factors with the first and second canonical axes (Corr. AX1 and Corr. AX2) are indicated as an importance value independent of the preceeding variables. The Variation Inflation Factor (VIF) indicates whether a variable is stable or whether it is correlated to another variable. Values of 0.0 and values above 20 are unstable. The climatic data are unstable because they are all closely correlated with each other. The scales are: Spatial variable (S), first hierarchical scale (E1), second hierarchical scale (E2) and third hierarchical scale (E3).

Variable	Expl.	cumul.	P-value	Corr. AX1	Corr. AX2	VIF	Explanation	Scale
XXY	0,47	0,47	0,005	**0,77**	0,00	**0,00**	Latitude*Latitude*Longitude	S
YYY	0,29	0,77	0,005	0,32	-0,20	**0,00**	Longitude **3	S
Y	0,26	1,03	0,005	0,32	-0,20	**27,28**	Longitude	S
ALTITUDE	0,16	1,19	0,005	**0,57**	0,33	4,95	Altitude	E2
ORGANIC	0,17	1,36	0,005	-0,29	**0,38**	5,75	Organic matter contents	E1
RJAN	0,14	1,5	0,005	-0,03	**0,60**	**325,21**	Rainfall in January	E2
RJULY	0,15	1,64	0,005	0,07	**0,58**	**1764,50**	Rainfall in July	E2
DISTELEV	0,14	1,78	0,005	-0,32	0,33	14,33	Distance * Elevation	E3
MAP	0,12	1,9	0,005	0,02	**0,59**	**2221,14**	Mean Annual Precipitation	E2
GRAVEL	0,1	2	0,01	-0,13	0,21	2,71	Percentage coarse material in soil	E3
BEDROCK	0,1	2,1	0,005	0,01	0,01	1,99	Cover area of Bedrock	E3
BOULDER	0,1	2,2	0,005	-0,20	**0,38**	2,58	Cover area of Boulders	E3
San	0,09	2,29	0,005	**0,41**	0,04	9,35	Table Mountain Group sandstone	E1
Til	0,1	2,39	0,01	**0,40**	0,02	5,91	Table Mountain Group tillite	E1
SLOPE	0,09	2,48	0,005	-0,18	0,06	2,81	Slope of river bank	E1
Sha	0,09	2,57	0,005	-0,25	**-0,42**	6,47	Malmesbury Group shale	E1
RSUMMER	0,09	2,66	0,005	0,19	0,23	**24,25**	Percentage of rainfall in summer	E1
RJAN_JUL	0,11	2,77	0,005	0,21	-0,30	**100,36**	Ratio of Rjuly to Rjan	E1
Gra	0,08	2,86	0,01	**-0,45**	**0,37**	5,17	Cape Granite Suite	E1
DISTANCE	0,07	2,93	0,025	-0,22	0,22	9,95	Distance from water's edge	E3
ELEV	0,08	3,01	0,05	**-0,38**	0,24	4,38	Elevation above water table	E3
GRAD2	0,07	3,08	0,065	-0,26	0,20	5,07	River's gradient in 100 meter-scale	E2
MSAND	0,07	3,15	0,05	-0,13	-0,20	4,22	Mass contents of Medium sand	E3
N	0,07	3,22	0,045	-0,21	-0,05	**39,98**	North aspect	E1
Fernwood	0,07	3,29	0,12	0,21	0,03	4,20	Fernwood Soil Form	E1
GRAD1	0,07	3,36	0,135	-0,25	0,24	5,54	River's gradient in 10 meter-scale	E2
SOILDEPT	0,07	3,42	0,15	-0,01	-0,17	3,06	Depth of soil	E3
S	0,06	3,49	0,145	-0,13	0,03	**41,08**	South Aspect	E1
LG_COBB	0,06	3,55	0,12	0,02	0,12	1,93	Cover area of large cobbles	E3
E	0,06	3,61	0,245	0,05	-0,09	**24,95**	East Aspect	E1
W	0,1	3,71	0,015	**0,35**	0,11	**33,16**	West Aspect	E1
Magwa	0,06	3,78	0,13	-0,19	0,26	5,68	Magwa Soil Form	E1
RESIS	0,06	3,84	0,165	0,09	-0,11	2,47	Electrical resistance of wet soil	E3
Mispah	0,06	3,9	0,26	**0,38**	-0,08	6,34	Mispah Soil Form	E1
PH	0,06	3,96	0,255	**-0,41**	-0,11	2,98	pH of Soil	E1
PEBB	0,06	4,02	0,285	-0,02	-0,10	1,92	Cover area of pebbles	E3
Oakleaf	0,06	4,07	0,385	-0,22	-0,02	6,13	Oakleaf Soil Form	E3
CSAND	0,05	4,12	0,49	0,25	0,10	4,27	Mass contents of Coarse Sand	E3
FSAND	0,05	4,18	0,56	-0,32	0,04	15,51	Mass contents of Fine Sand	E3
SILT	0,06	4,24	0,245	**-0,38**	0,09	18,97	Mass contents of Silt	E3
SM_COBB	0,05	4,29	0,57	0,06	0,02	2,03	Small Cobbles	E3
Glenrosa	0,05	4,33	0,63	-0,18	-0,18	4,52	Glenrosa Soil Form	E1

7.9 Discussion

The geographical gradient operating at the first hierarchical scale explains most variation and is the most important gradient in this study. This is probably because of the extremely high species turnover in the Fynbos Biome. The results of this study show clearly that this even accounts for azonal vegetation like riparian vegetation. This is also confirmed by A.B. Low, who compared river floras across the region, and found significant differences between those floras. Although many riparian species have a wide distribution and occur in many catchments, the total species composition of a specific river is often very different from the river next to it (pers. comm. A.B. Low). As the results of this study suggest, this can be mostly explained by differences in climate regime and geology but also the river itself will probably play a role: the seeds of some species are dispersed by water and for those species it will be easy to be dispersed downstream in the same catchment, while it will be difficult to cross inhospitable habitats to access another catchment. All in all, the geographical variation within the riparian vegetation in the Fynbos Biome stands out. In other biomes and in areas with less strong climatic gradients, the proportion of the variation explained by the geographical gradient would probably be much less. This study only investigates a relatively small area, so it would still be interesting to obtain data from other catchments throughout the Western Cape to get a total picture. The importance of the geographical gradient in a river ecosystem is also discussed by Malanson (1993).

The comparison of local floras is not the same as the comparison of diversity in vegetation types but it does give an indication of what one can expect. Cowling & Holmes (1992) give an indication of gamma diversity of non-riparian vegetation by comparing six local floras throughout the Fynbos Biome. They clearly show that the Southwestern part of the biome is the most diverse in species. It is likely that the variation in (riparian) vegetation would show a similar picture, but this is not necessarily so.

The lateral gradient is the next most important gradient. This gradient has been studied in many vegetation studies before (Kopecky 1969; Hupp & Osterkamp 1985; Glavaç *et al.* 1992; Boucher & Tlale 1999) and accounts for a high proportion of the variation because the environmental stresses next to a river are very specific (Gregory *et al.* 1991; Bendix 1999). It seems, however, that this variation is more obvious in the lower reaches of the rivers, where riparian zones are more clearly developed. In the highest reaches the riparian zones are often so much intertwined that they cannot be distinguished from each other. Also, discharges are often not very high in these reaches, so that different flood levels do not result in broad vegetation zones. Mountain streams return to base levels more rapidly than rivers on the flats, hence inundation periods are less determinative on the vegetation.

The longitudinal gradient, operating at the second hierarchical scale, is the least important and shows a large overlap with the geographical gradient, because, within a catchment, the variation in climate can still be quite large. The longitudinal gradient itself has a small influence. The reach differences within the mountains do not have a direct influence on the vegetation. The only aspect that is important about the reach is the degree of erosion and deposition and this influence is best visible in the vegetation zones closest to the river. It should be noted, however, that, within this study, only limited stretches of river have been studied and that if rivers would be studied in their entirety, including the lower reaches, the longitudinal gradient would play a major role, especially since, in the Western Cape, the geology often changes to shales and calcareous sands in the lower reaches of the rivers.

The type of analysis that was done in this study is a good way to get a total overview of the river ecosystem and to map complex gradients across the landscape. To recognize the three different scales in this study is important for the management of a river ecosystem (Ward & Wiens 2001). Disturbances can affect either of the nested gradients, for example channelization and alien shrubs affect the lateral gradient, and dams and weirs affect the longitudinal gradient. The geographical gradient can be distorted by climate change, but there is very little an individual manager can do about this. The nested gradient approach is also a good way to model the original vegetation in case of river rehabilitation after removal of severe infestations of aliens.

Except for a slight overlap between the longitudinal and geographical gradients, there is very little overlap in the explained variation of each of the three gradients. This demonstrates that the nested gradient approach is valid and that Variation Partitioning is a good method to describe it. Variation partitioning possibly also minimizes the ‘arch effect’ that occurs in CCA ordination diagrams, because this artefact is mainly caused by hierarchical complexity (Allen 1987).

The weakness of the method is that the different variables operating at the different scales have to be defined prior to the analysis. In general this is easy, but for some variables the relation to the spatial scale is unclear or they operate at different scales. For example, organic matter content is influenced by climate, so it operates at the level of the geographical gradient. On the other hand, the river washes organic matter out of the soil, so the lateral gradient also has an impact. In these cases it is best to choose the largest scale. The results of this study show that these variables, in general, do not explain a large part of the variation, with the notable exception of organic matter. This will also reflect in the overlap between different scales as illustrated in Figure 7.9.

The approach used in this study is in sharp contrast to that by Van Coller *et al.* (2000) who defined more nominal ‘patchy’ variables in riparian vegetation and set up a hierarchy of these nominal variables. This main difference lies in the simple fact that Van Coller *et al.* (2000) studied the lower reaches of the Sabie River, while this study aims at describing the mountain stream habitat. The morphological units as they are defined by Van Coller *et al.* (2000) are present in mountain streams but on a much smaller scale and are mostly not vegetated at all, because of the poor substrate. The gradients are however much sharper so the ‘nested gradient’ approach is more suitable for mountain streams, while the ‘nested patches’ approach is more suitable for the lower reaches. But in this case it is still possible to apply Variation Partitioning to lower river vegetation.

The methodology applied in Van Coller *et al.* (2000) and in this study revolves around an old question in vegetation science: Is it scientifically allowable to have preconceived ideas in order to describe the vegetation? In vegetation classification one is allowed to undertake a reconnaisance survey prior to the actual fieldwork, and broad vegetation and habitat units can be defined beforehand. This broad classification assists in the assessment of the number of samples to be done and it can offer useful guidelines for the final classification (Werger 1974; Westhoff & Van der Maarel 1973). The assumption of random sampling promoted mainly by followers of the American tradition has long been rejected (Whittaker 1973a; Shimwell 1971; Mueller-Dombois & Ellenberg

1974). This principle can be applied to gradient analysis as well. Just as it is useful for classification to make an assessment beforehand, it will offer gradient analysis useful guidelines if the existence of certain gradients is acknowledged beforehand, especially in cases where it is already obvious that there is a pattern of nested gradients. 'Random gradient analysis' would be an impossible prerequisite because the selection of environmental variables already shows that the researcher has preconceived assumptions. It should not be forgotten that gradient analysis is only a descriptive scientific method and that causal relationships should not be derived from this method anyway.

7.10 Conclusions

A combination of hierarchical scaling and variation partitioning according to these scales is a suitable method to describe a complex ecosystem with nested gradients. Riverine ecosystems fall into this category, especially in the mountain reaches where there are steep ecological gradients. In the lower reaches the geographical and longitudinal gradients are in general less steep, except in the case of very large stretches of river. To describe the more complex lateral gradients in the lower reaches the method of hierarchical patch dynamics is very suitable.

Within an entire river ecosystem, gradient analysis would be possible when combining the mountain reaches and the lower reaches. There will, however, be several systems within the riverine ecosystem that are physically connected to the river but are distinct systems of their own. The stagnant water conditions in the mires at the sources of rivers and the saline conditions in the estuaries makes these parts of the river somewhat different from the rest of the system and they should be studied separately. It would be interesting to apply the nested gradient approach also to other river systems, different reaches, larger stretches etc., so that general hypotheses about river ecosystems can be derived from the results of these studies.

This study shows clearly that gradients in the Fynbos Biome are very sharp and that this even reflects in the azonal vegetation types like the rivers. It is clear that azonal vegetation is not only determined by small-scale 'azonal' processes, but is also an expression of the large-scale climatic processes. Small fluctuations in climate, and the anticipated global warming, will have a profound effect on this vegetation, because the vegetation is very sensitive to the seasonal variation and amount of rainfall. In many cases, large-scale processes also have their influence on small-scale processes, for example rainfall determines the flow regime of the rivers (Hewlett 1982).

In the Fynbos Biome, not all riparian habitats are similar and to conserve the maximal diversity in riparian habitats as many rivers as possible should be included in conservation. In order to obtain this maximal variation, the three nested gradients in this study and the most important explanatory variables can be used as guidelines. Most mountain stream habitats are well conserved in South Africa because they are situated in mountain catchments and they fall under the Water Conservation Act. Conservation practices consist mainly of maintaining a natural flow regime and removing alien vegetation. But perhaps the most important factor is that the prevailing climate in an area remains unchanged. Global warming is an important threat to the Fynbos Biome and it should be monitored to determine the extent in which the climate in these particular catchments is affected by it. The wet habitats of the region will be the first ones to suffer from changes in climate. This study should be followed by others in the biome in order to monitor the effects of climate changes on the wet habitats of the biome.

8. Gamma diversity in an azonal vegetation type in the Fynbos Biome of South Africa

Keywords: Gamma diversity, Fynbos Biome, riparian vegetation, similarity indices, mountain catchment.

Nomenclature: Goldblatt & Manning (2000)

8.1 Abstract

Similarity indices are used to examine the gamma diversity relationships in the riparian floras of different catchment areas in the Hottentots Holland Mountain range in the Fynbos Biome. The catchments are all part of the same mountain range. Two similarity indices are used: the Jaccard Similarity Index and the Russell-Rao Similarity Index. Comparisons are made between the catchments, the different altitudinal zones and the different habitat types. Similarities are quite low, mainly because of the many rare species. The most common species have a wide distributional range, but there are some exceptions. There are only five species that were found in all the catchments, in all altitudinal zones and in all habitat types. The riparian vegetation, like the other vegetation types in the Fynbos Biome, has a high gamma diversity.

8.2 Introduction

The Fynbos Biome is known as one of the most species-rich floras in the world (Takhtajan 1969; Good 1974). The alpha and beta diversities are comparable to other mediterranean-type climates, but it is the gamma diversity that stands out particularly (Cowling *et al*. 1992). Kruger & Taylor (1979) mention areas that are only 25 km apart and show a species turnover of more than 50%. This species diversity in the Fynbos Biome can be explained partially by the origins of the fynbos species (Taylor 1978) but also by the extreme radiation that took place in the wide array of environmental conditions that can be found in the Western Cape (Campbell 1983; Deacon *et al.* 1992). Climatic gradients are quite strong and the amount of precipitation at the higher altitudes is many times that of the valleys (Wicht *et al*. 1969; Deacon *et al*. 1992). The species radiation has occurred more strongly in certain taxonomic groups than in others and the typical 'fynbos taxa' like Ericaceae, Restionaceae and Proteaceae have an extremely high turnover of species, while cosmopolitan families like Poaceae and Orchidaceae are under-represented when it comes to endemic species (Cowling *et al.* 1992).

Azonal vegetation, such as riparian vegetation, is rich in typical fynbos elements, but it is mostly not as species-rich as the vegetation in the uplands (Kruger 1978b; Taylor 1978). In this respect, the situation in the Cape is quite different from Australia (Hancock *et al*. 1996) or North America (Gregory *et al*. 1991). This situation is mostly due to the huge species richness of the fynbos itself. The question addressed here is whether the riparian vegetation elements reflect gamma diversity to the same degree as the adjacent fynbos. For this purpose a comparison is made between the riparian vegetation of five different catchments in the Hottentots Holland Mountains in the southwestern Cape (see Figure 2.1).

8.3 Study area

The five catchments that were chosen for this study are all situated in the Hottentots Holland Mountains. This Mountain Range is situated between the towns of Stellenbosch, Franschhoek, Somerset West and Grabouw. It receives the highest rainfall in South Africa with precipitations in excess of 3000 mm per annum recorded on the top of Victoria Peak (Schulze 1965; Deacon *et al.* 1992). There is a climatic gradient across the range from north to south, with a higher proportion of summer rainfall occurring in the south (see Chapter 7). The substrate consists mostly of sandstones of the Table Mountain Group, but granites occur on some of the lower slopes in the western part of the mountain range. The Eerste River has its main catchment in the mountains surrounding the Jonkershoek Valley. It has the greatest diversity of geological units of the five catchments studied here, with granite occurring on the valley bottom, Malmesbury Group shale on the southern slopes of Stellenbosch Mountain and sandstone dominant on all the higher slopes. The Lourens River drains the western slopes of the Hottentots Holland Mountains, near Somerset West. This river has a very small catchment and a very steep gradient. Its origin is in sandstone on the highest slopes of Somerset Sneeukop while it flows over Cape granites on the lower slopes of the range. The Berg River catchment is situated in the north and also contains some granite in its middle reaches especially in the Banghoek River tributary in the northwest. The Berg River is a very steep river that originates in sandstones in the steep gorges of Assegaaibosch Kloof. The Riviersonderend River flows over sandstones draining the eastern slopes of the Hottentots Holland Mountain range. It has the biggest catchment in the Hottentots Holland Mountains and has many subcatchments. The eastern slopes are gentler than the western and northern slopes so this river and the Palmiet River have less steep gradients. The Palmiet River, situated in the south, has extensive mires in its headwaters and flows, in its upper reaches, like the Riviersonderend River, entirely over Table Mountain Group sandstones.

8.4 Methodology

A phytosociological analysis of the riparian vegetation in the Hottentots Holland Mountains was undertaken (see Chapter 5). From this study complete lists of species occurring in riparian habitats in the different catchments were compiled. The species lists for each catchment were compared with one another by means of the Jaccard’s Similarity Indices (Podani 1994). The Russel-Rao Similarity Index was also calculated and the values obtained from the two indices were compared for interpretive purposes. The comparison between the different catchments is central to this analysis of biodiversity, although comparisons were also made between the different altitudinal zones and between the different broad habitat units. The following altitudinal zones were defined: the foothill zone (< 400 m), the mountain stream zone (400 – 900 m) and the headwall / seepage zone (> 900 m). The following broad habitat types are defined: The Wet Bank Zone for the riparian types that are inundated at least once every year, the Dry Bank for the riparian types that are inundated less frequently than once a year, the Forests for the vegetation types in which the tree layer dominates, irrespective of their inundation frequency and the Seepages for the Restionaceae-dominated headwaters of the rivers.

The species were divided into rarity classes on the basis of their number of occurrences and the distributions of the commonest species were examined in more detail.

8.5 Results

Table 8.1: Similarity indices between the different catchments using Jaccard and Russel/Rao Similarity Indices. The data set size for every catchment is indicated by n.

	n	Jaccard Index					Russel & Rao Index				
		R	P	E	B	L	R	P	E	B	L
Riviersonderend River	90	X					X				
Palmiet River	50	0.44	X				0.31	X			
Eerste River	56	0.28	0.22	X			0.23	0.16	X		
Berg River	47	0.28	0.21	0.4	X		0.21	0.13	0.23	X	
Lourens River	16	0.27	0.25	0.28	0.29	X	0.19	0.14	0.17	0.14	X

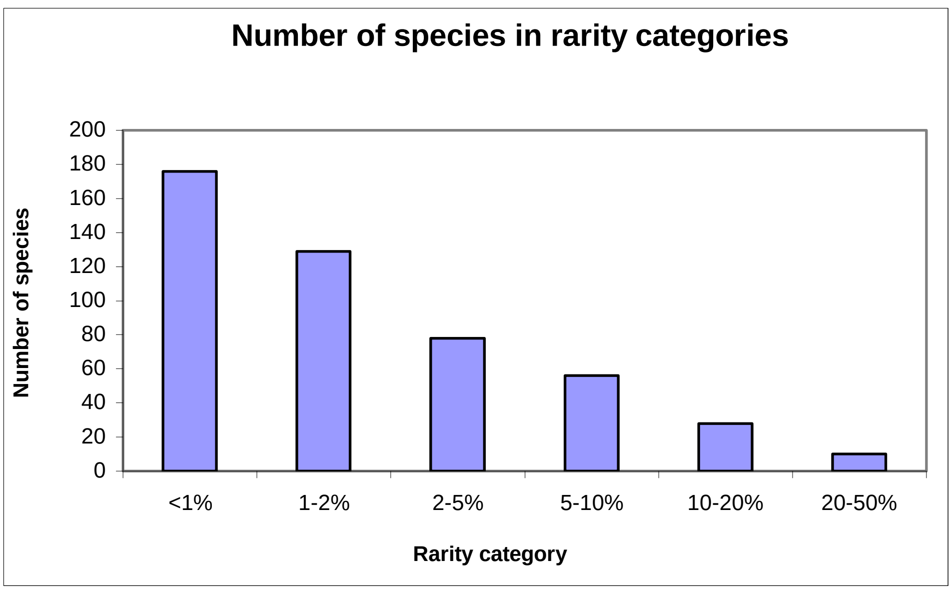


Figure 8.1: Rarity categories of the plant species in the riparian habitats of the Hottentots Holland Mountains. The categories indicate the percentage of the total number of relevés in which a species occurs.

Table 8.2: Jaccard Similarity Index with decreasing data set sizes to show the influence of the rare species. The similarities investigated are the Palmiet/Riviersonderend (P/R), the Eerste/Berg (E/B) and the Palmiet/Berg (P/B) (See Table 8.1).

Jaccard Similarity Indices				
Number of species		P/R	E/B	P/B
n=478	Complete data set	0.443	0.401	0.211
n=372	Single occurrences left out	0.509	0.485	0.232
n=301	First class of Figure 8.1 left out	0.572	0.549	0.257
n=172	First two classes of Figure 8.1 left out	0.684	0.635	0.353

The similarity indices between the different catchments are given in Table 8.1. The highest similarity is found between the Palmiet and Riviersonderend River catchments. The Jaccard Similarity Index here is still quite low (44%), and the Russel-Rao Index indicates an even lower value. The next most similar pair of rivers is the Eerste River and the Berg River with a Jaccard Similarity Index of 40%. The Lourens River catchment stands out as a singular catchment, with an average Jaccard Similarity Index of only 27% to any of the other catchments.

The low overall similarities are mainly due to the high number of rares. Figure 8.1 illustrates the distribution of species across several rarity classes. This figure is similar to a Raunkaier's 'J' curve for the entire set of riparian communities (Raunkaier 1928). However, it is different because it deals with an entire ecosystem and not with a single community and that is why Raunkaier's Law of Frequencies does not apply. This law states that most of the species would fall into the frequency categories 0-20%, 20-40% and 80-100%. The last category is not present at all in Figure 8.1, but would be more important if the frequency categories of a single community were studied (Raunkaier 1928; Kent & Coker 1994). Most species are found in only one or two relevés. Their impact on the similarity indices is high as is illustrated in Table 8.2, which indicates changes to the similarity indices after the rarest occurrences are left out.

Table 8.3: The flora of the intermediate altitudinal zones compared to the low altitudes and the high altitudes. The Russel/Rao Index can be used to assess the fraction of species that occur in all altitudinal zones. The number of relevés (n) is indicated for each category.

Similarity index	n	Jaccard	Russel/Rao
Low (<400 m)	56	0.394	0.367
Intermediate (400-900 m)	164	-	-
High (>900 m)	38	0.265	0.229
All altitudinal zones	258	-	0.103

Table 8.4: Russel/Rao Similarity Indices of the different habitat types. D = Dry Bank; W = Wet Bank; F = Forest and S = Seepage. The value n indicates the number of relevés in each category.

Russel/Rao Index					
	n	D	W	F	S
Dry Bank	80	X			
Wet Bank	58	0.33	X		
Forest	52	0.28	0.21	X	
Seepage	33	0.11	0.08	0.03	X

The different altitudinal zones also show different floras. The altitudes between 400 and 900 metres are the richest in species. The Similarity Indices between this zone and the altitudinal zones below and above it are shown in Table 8.3. The highest altitudes are markedly different probably because of the distinct habitats of the seepages found at these altitudes.

The comparisons of the different habitat types are illustrated in Table 8.4. The Dry Bank is clearly the most species-rich habitat type. The seepages are the most distinct habitat types, having an average Russel-Rao Similarity Index with any of the other habitat types of less than 10%.

Twenty-seven species occur in all the catchments, 49 species occur in all altitudinal zones and nine species occur in all habitat types. A list of the common species, with their distribution across these different classes, is presented in Table 8.5. The most interesting observations that can be derived from this table are that very common species, such as *Brabejum stellatifolium* and *Cassytha ciliolata*, are apparently restricted in their distribution across habitats, altitudes and catchments, and that species less frequently recorded, such as *Carpha glomerata* and *Centella eriantha*, can be found in all the habitat types.

Table 8.5: The most common and most widespread species in the data.

Species	All catchments	All altitudes	All habitat types	Number of occurrences	Species	All catchments	All altitudes	All habitat types	Number of occurrences
Brachylaena neriifolia	X			93	Blechnum punctulatum		X		26
Ischyrolepis subverticillata	X	X		88	Grubbia rosmarinifolia		X		25
Erica hispidula	X	X	X	72	Centella eriantha	X	X	X	24
Restio purpurascens	X	X	X	69	Pentaschistis pallida	X		X	24
Podalyria calyptrata	X			62	Anthochortus crinalis	X			22
Ehrharta rehmannii	X	X	X	61	Tetraria capillacea		X		20
Todea barbara	X	X		58	Hymenophyllum peltatum	X	X		19
Cassytha ciliolata				55	Pentameris thuarii	X	X		19
Metrosideros angustifolia .				55	Askidiosperma esterhuyseniae		X		18
Aristea major	X	X		53	Aristea confusa	X	X		17
Diospyros glabra	X			50	Stoebe cinerea	X	X		17
Cunonia capensis	X	X		46	Corymbium cymosum	X			17
Brabejum stellatifolium				45	Helichrysum cymosum		X		17
Tetraria cuspidata				45	Oxalis truncatula	X	X		16
Prionium serratum		X		40	Rapanea melanophloeos	X	X		16
Berzelia squarrosa		X	X	39	Restio bifidus		X		16
Asparagus scandens	X	X		38	Elegia neesii		X		15
Erica caffra				38	Lycopodiella caroliniana		X		15
Agathosma crenulata		X		36	Elegia thyrsifera		X	X	14
Pteridium aquilinum				36	Drosera aliciae		X		14
Isolepis digitata		X		35	Apodytes dimidiata	X	X		12
Cassine schinoides				35	Thesium strictum		X		12
Penaea cneorum		X		34	Cliffortia ruscifolia		X		11
Schizaea tenella		X		34	Othonna quinquedentata		X		10
Epischoenus villosus	X			32	Carpha glomerata		X	X	9
Chondropetalum mucronatum				32	Olea capensis		X		9
Schoenoxiphium lanceum				32	Restio echinatus	X			8
Stoebe plumose	X	X	X	31	Platylophus trifoliatus		X		8
Erica intervallaris		X		31	Psoralea aculeata		X		8
Disa tripetaloides		X		29	Gladiolus carneus	X			7
Struthiola myrsinites				29	Knowltonia vesicatoria		X		7
Brunia alopecuroides		X		28	Utricularia bisquamata		X		7
Leucadendron xanthoconus				27	Psoralea asarina		X		6
Pseudobaeckea africana				27	Anthoxanthum tongo		X		5
Metalasia cephalotes	X			26	Halleria lucida		X		5
Blechnum capense		X		26					

Table 8.6: The most important families based on the number of species

Eastern catchments		Western catchments		All catchments	
Restionaceae	50	Asteraceae	46	Asteraceae	63
Asteraceae	48	Restionaceae	31	Restionaceae	57
Cyperaceae	30	Cyperaceae	21	Cyperaceae	39
Ericaceae	23	Fabaceae	16	Ericaceae	27
Poaceae	22	Poaceae	16	Poaceae	25
Rosaceae	17	Ericaceae	14	Fabaceae	22
Iridaceae	14	Iridaceae	12	Iridaceae	21

The main distinction within the riparian flora of the area is between the flora of the catchments of the western slopes, which are partly on a granitic substrate and the catchments on the eastern slopes, which are completely on sandstones. The constituents of the riparian floras in these two groups are slightly different. The biggest families in the two floras are displayed in Table 8.6. The 'typical' fynbos families Ericaceae and Restionaceae are most prominent on the sandstone substrates of the eastern slopes. The western slopes also have a fairly large group of Restionaceae, but these are mainly from the higher altitudes and the seepage zones, which are on sandstone. The biggest family on the western slopes is the Asteraceae. This is the main constituent of Asteraceous Fynbos, which is typical for the fine-grained substrates on granite (Campbell 1986b).

8.6 Conclusions

Kruger & Taylor's (1979) conclusion about the high gamma-diversity in the Fynbos Biome can now be expanded to include the azonal riparian vegetation. Diversity is highest in the Dry Banks and decreases towards the river. Other species-poor habitats are the Seepage marshes at the sources of the rivers and the occasional forested river edges. The most distinct habitat type that is part of the riparian ecosystem, based on the presence and dominance of unique species is the seepage zone.

The low similarity between the different catchments is mainly due to the large number of rare species that were only found in a single relevé. The most common species generally also have a wide distribution across habitats, altitudinal ranges and catchments.

Interestingly enough, a few of the most common species found in this study have a fairly narrow distribution range such as *Ischyrolepis subverticillata*, *Restio purpurascens* and *Podalyria calyptrata*, all of which are more or less restricted to the extreme southwestern Cape (Goldblatt & Manning 2000). Other species are specific to the Fynbos Biome riparian habitats, e.g. *Brachylaena neriifolia*, *Prionium serratum* and *Metrosideros angustifolia*. Generalist plant species are a rare phenomenon in the Western Cape.

9 Conclusions

9.1 Environmental aspects of riparian vegetation patterns in the Hottentots Holland Mountains

The previous chapters dealt with several aspects about the riparian vegetation of the Hottentots Holland Mountains. They dealt subsequently with the classification of vegetation types, the impact of floods on the riparian zone, the environmental gradients in the study area and biodiversity patterns along mountain streams. The situation in the area reflects a nearly natural condition with minimal disturbance, so the vegetation types resulting from classification can be used as reference types for bio-monitoring. The seepage types described in Chapter 4 are probably very vulnerable to climatic change and the riparian vegetation and the seepages can change due to water abstraction. It is assumed that the vegetation will gradually change if the natural flood regime is abandoned. This has been recorded in the lower reaches of rivers on many occasions (Stevens *et al.* 1995; Tremolières *et al.* 1998). It is probably unique to the Fynbos Biome that large-scale environmental gradients like climatic variation have the highest impact on riparian vegetation. It can be questioned whether this impact would be similar in other parts of the biome. But it is quite obvious that climatic aspects play a major role in the maintenance of vegetation in the biome, even in vegetation types that seem to be determined largely by other processes.

Although the vegetation patterns in the mountains are not as obvious as in the lower reaches, the riparian zones identified by Boucher & Tlale (1999) can be maintained in the highest reaches. The only riparian zone that is virtually non-existent in the mountains is the Lower Dynamic Zone and if it is present it certainly does not support a distinct vegetation type.

The riparian zonation can also be described as a continuum, as was done in Chapter 7, but the results of this study support the notion of Glavaç *et al.* (1992) that vegetation borders in riparian zones are generally very sharp. The hydrological and hydraulic processes in rivers are very diverse, particularly in mountain streams where big boulders, bedrock, woody debris, numerous bends, cascades and pools all have their impact on local habitats. The local geomorphology determines whether the banks of a river during a flood are mainly inundation-determined or stream power determined. If inundation plays an important role, the vegetation will have to be adapted to a wet habitat and to anaerobic conditions in the soil. If stream power plays an important role, the plants growing on the river bank have to be adapted to mechanical disturbance and have a strong rooting system. Because of all these influences, riparian zones are never really extensive along the longitudinal axis and are broken up in many places, except in stretches that are straight and without obvious changes in gradient. To summarize, one can say that the dynamic nature of a river ecosystem is most obvious in a mountain stream.

The riparian vegetation is part of the surrounding landscape and the characteristics of a river are determined by processes in the catchment. In the Fynbos Biome, where virtually every single mountain catchment forms a unique habitat with endemic species, climatic and other large-scale processes play a major role. Every catchment has its own riparian vegetation and this makes classification quite difficult at this stage. Gradient analysis, as was done in Chapter 7, lends support to the classification of the vegetation units.

Some concluding remarks will be derived here in order to deal with management questions for riparian habitats in the mountains. At first it seems, that riparian habitats in the mountains do not have many threats. After all, they are all safe within the borders of a Nature Reserve or a Mountain Catchment Area and as long as the rest of the area is managed well, the riparian zones will not experience many problems. On the other hand there are some specific threats to riparian habitats that are dealt with here.

Alien vegetation

Rivers are quite susceptible to alien vegetation, because it is a habitat that is often disturbed naturally and some of the Australian *Acacia* species are very common invaders of riparian habitats. Alien vegetation also has its impact on the flow regime by abstracting more water than the natural vegetation (Boucher & Marais 1995; Dye 1996). The Working for Water Programme is a countrywide government programme that deals with this threat by employing low-skilled workers to remove the alien vegetation manually. This results in gains for water conservation, nature management and social welfare. The Programme is also beneficial for education and skills development. Handicraft products made from alien vegetation are sold locally and people are educated to contribute to eco-tourism (pers. comm. D. Magadlela, Working for Water Programme). There is potential to expand the Working for Water Programme with restoration projects to bring the natural vegetation back in places where the alien *Acacia*'s have invaded the entire riparian zone. The vegetation units described in this study and other riparian studies (e.g. Brown & Day 1998; Boucher 1996) can be used as guidelines for such a project.

It should be mentioned that within the study area, alien vegetation encroaching into riparian zones is quite rare. The worst affected areas are Boesmans Kloof and Banghoek Kloof. Alien vegetation consisting of pines is not specifically riparian but it is a real threat on Franschhoek Peak and in Wesselsgat. The riparian vegetation just outside the borders of the Nature Reserve is in a much worse condition. Here the rivers often flow through pine plantations and the riverbanks are mostly vegetated by alien species. If present management practices aimed at the control of alien vegetation are not continued, the present relatively pristine nature of the mountain riparian vegetation could change quite dramatically for the worse.

Flood regime

Based on arguments presented in Chapter 6 it is clear that inter-annual floods have an important effect on riparian vegetation of mountain streams although they do not lead to the same degree of diversification of habitats as they do in the lower reaches. The results of Chapter 8 show however that the Dry Bank is the most species-rich riparian zone so the inter-annual floods are very important to maintain species diversity in the riparian zone. Riparian forests are poorer in species but form a distinct habitat especially for birds but also for other animals. They are found in places that are sheltered from fire (Manders *et al*. 1992) and they serve as a refuge for animals after a fire. The results of this study suggest that they are not affected to any degree by the flood regime. However, it is likely that they are mainly impacted upon by ground water level changes. Close to the river, the ground water level is generally higher and this is probably one of the factors that enable Afromontane Forests to grow here. The soil water regime is probably still the most important factor that maintains a natural riparian ecosystem in the mountains. Water abstraction in the mountains should be prohibited as far as possible to protect these systems in a natural state.

The floods in the higher reaches will always have impact in the lower reaches, so in a catchment-based management plan it is important to leave the upper reaches mostly intact. Alterations to the original flow regime can only be partially corrected by other tributaries that join the main stem downstream of the point of impoundment. More information about the role of floods can be found in Ward & Stanford (1979).

Climatic regime

The above-mentioned management problems are easily controlled, because they mainly operate at a small scale, within the borders of the nature reserve. In Chapter 7 it can be seen that large-scale environmental factors have an impact on vegetation that is just as high or even higher than small-scale environmental factors. Conservationists within a nature reserve are mostly concerned with small-scale processes that can be controlled within the reserve, but in the case of fynbos and its sharp environmental gradients, sufficient attention must also be paid to the large-scale processes that the reserve is subjected to. It is difficult for managers to make a positive impact on the large-scale environmental processes, although other people, mainly in the cities, do not have many problems in affecting them negatively. Only an awareness campaign about the environmental problems aimed at changing the behaviour of people and their use of water, energy and waste can influence things in this respect. Global warming and the resulting desertification will have a high impact on the Fynbos Biome and all its vegetation types (Rutherford *et al.* 1999). Monitoring programmes should be set up in order to follow the changes and assess their severity. The wet habitats, that are the most vulnerable, should be monitored carefully and more weather stations should be set up on the tops of the mountains. These wet habitats contain many endemic species and are the sources of our drinking water so they are of great importance.

<u>The mountain stream in a fynbos environment</u>

In all other respects, riverine vegetation should be managed as a part of the entire mountain catchment. It is situated within the Mountain Fynbos, which implies that it occurs in a fire-prone environment. Most riparian species do not have specific fire responses like serotiny or fire-induced flowering. However, if one has a look at the riparian vegetation after a fire, it appears that this vegetation does not burn readily. Only the Back Dynamic Zone is really fire-prone, but the other zones are mostly protected because of the wet habitat, the seemingly low flammability levels of the vegetation or the low density of the vegetation in the Wet Banks. After a fire, the runoff in rivers increases with rains (Bosch & Versfeld 1982) and the rivers are then prone to flooding, which enlarges the wet habitat. Dense stands of exotic *Acacia* plants can change the situation and increase the fuel load, the fire temperatures and the fire intensity on the river bank and thus increase the probability that naturally protected areas will burn as well (Versfeld & Van Wilgen 1986). Many riparian habitats are also naturally sheltered from fires, for example when they are located in steep gorges. In some cases, riparian habitats act as 'natural fire-breaks' protecting large pieces of fynbos from fire. In the 1999 fire in the Hottentots Holland Mountains, a part of the Boegoekloof did not burn, because it was enclosed between two gorges, a steep slope of Victoria Peak, and the Riviersonderend River. Such areas serve as refuges for animals and plants during and after the fire, in addition to the riparian habitats themselves.

A problem starts when man-made fires are ignited in the riparian vegetation, when the fuel load is larger such as after felling alien plants. This should never be done, because the riparian vegetation is not adapted to survive hot fires.

For the rest, fire management does not have to take riparian vegetation into account. Riparian vegetation seems to be able to protect itself against fires and the vegetation is only affected by very intense fires. In managed fires, the riparian zones should be avoided, particularly if very intense fires could result.

9.2 The future of phytosociological research in the Fynbos Biome

The VEGMAP project (McDonald 1997; Mucina *et al.* 2000) has for the first time compiled all the vegetation data that is available in the Fynbos Biome into a single database. One of the clear messages that has come out of this compilation is that the Fynbos Biome is seriously undersampled. The consequences of the VEGMAP project for the documentation of vegetation types in the Fynbos Biome have been assessed by McDonald & Boucher (1999). The completion of this study of riverine vegetation offers a good opportunity to evaluate the directions that phytosociological research in the Fynbos Biome has to take. The times have changed since Taylor (1969), Boucher (1972) and Werger *et al*. (1972) made the first efforts to apply the Braun-Blanquet method in the Fynbos Biome, but it has now been proven beyond doubt that this method can be used successfully in the Fynbos Biome.

What is even more, the method has been applied to nearly all species-rich vegetation types in the tropics and subtropics and it is nowadays, in combination with gradient analysis, generally accepted as a scientific standard for studying vegetation (Kent & Coker 1992). And yet, in most parts of the world, except in Europe where the Braun-Blanquet method originated, the final steps of creating a hierarchical system are still largely non-existent. This is in many cases due to a shortage of data and this applies particularly to the Fynbos Biome.

Since Campbell (1985, 1986a, 1986b) wrote his elaborate report on the structural subdivision of Mountain Fynbos, an ongoing discussion about the feasibility of applying the Braun-Blanquet method on a wide scale in the Fynbos Biome has been started (Boucher 1987; McDonald & Boucher 1999). It is a pity that this discussion has in certain ways blocked the ongoing collection of phytosociological data, while Campbell’s (1986b) structural classification itself is very useful as a first comprehensive draft to tackle this very complex vegetation. I think that by now, the focus in this discussion should be shifted. Theoretically, a phytosociological classification of the Fynbos Biome is very feasible, but it will not happen overnight. The discussion should focus now on which vegetation types are undersampled and should have preference to be surveyed.

Before I continue my demonstration, I want to look at the reasons why the Braun-Blanquet method was so successful in Europe and comment on the differences from the situation in Africa. As in other disciplines of science that Europeans introduced to Africa it is important to find ‘an African solution for African problems’, without disregarding scientific standards.

A complete survey of all vegetation types did not happen overnight in Europe, just as it will not happen rapidly in South Africa. By the time Europe started to study its vegetation, a large portion of land had already been transformed. The processes of exploitation of the vegetation and the description of it went hand in hand. The ‘islands’ of natural areas that are left behind, are also ‘exploited’ for recreational purposes, nature conservation and nature study. One must not forget that a vegetation association, like its taxonomic equivalent the species, is basically a human construct. For a large portion of the European population it was easy to visit the ‘remnant’ natural areas and see the vegetation types that were described, so a ‘concept’ of these vegetation types developed in the minds of not only the scientists but also of other people who were concerned about the survival of natural vegetation. As a result, syntaxonomic description and classification of the vegetation found a broad support base among the whole society.

These are some of the considerations I would like to take to the South African context. What one must bear in mind is that phytosociology, like all natural sciences does not necessarily say as much about its subject, vegetation, as it does about ourselves. It has always been the elements in nature that live in a close relationship with the human species that receive the most attention. However much we try to be objective in science, we always come back to these same species, ecosystems or processes, while others, that are ‘scientifically’ just as interesting, seem to escape our devotion forever.

When it comes to the classification of Mountain Fynbos, we must consider that there is no way that we can claim a special ‘scientific’ importance in descriptive sciences like vegetation science. This importance is determined by ourselves and the relation that we as a society have with the object of our study. Fynbos itself does not care about how it is classified, so as long as there is no base of interest among a significant part of the population, Mountain Fynbos will just remain Mountain Fynbos and nothing more. Even if there is a more detailed subdivision that is used by a small group of scientists, if the concept of this vegetation type does not ‘come alive’ among a broader base, like nature conservationists, amateurs, and scientists of other disciplines, like geologists, agriculturalists and plant taxonomists, it is questionable whether the classification has achieved its aim. The CAPE project (Cape Action Plan for the Environment), currently launched in the Western Cape (World Wildlife Fund – South Africa 2000), will provide a good opportunity not only to do more research in the field, but also to carry the phytosociological knowledge out to other disciplines.

The way we look at our vegetation is also mostly determined by our direct environment. Someone living in a desert will develop a completely different understanding of the concept of vegetation from someone else living in a tropical rainforest. The concept of classification originated in Europe, while in America the approach of gradient analysis was preferred (Whittaker 1967). Also in Australia, much attention was paid to environmental gradients (for example Austin 1987). Westhoff & De Smidt (1995) point out that this is a logical outcome of the local situation. In America, vast stretches of natural vegetation were still present at the time when the vegetation research started, which made the natural gradients that occurred much more obvious. The reason why the approach of classification found more appeal in Europe is because the vegetation there was already present in remnant pieces that could be classified with more ease. It should be noted that the original form of ordination was developed by a Russian vegetation scientist, Ramenski, who also lived in a country where large areas of natural vegetation remained as in America (Sobolov & Utekhin 1973).

South Africa, considering its vast stretches of unaffected vegetation, its strong gradients and the complexity of its vegetation, actually chose the wrong approach. Most of the focus has been on the classification of vegetation, mainly because of the stronger cultural links with Europe and the influence of Dutch phytosociologists like M.J.A Werger, E.M. van Zinderen Bakker and F. van der Meulen. However, the vegetation itself is more suitable to use approaches of ordination, but multivariate techniques have so far received relatively little attention in the country. Canonical Correspondence Analysis is still rarely used, while it is a very good technique to reveal the complex processes underlying most of the country's vegetation gradients. The combination of constrained and unconstrained ordination the way Økland (1994) proposes is only used very rarely.

It does not mean that multivariate techniques are the one and only answer for the vegetation in South Africa. Since the seventies it is common practice to use both classification and ordination in vegetation studies, because both of them reveal certain characteristics in the vegetation (Whittaker 1972; Van der Maarel 1975). Because of the complexity of the vegetation, however, it is likely that ordination will provide more information in the initial stages that might prove more useful for conservation as well. The underlying structure of a hierarchical classification only becomes apparent if the data set becomes significantly large. Data collection in the Fynbos Biome should continue to happen, even though the long-term goal of a hierarchical classification is not yet achievable. On the other hand, the short-term goal is to get an overview and an understanding of the ecological processes affecting the fynbos vegetation. The collection of phytosociological data is part of this process, because relevé data can be used in many analyses afterwards and it forms the most efficient way of data collection. The focus should be with the environmental aspects and not just with the description of the vegetation.

In my view, the vegetation types that should be given priority in sampling are mainly those which have a special relationship with human society or those that are most threatened. Of both types I will mention some specific examples:

- Riparian vegetation: this vegetation has a specific relationship with human society, because it plays a major role in the exploitation of our drinking water and it can be affected by the way we abstract that water. And on top of that there are thousands of South Africans who have their daily work in the riparian vegetation and would like to monitor the results of their efforts: the participants in the Working for Water Project.
- The coastal vegetation: this vegetation suffers a great impact from the populace because of mass recreation and it has specific threats because of coastal development.

- Ecotourism areas: for example the area of the Kogelberg Biosphere Reserve and the proposed West Coast Biosphere Reserve. There should be sufficient understanding of the ecological processes in areas that expect high numbers of tourists, because of the conservation priorities. Much interest in the vegetation can be expected from the tourists themselves and the people who make their living out of ecotourism.
- The habitats of economically important species: These habitats should be conserved as a gene pool for the economically important species such as rooibos (*Aspalathus linearis*), boegoe (*Agathosma betulina* / *A. crenulata*) and proteas (*Protea* ssp. and *Leucospermum* ssp.).
- Lowland Renosterveld and Sandplain Fynbos: these are the most threatened habitats because they have mostly been transformed for agriculture or urbanization. For effective conservation of these habitats, virtually every remnant patch of these vegetation types should get some conservation status. For eventual restoration purposes, it would be advisable to collect as much information about these habitats as possible.
- Wet habitats in the mountains and in the lowlands: these are quite susceptible to climate change, which might play a bigger role in the Fynbos Biome in the future.

The CAPE project, launched in September 2000 in Cape Town, promotes research into the biodiversity of the Fynbos Biome in combination with the sustainable use of resources and strengthening of institutions (World Wildlife Fund – South Africa 2000). Phytosociology will play a major role in this new stimulation of fynbos research. In combination with synecology it can provide many answers to questions about ecological processes and the autecology of single species. The vegetation data itself can be used as a reference in monitoring or restoration projects. The Braun-Blanquet method offers the most efficient way to collect and store vegetation data and can offer the CAPE Project a great service.

The phytosociological work to be done in the Fynbos Biome before a hierarchical classification is feasible, seems immense. If work is focused on a few priority areas an overview of the task will be achievable. The work presented in this thesis does not mean an end to the research on riparian vegetation in the Fynbos Biome: it is just the beginning. However, it offers a good basis for riparian vegetation classification and the ecological processes that operate on riparian communities. One day, an overview of all riparian vegetation types in the Biome will be feasible.

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Appendices

Appendix A: Climate stations around Hottentots Holland

	1	2		3	4	5	6	
1	**0005/545**	**Somerset West-Dyn**		**34°05'**	**18°49'**	**8**	**1934-1984**	
Month	**T_{dmax}**	**T_{dmin}**	**T_{mmax}**	**T_{mmin}**	**Rel. H.**	**P**	**n_{10}**	**Cloud.**
Jul	17.3	7.2	24.4	2.7	87	83	2.7	4
Aug	17.6	7.9	26.2	3.3	85	83	3.1	4
Sep	19.3	9.5	26.8	4.5	82	49	1.5	3.8
Oct	21.4	11.7	29	6.1	76	44	1.4	3.7
Nov	23.9	14.2	31.7	8.6	68	24	0.7	3
Dec	25.4	15.8	33.7	10.5	66	19	0.4	2.5
Jan	26.5	16.7	34.8	11.5	69	17	0.3	1.6
Feb	26.7	16.5	34.5	11.9	73	25	0.7	2.1
Mar	25.3	15	32.7	10.1	78	24	0.6	2.8
Apr	22.5	12.3	30.5	7.3	85	53	1.7	3.6
May	19.6	9.8	26.9	5	85	91	3.1	4.3
Jun	18.1	7.8	25.7	3.2	84	94	3.4	3.5
Ann	22	12	29.7	7	78	606	19.6	3.2

2	**0005/611**	**Steenbras Dam**		**34°11'**	**18°51'**	**339**	**1926-1960**	
Month	**T_{dmax}**	**T_{dmin}**	**T_{mmax}**	**T_{mmin}**	**Rel. H.**	**P**	**n_{10}**	**Cloud.**
Jul	15	7.6	22.6	2.5	83	118	3.9	4.6
Aug	15.1	7.7	25.4	2.8	82	130	5	4.7
Sep	17.2	8.9	27.2	4.4	80	72	3.1	4.6
Oct	18.7	9.9	28.1	5.3	78	74	3	4.2
Nov	22.2	12.6	30.8	7.5	74	37	1.5	4.1
Dec	24.7	14	32.2	8.7	72	25	0.7	3.2
Jan	26	15.3	33.7	9.9	72	23	0.8	2.6
Feb	25.8	15.6	33.2	11.2	75	46	1.4	3.1
Mar	24	14.3	31	9.2	79	34	1	3.3
Apr	19.5	11.4	29.5	7.2	84	107	3.9	4.2
May	16.5	9.8	25.6	4.7	85	183	6.5	4.8
Jun	15.7	8.4	23.7	3.1	81	139	4.8	4.6
Ann	20	11.3	28.5	6.3	79	988	35.6	4

3	**0005/635**	**Bizweni**		**34°05'**	**18°52'**	**46**	**1930-1959**	
Month	**T_{dmax}**	**T_{dmin}**	**T_{mmax}**	**T_{mmin}**	**Rel. H.**	**P**	**n_{10}**	**Cloud.**
Jul	17.2	6.5	25	2.1	87	106	3.5	4.3
Aug	17.7	6.7	26.7	2.4	81	120	5	4.3
Sep	19.6	8.2	28.5	3.6	83	48	1.5	4.3
Oct	21.3	9.4	29.6	4.7	81	56	2	4
Nov	24.4	12.1	32.6	7.2	73	38	1.2	3.7
Dec	26.4	13.9	34.1	9.4	69	13	0.4	2.6
Jan	27.9	14.8	35.3	9.9	73	14	0.4	2.4
Feb	27.9	14.9	35.4	10.3	81	29	0.7	3
Mar	26.6	13.1	33.7	8.7	76	25	0.7	3
Apr	22.4	10.4	31.5	6.3	89	74	2.6	4.2
May	19.8	8.9	27.7	4.3	85	119	3.6	4.6
Jun	18.5	7.3	26.3	2.9	83	105	3.7	4.5
Ann	22.5	10.5	30.5	5.9	80	747	25.3	3.7

4	0006/039	Grabouw-Bos		34°09'	19°02'	258	1927-1967	
Month	T_{dmax}	T_{dmin}	T_{mmax}	T_{mmin}	**Rel. H.**	**P**	n_{10}	**Cloud.**
Jul	16.5	3.1	23.4	-1.3	90	164	4.7	4
Aug	16.8	3.7	27.1	-1.1	88	195	6.1	4
Sep	18.6	5.6	29	0.5	86	78	2.7	4.1
Oct	19.8	7.4	29.9	2	84	89	3.1	4.1
Nov	22.8	10	32.6	4.5	76	51	1.6	3.8
Dec	24.7	11.5	34.1	6	78	30	1	3.6
Jan	25.8	12.1	34.9	6.8	80	35	1	3.5
Feb	25.7	12.8	34.8	7	86	41	1.4	3.6
Mar	24.3	11.1	33.3	5.3	91	47	1.7	3.7
Apr	21.7	7.8	31.6	2.5	90	92	2.7	4.3
May	18.8	5.6	27	0	90	145	4.5	4.2
Jun	17.3	3.8	24.9	-1.5	85	169	5.2	4.1
Ann	21	7.9	30.2	2.5	85	1136	35.7	3.9

5	0021/591A	Elsenburg II Agr		33°51'	18°50'	162	1903-1984	
Month	T_{dmax}	T_{dmin}	T_{mmax}	T_{mmin}	**Rel. H.**	**P**	n_{10}	**Cloud.**
Jul	16.7	7	24.3	2.8	83	87	3.3	3.3
Aug	16.9	7.3	25.5	2.7	85	87	3.2	3.5
Sep	19.1	8	28.6	3.5	84	49	1.5	3.4
Oct	21.7	9.3	31.7	4.7	80	40	1.3	2.9
Nov	24.9	11.6	33.7	6.6	71	26	0.7	2.4
Dec	26.6	13.2	35.3	8.4	69	20	0.5	2.1
Jan	28.1	14.2	36.7	9.6	72	15	0.2	2
Feb	28.3	14.3	36.7	9.7	77	22	0.6	2
Mar	27	13.2	35.8	8.5	81	23	0.7	2.3
Apr	23.6	11.2	33.4	6.7	83	54	1.8	2.8
May	19.5	9.3	28.4	4.6	83	95	3.4	3.5
Jun	17.6	8.1	25.2	2.9	81	101	3.6	3.5
Ann	22.5	10.6	31.2	5.8	79	619	20.8	2.8

6	0021/656	Welgevallen-Agr		33°56'	18°52'	119	1925-1968	
Month	T_{dmax}	T_{dmin}	T_{mmax}	T_{mmin}	**Rel. H.**	**P**	n_{10}	**Cloud.**
Jul	17.5	5.9	25.2	1.7	89	106	3.7	3.6
Aug	17.9	6.2	27.9	1.9	86	119	4.7	3.5
Sep	19.9	7.9	30.2	3.1	87	58	1.9	3.6
Oct	22.3	9.3	31.9	4.1	85	53	1.8	3.1
Nov	24.9	11.7	34	6.5	78	40	1.1	3.1
Dec	26.7	13	35.8	7.8	73	17	0.4	2.4
Jan	28	14	36.8	8.9	77	15	0.3	1.8
Feb	27.8	13.7	36.5	9.3	83	30	0.6	2.3
Mar	26.8	12.8	35	8.1	89	29	1.1	2.5
Apr	23.1	10.2	32.9	5.6	90	77	2.6	3.1
May	20	8.4	28.5	3.4	91	118	3.8	4.1
Jun	18.2	6.9	26.7	2.1	87	135	5.3	3.3
Ann	22.8	10	31.7	5.2	85	797	27.3	3

7	0021/892	Groot Drakenstein		33°52'	19°00'	146	1920-1969	
Month	**T_{dmax}**	**T_{dmin}**	**T_{mmax}**	**T_{mmin}**	**Rel. H.**	**P**	**n_{10}**	**Cloud.**
Jul	17.7	5.3	25.7	1.1	90	140	5.3	3.3
Aug	18.5	6	28.3	1.4	88	126	4.9	3.4
Sep	20.5	7.9	31.3	2.9	84	82	2.6	3.3
Oct	23.1	10	32.9	4.3	76	60	1.9	2.8
Nov	26.5	12.7	35.7	7	73	39	1.2	2.3
Dec	28.3	14	37	8.4	70	23	0.5	2.1
Jan	29.8	15.5	38.3	9.6	70	26	0.7	1.5
Feb	29.8	15.4	38.1	9.9	76	22	0.9	1.8
Mar	28.4	13.9	37.3	8.1	81	30	1.1	2.2
Apr	24.4	10.7	34.1	5.4	86	80	2.9	2.7
May	20.6	7.9	29.4	3.2	88	138	5.3	3.5
Jun	18.7	6	26.3	1.5	88	167	5.7	3.1
Ann	23.9	10.5	32.8	4.8	81	933	33	2.7

8	0021/778	Jonkershoek-Bos		33°58'	18°56'	244	1935-1984	
Month	**T_{dmax}**	**T_{dmin}**	**T_{mmax}**	**T_{mmin}**	**Rel. H.**	**P**	**n_{10}**	**Cloud.**
Jul	17	6.1	25.2	1.6	81	155	5.4	3.9
Aug	17.4	6.4	27.1	1.9	80	151	5.3	4.1
Sep	19.1	7.4	29.4	2.4	80	100	3.3	4
Oct	21.4	9.2	31.1	3.4	78	79	2.6	3.8
Nov	24.4	11.2	33.2	5.6	70	51	1.6	3.2
Dec	26.3	12.4	34.8	6.7	67	39	1.2	2.6
Jan	28	13.9	36.3	8.2	69	31	1	2.2
Feb	28.2	13.7	36.2	8.4	74	34	0.9	2.3
Mar	26.8	12.6	35.4	7.4	80	37	1.3	2.7
Apr	23.1	10.2	32.3	5.2	85	96	3.1	3.6
May	19.6	8.3	28.2	3.4	83	156	5.5	4.2
Jun	17.8	6.9	25.9	2	77	167	6	3.8
Ann	22.4	9.8	31.3	4.4	77	1096	37.2	3.4

9	0021/745	Glen Arum		33°55'	18°55'	396	1951-1957	
Month	**T_{dmax}**	**T_{dmin}**	**T_{mmax}**	**T_{mmin}**	**Rel. H.**	**P**	**n_{10}**	**Cloud.**
Jul	15.6	7.3	23.9	3.4	81	184	5.8	4.3
Aug	16.2	7.5	26.7	3.1	82	157	5.3	4.5
Sep	18.4	8.7	30	4.3	77	70	2.2	4
Oct	20.1	9.3	29	4.8	80	68	2.2	3.7
Nov	23.8	11.5	32.7	7.7	70	52	1.7	3
Dec	25.9	12.8	35	7.6	69	19	0.5	2.5
Jan	28.4	15.1	36.7	9.7	66	13	0.2	2
Feb	28.1	15.4	36.8	11.3	74	43	1.1	2.2
Mar	26.1	14.2	35	9.8	77	25	1	2.3
Apr	21.4	11.5	31.3	7.5	82	105	3.4	3.8
May	18.6	10.3	27.3	6.2	82	150	5.1	4.3
Jun	17.2	8.8	24.6	3.9	74	153	5.1	3.5
Ann	21.7	11	30.7	6.6	76	1039	33.6	3.3

Legend: 1 = Station number; 2 = Station name; 3 = Latitude; 4 = Longitude; 5 = Altitude; 6 = Years of record. T_{dmax} = Daily maximum temperature; T_{dmin} = Daily minimum temperature; T_{mmax} = Monthly maximum temperature; T_{mmin} = Monthly minimum temperature; Rel. H. = Relative humidity at 8:00 in maximum temperature; T_{mmin} = Monthly minimum temperature; Rel. H. = Relative humidity at 8:00 in the morning; P = average precipitation; n_{10} = average number of days with more than 10 mm of rainfall; Cloud. = Cloudiness measured in a scale from 1-8 at 8:00 in the morning

Appendix B: water quality variables

Temperature:

Temperature is a system variable that regulates many processes such as spawning and migration. The organisms in the river are adapted to the natural variations in water temperature that occur in diel and seasonal cycles. Disruptions of these natural temperature cycles may have severe impacts on ecosystem functioning and may be caused by thermal pollution, discharge of water from impoundments and removal of riparian vegetation cover.

Dissolved oxygen:

The concentrations of dissolved oxygen (DO) are critical for the survival of aquatic organisms because all organisms use oxygen for their respiration. There is a natural diel cycle in DO-concentrations because of photosynthesis by aquatic plants during the day. In the natural situation, DO-concentrations are often close to saturation. Organic wastes and suspended material will decrease the DO-concentration. This may also increase the effect of toxic waste if present.

pH:

pH is a steering variable for many physical and chemical processes. For example, acidification will mobilize aluminium, which is potentially lethal to aquatic organisms. Natural variations in pH occur in response to diel and seasonal cycles. In the Western Cape pH is likely to be lowest in winter, highest in summer and most variable in autumn. pH can fluctuate as much as one pH unit during a day. In rivers flowing through Mountain Fynbos, the water tends to be acidic because of humic substances that are present in the plant material.

Conductivity and Total Dissolved Solids:

Conductivity (EC) refers to the ability of water to conduct an electrical current. This ability is the result of ions present in the water such as carbonate, sulphate, chloride, sodium etc., all of which carry an electrical charge. TDS (Total Dissolved Solids) is a measure of all dissolved salts in the water. EC and TDS are often positively correlated, although TDS also includes organic compounds that do not carry an electrical charge. Both EC and TDS are dependent on the geological formations, that the water flows through and vary regionally. In the Western Cape EC and TDS tend to be lowest in winter, highest in summer and most variable in autumn.

Turbidity and Total Suspended Solids:

Turbidity is a measure of the clarity of the water and TSS (Total Suspended Solids) concentration is a measure of the amount of material suspended in the water. They are positively correlated. TSS concentrations increase when there is a high sediment load in the river. Anthropogenic factors that influence TSS are agriculture, removal of riparian vegetation and afforestation.

Nutrients:

Nutrients such as nitrate, nitrite, ammonia and phosphate are required for plant growth. They normally occur in low concentrations in the river. Some of them, like nitrite and ammonia, are toxic when they occur in higher concentrations. Toxicity of ammonia will increase with temperature and pH. In South Africa, the principle nutrient controlling eutrophication of aquatic ecosystems is phosphorus. This nutrient, together with inorganic nitrogen has a stimulatory effect on the growth of algae. Eutrophication can occur as a point-source, such as industrial and domestic effluents, or as a diffuse source, such as agricultural runoff (Dallas 1998).

Appendix C: Species list

(Notes: * = exotic species, O = only recorded outside Hottentots Holland Mountains, -- = only recorded in discarded releve)

Species name	Herbarium codes	Notes	Synonym (Bond & Goldblatt 1984)
LYCOPODIACEAE			
Lycopodiella caroliniana (L.) Pic. Serm	ES 54		Lycopodium carolinianum L.
Lycopodium clavatum L.	ES 888		
OSMUNDACEAE			
Todea barbara (L.) T.Moore	ES 121, ES 378		
ANEMIACEAE			
Mohria caffrorum (L.) Desv.	ES 301		
SCHIZAEACEAE			
Schizaea pectinata (L.) Sw.	ES 104		
Schizaea tenella Kaulf.	ES 29		
GLEICHENIACEAE			
Gleichenia polypodioides (L.) Sm.	ES 222		
HYMENOPHYLLACEAE			
Sphaerocionium aeruginosum (Poir.) Pic.Serm.	ES 650		Hymenophyllum marlothii Brause
Hymenophyllum peltatum (Poir.) Desv.	ES 275		
CYATHEACEAE			
Cyathea capensis (L.f.) Sm.	ES 653, ES 655		
DENNSTAEDTIACEAE			
Histiopteris incisa (Thunb.) J.Sm.	ES 566		
Hypolepis sparsisora (Schrad.) Kuhn	ES 563		
Pteridium aquilinum (L.) Kuhn	ES 126		
PTERIDACEAE			
Pellaea pteroides (L.) Prantl	ES 188		
ASPLENIACEAE			
Asplenium aethiopicum (Burm.f.) Bech.	ES 278, ES 391, ES 196		
THELYPTERIDACEAE			
Thelypteris confluens (Thunb.) Morton	ES 733		
LOMARIOPSIDACEAE			
Elaphoglossum angustatum (Schrad.) Hieron.	ES 541		
Elaphoglossum conforme (Sw.) J.Sm.	ES 342		
BLECHNACEAE			
Blechnum capense Burm.f.	ES 129, ES 238		
Blechnum punctulatum Sw.	ES 270, ES 298, ES 347, ES 572		
Blechnum punctulatum Sw.	ES 651, ES 663		Blechnum attenuatum (Sw.) Mett.
Blechnum tabulare (Thunb.) Kuhn	ES 633		
PODOCARPACEAE			
Podocarpus cf. elongatus (Aiton) L'Her. ex Pers.	ES 816		

Podocarpus latifolius (Thunb.) R.Br. ex Mirb.	ES 666, ES 816A		
PINACEAE			
Pinus cf. pinaster Aiton	ES 738	*	
CUPRESSACEAE			
Widdringtonia nodiflora (L.) Powrie	ES 77		
LAURACEAE			
Cassytha ciliolata Nees	ES 25		
CYPERACEAE			
Carpha glomerata (Thunb.) Nees	ES 147, ES 472, ES 252		
Cyperus denudatus L.f.	ES 588		
Cyperus fastigiatus Rottb.	ES 818		
Ficinia acuminata (Nees) Nees	ES 310, ES 467, ES 528, ES 677		
Ficinia cf. acuminata (Nees) Nees	ES 897	O	Ficinia involuta Nees
Ficinia argyropa Nees	ES 867, ES 869		
Ficinia brevifolia Nees ex Kunth	ES 186, ES 700, ES 756		
Ficinia distans C.B.Clarke	ES 561, ES 577, ES 669		
Ficinia oligantha (Steud.) J.Raynal	ES 312, ES 439		Ficinia filiformis (Lam.) Schrad. (ES 439)
Ficinia nigrescens (Schrad.) J.Raynal	ES 424, ES 478, ES 507		
Ficinia ramosissima Kunth	ES 459		
Ficinia trichodes (Schrad.) Benth. & Hook.f.	ES 137, ES 235, ES 490		
Ficinia species 1	ES 366		
Ficinia species 2	ES 872		
Isolepis digitata Schrad.	ES 711		
Isolepis fluitans (L.) R.Br.	ES 691, ES 854		
Isolepis prolifer R.Br.	ES 679		
Epischoenus complanatus Levyns	ES 632		
Epischoenus quadrangularis (Boeck.) C.B.Clarke	ES 775		
Epischoenus villosus Levyns	ES 451, ES 866, ES 868		
Epischoenus gracilis Levyns	ES 910	O	
Cyathocoma hexandrum (Nees) J. Browning	ES 919	O	Macrochaetium hexandrum (Nees) Pfeiffer
Capeobolus brevicaulis (C.B.Clarke) J.Browning	ES 90		Tetraria brevicaulis C.B.Clarke
Tetraria bolusii C.B.Clarke	ES 217		
Tetraria bromoides (Lam.) Pfeiff.	ES 477		
Tetraria capillacea (Thunb.) C.B.Clarke	ES 395, ES 434		
Tetraria crassa Levyns	ES 612		
Tetraria cuspidata (Rottb.) C.B.Clarke	ES 102		
Tetraria fasciata (Rottb.) C.B.Clarke	ES 849		
Tetraria pillansii Levyns	ES 611, ES 828		
Tetraria thermalis (L.) C.B.Clarke	ES 609		
Neesenbeckia punctoria (Vahl) Levyns	ES 45		
Chrysithrix capensis L.	ES 108		
Chrysithrix dodii C.B.Clarke	ES 453		
Chrysithrix junciformis Nees	ES 457		
Schoenoxiphium lanceum (Thunb.) Kük.	ES 253, ES 273, ES 285, ES 383, ES 508		
Cyperaceae species 1	ES 175, ES 210, ES 846		
Cyperaceae species 2	ES 534		
Cyperaceae species 3	ES 669		
ARACEAE			

Zantedeschia aethiopica (L.) Spreng.	ES 499		
RESTIONACEAE			
Staberoha cernua (L.f.) T.Durand & Schinz	ES 397		
Staberoha cf. vaginata (Thunb.) Pillans	ES 610, ES 614		
Ischyrolepis cincinnata (Mast.) H.P.Linder	ES 158		
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Corymbium cymosum E.Mey. ex DC.	ES 91, ES 266		
Corymbium villosum L.f.	ES 496		
Felicia cymbalariae (Aiton) Bolus & Wolley-Dod ex Adamson & Salter	ES 557		
Felicia cf. hyssopifolia (P.J.Bergius) Nees	ES 714		
Conyza scabrida DC.	ES 482, ES 568		
Chrysocoma spec.	ES 379		
Brachylaena neriifolia (L.) R.Br.	ES 05		
Plecostachys polifolia (Thunb.) Hilliard & B.L.Burtt	ES 261		
Gamochaeta subfalcata (Cabrera) Cabrera	ES 822	*	
Phaenocoma prolifera (L.) D.Don	ES 419		
Anaxeton asperum (Thunb.) DC.	ES 191		
Helichrysum cymosum (L.) D.Don	ES 192, ES 297, ES 692		
Helichrysum felinum Less.	ES 118		
Helichrysum foetidum (L.) Moench	ES 770, ES 821		
Helichrysum helianthemifolium (L.) D.Don	ES 565, ES 594, ES 690		
Helichrysum patulum (L.) D.Don	ES 360		
Helichrysum tinctum (Thunb.) Hilliard & B.L.Burtt	ES 525		
Helichrysum species 1	ES 887		
Helichrysum species 2	ES 904	O	
Edmondia pinifolia (Lam.) Hilliard	ES 334, ES 624		
Stoebe cinerea (L.) Thunb.	ES 225		
Stoebe incana Thunb.	ES 781		
Stoebe plumosa (L.) Thunb.	ES 549		
Elytropappus longifolius (DC.) Levyns	ES 49		
Metalasia cephalotes (Thunb.) Less.	ES 83, ES 172, ES 406, ES 527		
Metalasia densa (Lam.) P.O.Karis	ES 446		
Metalasia humilis Karis	ES 921	O	
Heterolepis aliena (L.f.) Druce	ES 426		
Osmitopsis afra (L.) K.Bremer	ES 443		
Osmitopsis pinnatifida (DC.) K.Bremer	ES 834		
Athanasia trifurcata (L.) L.	ES 732		
Cotula turbinata L.	ES 573		
Hippia pilosa (P.J. Bergius) Druce	ES 553		Hippia bolusae Hutch.
Hippia cf. frutescens (L.) L.	ES 331, ES 676		
Senecio agapetes C. Jeffrey	ES 768		Senecio amabilis DC.
Senecio coleophyllus Turcz.	ES 461		
Senecio crispus Thunb.	ES 558, ES 743		
Senecio umbellatus L.	ES 556		Senecio grandiflorus P.J.Bergius
Senecio cf. hastatus L.	ES 356, ES 689		
Senecio pinnulatus Thunb.	ES 517, ES 693		
Senecio pterophorus DC.	ES 819		
Senecio pubigerus L.	ES 870, ES 925		
Senecio rigidus L.	ES 634		Senecio subcanescens (DC.) Compton
Senecio cf. vulgaris L.	ES 694	*	
Euryops abrotanifolius	ES 504		
Euryops rupestris Schltr.	ES 415, ES 505		
Othonna parviflora P.J.Bergius	ES 526		
Othonna quinquedentata Thunb.	ES 113, ES 197		
Osteospermum ciliatum P.J.Bergius	ES 315, ES 582		
Gibbaria ilicifolia (L.) Norl.	ES 202, ES 442		
Chrysanthemoides monilifera (L.) Norl.	ES 377		
Ursinia caledonica (E.Phillips) Prassler	ES 447		
Ursinia dentata (L.) Poir.	ES 871		

Ursinia eckloniana (Sond.) N.E.Br.	ES 341, ES 460	
Ursinia paleacea (L.) Moench	ES 698	
Ursinia quinquepartita (DC.) N.E.Br.	ES 404	
Ursinia scariosa (Aiton) Poir.	ES 262, ES 293, ES 344	
Haplocarpha lanata (Thunb.) Less.	ES 294	
Cullumia setosa (L.) R.Br.	ES 242, ES 801, ES 820	
Berkheya herbacea (L.f.) Druce	ES 445	
Hypochaeris radicata L.	ES 211, ES 840, ES 889	*
Lactuca serriola L.	ES 595A	*
Sonchus oleraceus L.	ES 900	O*
Asteraceae species 1	ES 89	
Asteraceae species 2	ES 636	

OTHER

Unknown species 1	ES 318, ES 480, ES 536	
Unknown species 2	ES 895	O

MOSSES (no herbarium material available, labels were lost)
Campylopus pyriformis (Schultz) Brid.
Campylopus stenopelma (C.Mull.) Paris
Dicranella subsubulata (C.Mull.) A.Jaeger
Dicranoloma billardieri (Brid.) Paris
Ditrichum species
Fissidens fasciculatus Hornsch.
Fissidens glaucescens Hornsch.
Fissidens marginatus Schimp. ex C.Mull.
Fissidens plumosus Hornsch.
Fontinalis antipyretica
Hypnum cupressiforme Hedw.
Hypodontium pomiforme (Hook.) C.Mull.
Jamesoniella colorata (Lehm.) Spruce
Leucoloma sprengelianum (C.Mull.) A.Jaeger
Platyhypnidium macowanianum (Paris) M.Fleisch.
Pyrrhobryum spiniforme (Hedw.) Mitt.
Pyrrhobryum vallis-gratiae (Hampe) Manuel
Sematophyllum dregei (C.Mull.) Magill
Sphagnum capense Hornsch.
Sphagnum truncatum Hornsch.

LIVERWORTS (no herbarium material available, labels were lost)
Plagiochila species
Riccardia species
Symphyogyna podophylla (Thunb.) Nees & Mont.

Legit	Ger	Spe	F	(	Species_name1	
E. Sieben 0737	##	##	F	/	longifolia (Andrews) Willd.	Acacia longifolia (Andrews) Willd.
E. Sieben 0695	##	##	F	/	mearnsii De Wild.	Acacia mearnsii De Wild.
E. Sieben 0146	##	##	F	/	saligna (Labill.) H.L.Wendl.	Acacia saligna (Labill.) H.L.Wendl.
E. Sieben 0606	##	##	R	/	acuta Schltr.	Adenandra acuta Schltr.
E. Sieben 0771	##	##	S	/	dubia (L.) Hutch.	Agathelpis dubia (L.) Hutch.
E. Sieben 0254	##	##	R	/	capensis (L.) Dummer	Agathosma capensis (L.) Dummer
E. Sieben 0076	##	##	R	/	crenulata (L.) Pillans	Agathosma crenulata (L.) Pillans
E. Sieben 0100	##	##	R	/	crenulata (L.) Pillans	Agathosma crenulata (L.) Pillans
E. Sieben 0735	##	50	P	/	cf. avenacea C.C.Gmel.	Agrostis cf. avenacea C.C.Gmel.
E. Sieben 0380	##	##	A	/	comptonii Reynolds	Aloe comptonii Reynolds
E. Sieben 0510	##	##	A	/	plicatilis (L.) Mill.	Aloe plicatilis (L.) Mill.
E. Sieben 0191	##	##	A	/	asperum (Thunb.) DC.	Anaxeton asperum (Thunb.) DC.
E. Sieben 0729	##	##	R	/	cf. aethiopicum L.	Anthospermum cf. aethiopicum L.
E. Sieben 0232	##	##	R	/	galioides Rchb.f.	Anthospermum galioides Rchb.f.
E. Sieben 0429	##	##	R	/	galioides Rchb.f.	Anthospermum galioides Rchb.f.
E. Sieben 0462	##	##	R	/	hirtum Cruse	Anthospermum hirtum Cruse
E. Sieben 0748	##	##	R	/	cf. spathulatum Spreng.	Anthospermum cf. spathulatum Spreng.
E. Sieben 0524	##	##	P	/	tongo (Trin.) Stapf	Anthoxanthum tongo (Trin.) Stapf
E. Sieben 0559	##	##	P	/	tongo (Trin.) Stapf	Anthoxanthum tongo (Trin.) Stapf
E. Sieben 0702	##	##	P	/	tongo (Trin.) Stapf	Anthoxanthum tongo (Trin.) Stapf
E. Sieben 0452	##	##	R	/	crinalis (Mast.) H.P.Linder	Antochortus crinalis (Mast.) H.P.Linder
E. Sieben 0637	##	##	R	/	crinalis (Mast.) H.P.Linder	Antochortus crinalis (Mast.) H.P.Linder
E. Sieben 0826	##	##	R	/	crinalis (Mast.) H.P.Linder	Antochortus crinalis (Mast.) H.P.Linder
E. Sieben 0865	##	##	R	/	crinalis (Mast.) H.P.Linder	Antochortus crinalis (Mast.) H.P.Linder
E. Sieben 0864	##	##	R	/	ecklonii Nees	Antochortus ecklonii Nees
E. Sieben 0832	##	##	R	/	cf. graminifolius (Kunth) H.P.I	Antochortus cf. graminifolius (Kunth) H.P.Linder
E. Sieben 0030	##	##	R	/	laxiflorus (Nees) H.P.Linder	Antochortus laxiflorus (Nees) H.P.Linder
E. Sieben 0784	##	##	R	/	laxiflorus (Nees) H.P.Linder	Antochortus laxiflorus (Nees) H.P.Linder
E. Sieben 0338	##	##	I(	/	dimidiata E.Mey. ex Arn.	Apodytes dimidiata E.Mey. ex Arn.
E. Sieben 0343	##	##	I(	/	dimidiata E.Mey. ex Arn.	Apodytes dimidiata E.Mey. ex Arn.
E. Sieben 0539	##	##	I(	/	dimidiata E.Mey. ex Arn.	Apodytes dimidiata E.Mey. ex Arn.
E. Sieben 0481	##	##	F	/	lanceolatum Eckl. & Zeyh.	Argyrolobium lanceolatum Eckl. & Zeyh.
E. Sieben 0177	##	##	IF	/	cf. africana (L.) Hoffmanns.	Aristea cf. africana (L.) Hoffmanns.
E. Sieben 0133	##	##	IF	/	confusa Goldblatt	Aristea confusa Goldblatt
E. Sieben 0190	##	##	IF	/	confusa Goldblatt	Aristea confusa Goldblatt
E. Sieben 0414	##	##	IF	/	confusa Goldblatt	Aristea confusa Goldblatt
E. Sieben 0488	##	##	IF	/	confusa Goldblatt	Aristea confusa Goldblatt
E. Sieben 0652	##	##	IF	/	latifolia G.J.Lewis	Aristea latifolia G.J.Lewis
E. Sieben 0068	##	##	IF	/	major Andrews	Aristea major Andrews
E. Sieben 0110	##	##	IF	/	major Andrews	Aristea major Andrews
E. Sieben 0233	##	##	IF	/	major Andrews	Aristea major Andrews
E. Sieben 0352	##	##	IF	/	major Andrews	Aristea major Andrews
E. Sieben 0319	##	##	R	/	cf. chartaceum (Pillans) H.P.I	Askidiosperma cf. chartaceum (Pillans) H.P.Linder
E. Sieben 0007	##	##	R	/	esterhuyseniae (Pillans) H.P.	Askidiosperma esterhuyseniae (Pillans) H.P.Linder
E. Sieben 0009	##	##	R	/	esterhuyseniae (Pillans) H.P.	Askidiosperma esterhuyseniae (Pillans) H.P.Linder
E. Sieben 0060A	##	##	R	/	esterhuyseniae (Pillans) H.P.	Askidiosperma esterhuyseniae (Pillans) H.P.Linder
E. Sieben 0062	##	##	R	/	esterhuyseniae (Pillans) H.P.	Askidiosperma esterhuyseniae (Pillans) H.P.Linder
E. Sieben 0098	##	##	R	/	esterhuyseniae (Pillans) H.P.	Askidiosperma esterhuyseniae (Pillans) H.P.Linder
E. Sieben 0160	##	##	R	/	esterhuyseniae (Pillans) H.P.	Askidiosperma esterhuyseniae (Pillans) H.P.Linder
E. Sieben 0753	##	##	F	/	ciliaris L.	Aspalathus ciliaris L.
E. Sieben 0497	##	##	F	/	laricifolia P.J.Bergius	Aspalathus laricifolia P.J.Bergius
E. Sieben 0278	##	##	A	/	aethiopicum (Burm.f.) Bech.	Asplenium aethiopicum (Burm.f.) Bech.
E. Sieben 0391	##	##	A	/	aethiopicum (Burm.f.) Bech.	Asplenium aethiopicum (Burm.f.) Bech.
E. Sieben 0196	##	##	A	/	aethiopicum (Burm.f.) Bech.	Asplenium aethiopicum (Burm.f.) Bech.
E. Sieben 0732	##	##	A	/	trifurcata (L.) L.	Athanasia trifurcata (L.) L.
E. Sieben 0445	##	##	A	E	herbacea (L.f.) Druce	Berkheya herbacea (L.f.) Druce
E. Sieben 0012A	##	##	B	E	lanuginosa (L.) Brongn.	Berzelia lanuginosa (L.) Brongn.
E. Sieben 0037	##	##	B	E	lanuginosa (L.) Brongn.	Berzelia lanuginosa (L.) Brongn.
E. Sieben 0011	##	##	B	E	squarrosa (Thunb.) Sond.	Berzelia squarrosa (Thunb.) Sond.
E. Sieben 0330	##	##	B	E	squarrosa (Thunb.) Sond.	Berzelia squarrosa (Thunb.) Sond.

E. Sieben 0398	##	##	B B	squarrosa (Thunb.) Sond.	Berzelia squarrosa (Thunb.) Sond.
E. Sieben 0651	##	50	B B	attenuatum (Sw.) Mett.	Blechnum attenuatum (Sw.) Mett.
E. Sieben 0663	##	50	B B	attenuatum (Sw.) Mett.	Blechnum attenuatum (Sw.) Mett.
E. Sieben 0129	##	##	B B	capense Burm.f.	Blechnum capense Burm.f.
E. Sieben 0238	##	##	B B	capense Burm.f.	Blechnum capense Burm.f.
E. Sieben 0270	##	##	B B	punctulatum Sw.	Blechnum punctulatum Sw.
E. Sieben 0298	##	##	B B	punctulatum Sw.	Blechnum punctulatum Sw.
E. Sieben 0347	##	##	B B	punctulatum Sw.	Blechnum punctulatum Sw.
E. Sieben 0572	##	##	B B	punctulatum Sw.	Blechnum punctulatum Sw.
E. Sieben 0633	##	##	B B	tabulare (Thunb.) Kuhn	Blechnum tabulare (Thunb.) Kuhn
E. Sieben 0174	##	##	IF B	gladiata (L.f.) Ker Gawl.	Bobartia gladiata (L.f.) Ker Gawl.
E. Sieben 0216	##	##	IF B	indica L.	Bobartia indica L.
E. Sieben 0589	##	##	F B	bituminosa (L.) Kuntze	Bolusafra bituminosa (L.) Kuntze
E. Sieben 0050	##	##	P B	stellatifolium L.	Brabejum stellatifolium L.
E. Sieben 0141	##	##	P B	stellatifolium L.	Brabejum stellatifolium L.
E. Sieben 0005	##	##	A B	neriifolia (L.) R.Br.	Brachylaena neriifolia (L.) R.Br.
E. Sieben 0696	##	##	P B	maxima L.	Briza maxima L.
E. Sieben 0012	##	##	B B	alopecuroides Thunb.	Brunia alopecuroides Thunb.
E. Sieben 0037A	##	##	B B	alopecuroides Thunb.	Brunia alopecuroides Thunb.
E. Sieben 0097	##	##	B B	alopecuroides Thunb.	Brunia alopecuroides Thunb.
E. Sieben 0671	##	##	A B	tuberosa (Mill.) Oberm.	Bulbine tuberosa (Mill.) Oberm.
E. Sieben 0578	##	##	A C	contorta (L.f.) T.Durand & Sc	Caesia contorta (L.f.) T.Durand & Schinz
E. Sieben 0357	##	##	R C	paniculata (Rottb.) Desv.	Calopsis paniculata (Rottb.) Desv.
E. Sieben 0140	##	##	R C	virgata (Rottb.) Steud.	Cannomois virgata (Rottb.) Steud.
E. Sieben 0209	##	##	R C	virgata (Rottb.) Steud.	Cannomois virgata (Rottb.) Steud.
E. Sieben 0075	##	##	R C	spermacocea (Rchb.f.) Sond.	Carpacoce spermacocea (Rchb.f.) Sond.
E. Sieben 0403	##	##	R C	spermacocea (Rchb.f.) Sond.	Carpacoce spermacocea (Rchb.f.) Sond.
E. Sieben 0147	##	##	C C	glomerata (Thunb.) Nees	Carpha glomerata (Thunb.) Nees
E. Sieben 0472	##	##	C C	glomerata (Thunb.) Nees	Carpha glomerata (Thunb.) Nees
E. Sieben 0252	##	##	C C	glomerata (Thunb.) Nees	Carpha glomerata (Thunb.) Nees
E. Sieben 0025	##	##	L C	ciliolata Nees	Cassytha ciliolata Nees
E. Sieben 0618	##	##	A C	af. caespitosa Adamson	Centella af. caespitosa Adamson
E. Sieben 0776	##	##	A C	af. difformis (Eckl. & Zeyh.) A	Centella af. difformis (Eckl. & Zeyh.) Adamson
E. Sieben 0073	##	##	A C	af. laevis Adamson	Centella af. laevis Adamson
E. Sieben 0249	##	##	A C	af. laevis Adamson	Centella af. laevis Adamson
E. Sieben 0292	##	##	A C	af. laevis Adamson	Centella af. laevis Adamson
E. Sieben 0438	##	##	A C	af. macrocarpa (Rich.) Adam	Centella af. macrocarpa (Rich.) Adamson
E. Sieben 0291	##	##	A C	af. montana (Cham. & Schltd	Centella af. montana (Cham. & Schltdl.) Domin
E. Sieben 0487	##	##	A C	af. montana (Cham. & Schltd	Centella af. montana (Cham. & Schltdl.) Domin
E. Sieben 0115A	##	##	R C	argenteum Nees ex Kunth	Ceratocaryum argenteum Nees ex Kunth
E. Sieben 0323	##	##	R C	argenteum Nees ex Kunth	Ceratocaryum argenteum Nees ex Kunth
E. Sieben 0354	##	##	IF C	aethiopica (L.) N.E.Br.	Chasmanthe aethiopica (L.) N.E.Br.
E. Sieben 0368	##	##	G C	baccifera L.	Chironia baccifera L.
E. Sieben 0755	##	##	G C	baccifera L.	Chironia baccifera L.
E. Sieben 0109	##	##	G C	jasminoides L.	Chironia jasminoides L.
E. Sieben 0165A	##	##	R C	deustum Rottb.	Chondropetalum deustum Rottb.
E. Sieben 0332	##	##	R C	deustum Rottb.	Chondropetalum deustum Rottb.
E. Sieben 0796	##	##	R C	ebracteatum (Kunth) Pillans	Chondropetalum ebracteatum (Kunth) Pillans
E. Sieben 0014	##	##	R C	mucronatum (Nees) Pillans	Chondropetalum mucronatum (Nees) Pillans
E. Sieben 0115	##	##	R C	mucronatum (Nees) Pillans	Chondropetalum mucronatum (Nees) Pillans
E. Sieben 0163	##	##	R C	mucronatum (Nees) Pillans	Chondropetalum mucronatum (Nees) Pillans
E. Sieben 0393	##	##	R C	mucronatum (Nees) Pillans	Chondropetalum mucronatum (Nees) Pillans
E. Sieben 0377	##	##	A C	monilifera (L.) Norl.	Chrysanthemoides monilifera (L.) Norl.
E. Sieben 0108	##	##	C C	capensis L.	Chrysitrix capensis L.
E. Sieben 0453	##	##	C C	dodii C.B.Clarke	Chrysitrix dodii C.B.Clarke
E. Sieben 0457	##	##	C C	junciformis Nees	Chrysitrix junciformis Nees
E. Sieben 0379	##	30	A C	candelabrum Ehr.Bayer	Chrysocoma candelabrum Ehr.Bayer
E. Sieben 0329	##	##	R C	apiculata Weim.	Cliffortia apiculata Weim.
E. Sieben 0070	##	##	R C	atrata Weim.	Cliffortia atrata Weim.
E. Sieben 0159	##	##	R C	atrata Weim.	Cliffortia atrata Weim.
E. Sieben 0324	##	##	R C	atrata Weim.	Cliffortia atrata Weim.

E. Sieben 0417	##	##	R (	atrata Weim.	Cliffortia atrata Weim.
E. Sieben 0441	##	##	R (	atrata Weim.	Cliffortia atrata Weim.
E. Sieben 0516	##	##	R (	atrata Weim.	Cliffortia atrata Weim.
E. Sieben 0520	##	##	R (	complanata E.Mey.	Cliffortia complanata E.Mey.
E. Sieben 0718	##	##	R (	complanata E.Mey.	Cliffortia complanata E.Mey.
E. Sieben 0747	##	##	R (	complanata E.Mey.	Cliffortia complanata E.Mey.
E. Sieben 0244	##	##	R (	cuneata Aiton	Cliffortia cuneata Aiton
E. Sieben 0214	##	##	R (	dodecandra Weim.	Cliffortia dodecandra Weim.
E. Sieben 0435	##	##	R (	dodecandra Weim.	Cliffortia dodecandra Weim.
E. Sieben 0555	##	##	R (	eriocephalina Cham.	Cliffortia eriocephalina Cham.
E. Sieben 0744	##	##	R (	graminea L.f.	Cliffortia graminea L.f.
E. Sieben 0213	##	##	R (	grandifolia Eckl. & Zeyh.	Cliffortia grandifolia Eckl. & Zeyh.
E. Sieben 0016	##	##	R (	hirsuta Eckl. & Zeyh.	Cliffortia hirsuta Eckl. & Zeyh.
E. Sieben 0808	##	##	R (	integerrima Weim.	Cliffortia integerrima Weim.
E. Sieben 0583	##	##	R (	odorata L.f.	Cliffortia odorata L.f.
E. Sieben 0802	##	##	R (	ovalis Weim.	Cliffortia ovalis Weim.
E. Sieben 0625	##	##	R (	ovalis Weim.	Cliffortia ovalis Weim.
E. Sieben 0051	##	##	R (	pedunculata Schltr.	Cliffortia pedunculata Schltr.
E. Sieben 0243	##	##	R (	polygonifolia L.	Cliffortia polygonifolia L.
E. Sieben 0726	##	##	R (	polygonifolia L.	Cliffortia polygonifolia L.
E. Sieben 0184	##	##	R (	ruscifolia L.	Cliffortia ruscifolia L.
E. Sieben 0070A	##	##	R (	cf. sericea Eckl. & Zeyh.	Cliffortia cf. sericea Eckl. & Zeyh.
E. Sieben 0697	##	##	R (	strobilifera Murray	Cliffortia strobilifera Murray
E. Sieben 0643	##	##	R (	tricuspidata Harv.	Cliffortia tricuspidata Harv.
E. Sieben 0586	##	##	E (	alaternoides L.	Clutia alaternoides L.
E. Sieben 0596	##	##	E (	alaternoides L.	Clutia alaternoides L.
E. Sieben 0316	##	##	E (	laxa Eckl. ex Sond.	Clutia laxa Eckl. ex Sond.
E. Sieben 0237A	##	##	E (	polygonoides L.	Clutia polygonoides L.
E. Sieben 0607	##	##	E (	polygonoides L.	Clutia polygonoides L.
E. Sieben 0794	##	##	E (	polygonoides L.	Clutia polygonoides L.
E. Sieben 0673	##	##	E (	rubricaulis Eckl. ex Sond.	Clutia rubricaulis Eckl. ex Sond.
E. Sieben 0759	##	##	E (	rubricaulis Eckl. ex Sond.	Clutia rubricaulis Eckl. ex Sond.
E. Sieben 0432	##	##	R (	juniperinum Sond.	Coleonema juniperinum Sond.
E. Sieben 0482	##	##	A (	scabrida DC.	Conyza scabrida DC.
E. Sieben 0568	##	##	A (	scabrida DC.	Conyza scabrida DC.
E. Sieben 0626	##	##	A (	congestum E.Mey. ex DC.	Corymbium congestum E.Mey. ex DC.
E. Sieben 0091	##	##	A (	cymosum E.Mey. ex DC.	Corymbium cymosum E.Mey. ex DC.
E. Sieben 0266	##	##	A (	cymosum E.Mey. ex DC.	Corymbium cymosum E.Mey. ex DC.
E. Sieben 0496	##	##	A (	villosum L.f.	Corymbium villosum L.f.
E. Sieben 0573	##		A (	turbinata L.	Cotula turbinata L.
E. Sieben 0519	##	##	C (	capensis (L.) Baill.	Crassula capensis (L.) Baill.
E. Sieben 0521	##	##	C (	capensis (L.) Baill.	Crassula capensis (L.) Baill.
E. Sieben 0193	##	##	C (	dejecta Jacq.	Crassula dejecta Jacq.
E. Sieben 0758	##	##	C (	dejecta Jacq.	Crassula dejecta Jacq.
E. Sieben 0824	##	##	C (	dejecta Jacq.	Crassula dejecta Jacq.
E. Sieben 0514	##	##	C (	muscosa L.	Crassula muscosa L.
E. Sieben 0532	##	##	C (	nudicaulis L.	Crassula nudicaulis L.
E. Sieben 0242	##	##	A (	setosa (L.) R.Br.	Cullumia setosa (L.) R.Br.
E. Sieben 0801	##	##	A (	setosa (L.) R.Br.	Cullumia setosa (L.) R.Br.
E. Sieben 0820	##	##	A (	setosa (L.) R.Br.	Cullumia setosa (L.) R.Br.
E. Sieben 0142	##	##	C (	capensis L.	Cunonia capensis L.
E. Sieben 0811	##	##	C (	dentata (Burm.f.) C.A.Sm.	Curtisia dentata (Burm.f.) C.A.Sm.
E. Sieben 0713	##	##	C (	nitida E. Mey. ex Choisy	Cuscuta nitida E. Mey. ex Choisy
E. Sieben 0653	##	##	C (	capensis (L.f.) Sm.	Cyathea capensis (L.f.) Sm.
E. Sieben 0655	##	##	C (	capensis (L.f.) Sm.	Cyathea capensis (L.f.) Sm.
E. Sieben 0672	##	##	F (	maculata (Andrews) Kies	Cyclopia maculata (Andrews) Kies
E. Sieben 0675	##	##	F (	maculata (Andrews) Kies	Cyclopia maculata (Andrews) Kies
E. Sieben 0502	##	##	P (	cf. marginatus (Steud.) Stapf	Cymbopogon cf. marginatus (Steud.) Stapf ex Burtt Davy
E. Sieben 0588	##	##	C (	denudatus L.f.	Cyperus denudatus L.f.
E. Sieben 0818	##	##	C (	fastigiatus Rottb.	Cyperus fastigiatus Rottb.
E. Sieben 0372	##	##	L (	volubilis (Burm.f.) Willd.	Cyphia volubilis (Burm.f.) Willd.

E. Sieben 0484	##	##	L (	volubilis (Burm.f.) Willd.	Cyphia volubilis (Burm.f.) Willd.
E. Sieben 0590	##	##	L (	volubilis (Burm.f.) Willd.	Cyphia volubilis (Burm.f.) Willd.
E. Sieben 0800	##	##	H [	viscosa L.f.	Dilatris viscosa L.f.
E. Sieben 0752	##	##	R [	cf. hirsuta L.	Diosma cf. hirsuta L.
E. Sieben 0806	##	##	R [	thyrsophora Eckl. & Zeyh.	Diosma thyrsophora Eckl. & Zeyh.
E. Sieben 0263	##	##	E [	glabra (L.) De Winter	Diospyros glabra (L.) De Winter
E. Sieben 0296	##	##	E [	glabra (L.) De Winter	Diospyros glabra (L.) De Winter
E. Sieben 0200	##	##	E [	glabra (L.) De Winter	Diospyros glabra (L.) De Winter
E. Sieben 0813	##	##	E [	whyteana (Hiern) F.White	Diospyros whyteana (Hiern) F.White
E. Sieben 0304	##	##	F [	lignosus (L.) Verdc.	Dipogon lignosus (L.) Verdc.
E. Sieben 0717	##	##	C [	tripetaloides (L.f.) N.E.Br.	Disa tripetaloides (L.f.) N.E.Br.
E. Sieben 0535	##	##	F [	decumbens Thunb.	Dolichos decumbens Thunb.
E. Sieben 0040	##	##	D [	aliciae Raym.-Hamet	Drosera aliciae Raym.-Hamet
E. Sieben 0707	##	##	D [	capensis L.	Drosera capensis L.
E. Sieben 0719	##	##	D [	glabripes (Harv.) Stein	Drosera glabripes (Harv.) Stein
E. Sieben 0334	##	##	A [	pinifolia (Lam.) Hilliard	Edmondia pinifolia (Lam.) Hilliard
E. Sieben 0624	##	##	A [	pinifolia (Lam.) Hilliard	Edmondia pinifolia (Lam.) Hilliard
E. Sieben 0132	##	##	P [	erecta Lam.	Ehrharta erecta Lam.
E. Sieben 0388	##	##	P [	erecta Lam.	Ehrharta erecta Lam.
E. Sieben 0597	##	##	P [	erecta Lam.	Ehrharta erecta Lam.
E. Sieben 0074	##	##	P [	rehmannii Stapf	Ehrharta rehmannii Stapf
E. Sieben 0597	##	##	P [	rehmannii Stapf	Ehrharta rehmannii Stapf
E. Sieben 0454	##	##	P [	setacea Nees subsp. setace	Ehrharta setacea Nees subsp. setacea
E. Sieben 0465	##	##	P [	setacea Nees subsp. uniflora	Ehrharta setacea Nees subsp. uniflora (Burch. ex Stapf) (
E. Sieben 0547	##	##	P [	setacea Nees subsp. uniflora	Ehrharta setacea Nees subsp. uniflora (Burch. ex Stapf) (
E. Sieben 0551	##	##	P [	setacea Nees subsp. uniflora	Ehrharta setacea Nees subsp. uniflora (Burch. ex Stapf) (
E. Sieben 0541	##	##	L [	angustatum (Schrad.) Hieron	Elaphoglossum angustatum (Schrad.) Hieron.
E. Sieben 0342	##	##	L [	conforme (Sw.) J.Sm.	Elaphoglossum conforme (Sw.) J.Sm.
E. Sieben 0236	##	##	R [	asperiflora (Nees) Kunth	Elegia asperiflora (Nees) Kunth
E. Sieben 0127	##	##	R [	capensis (Burm.f.) Schelpe	Elegia capensis (Burm.f.) Schelpe
E. Sieben 0830	##	##	R [	grandis (Nees) Kunth	Elegia grandis (Nees) Kunth
E. Sieben 0021	##	##	R [	intermedia (Steud.) Pillans	Elegia intermedia (Steud.) Pillans
E. Sieben 0543	##	##	R [	intermedia (Steud.) Pillans	Elegia intermedia (Steud.) Pillans
E. Sieben 0550	##	##	R [	intermedia (Steud.) Pillans	Elegia intermedia (Steud.) Pillans
E. Sieben 0645	##	##	R [	intermedia (Steud.) Pillans	Elegia intermedia (Steud.) Pillans
E. Sieben 0060	##	##	R [	neesii Mast.	Elegia neesii Mast.
E. Sieben 0156	##	##	R [	persistens Mast.	Elegia persistens Mast.
E. Sieben 0630	##	##	R [	racemosa (Poir.) Pers.	Elegia racemosa (Poir.) Pers.
E. Sieben 0638	##	##	R [	racemosa (Poir.) Pers.	Elegia racemosa (Poir.) Pers.
E. Sieben 0642	##	##	R [	racemosa (Poir.) Pers.	Elegia racemosa (Poir.) Pers.
E. Sieben 0178	##	##	R [	spathacea Mast.	Elegia spathacea Mast.
E. Sieben 0402	##	##	R [	spathacea Mast.	Elegia spathacea Mast.
E. Sieben 0706	##	##	R [	spathacea Mast.	Elegia spathacea Mast.
E. Sieben 0792	##	##	R [	spathacea Mast.	Elegia spathacea Mast.
E. Sieben 0049	##	##	A [	longifolius (DC.) Levyns	Elytropappus longifolius (DC.) Levyns
E. Sieben 0264	##	##	R [	unicapsulare (L.f.) Skeels	Empleurum unicapsulare (L.f.) Skeels
E. Sieben 0632	##	##	C [	complanatus Levyns	Epischoenus complanatus Levyns
E. Sieben 0775	##	##	C [	quadrangularis (Boeck.) C.B.	Epischoenus quadrangularis (Boeck.) C.B.Clarke
E. Sieben 0451	##	##	C [	villosus Levyns	Epischoenus villosus Levyns
E. Sieben 0866	##	##	C [	villosus Levyns	Epischoenus villosus Levyns
E. Sieben 0868	##	##	C [	villosus Levyns	Epischoenus villosus Levyns
E. Sieben 0300	##	##	P [	curvula (Schrad.) Nees	Eragrostis curvula (Schrad.) Nees
E. Sieben 0613	##	##	E [	autumnalis L.Bolus	Erica autumnalis L.Bolus
E. Sieben 0631	##	##	E [	autumnalis L.Bolus	Erica autumnalis L.Bolus
E. Sieben 0647	##	##	E [	autumnalis L.Bolus	Erica autumnalis L.Bolus
E. Sieben 0470	##	##	E [	caffra L.	Erica caffra L.
E. Sieben 0602	##	##	E [	calycina L.	Erica calycina L.
E. Sieben 0600	##	##	E [	coccinea L.	Erica coccinea L.
E. Sieben 0859	##	##	E [	corifolia L.	Erica corifolia L.
E. Sieben 0741	##	##	E [	curviflora L.	Erica curviflora L.
E. Sieben 0080	##	##	E [	curvirostris Salisb.	Erica curvirostris Salisb.

E. Sieben 0106	##	##	E E	curvirostris Salisb.	Erica curvirostris Salisb.
E. Sieben 0187	##	##	E E	curvirostris Salisb.	Erica curvirostris Salisb.
E. Sieben 0601	##	##	E E	fastigiata L.	Erica fastigiata L.
E. Sieben 0059	##	##	E E	hispidula L.	Erica hispidula L.
E. Sieben 0082	##	##	E E	hispidula L.	Erica hispidula L.
E. Sieben 0407	##	##	E E	hispidula L.	Erica hispidula L.
E. Sieben 0545	##	##	E E	hispidula L.	Erica hispidula L.
E. Sieben 0437	##	##	E E	imbricata L.	Erica imbricata L.
E. Sieben 0409	##	##	E E	intervallaris Salisb.	Erica intervallaris Salisb.
E. Sieben 0449	##	##	E E	intervallaris Salisb.	Erica intervallaris Salisb.
E. Sieben 0621	##	##	E E	intervallaris Salisb.	Erica intervallaris Salisb.
E. Sieben 0418	##	##	E E	longifolia Aiton	Erica longifolia Aiton
E. Sieben 0473	##	##	E E	lucida Salisb.	Erica lucida Salisb.
E. Sieben 0117	##	##	E E	lutea P.J.Bergius	Erica lutea P.J.Bergius
E. Sieben 0223	##	##	E E	nudiflora L.	Erica nudiflora L.
E. Sieben 0048	##	##	E E	equisetifolia	Erica equisetifolia
E. Sieben 0081	##	##	E E	equisetifolia	Erica equisetifolia
E. Sieben 0399	##	##	E E	equisetifolia	Erica equisetifolia
E. Sieben 0777	##	##	E E	equisetifolia	Erica equisetifolia
E. Sieben 0842	##	##	E E	pinea Thunb.	Erica pinea Thunb.
E. Sieben 0621A	##	##	E E	plukenetii L.	Erica plukenetii L.
E. Sieben 0107	##	##	E E	sessiliflora L.f.	Erica sessiliflora L.f.
E. Sieben 0603	##	##	E E	sitiens Klotzsch	Erica sitiens Klotzsch
E. Sieben 0773	##	##	E E	sitiens Klotzsch	Erica sitiens Klotzsch
E. Sieben 0295	##	##	E E	sphaeroidea Dulfer	Erica sphaeroidea Dulfer
E. Sieben 0750	##	##	E E	strigosa Sol.	Erica strigosa Sol.
E. Sieben 0181	##	##	E E	tegulifolia Salisb.	Erica tegulifolia Salisb.
E. Sieben 0259	##	##	E E	triflora L.	Erica triflora L.
E. Sieben 0646	##	##	E E	triflora L.	Erica triflora L.
E. Sieben 0829	##	##	R E	glabra I.Williams	Euchaetis glabra I.Williams
E. Sieben 0314	##	##	E E	epicyparissias E.Mey. ex Bois	Euphorbia epicyparissias E.Mey. ex Boiss.
E. Sieben 0504	##	##	A E	abrotanifolius	Euryops abrotanifolius
E. Sieben 0415	##	##	A E	rupestris Schltr.	Euryops rupestris Schltr.
E. Sieben 0505	##	##	A E	rupestris Schltr.	Euryops rupestris Schltr.
E. Sieben 0557	##	##	A F	cymbalariae (Aiton) Bolus & V	Felicia cymbalariae (Aiton) Bolus & Wolley-Dod ex Adam
E. Sieben 0714	##	##	A F	cf. hyssopifolia (P.J.Bergius)	Felicia cf. hyssopifolia (P.J.Bergius) Nees
E. Sieben 0310	##	##	C F	acuminata (Nees) Nees	Ficinia acuminata (Nees) Nees
E. Sieben 0467	##	##	C F	acuminata (Nees) Nees	Ficinia acuminata (Nees) Nees
E. Sieben 0528	##	##	C F	acuminata (Nees) Nees	Ficinia acuminata (Nees) Nees
E. Sieben 0677	##	##	C F	acuminata (Nees) Nees	Ficinia acuminata (Nees) Nees
E. Sieben 0867	##	##	C F	argyropa Nees	Ficinia argyropa Nees
E. Sieben 0869	##	##	C F	argyropa Nees	Ficinia argyropa Nees
E. Sieben 0700	##	##	C F	brevifolia Nees ex Kunth	Ficinia brevifolia Nees ex Kunth
E. Sieben 0756	##	##	C F	brevifolia Nees ex Kunth	Ficinia brevifolia Nees ex Kunth
E. Sieben 0561	##	##	C F	distans C.B.Clarke	Ficinia distans C.B.Clarke
E. Sieben 0577	##	##	C F	distans C.B.Clarke	Ficinia distans C.B.Clarke
E. Sieben 0669	##	##	C F	distans C.B.Clarke	Ficinia distans C.B.Clarke
E. Sieben 0439	##	##	C F	filiformis (Lam.) Schrad.	Ficinia filiformis (Lam.) Schrad.
E. Sieben 0424	##	##	C F	nigrescens (Schrad.) J.Rayna	Ficinia nigrescens (Schrad.) J.Raynal
E. Sieben 0478	##	##	C F	nigrescens (Schrad.) J.Rayna	Ficinia nigrescens (Schrad.) J.Raynal
E. Sieben 0507	##	##	C F	nigrescens (Schrad.) J.Rayna	Ficinia nigrescens (Schrad.) J.Raynal
E. Sieben 0312	##	##	C F	oligantha (Steud.) J.Raynal	Ficinia oligantha (Steud.) J.Raynal
E. Sieben 0459	##	##	C F	ramosissima Kunth	Ficinia ramosissima Kunth
E. Sieben 0137	##	##	C F	trichodes (Schrad.) Benth. &	Ficinia trichodes (Schrad.) Benth. & Hook.f.
E. Sieben 0235	##	##	C F	trichodes (Schrad.) Benth. &	Ficinia trichodes (Schrad.) Benth. & Hook.f.
E. Sieben 0490	##	##	C F	trichodes (Schrad.) Benth. &	Ficinia trichodes (Schrad.) Benth. & Hook.f.
E. Sieben 0581	##	##	F F	muralis Sond. ex W.D.J.Koch	Fumaria muralis Sond. ex W.D.J.Koch
E. Sieben 0822	##	##	A G	subfalcata (Cabrera) Cabrera	Gamochaeta subfalcata (Cabrera) Cabrera
E. Sieben 0522	##	##	IF G	ovalifolia R.C.Foster	Geissorhiza ovalifolia R.C.Foster
E. Sieben 0617	##	##	IF G	umbrosa G.J.Lewis	Geissorhiza umbrosa G.J.Lewis
E. Sieben 0202	##	##	A G	ilicifolia (L.) Norl.	Gibbaria ilicifolia (L.) Norl.

E. Sieben 0442	##	##	A (	ilicifolia (L.) Norl.	Gibbaria ilicifolia (L.) Norl.
E. Sieben 0667	##	##	IF (	carneus D.Delaroche	Gladiolus carneus D.Delaroche
E. Sieben 0787	##	##	IF (	carneus D.Delaroche	Gladiolus carneus D.Delaroche
E. Sieben 0795	##	##	IF (	carneus D.Delaroche	Gladiolus carneus D.Delaroche
E. Sieben 0222	##	##	G (	polypodioides (L.) Sm.	Gleichenia polypodioides (L.) Sm.
E. Sieben 0376	##	##	A (	prolifera (Burm.f.) B.L.Burtt	Glia prolifera (Burm.f.) B.L.Burtt
E. Sieben 0839	##	##	A (	prolifera (Burm.f.) B.L.Burtt	Glia prolifera (Burm.f.) B.L.Burtt
E. Sieben 0229	##	##	T (	cf. anomala Meisn.	Gnidia cf. anomala Meisn.
E. Sieben 0608	##	##	T (	galpinii C.H.Wright	Gnidia galpinii C.H.Wright
E. Sieben 0774	##	##	T (	galpinii C.H.Wright	Gnidia galpinii C.H.Wright
E. Sieben 0803	##	##	T (	galpinii C.H.Wright	Gnidia galpinii C.H.Wright
E. Sieben 0413	##	##	T (	oppositifolia L.	Gnidia oppositifolia L.
E. Sieben 0039	##	##	G (	rosmarinifolia P.J.Bergius	Grubbia rosmarinifolia P.J.Bergius
E. Sieben 0448	##	##	G (	rosmarinifolia P.J.Bergius	Grubbia rosmarinifolia P.J.Bergius
E. Sieben 0709	##	##	G (	rosmarinifolia P.J.Bergius	Grubbia rosmarinifolia P.J.Bergius
E. Sieben 0847	##	##	P I	sericea Schrad.	Hakea sericea Schrad.
E. Sieben 0282	##	##	S I	elliptica Thunb.	Halleria elliptica Thunb.
E. Sieben 0546	##	##	S I	lucida L.	Halleria lucida L.
E. Sieben 0294	##	##	A I	lanata (Thunb.) Less.	Haplocarpha lanata (Thunb.) Less.
E. Sieben 0189	##	##	C I	schinoides (Spreng.) Codd	Hartogiella schinoides (Spreng.) Codd
E. Sieben 0255	##	##	C I	schinoides (Spreng.) Codd	Hartogiella schinoides (Spreng.) Codd
E. Sieben 0764	##	##	A I	argentea (Thunb.) Meisn.	Heeria argentea (Thunb.) Meisn.
E. Sieben 0192	##	##	A I	cymosum (L.) D.Don	Helichrysum cymosum (L.) D.Don
E. Sieben 0297	##	##	A I	cymosum (L.) D.Don	Helichrysum cymosum (L.) D.Don
E. Sieben 0692	##	##	A I	cymosum (L.) D.Don	Helichrysum cymosum (L.) D.Don
E. Sieben 0118	##	##	A I	felinum Less.	Helichrysum felinum Less.
E. Sieben 0770	##	##	A I	foetidum (L.) Moench	Helichrysum foetidum (L.) Moench
E. Sieben 0821	##	##	A I	foetidum (L.) Moench	Helichrysum foetidum (L.) Moench
E. Sieben 0565	##	##	A I	helianthemifolium (L.) D.Don	Helichrysum helianthemifolium (L.) D.Don
E. Sieben 0594	##	##	A I	helianthemifolium (L.) D.Don	Helichrysum helianthemifolium (L.) D.Don
E. Sieben 0690	##	##	A I	helianthemifolium (L.) D.Don	Helichrysum helianthemifolium (L.) D.Don
E. Sieben 0360	##	##	A I	patulum (L.) D.Don	Helichrysum patulum (L.) D.Don
E. Sieben 0525	##	##	A I	tinctum (Thunb.) Hilliard & B.	Helichrysum tinctum (Thunb.) Hilliard & B.L.Burtt
E. Sieben 0584	##	##	S I	montana L.f.	Hemimeris montana L.f.
E. Sieben 0585	##	##	S I	alnifolia L.	Hermannia alnifolia L.
E. Sieben 0426	##	##	A I	aliena (L.f.) Druce	Heterolepis aliena (L.f.) Druce
E. Sieben 0595	##	##	M I	trionum L.	Hibiscus trionum L.
E. Sieben 0553	##	##	A I	bolusae Hutch.	Hippia bolusae Hutch.
E. Sieben 0331	##	##	A I	cf. frutescens (L.) L.	Hippia cf. frutescens (L.) L.
E. Sieben 0676	##	##	A I	cf. frutescens (L.) L.	Hippia cf. frutescens (L.) L.
E. Sieben 0566	##	##	D I	incisa (Thunb.) J.Sm.	Histiopteris incisa (Thunb.) J.Sm.
E. Sieben 0427	##	##	C I	villosa Lindl.	Holothrix villosa Lindl.
E. Sieben 0538	##	##	C I	villosa Lindl.	Holothrix villosa Lindl.
E. Sieben 0476	##	##	IF I	collina (Thunb.) Salisb.	Homeria collina (Thunb.) Salisb.
E. Sieben 0529	##	##	IF I	collina (Thunb.) Salisb.	Homeria collina (Thunb.) Salisb.
E. Sieben 0650	##	##	H I	marlothii Brause	Hymenophyllum marlothii Brause
E. Sieben 0275	##	##	H I	peltatum (Poir.) Desv.	Hymenophyllum peltatum (Poir.) Desv.
E. Sieben 0560	##	##	F I	sophoroides (P.J.Bergius) Ba	Hypocalyptus sophoroides (P.J.Bergius) Baill.
E. Sieben 0211	##	##	A I	radicata L.	Hypochoeris radicata L.
E. Sieben 0840	##	##	A I	radicata L.	Hypochoeris radicata L.
E. Sieben 0889	##	##	A I	radicata L.	Hypochoeris radicata L.
E. Sieben 0620	##	##	R I	aristatus (Thunb.) Krauss	Hypodiscus aristatus (Thunb.) Krauss
E. Sieben 0563	##	##	D I	sparsisora (Schrad.) Kuhn	Hypolepis sparsisora (Schrad.) Kuhn
E. Sieben 0124	##	##	A I	mitis (L.) Radlk.	Ilex mitis (L.) Radlk.
E. Sieben 0276	##	##	A I	mitis (L.) Radlk.	Ilex mitis (L.) Radlk.
E. Sieben 0158	##	##	R I	cincinnata (Mast.) H.P.Linder	Ischyrolepis cincinnata (Mast.) H.P.Linder
E. Sieben 0863	##	##	R I	curviramis (Kunth) H.P.Linde	Ischyrolepis curviramis (Kunth) H.P.Linder
E. Sieben 0359	##	##	R I	gaudichaudiana (Kunth) H.P.	Ischyrolepis gaudichaudiana (Kunth) H.P.Linder
E. Sieben 0486	##	##	R I	gaudichaudiana (Kunth) H.P.	Ischyrolepis gaudichaudiana (Kunth) H.P.Linder
E. Sieben 0877	##	##	R I	gaudichaudiana (Kunth) H.P.	Ischyrolepis gaudichaudiana (Kunth) H.P.Linder
E. Sieben 0023	##	##	R I	gaudichaudiana (Kunth) H.P.	Ischyrolepis gaudichaudiana (Kunth) H.P.Linder

E. Sieben 0793	##	##	R I	helenae (Mast.) H.P.Linder	Ischyrolepis helenae (Mast.) H.P.Linder
E. Sieben 0041	##	##	R I	subverticillata Steud.	Ischyrolepis subverticillata Steud.
E. Sieben 0861	##	##	R I	subverticillata Steud.	Ischyrolepis subverticillata Steud.
E. Sieben 0069	##	##	R I	triflora (Rottb.) H.P.Linder	Ischyrolepis triflora (Rottb.) H.P.Linder
E. Sieben 0791	##	##	R I	triflora (Rottb.) H.P.Linder	Ischyrolepis triflora (Rottb.) H.P.Linder
E. Sieben 0711	##	##	C I	digitata Schrad.	Isolepis digitata Schrad.
E. Sieben 0691	##	##	C I	fluitans (L.) R.Br.	Isolepis fluitans (L.) R.Br.
E. Sieben 0854	##	##	C I	fluitans (L.) R.Br.	Isolepis fluitans (L.) R.Br.
E. Sieben 0679	##	##	C I	prolifer R.Br.	Isolepis prolifer R.Br.
E. Sieben 0681	##	##	J J	capensis Thunb.	Juncus capensis Thunb.
E. Sieben 0684	##	##	J J	cephalotes Thunb.	Juncus cephalotes Thunb.
E. Sieben 0701	##	##	J J	effusus L.	Juncus effusus L.
E. Sieben 0245	##	##	J J	lomatophyllus Spreng.	Juncus lomatophyllus Spreng.
E. Sieben 0340	##	##	J J	lomatophyllus Spreng.	Juncus lomatophyllus Spreng.
E. Sieben 0277	##	##	F K	africana L.	Kiggelaria africana L.
E. Sieben 0382	##	##	F K	africana L.	Kiggelaria africana L.
E. Sieben 0389	##	##	F K	africana L.	Kiggelaria africana L.
E. Sieben 0564	##	##	F K	africana L.	Kiggelaria africana L.
E. Sieben 0552	##	##	A K	tabularis Marloth	Kniphofia tabularis Marloth
E. Sieben 0825	##	##	R K	capensis (L.) Huth	Knowltonia capensis (L.) Huth
E. Sieben 0509	##	##	R K	vesicatoria (L.f.) Sims	Knowltonia vesicatoria (L.f.) Sims
E. Sieben 0595A	##	##	A L	serriola L.	Lactuca serriola L.
E. Sieben 0727	##	##	H L	repens P.J.Bergius subsp. br	Laurembergia repens P.J.Bergius subsp. brachypoda (Hi
E. Sieben 0682	##	##	L L	arabidea (C.Presl) A.DC.	Laurentia arabidea (C.Presl) A.DC.
E. Sieben 0591	##	##	L L	leonurus (L.) R.Br.	Leonotis leonurus (L.) R.Br.
E. Sieben 0412	##	##	P L	cf. gandogeri Schinz ex Ganc	Leucadendron cf. gandogeri Schinz ex Gand.
E. Sieben 0046	##	##	P L	cf. laureolum (Lam.) Fourc.	Leucadendron cf. laureolum (Lam.) Fourc.
E. Sieben 0886	##	##	P L	cf. laureolum (Lam.) Fourc.	Leucadendron cf. laureolum (Lam.) Fourc.
E. Sieben 0809	##	##	P L	microcephalum (Gand.) Ganc	Leucadendron microcephalum (Gand.) Gand. & Schinz
E. Sieben 0122	##	##	P L	xanthoconus (Kuntze) K.Schu	Leucadendron xanthoconus (Kuntze) K.Schum.
E. Sieben 0493	##	##	A L	lacera Cham. & Schltdl.	Lichtensteinia lacera Cham. & Schltdl.
E. Sieben 0283	##	##	C L	parvifolia (P.J.Bergius) Adam	Lightfootia parvifolia (P.J.Bergius) Adamson
E. Sieben 0580	##	##	L L	erinus L.	Lobelia erinus L.
E. Sieben 0639	##	##	L L	jasionoides (A.DC.) E.Wimm.	Lobelia jasionoides (A.DC.) E.Wimm.
E. Sieben 0054	20	##	L L	carolinianum L.	Lycopodium carolinianum L.
E. Sieben 0888	20	##	L L	clavatum L.	Lycopodium clavatum L.
E. Sieben 0852	##	##	R M	digitata (Thunb.) Gilg-Ben.	Mastersiella digitata (Thunb.) Gilg-Ben.
E. Sieben 0387	##	##	C M	acuminata (L.f.) Loes.	Maytenus acuminata (L.f.) Loes.
E. Sieben 0390	##	##	C M	oleoides (Lam.) Loes.	Maytenus oleoides (Lam.) Loes.
E. Sieben 0679	##	##	P M	cincta (Nees) Conert	Merxmuellera cincta (Nees) Conert
E. Sieben 0083	##	##	A M	cephalotes (Thunb.) Less.	Metalasia cephalotes (Thunb.) Less.
E. Sieben 0172	##	##	A M	cephalotes (Thunb.) Less.	Metalasia cephalotes (Thunb.) Less.
E. Sieben 0406	##	##	A M	cephalotes (Thunb.) Less.	Metalasia cephalotes (Thunb.) Less.
E. Sieben 0527	##	##	A M	cephalotes (Thunb.) Less.	Metalasia cephalotes (Thunb.) Less.
E. Sieben 0446	##	##	A M	densa (Lam.) P.O.Karis	Metalasia densa (Lam.) P.O.Karis
E. Sieben 0125	##	##	M M	angustifolia (L.) Sm.	Metrosideros angustifolia (L.) Sm.
E. Sieben 0301	##	##	S M	caffrorum (L.) Desv.	Mohria caffrorum (L.) Desv.
E. Sieben 0683	##	##	L M	lutea (L.) Urb.	Monopsis lutea (L.) Urb.
E. Sieben 0494	##	##	M M	caryophyllacea Thunb.	Montinia caryophyllacea Thunb.
E. Sieben 0367	##	##	P M	alba Levyns	Muraltia alba Levyns
E. Sieben 0230	##	##	P M	heisteria (L.) DC.	Muraltia heisteria (L.) DC.
E. Sieben 0205	##	##	P M	heisteria (L.) DC.	Muraltia heisteria (L.) DC.
E. Sieben 0498	##	##	P M	vulpina Chodat	Muraltia vulpina Chodat
E. Sieben 0686	##	##	M M	serrata Lam.	Myrica serrata Lam.
E. Sieben 0303	##	##	M M	africana L.	Myrsine africana L.
E. Sieben 0512	##	##	M M	africana L.	Myrsine africana L.
E. Sieben 0518	##	##	A M	scandens (Thunb.) Oberm.	Myrsiphyllum scandens (Thunb.) Oberm.
E. Sieben 0570	##	##	A M	volubile (Thunb.) Oberm.	Myrsiphyllum volubile (Thunb.) Oberm.
E. Sieben 0571	##	##	A M	volubile (Thunb.) Oberm.	Myrsiphyllum volubile (Thunb.) Oberm.
E. Sieben 0401	##	##	B N	fragarioides (Willd.) Kuntze	Nebelia fragarioides (Willd.) Kuntze
E. Sieben 0045	##	##	C N	punctoria (Vahl) Levyns	Neesenbeckia punctoria (Vahl) Levyns

E. Sieben 0042	##	##	R I	obtusissima (Steud.) H.P.Lin(	Nevillea obtusissima (Steud.) H.P.Linder
E. Sieben 0474	##	##	S (	africana (L.) Bocq.	Oftia africana (L.) Bocq.
E. Sieben 0544	##	##	C (	capensis L.	Olea capensis L.
E. Sieben 0812	##	##	C (	capensis L.	Olea capensis L.
E. Sieben 0662	##	##	C (	europaea L. subsp. africana (	Olea europaea L. subsp. africana (Mill.) P.S.Green
E. Sieben 0814	##	##	C (	ventosa (L.) Cufod.	Olinia ventosa (L.) Cufod.
E. Sieben 0443	##	##	A (	afra (L.) K.Bremer	Osmitopsis afra (L.) K.Bremer
E. Sieben 0834	##	##	A (	pinnatifida (DC.) K.Bremer	Osmitopsis pinnatifida (DC.) K.Bremer
E. Sieben 0315	##	##	A (	ciliatum P.J.Bergius	Osteospermum ciliatum P.J.Bergius
E. Sieben 0582	##	##	A (	ciliatum P.J.Bergius	Osteospermum ciliatum P.J.Bergius
E. Sieben 0492	##	##	F (	obliquum (E.Mey.) C.H.Stirt.	Otholobium obliquum (E.Mey.) C.H.Stirt.
E. Sieben 0674	##	##	F (	obliquum (E.Mey.) C.H.Stirt.	Otholobium obliquum (E.Mey.) C.H.Stirt.
E. Sieben 0526	##	##	A (	parviflora P.J.Bergius	Othonna parviflora P.J.Bergius
E. Sieben 0113	##	##	A (	quinquedentata Thunb.	Othonna quinquedentata Thunb.
E. Sieben 0197	##	##	A (	quinquedentata Thunb.	Othonna quinquedentata Thunb.
E. Sieben 0531	##	##	C (	cf. corniculata L.	Oxalis cf. corniculata L.
E. Sieben 0272	##	##	C (	cf. dentata Jacq.	Oxalis cf. dentata Jacq.
E. Sieben 0365	##	##	C (	lanata L.f.	Oxalis lanata L.f.
E. Sieben 0364	##	##	C (	livida Jacq.	Oxalis livida Jacq.
E. Sieben 0219	##	##	C (	cf. nidulans Eckl. & Zeyh.	Oxalis cf. nidulans Eckl. & Zeyh.
E. Sieben 0317	##	##	C (	cf. nidulans Eckl. & Zeyh.	Oxalis cf. nidulans Eckl. & Zeyh.
E. Sieben 0363	##	##	C (	purpurea L.	Oxalis purpurea L.
E. Sieben 0513	##	##	C (	purpurea L.	Oxalis purpurea L.
E. Sieben 0444	##	##	C (	truncatula Jacq.	Oxalis truncatula Jacq.
E. Sieben 0485	##	##	C (	truncatula Jacq.	Oxalis truncatula Jacq.
E. Sieben 0495	##	##	C (	cf. versicolor L.	Oxalis cf. versicolor L.
E. Sieben 0723	##	##	P I	maximum Jacq.	Panicum maximum Jacq.
E. Sieben 0730	##	##	P I	urvillei Steud.	Paspalum urvillei Steud.
E. Sieben 0823	##	##	P I	urvillei Steud.	Paspalum urvillei Steud.
E. Sieben 0728	##	##	T I	vulgaris Thoday	Passerina vulgaris Thoday
E. Sieben 0587	##	##	G I	columbinum Jacq.	Pelargonium columbinum Jacq.
E. Sieben 0284	##	##	G I	cucullatum (L.) L'Hér.	Pelargonium cucullatum (L.) L'Hér.
E. Sieben 0576	##	##	G I	elongatum (Cav.) Salisb.	Pelargonium elongatum (Cav.) Salisb.
E. Sieben 0250	##	##	G I	hermanniifolium (P.J.Bergius	Pelargonium hermanniifolium (P.J.Bergius) Jacq.
E. Sieben 0306	##	##	G I	patulum Jacq.	Pelargonium patulum Jacq.
E. Sieben 0506	##	##	G I	patulum Jacq.	Pelargonium patulum Jacq.
E. Sieben 0844	##	##	G I	patulum Jacq.	Pelargonium patulum Jacq.
E. Sieben 0349	##	##	G I	tomentosum Jacq.	Pelargonium tomentosum Jacq.
E. Sieben 0188	##	##	A I	pteroides (L.) Prantl	Pellaea pteroides (L.) Prantl
E. Sieben 0712	##	##	P I	cneorum Meerb.	Penaea cneorum Meerb.
E. Sieben 0221	##	##	P I	mucronata L.	Penaea mucronata L.
E. Sieben 0687	##	##	P I	macrourum Trin.	Pennisetum macrourum Trin.
E. Sieben 0734	##	50	P I	distichophylla (Lehm.) Nees	Pentameris distichophylla (Lehm.) Nees
E. Sieben 0628	##	##	P I	hirtiglumis N.P.Barker	Pentameris hirtiglumis N.P.Barker
E. Sieben 0629	##	##	P I	hirtiglumis N.P.Barker	Pentameris hirtiglumis N.P.Barker
E. Sieben 0416	##	##	P I	macrocalycina (Steud.) Schw	Pentameris macrocalycina (Steud.) Schweick.
E. Sieben 0857	##	##	P I	obtusifolia (Hochst.) Schweic	Pentameris obtusifolia (Hochst.) Schweick.
E. Sieben 0206	##	##	P I	thuarii P.Beauv.	Pentameris thuarii P.Beauv.
E. Sieben 0464	##	##	P I	thuarii P.Beauv.	Pentameris thuarii P.Beauv.
E. Sieben 0479	##	##	P I	thuarii P.Beauv.	Pentameris thuarii P.Beauv.
E. Sieben 0240	##	##	P I	ampla (Nees) McClean	Pentaschistis ampla (Nees) McClean
E. Sieben 0761	##	##	P I	ampla (Nees) McClean	Pentaschistis ampla (Nees) McClean
E. Sieben 0112	##	##	P I	curvifolia (Schrad.) Stapf	Pentaschistis curvifolia (Schrad.) Stapf
E. Sieben 0688	##	##	P I	densifolia (Nees) Stapf	Pentaschistis densifolia (Nees) Stapf
E. Sieben 0430	##	##	P I	holciformis (Nees) H.P.Linder	Pentaschistis holciformis (Nees) H.P.Linder
E. Sieben 0853	##	##	P I	holciformis (Nees) H.P.Linder	Pentaschistis holciformis (Nees) H.P.Linder
E. Sieben 0088	##	##	P I	malouinensis (Steud.) Clayto	Pentaschistis malouinensis (Steud.) Clayton
E. Sieben 0720	##	##	P I	malouinensis (Steud.) Clayto	Pentaschistis malouinensis (Steud.) Clayton
E. Sieben 0885	##	##	P I	malouinensis (Steud.) Clayto	Pentaschistis malouinensis (Steud.) Clayton
E. Sieben 0333	##	##	P I	pallida (Thunb.) H.P.Linder	Pentaschistis pallida (Thunb.) H.P.Linder
E. Sieben 0337	##	##	P I	pallida (Thunb.) H.P.Linder	Pentaschistis pallida (Thunb.) H.P.Linder

E. Sieben 0530	##	##	P	pallida (Thunb.) H.P.Linder	Pentaschistis pallida (Thunb.) H.P.Linder
E. Sieben 0668	##	##	P	pallida (Thunb.) H.P.Linder	Pentaschistis pallida (Thunb.) H.P.Linder
E. Sieben 0716	##	##	P	pallida (Thunb.) H.P.Linder	Pentaschistis pallida (Thunb.) H.P.Linder
E. Sieben 0703	##	##	A	galbaniopse H.Wolff	Peucedanum galbaniopse H.Wolff
E. Sieben 0182	##	##	A	galbanum (L.) Drude	Peucedanum galbanum (L.) Drude
E. Sieben 0475	##	##	A	cf. strictum (Spreng.) B.L.Bur	Peucedanum cf. strictum (Spreng.) B.L.Burtt
E. Sieben 0419	##	##	A	prolifera (L.) D.Don	Phaenocoma prolifera (L.) D.Don
E. Sieben 0836	##	##	R	callosa L.f.	Phylica callosa L.f.
E. Sieben 0425	##	##	R	ericoides L.	Phylica ericoides L.
E. Sieben 0860	##	##	R	ericoides L.	Phylica ericoides L.
E. Sieben 0237	##	##	R	gracilis (Eckl. & Zeyh.) D.Diet	Phylica gracilis (Eckl. & Zeyh.) D.Dietr.
E. Sieben 0760	##	##	R	imberbis P.J.Bergius	Phylica imberbis P.J.Bergius
E. Sieben 0862	##	##	R	imberbis P.J.Bergius	Phylica imberbis P.J.Bergius
E. Sieben 0705	##	##	R	plumosa L.	Phylica plumosa L.
E. Sieben 0738	##	##	P	cf. pinaster Aiton	Pinus cf. pinaster Aiton
E. Sieben 0386	##	##	P	undulatum Vent.	Pittosporum undulatum Vent.
E. Sieben 0135	##	##	R	callistachyus (Kunth) H.P.Lin	Platycaulos callistachyus (Kunth) H.P.Linder
E. Sieben 0859	##	##	R	callistachyus (Kunth) H.P.Lin	Platycaulos callistachyus (Kunth) H.P.Linder
E. Sieben 0785	##	##	R	cascadensis (Pillans) H.P.Lin	Platycaulos cascadensis (Pillans) H.P.Linder
E. Sieben 0644	##	##	R	depauperatus (Kunth) H.P.Li	Platycaulos depauperatus (Kunth) H.P.Linder
E. Sieben 0742	##	##	R	depauperatus (Kunth) H.P.Li	Platycaulos depauperatus (Kunth) H.P.Linder
E. Sieben 0148	##	##	C	trifoliatus (L.f.) D.Don	Platylophus trifoliatus (L.f.) D.Don
E. Sieben 0261	##	##	A	polifolia (Thunb.) Hilliard & B.	Plecostachys polifolia (Thunb.) Hilliard & B.L.Burtt
E. Sieben 0099	##	##	F	calyptrata (Retz.) Willd.	Podalyria calyptrata (Retz.) Willd.
E. Sieben 0616	##	##	F	montana Hutch.	Podalyria montana Hutch.
E. Sieben 0816	##	##	P	cf. elongatus (Aiton) L'H,r. ex	Podocarpus cf. elongatus (Aiton) L'H,r. ex Pers.
E. Sieben 0666	##	##	P	latifolius (Thunb.) R.Br. ex Mi	Podocarpus latifolius (Thunb.) R.Br. ex Mirb.
E. Sieben 0816A	##	##	P	latifolius (Thunb.) R.Br. ex Mi	Podocarpus latifolius (Thunb.) R.Br. ex Mirb.
E. Sieben 0085	##	##	P	cf. nematocaulis Levyns	Polygala cf. nematocaulis Levyns
E. Sieben 0845	##	##	F	capitata DC.	Priestleya capitata DC.
E. Sieben 0152	##	##	J	serratum (L.f.) DrŠge ex E.M	Prionium serratum (L.f.) DrŠge ex E.Mey.
E. Sieben 0875	##	##	J	serratum (L.f.) DrŠge ex E.M	Prionium serratum (L.f.) DrŠge ex E.Mey.
E. Sieben 0469	##	##	A	retrofractus (L.) Oberm.	Protasparagus retrofractus (L.) Oberm.
E. Sieben 0486	##	##	A	rubicundus (P.J.Bergius) Ob	Protasparagus rubicundus (P.J.Bergius) Oberm.
E. Sieben 0884	##	##	P	amplexicaulis (Salisb.) R.Br.	Protea amplexicaulis (Salisb.) R.Br.
E. Sieben 0065	##	##	P	cynaroides (L.) L.	Protea cynaroides (L.) L.
E. Sieben 0810	##	##	P	grandiceps Tratt.	Protea grandiceps Tratt.
E. Sieben 0423	##	##	P	longifolia Andrews	Protea longifolia Andrews
E. Sieben 0422	##	##	P	mundii Klotzsch	Protea mundii Klotzsch
E. Sieben 0704	##	##	P	neriifolia R.Br.	Protea neriifolia R.Br.
E. Sieben 0767	##	##	P	nitida Mill.	Protea nitida Mill.
E. Sieben 0004	##	##	B	africana (Burm.f.) Pillans	Pseudobaeckea africana (Burm.f.) Pillans
E. Sieben 0408	##	##	B	africana (Burm.f.) Pillans	Pseudobaeckea africana (Burm.f.) Pillans
E. Sieben 0094	##		F	aculeata	Psoralea aculeata
E. Sieben 0440	##	##	F	aphylla L.	Psoralea aphylla L.
E. Sieben 0574	##	##	F	asarina (P.J.Bergius) Salter	Psoralea asarina (P.J.Bergius) Salter
E. Sieben 0134	##		F	af. fleta C. H. Stirton	Psoralea af. fleta C. H. Stirton
E. Sieben 0471	##		F	af. fleta C. H. Stirton	Psoralea af. fleta C. H. Stirton
E. Sieben 0575	##	##	F	pinnata L.	Psoralea pinnata L.
E. Sieben 0126	##	##	D	aquilinum (L.) Kuhn	Pteridium aquilinum (L.) Kuhn
E. Sieben 0569	##	##	C	rostratus Walp.	Pterocelastrus rostratus Walp.
E. Sieben 0540	##	##	M	melanophloeos (L.) Mez	Rapanea melanophloeos (L.) Mez
E. Sieben 0783	##	##	B	microphylla (Thunb.) Brongn.	Raspalia microphylla (Thunb.) Brongn.
E. Sieben 0649	##	##	B	virgata (Brongn.) Pillans	Raspalia virgata (Brongn.) Pillans
E. Sieben 0320	##	##	R	bifarius Mast.	Restio bifarius Mast.
E. Sieben 0874	##	##	R	bifidus Thunb.	Restio bifidus Thunb.
E. Sieben 0827	##	##	R	bifurcus Nees ex Mast.	Restio bifurcus Nees ex Mast.
E. Sieben 0790	##	##	R	burchellii Pillans	Restio burchellii Pillans
E. Sieben 0848	##	##	R	burchellii Pillans	Restio burchellii Pillans
E. Sieben 0400	##	##	R	corneolus Esterh.	Restio corneolus Esterh.
E. Sieben 0322	##	##	R	corneolus Esterh.	Restio corneolus Esterh.

E. Sieben 0420	##	##	R	debilis Nees	Restio debilis Nees
E. Sieben 0326	##	##	R	degenerans Pillans	Restio degenerans Pillans
E. Sieben 0463	##	##	R	degenerans Pillans	Restio degenerans Pillans
E. Sieben 0548	##	##	R	degenerans Pillans	Restio degenerans Pillans
E. Sieben 0780	##	##	R	degenerans Pillans	Restio degenerans Pillans
E. Sieben 0843	##	##	R	dispar Mast.	Restio dispar Mast.
E. Sieben 0165	##	##	R	echinatus Kunth	Restio echinatus Kunth
E. Sieben 0850	##	##	R	egregius Hochst.	Restio egregius Hochst.
E. Sieben 0851	##	##	R	egregius Hochst.	Restio egregius Hochst.
E. Sieben 0604	##	##	R	ejuncidus Mast.	Restio ejuncidus Mast.
E. Sieben 0533	##	##	R	filiformis Poir.	Restio filiformis Poir.
E. Sieben 0431	##	##	R	nuwebergensis Esterh.	Restio nuwebergensis Esterh.
E. Sieben 0154	##	##	R	occultus (Mast.) Pillans	Restio occultus (Mast.) Pillans
E. Sieben 0066	##	##	R	cf. perplexus Kunth	Restio cf. perplexus Kunth
E. Sieben 0724	##	##	R	cf. perplexus Kunth	Restio cf. perplexus Kunth
E. Sieben 0881	##	##	R	cf. perplexus Kunth	Restio cf. perplexus Kunth
E. Sieben 0022	##	##	R	purpurascens Nees ex Mast.	Restio purpurascens Nees ex Mast.
E. Sieben 0247	##	##	R	quadratus Mast.	Restio quadratus Mast.
E. Sieben 0799	##	##	R	stokoei Pillans	Restio stokoei Pillans
E. Sieben 0450	##	##	R	subtilis Nees ex Mast.	Restio subtilis Nees ex Mast.
E. Sieben 0456	##	##	R	af. versatilis H.P.Linder	Restio af. versatilis H.P.Linder
E. Sieben 0605	##	##	R	af. versatilis H.P.Linder	Restio af. versatilis H.P.Linder
E. Sieben 0615	##	##	R	af. versatilis H.P.Linder	Restio af. versatilis H.P.Linder
E. Sieben 0251	##	##	A	angustifolia L.	Rhus angustifolia L.
E. Sieben 0351	##	##	A	tomentosa L.	Rhus tomentosa L.
E. Sieben 0779	##	##	C	dregeana A.DC.	Roella dregeana A.DC.
E. Sieben 0361	##	##	R	cf. pinnatus Willd.	Rubus cf. pinnatus Willd.
E. Sieben 0680	##	##	R	cf. rigidus Sm.	Rubus cf. rigidus Sm.
E. Sieben 0350	##	##	L	chamelaeagnea P.J.Bergius	Salvia chamelaeagnea P.J.Bergius
E. Sieben 0104	##	##	S	pectinata (L.) Sw.	Schizaea pectinata (L.) Sw.
E. Sieben 0029	##	##	S	tenella Kaulf.	Schizaea tenella Kaulf.
E. Sieben 0253	##	##	C	lanceum (Thunb.) Kük.	Schoenoxiphium lanceum (Thunb.) Kük.
E. Sieben 0273	##	##	C	lanceum (Thunb.) Kük.	Schoenoxiphium lanceum (Thunb.) Kük.
E. Sieben 0285	##	##	C	lanceum (Thunb.) Kük.	Schoenoxiphium lanceum (Thunb.) Kük.
E. Sieben 0383	##	##	C	lanceum (Thunb.) Kük.	Schoenoxiphium lanceum (Thunb.) Kük.
E. Sieben 0508	##	##	C	lanceum (Thunb.) Kük.	Schoenoxiphium lanceum (Thunb.) Kük.
E. Sieben 0749	##	##	E	micrantha (Benth.) N.E.Br.	Scyphogyne micrantha (Benth.) N.E.Br.
E. Sieben 0879	##	##	E	micrantha (Benth.) N.E.Br.	Scyphogyne micrantha (Benth.) N.E.Br.
E. Sieben 0754	##	##	A	alpini Schult.	Secamone alpini Schult.
E. Sieben 0290	##	##	S	serrata P.J.Bergius	Selago serrata P.J.Bergius
E. Sieben 0370	##	##	S	serrata P.J.Bergius	Selago serrata P.J.Bergius
E. Sieben 0817	##	##	S	serrata P.J.Bergius	Selago serrata P.J.Bergius
E. Sieben 0768	##	##	A	amabilis DC.	Senecio amabilis DC.
E. Sieben 0461	##	##	A	coleophyllus Turcz.	Senecio coleophyllus Turcz.
E. Sieben 0558	##	##	A	crispus Thunb.	Senecio crispus Thunb.
E. Sieben 0743	##	##	A	crispus Thunb.	Senecio crispus Thunb.
E. Sieben 0556	##	##	A	grandiflorus P.J.Bergius	Senecio grandiflorus P.J.Bergius
E. Sieben 0356	##	##	A	cf. hastatus L.	Senecio cf. hastatus L.
E. Sieben 0689	##	##	A	cf. hastatus L.	Senecio cf. hastatus L.
E. Sieben 0517	##	##	A	pinnulatus Thunb.	Senecio pinnulatus Thunb.
E. Sieben 0693	##	##	A	pinnulatus Thunb.	Senecio pinnulatus Thunb.
E. Sieben 0819	##	##	A	pterophorus DC.	Senecio pterophorus DC.
E. Sieben 0870	##	##	A	pubigerus L.	Senecio pubigerus L.
E. Sieben 0634	##	##	A	subcanescens (DC.) Compto	Senecio subcanescens (DC.) Compton
E. Sieben 0694	##	##	A	cf. vulgaris L.	Senecio cf. vulgaris L.
E. Sieben 0567	##	##	S	retroflexum Dunal	Solanum retroflexum Dunal
E. Sieben 0397	##	##	R	cernua (L.f.) T.Durand & Sch	Staberoha cernua (L.f.) T.Durand & Schinz
E. Sieben 0610	##	##	R	cf. vaginata (Thunb.) Pillans	Staberoha cf. vaginata (Thunb.) Pillans
E. Sieben 0614	##	##	R	cf. vaginata (Thunb.) Pillans	Staberoha cf. vaginata (Thunb.) Pillans
E. Sieben 0593	##	##	L	aethiopica L.	Stachys aethiopica L.
E. Sieben 0339	##	##	S	mucronata N.E.Br.	Stilbe mucronata N.E.Br.

E. Sieben 0225	##	##	A S	cinerea (L.) Thunb.	Stoebe cinerea (L.) Thunb.
E. Sieben 0781	##	##	A S	incana Thunb.	Stoebe incana Thunb.
E. Sieben 0549	##	##	A S	plumosa (L.) Thunb.	Stoebe plumosa (L.) Thunb.
E. Sieben 0212	##	##	T S	ciliata (L.) Lam.	Struthiola ciliata (L.) Lam.
E. Sieben 0721	##	##	T S	martiana Meisn.	Struthiola martiana Meisn.
E. Sieben 0797	##	##	T S	martiana Meisn.	Struthiola martiana Meisn.
E. Sieben 0394	##	##	T S	myrsinites Lam.	Struthiola myrsinites Lam.
E. Sieben 0358	##	##	S S	hispida (Thunb.) Druce	Sutera hispida (Thunb.) Druce
E. Sieben 0031	##	##	E S	labialis (Salisb.) Druce	Sympieza labialis (Salisb.) Druce
E. Sieben 0769	##	##	F T	capensis (Jacq.) Pers.	Tephrosia capensis (Jacq.) Pers.
E. Sieben 0217	##	##	C T	bolusii C.B.Clarke	Tetraria bolusii C.B.Clarke
E. Sieben 0090	##	##	C T	brevicaulis C.B.Clarke	Tetraria brevicaulis C.B.Clarke
E. Sieben 0477	##	##	C T	bromoides (Lam.) Pfeiff.	Tetraria bromoides (Lam.) Pfeiff.
E. Sieben 0395	##	##	C T	capillacea (Thunb.) C.B.Clark	Tetraria capillacea (Thunb.) C.B.Clarke
E. Sieben 0434	##	##	C T	capillacea (Thunb.) C.B.Clark	Tetraria capillacea (Thunb.) C.B.Clarke
E. Sieben 0612	##	##	C T	crassa Levyns	Tetraria crassa Levyns
E. Sieben 0102	##	##	C T	cuspidata (Rottb.) C.B.Clarke	Tetraria cuspidata (Rottb.) C.B.Clarke
E. Sieben 0849	##	##	C T	fasciata (Rottb.) C.B.Clarke	Tetraria fasciata (Rottb.) C.B.Clarke
E. Sieben 0611	##	##	C T	pillansii Levyns	Tetraria pillansii Levyns
E. Sieben 0828	##	##	C T	pillansii Levyns	Tetraria pillansii Levyns
E. Sieben 0609	##	##	C T	thermalis (L.) C.B.Clarke	Tetraria thermalis (L.) C.B.Clarke
E. Sieben 0089	##	##	A T	cf. mundii Harv.	Thaminophyllum cf. mundii Harv.
E. Sieben 0436	##	##	R T	fruticosus P.J.Bergius	Thamnochortus fruticosus P.J.Bergius
E. Sieben 0489	##	##	R T	fruticosus P.J.Bergius	Thamnochortus fruticosus P.J.Bergius
E. Sieben 0428	##	##	R T	lucens (Poir.) H.P.Linder	Thamnochortus lucens (Poir.) H.P.Linder
E. Sieben 0804	##	##	R T	lucens (Poir.) H.P.Linder	Thamnochortus lucens (Poir.) H.P.Linder
E. Sieben 0733	##	##	T T	confluens (Thunb.) Morton	Thelypteris confluens (Thunb.) Morton
E. Sieben 0491	##	##	P T	triandra Forssk.	Themeda triandra Forssk.
E. Sieben 0765	##	##	P T	triandra Forssk.	Themeda triandra Forssk.
E. Sieben 0858	##	##	S T	cf. capituliflorum Sond.	Thesium cf. capituliflorum Sond.
E. Sieben 0736	##	##	S T	carinatum DC.	Thesium carinatum DC.
E. Sieben 0287	##	##	S T	paniculatum L.	Thesium paniculatum L.
E. Sieben 0766	##	##	S T	scabrum L.	Thesium scabrum L.
E. Sieben 0751	##	##	S T	cf. spicatum L.	Thesium cf. spicatum L.
E. Sieben 0207	##	##	S T	strictum P.J.Bergius	Thesium strictum P.J.Bergius
E. Sieben 0309	##	##	S T	strictum P.J.Bergius	Thesium strictum P.J.Bergius
E. Sieben 0537	##	##	S T	strictum P.J.Bergius	Thesium strictum P.J.Bergius
E. Sieben 0807	##	##	S T	viridifolium Levyns	Thesium viridifolium Levyns
E. Sieben 0121	90	##	C T	barbara (L.) T.Moore	Todea barbara (L.) T.Moore
E. Sieben 0378	90	##	C T	barbara (L.) T.Moore	Todea barbara (L.) T.Moore
E. Sieben 0511	##	##	A T	hirsuta (Thunb.) Kunth	Trachyandra hirsuta (Thunb.) Kunth
E. Sieben 0678	##	##	A T	tabularis (Baker) Oberm.	Trachyandra tabularis (Baker) Oberm.
E. Sieben 0241	##	##	P T	cf. brachystachyum (Nees) R	Tribolium cf. brachystachyum (Nees) Renvoize
E. Sieben 0699	##	##	P T	cf. brachystachyum (Nees) R	Tribolium cf. brachystachyum (Nees) Renvoize
E. Sieben 0421	##	##	IF T	dodii (G.J.Lewis) G.J.Lewis	Tritoniopsis dodii (G.J.Lewis) G.J.Lewis
E. Sieben 0078	##	##	IF T	lata (L.Bolus) G.J.Lewis	Tritoniopsis lata (L.Bolus) G.J.Lewis
E. Sieben 0447	##	##	A U	caledonica (E.Phillips) Prassl	Ursinia caledonica (E.Phillips) Prassler
E. Sieben 0871	##	##	A U	dentata (L.) Poir.	Ursinia dentata (L.) Poir.
E. Sieben 0341	##	##	A U	eckloniana (Sond.) N.E.Br.	Ursinia eckloniana (Sond.) N.E.Br.
E. Sieben 0460	##	##	A U	eckloniana (Sond.) N.E.Br.	Ursinia eckloniana (Sond.) N.E.Br.
E. Sieben 0698	##	##	A U	paleacea (L.) Moench	Ursinia paleacea (L.) Moench
E. Sieben 0404	##	##	A U	quinquepartita (DC.) N.E.Br.	Ursinia quinquepartita (DC.) N.E.Br.
E. Sieben 0262	##	##	A U	scariosa (Aiton) Poir.	Ursinia scariosa (Aiton) Poir.
E. Sieben 0293	##	##	A U	scariosa (Aiton) Poir.	Ursinia scariosa (Aiton) Poir.
E. Sieben 0344	##	##	A U	scariosa (Aiton) Poir.	Ursinia scariosa (Aiton) Poir.
E. Sieben 0622	##	##	L U	bisquamata Schrank	Utricularia bisquamata Schrank
E. Sieben 0710	##	##	L U	bisquamata Schrank	Utricularia bisquamata Schrank
E. Sieben 0033	##	##	G V	capensis (Houtt.) Merr.	Villarsia capensis (Houtt.) Merr.
E. Sieben 0890	##	##	F V	oroboides (P.J.Bergius) Salte	Virgilia oroboides (P.J.Bergius) Salter
E. Sieben 0381	##	##	V V	pauciflorum L.f.	Viscum pauciflorum L.f.
E. Sieben 0665	##	##	H W	brachyandra W.F.Barker	Wachendorfia brachyandra W.F.Barker

E. Sieben 0725	##	##	H	\	thyrsiflora Burm.	Wachendorfia thyrsiflora Burm.
E. Sieben 0798	##	##	C	\	procumbens (Thunb.) A.DC.	Wahlenbergia procumbens (Thunb.) A.DC.
E. Sieben 0831	##	##	C	\	procumbens (Thunb.) A.DC.	Wahlenbergia procumbens (Thunb.) A.DC.
E. Sieben 0664	##	##	IF	\	borbonica (Pourr.) Goldblatt	Watsonia borbonica (Pourr.) Goldblatt
E. Sieben 0855	##	##	IF	\	schlechteri L.Bolus	Watsonia schlechteri L.Bolus
E. Sieben 0077	##	##	C	\	nodiflora (L.) Powrie	Widdringtonia nodiflora (L.) Powrie
E. Sieben 0789	##	##	R	\	sulcata Mast.	Willdenowia sulcata Mast.
E. Sieben 0499	##	##	A	Z	aethiopica (L.) Spreng.	Zantedeschia aethiopica (L.) Spreng.

Appendix D

The transects 1 to 123 were collected in the Hottentots Holland Mountains. Each of them contains between 1 and 7 vegetation samples.
The last transects, numbers 125 to 133, each with a single vegetation sample (numbers 259 to 267), were collected in several areas.
Transects 125 to 128 were collected in the upper reaches of the Wit River catchment in the Dutoitskloof Mountains.
Transects 129 and 130 were collected in the Groenland Mountains, nowadays also part of the Hottentots Holland Nature Reserve.
Transects 131 and 132 were collected in Bains Kloof in the upper reaches of the Breede River.
Transect 133 was collected on the Akkedisberg near Stanford.

Transect no.	Relevés	Latitude	Longitude	Altitude	River Catchment
1	1 to 3	34°03'20"	19°02'30"	620	Palmiet River
2	4 to 7	34°03'45"	19°04'12"	300	Riviersonderend
3	8 to 11	34°02'36"	19°01'55"	620	Riviersonderend
4	12 to 15	34°02'35"	19°02'24"	545	Riviersonderend
5	16 to 19	34°00'25"	19°05'35"	315	Riviersonderend
6	20 to 23	34°00'12"	19°06'25"	295	Riviersonderend
7	24 to 28	34°02'00"	19°04'05"	690	Riviersonderend
8	29 to 31	33°57'02"	19°01'50"	510	Berg River
9	32 to 36	33°56'12"	19°09'45"	560	Riviersonderend
10	37 to 43	33°59'25"	18°59'25"	760	Eerste River
11	44 to 47	34°00'06"	18°59'50"	540	Eerste River
12	48 to 51	33°59'45"	18°57'30"	420	Eerste River
13	52 to 55	33°57'20"	18°58'48"	480	Berg River
14	56 to 59	34°01'55"	19°01'45"	700	Riviersonderend
15	60 to 62	34°01'40"	19°01'05"	770	Riviersonderend
16	63 to 65	34°02'40"	19°00'48"	880	Riviersonderend
17	66 to 68	33°59'35"	18°53'35"	270	Eerste River
18	69,70	33°59'09"	18°58'18"	420	Eerste River
19	71 to 74	34°06'41"	18°58'56"	680	Palmiet River
20	75 to 78	34°06'45"	18°58'58"	680	Palmiet River
21	79,80	34°03'14"	19°02'16"	635	Palmiet River
22	81,82	34°03'19"	19°02'09"	670	Palmiet River
23	83 to 85	33°57'41"	19°09'08"	485	Riviersonderend
24	86	34°02'58"	19°00'18"	1075	Palmiet River
25	87	34°02'58"	19°00'18"	1060	Palmiet River
26	88 to 91	34°02'06"	19°03'18"	675	Riviersonderend
27	92 to 95	33°59'37"	18°58'32"	380	Eerste River
28	96 to 99	33°59'37"	18°58'25"	370	Eerste River
29	100 to103	33°59'14"	19°02'25"	450	Berg River
30	104,105	33°59'14"	19°02'25"	470	Berg River
31	106,107	33°59'08"	19°02'29"	405	Berg River
32	108,109	33°59'17"	19°02'03"	455	Berg River
33	110	34°04'20"	19°00'04"	1060	Palmiet River
34	111	34°02'18"	18°59'18"	1365	Riviersonderend
35	112	33°59'33"	18°57'14"	360	Eerste River
36	113	33°59'33"	18°57'14"	360	Eerste River
37	114,115	33°59'18"	18°57'21"	350	Eerste River
38	116	34°00'32"	18°57'46"	870	Eerste River
39	117,118	33°59'39"	18°53'42"	280	Eerste River
40	119,120	33°59'35"	18°53'35"	270	Eerste River
41	122	33°59'35"	18°53'35"	265	Eerste River
42	123,124	34°03'35"	19°00'39"	1000	Palmiet River
43	125,126	34°03'35"	19°00'39"	995	Palmiet River
44	127,128	34°03'43"	19°00'50"	980	Palmiet River
45	129	34°02'56"	19°00'34"	1060	Palmiet River
46	130,131	34°03'36"	18°59'07"	1160	Palmiet River
47	132 to 134	34°03'36"	18°59'07"	1145	Palmiet River
48	135	34°03'34"	18°59'05"	1180	Palmiet River
49	136	34°03'34"	18°59'45"	1175	Palmiet River
50	137,138,250	34°02'40"	19°00'45"	860	Riviersonderend
51	139,140	34°02'40"	19°00'45"	880	Riviersonderend
52	141,142	33°58'55"	18°58'30"	470	Eerste River
53	143 to 145	34°00'20"	18°59'19"	440	Eerste River
54	146 to 148	33°56'41"	19°10'09"	360	Riviersonderend
55	149	34°00'08"	18°59'40"	520	Eerste River
56	150,151	34°00'05"	18°59'48"	530	Eerste River
57	152,153	34°03'40"	19°04'06"	335	Riviersonderend
58	154,155	34°03'25"	19°04'05"	350	Riviersonderend

Transect no.	Relevés	Latitude	Longitude	Altitude	River Catchment
59	156 to 158	34°02'34"	19°02'00"	680	Riviersonderend
60	159,160	33°56'49"	19°10'07"	360	Riviersonderend
61	161,162	33°56'40"	19°10'16"	360	Riviersonderend
62	163	34°03'31"	19°00'15"	1075	Palmiet River
63	164	34°03'31"	19°00'15"	1075	Palmiet River
64	165	34°04'00"	19°00'21"	1170	Palmiet River
65	166,268	33°59'24"	19°01'45"	540	Berg River
66	167,168	33°59'30"	19°01'37"	580	Berg River
67	169	33°59'30"	19°01'37"	570	Berg River
68	170	33°59'39"	19°01'50"	580	Berg River
69	171,172	33°59'39"	19°01'50"	570	Berg River
70	173	33°56'36"	19°01'15"	380	Berg River
71	174,175	33°57'30"	18°59'22"	590	Berg River
72	176 to 178, 269	33°57'30"	18°59'12"	540	Berg River
73	179,180	33°57'30"	18°59'05"	520	Berg River
74	181	33°59'20"	18°56'21"	490	Eerste River
75	182 to 184	34°05'21"	19°00'06"	560	Palmiet River
76	185 to 187	34°05'28"	19°00'28"	520	Palmiet River
77	188	34°02'50"	19°00'06"	1070	Riviersonderend
78	189	34°02'50"	19°00'06"	1075	Riviersonderend
79	190	34°03'22"	18°58'06"	570	Lourens River
80	191	34°03'22"	18°58'06"	540	Lourens River
81	192,193	34°01'38"	18°57'45"	390	Lourens River
82	194	34°01'33"	18°57'54"	400	Lourens River
83	195,196	34°01'38"	18°57'45"	380	Lourens River
84	197,198	34°01'25"	18°57'54"	410	Lourens River
85	199	34°01'33"	18°57'54"	410	Lourens River
86	200	34°01'33"	18°57'54"	410	Lourens River
87	201	34°00'24"	19°01'03"	1280	Eerste River
88	202	34°00'24"	19°01'03"	1280	Eerste River
89	203	34°00'24"	19°01'03"	1270	Eerste River
90	204,205	33°56'35"	19°00'46"	540	Berg River
91	206 to 208	33°56'35"	19°00'46"	520	Berg River
92	209,210	33°57'02"	19°01'23"	520	Berg River
93	211	33°57'02"	19°01'23"	520	Berg River
94	212,214	33°56'22"	19°09'36"	560	Riviersonderend
95	215 to 217	34°03'36"	19°01'47"	770	Palmiet River
96	218 to 220	34°03'36"	19°01'47"	760	Palmiet River
97	221 to 223	34°02'04"	19°04'03"	690	Riviersonderend
98	224,225	34°02'13"	19°03'43"	650	Riviersonderend
99	226	33°59'57"	19°00'54"	1200	Berg River
100	227	33°59'57"	19°00'54"	1200	Berg River
101	228	33°59'57"	19°00'54"	1200	Berg River
102	229	33°59'57"	19°00'54"	1200	Berg River
103	230	33°59'57"	19°00'54"	1200	Berg River
104	231	34°01'25"	18°59'02"	1370	Riviersonderend
105	232	34°01'25"	18°59'02"	1370	Riviersonderend
106	233	34°02'05"	18°59'24"	1460	Riviersonderend
107	234	34°02'56"	19°00'34"	1060	Palmiet River
108	235 to 238	34°01'45"	19°01'15"	730	Riviersonderend
109	239,240	34°03'19"	19°02'09"	670	Palmiet River
110	241	34°00'56"	18°58'42"	1100	Lourens River
111	242	34°00'56"	18°58'42"	1100	Lourens River
112	243	34°00'57"	18°58'15"	1125	Eerste River
113	244	34°00'57"	18°58'15"	1125	Eerste River
114	245,246	33°56'22"	19°09'36"	560	Riviersonderend
115	247,248	33°56'22"	19°09'36"	560	Riviersonderend

116	249	33°56'49"	19°10'07"	360	Riviersonderend
117	251	33°59'50"	18°53'57"	280	Eerste River
118	252	33°59'50"	18°53'57"	280	Eerste River
119	253,254	33°59'39"	18°53'42"	280	Eerste River
120	255	34°01'25"	18°57'54"	410	Lourens River
121	256	34°01'25"	18°57'54"	410	Lourens River
122	257	34°01'35"	18°57'37"	390	Lourens River
123	258	33°56'20"	19°09'32"	390	Lourens River

Transects outside the Hottentots Holland Mountains

Transect no.	Relevés	Latitude	Longitude	Altitude	River Catchment
125	259	33°40'35"	19°05'36"		Wit River
126	260	33°41'08"	19°05'50"		Wit River
127	261	33°41'08"	19°05'50"		Wit River
128	262	33°41'08"	19°06'08"		Wit River
129	263	34°07'59"	19°09'22"	700	Riviersonderend
130	264	34°07'27"	19°06'17"	1020	Riviersonderend
131	265	33°00'00"	19°00'00"		Breede River
132	266	33°00'00"	19°00'00"		Breede River
133	267	34°23'07"	19°41'24"		Klein River

Appendix E: Vegetation Tables

Legend:

Codes for River name	L:	Lourens River
	B:	Berg River
	R:	Riviersonderend River
	E:	Eerste River
	P:	Palmiet River
	W:	Wit River
	Br:	tributaries of Breede River

The plant name is followed by two codes. The first of these indicates the vegetation types for which a species is differential.

d1.2	differential for community 1.2
d1.2-4	differential for communities 1.2 to 1.4
d1	differential for community group 1

The second code indicates the stratum in which it is found. Sometimes more than one stratum is indicated.

t3	tree layer
s1	tall shrub layer (2 – 6 m)
s2	low shrub layer (0.5 – 2 m)
hl	herb layer
ml	moss layer
jl	juveniles

Table 1: High altitude Fens and Mires

Community Group S1: Fens
- Ass. 1.1: Protea lacticolor-Hippia pilosa Tall Shrubland
- Ass. 1.2: Elegia thyrsifera-Centella laevis Closed Herbland
- Ass. 1.3: Anthochorto crinalis-Elegietum intermediae
- Ass. 1.4: Ficinio argyropae-Epischoenetum villosi
- Ass. 1.5: Restio bifurcus-Anthochortus crinalis Short Restioland

Community Group S2: Restio marshlands
- Ass. 2.1: Platycaulos depauperatus Short Herbland
- Ass. 2.2: Erica autumnalis-Restio purpurascens Tall Restioland
- Ass. 2.3: Grubbia rosmarinifolia-Restio aff. versatilis Closed Shrubland
- Ass. 2.4: Tetrario capillaceae-Restietum subtilis

Community type			1.1		1.2		1.3				1.4						1.5				2.1			2.2		2.3			2.4								
Relevé number			111	233	241	242	227	228	229	230	226	231	232	243	244	259	188	201	202	203	135	136	165	131	134	124	127	128	86	87	123	129	163	164	189	234	262
Transect no			34	106	110	111	100	101	102	103	99	104	105	112	113	125	77	87	88	89	48	49	64	46	47	42	44	44	24	25	42	45	62	63	78	107	128
River name			R	R	L	L	B	B	B	B	B	R	R	E	E	W	R	E	E	E	P	P	P	P	P	P	P	P	P	P	P	P	P	P	R	P	W
Environment			slopes				flat areas																														
			shale		TMS		poorly drained														transition					well-drained											
Protea lacticolor	d1.1	s1	3	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Restio perplexus	d1.1	hl	a	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ursinia eckloniana	d1.2	hl	.	.	1	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Centella eriantha	d1.2	hl	.	.	a	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Othonna quinquedentata	d1.2	hl	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carpacoce spermacocea	d1.2	hl	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Elegia intermedia	d1.3	hl	.	.	.	.	5	5	5	5	1	a	a	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ficinia argyropa	d1.4	hl	.	.	.	.	.	.	.	.	1	1	3	1	a	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carpha glomerata	d1.4	hl	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio umbellatus	d1.1-2,4	hl	1	a	b	a	.	.	.	.	a	1	a	r	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Anthoxanthum tongo	d1.1-2,4	hl	1	+	.	.	.	.	.	.	1	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Restio bifurcus	d1.5	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Prionium serratum	d1.5	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gladiolus carneus	d1.5	hl	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.
Anthochortus cf. graminifolius	d1.5	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stoebe plumosa	d1	hl	3	b	.	.	.	.	.	.	1	.	+	.	.	+	.	+	1	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Cliffortia tricuspidata	d1	hl	.	.	.	.	.	.	.	+	.	a	a	.	+	b	.	.	b	4	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Elegia grandis	d1	hl	.	.	.	.	.	.	.	.	.	.	.	1	a	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Platycaulos depauperatus	d2.1	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	5	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pentameris hirtiglumis	d2.1	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	+	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.
Kniphofia tabularis	d2.1	hl	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Erica autumnalis	d2.2	hl	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	3	1	.	.	.	.	.	.	.	.	.	.	.	.
Cliffortia ovalis	d2.2	hl	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Aristea bakeri	d2.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Elegia racemosa	d2.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.
Asteraceae species	d2.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Hippia pilosa	d1.1-2, d2.2	hl	m	3	b	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	r	.	.	.	.	.	.	.	.	.	.	.	.
Elegia thyrsifera	d1.1-2, d2.2	hl	4	.	5	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	b	.	.	1	.	.	.	.	.	.	a	.	.
Tetraria cuspidata	d1.1-2, d2.2	hl	1	.	a	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio crispus	d2.1-2	hl	+	.	.	.	+	.	+	+	a	1	1	.	.	1	+	+	a	a	1	1	m	1	1	.	.	.	.	.	.	.	.	.	.	.	+
Restio bifidus	d2.3	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	m	.	.	.	.	.	+	.	.	.
Brunia alopecuroides	d2.3	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	.	.	.	1	.	.	.	.	.
Erica lutea	d2.3	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.
Erica sitiens	d2.3	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+	.	.	.	.	.	.	.	.	.
Adenandra acuta	d2.3	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.
Erica coccinea	d2.3	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	+	.	+	.	.	.	.	.	.	.	.	.
Gnidia galpinii	d2.3	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.
Stoebe cinerea	d2.3	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.
Clutia polygonoides	d2.3	hl,jl	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	1	.	+	.	.	.	.	.	.	.	.	.
Chrysithrix junciformis	d2.4	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	.	.	.	.	.	.	.	m	.	.	1	.	.	m	+	.
Chrysithrix dodii	d2.4	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	m	.	.	.	.	.	1	.	1
Grubbia rosmarinifolia	d2.3-4	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	4	+	a	4	.	+	4	b	+	+	r	.
Berzelia squarrosa	d2.3-4	hl	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	5	.	.	+	1	.	.	.	+	+
Erica fastigiata	d2.3-4	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	+	r	+	.	.	.	1	.	.	.	+	.
Restio burchellii	d2.3-4	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	1	.	.	1	.	.	1	a	.
Erica curviflora	d2.3-4	s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	1	+	.	.	.
Restio subtilis	d2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	4	a	b	.	.	3	.	.	5	5	m	3	m	4	4	5	.
Restio purpurascens	d2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	+	3	+	4	5	4	1	3	.	3	1	.	+	1	.	.	.
Restio aff. versatilis	d2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	.	.	.	.	m	a	a	m	.	1	.	1	.	.	a	.
Chondropetalum deustum	d2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	m	1	1	.	m	.	.	.	1	+	a	m	.	.
Erica hispidula	d2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	b	a	1	.	+	.	+	.	+	.	.	.	.	1
Elegia neesii	d2	hl	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	.	1	1	.	m	.	m	.	.	.	.	.	b	.	.	.
Restio ejuncidus	d2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	a	.	.	.	m	.	.	.	.	.	.
Sphagnum capense	d2	ml	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	m	.	.	.	.	.	.	.	.	.	.	m	.	m	.	.
Chondropetalum mucronatun	d1.5	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	4	.	.	3	.	4	1	.	a	1	+	b	m	.	3	3	a	a	3	.
Tetraria capillacea	d1.5	hl	.	.	.	.	.	.	.	.	.	.	.	b	.	.	+	1	.	.	m	.	1	m	.	1	.	.	m	+	1	a	a	.	1	m	.
Restio corneolus	d1.5	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	1	.	.	.	.	.	1	.	1	1	m	.	+	.	1	1	.	.
Epischoenus villosus	d1, d2	hl	+	a	.	.	m	m	1	1	3	4	3	4	4	m	a	m	4	b	m	1	m	.	.	m	.	.	a	m	.	+	a	m	a	.	.
Anthochortus crinalis	d1, d2	hl	.	.	.	1	a	3	b	b	5	m	a	3	3	4	4	3	3	4	.	.	.	a	a	m	.	.	m	m	m	.	4	.	3	.	5

Ehrharta setacea s. setacea	d1, d2	hl	.	+	.	.	.	.	.	.	m	1	3	m	.	b	m	a	b	a	m	a	m	a	+	m	.	.	m	1	.	+	.	1	m	.	1
Erica intervallaris	d1, d2	hl	.	.	.	.	.	.	.	.	.	.	.	b	1	1	.	b	.	.	a	+	a	a	.	.	+	.	a	.	.	a	a	3	1	a	1
Ursinia caledonica	d1, d2	hl	.	.	.	.	.	.	.	.	.	.	.	b	4	.	+	a	.	.	.	1	.	m	+	1	.	.	b	3	.	a	.	.	1	1	.
Ehrharta rehmannii		hl	1	1	.	1	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	a	.	1	1	.	.	.	.	.		.	.	1	.
Drosera aliciae		hl	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	+	.	.	.	.	+	1	.	.	.	.	.	+	+	.	.	.
Gnidia oppositifolia		hl	.	.	1	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	+	.	.	1
Oxalis truncatula		hl	1	+	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	r	+	r	.	1	.	.	.	.	.	.	.	.	.
Erica curviflora		hl	.	.	+	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	.	.	.
Restio echinatus		hl	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	1	.	.	m	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.	m
Erica calycina		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	1	.	.	r	.	.	.	.	.	.	.	.	.	.	.
Campylopus stenopelma		ml	.	.	.	.	1	.	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	.	a	m	.	.	.	.	.	.	.
Elegia spathacea		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+
Nebelia fragarioides		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	1	.	.	.	.	.	+	.	.	.	.	.
Erica triflora		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Askidiosperma esterhuyseniae		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	.	.	.
Wahlenbergia procumbens		hl	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Epischoenus complanatus		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Restio pedicellatus		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Protea cynaroides		s2	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Staberoha vaginata		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.
Villarsia capensis		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.
Tetraria pillansii		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ursinia dentata		hl	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Todea barbara		hl	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Cliffortia eriocephalina		hl	1	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Euryops abrotanifolius		hl	.	1	.	.	.	.	.	.	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Disa tripetaloides		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	m	.	.	.	.	.	.

Rare species and the relevés in which they occur with their cover values between brackets:

Agathosma pentachotoma 262(2a), Askidiosperma chartaceum 262(2a), Berzelia lanuginosa 262(+), Blechnum tabulare 131(+), Bobartia gladiata 259(+), Chironia decumbens 262(r), Cliffortia graminea 165(1), Cliffortia ruscifolia 233(2a), Corymbium congestum 131(1), Corymbium cymosum 131(+), Dicranoloma billardieri 123(2a), Edmondia pinifolia 131(+), Ehrharta ramosa 259(1), Ehrharta setacea subsp. uniflora 111(2m), Epischoenus gracilis 262(2a), Erica longifolia 262(r), Euchaetis glabra 201(1), Felicia cymbalariae 111(1), Ficinia cf. involuta 259(3), Ficinia species 233(1), Fissidens plumosus 111(2m), Geissorhiza umbrosa 131(+), Helichrysum cymosum 233(2a), Hymenophyllum peltatum 131(2m), Hypochaeris radicata 259(+), Ischyrolepis triflora 262(1), Isolepis digitata 135(2m), Lobelia jasionoides 134(+), Lycopodiella caroliniana 123(+), Osmitopsis afra 241(+), Oxalis nidulans 202(+), Pentameris thuarii 233(2b), Pentaschistis pallida 135(+), Psoralea aculeata 241(2a), Raspalia virgata 136(2a), Restio bifarius 131(+), Restio intermedius 128(3), Restio obscurus 262(1), Schizaea tenella 127(1), Senecio coleophyllus 134(2a), Senecio pubigerus 233(1), Senecio rigidus cernua 234(1), Kogelbergia verticillata 127(+), Stoebe plumosa-jl 188(r), Tetraria thermalis 124(r), Utricularia bisquamata 163(+), Watsonia borbonica

Table 2: Aquatic communities

Community Group 1: Aquatic communities
Ass. 1.1: Fontinali antipyreticae-Isolepidetum digitatae
Ass. 1.2: Pentaschistido pallidae-Isolepidetum digiatatae

Community type			1.1																										1.2					
Relevé number			1	21	24	33	48	96	182	221	235	8	12	17	29	40	56	60	71	75	178	4	65	88	52	44	92	100	130	132	250	167	204	205
Transect no			1	6	7	9	12	28	75	97	108	3	4	5	8	10	14	15	19	20	22	7	26	16	23	11	17	29	46	47	50	66	90	90
River name			P	R	R	R	E	E	P	R	R	R	R	R	B	E	R	R	P	P	B	R	R	R	B	E	E	B	P	P	R	B	B	B
Environment			Boulders, water depth > 10 cm																										Bedrock					
Pentaschistis pallida	d1.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	m	+	a	3	3
Symphyogyna podophylla	d1.2	ml	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	1	b
Todea barbara	d1.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	a	.	.
Brachylaena neriifolia	d1.2	jl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+
Cunonia capensis	d1.2	jl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	r
Campylopus pyriformis	d1.2	ml	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	b
Fissidens glaucescens	d1.2	ml	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	b
Juncus lomatophyllus	d1.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	1
Isolepis digitata	d1	hl	m	m	m	1	m	m	1	b	4	4	a	m	m	b	a	3	3	3	m	m	b	m	+	.	.	.	.	m	m	a	4	3
Fontinalis antipyretica	d1	ml	.	.	.	.	.	.	.	.	.	m	m	m	m	b	m	a	m	m	m	a	3	a	a	m	m	1	a	b	.	.	a	a

Rare species with the relevés in which they occur and their abundance in brackets

Blechnum capense 205(+), Brachylaena neriifolia 204(r), Campylopus stenopelma 130(2m), Cliffortia polygonifolia 167(r), Disa tripetaloides 205(+), Hymenophyllum peltatum 167(2m), Ilex mitis 205(r), Ischyrolepis subverticillata 205(+), Kiggelaria africana 167(+), Osmitopsis pinnatifida 205(+), Prionium serratum 12(2m), Pyrrhobryum vallis-gratae 167(2b), Restio purpurascens 130(+), Sematophyllum dregei 130(2m), Utricularia bisquamata 205(+)

Table 3: Wet Bank Zones (Community Groups 2, 3 and 4)

Community Group 2: Pioneer Wet Banks
- Ass. 2.1: Symphyogyna podophylla-Sematophyllum dregei Moss Community
- Ass. 2.2: Brachylaena neriifolia-Metrosideros angustifolia Pioneer Community

Community Group 3: Erosion Wet Banks
- Ass. 3.1: Symphyogyno podophyllae-Schizietum tenellae
- Ass. 3.2: Sphagno capensis-Disetum tripetaloidis
- Ass. 3.3: Pseudobaeckeo africanae-Prionietum serrati

Community Group 4: Deposition Wet Banks
- Ass. 4.1: Wimmerello bifidae-Juncetum lomatophylli

Community type			2.1	2.2	3.1	3.2	3.3	4.1
Relevé number			16 34 53 66 93 117 141 41 69 137 139 268 269	32 212 239 245 247	39 45 49 63 133 145	5 9 25 57 72 76 81 154	2 6 13 26 58 61 79 89 152 155 156 157 183 185 186 215 218 222 224 236	146 147 159 161 195 249
Transect no			5A 9 13 17 27 39 52 10B 18 50 51 65 72	9 94 109 114 115	10A 11 12 16 47 53	2 3 7 14 19 20 22 58	1 2 4 7 14 15 21 26 57 58 59 59 75 76 76 95 96 97 98 108	54 54 60 61 83 116
River name			R R B E E E E E E R R B B	R R P R R	E E E R P E	R R R R P P P R	P R R R R R P R R R R R P P P P P R R R	R R R R L R
Environment			Erosion-dominated, no substrate, pioneer: Shady conditions	Erosion-dominated, no substrate, pioneer: Light conditions	Erosion-dominated, poor substrate: High inundation frequency: Shade	Erosion-dominated, poor substrate: High inundation frequency: Light	Erosion-dominated, poor substrate: Higher up the bank, Low inundation frequency	Deposition-dominated
Metrosideros angustifolia	d2.1	s1,s2	. + + . a 3	 3	. . . . . .	. . . .	. . . .	1 . r . . .
Blechnum capense	d2.1	hl,jl	+ . . + + 1 + ...	. . . . +	. . . . . .	. . . .	. . . .	. . r . . .
Brabejum stellatifolium	d2.1	s1,s2	. 1 . . . b	. . . . .	. . . . . .	. . . .	. . . .	. . . . . .
Ehrharta rehmannii	d2.1	hl	. . . . m 1	. . . . .	. . . . . .	. . . .	. . . .	. 1 . . . .
Dicranella subsubulata	d2.1	ml	. . . m m	. . . . .	. 1	. . . .	. . . .	. . . . . .
Leucoloma sprengelianum	d2.1	ml	. . . . m 1	. . . . .	. . . b . .	. . . .	. . . . m . . .	. . . . . .
Fissidens fasciculatus	d2.1	ml	. . . . m 1	. . . . .	. . . . . .	. . . . . . 1 .	. . . .	. . . . . .
Brachylaena neriifolia	d3.3	s1,s2	a 3 . . + ...	. . . . +	. . . . . .	. . . .	a a . a 3 . r . 3 a . b . . a . + 3 b b	. . . . + .
Tetraria cuspidata	d3.3	hl	m	. . . . .	. . . . . .	. . . .	1 m m . m . . . m m m m . . . m . . m a	. . . . . .
Erica lutea	d3.3	hl	. . . .	. . . . .	. . . . . .	. . . .	. . . . m + 1 a . . + b + . 1 . a . + a	. . . . . .
Erica hispidula	d3.3	hl	. . . .	. . . . .	. . . . . .	. . . .	. 1 + + . . 1 . . . . 1 + . r . . + 1 +	. . . . . .
Penaea cneorum	d3.3	s2,hl,jl	. . . .	. . . . .	. . . . . .	. . . . +	. a . 1 . + . . . b . a . + a . 1 . 1 1	. . . . . .
Grubbia rosmarinifolia	d3.3	hl,s2	. . . .	. . . . .	. . . . . .	. . . .	. 3 . a . . . . . . + . . + . + . 1 + +	. . . . . .
Berzelia squarrosa	d3.3	hl,s2	. . . .	. . . . .	. . . . . .	. . . .	. . . 1 + . + . . . r . . . . r . + . +	. . . . . .
Pentaschistis pallida	d3.3	hl	. . . . + . .	. . . . .	. . . 1 . .	. . . .	. . . . + a . a . . 1 1 . . . . a	. . . . . .
Askidiosperma esterhuysiana	d3.3	hl	. . . .	. . . . .	. . . . . .	. . . .	m . . m . . . . 3 . . . . . + a .	. . . . . .
Agathosma crenulata	d3.3	hl	. . . .	. . . . .	. . . . . .	. . . .	. + ... 1 + . + ... + .	. . . . . .
Erica curvirostris	d3.3	hl	. . . .	. . . . .	. . . . . .	. . . .	. . + + . . r . . . . + ... +	. . . . . .
Podalyria calyptrata	d3.3	s1	. . . .	. . . . .	. . . . . .	. . . .	. . . . a . . . . . . 3 . . b . . a . .	. . . . . .
Cassytha ciliolata	d3.3	-	. . . .	. . . . .	. . . . . .	. . . .	+ m . . . . 1 . . m . .	. . . . . r
Restio bifarius	d3.3	hl	. . . .	. . . . .	. . . . . .	. . . .	. . . a a . . . . 1 . . 1	. . . . . .
Erica curviflora	d3.3	hl	. . . .	. . . . +	. . . . . .	. . . .	. . . 1 . . . . + + . . 1	. . . . . .
Brunia alopecuroides	d3.3	hl,s2	. . . .	. . . . .	. . . . . .	. . . . + . . .	. . . + ... r . . . r . . . +	. . . . . r
Psoralea pinnata	d3.3	s1	. . . .	. . . . .	. . . . . .	. . . .	. . . . a . + . . r	. . . . . .
Chondropetalum deustum	d3.3	hl	. . . .	. . . . .	. . . . . .	. . . .	. . . . 1 . 1 . . . . m	. . . . . .
Restio bifidus	d3.3	hl	. . . .	. . . . .	. . . . . .	. . . .	. m . . . . + . . a	. . . . . .
Prionium serratum	d3.2-3	hl	. b . . 1	. . a . 1	. . . . . .	a 1 . . . . + a	4 a a 5 a 1 b . a a 3 a 3 1 3 4 a 3 a b	. . . . . r
Drosera capensis	d3.2-3	hl	. . . .	. r . . .	. . . . . .	a . 1 . 1 1 r 1	1 . 1 . . + + . b 1 1 . . 1 . . + . 1 +	. . . r . .
Restio purpurascens	d3.2-3	hl	. . . .	. . r . .	. . . . . .	. . . . b b + a	m 3 . . . + m . m 3 . + + 1 1 . 1 1 1 b	. . . . . .
Pseudobaeckea africana	d3.2-3	s1,s2	+	. . . . .	. . . . . .	. a . a 1 a + .	a . + 1 1 . . . 1 1 . . . . + a a . . +	. . . . . .
Lycopodiella caroliniana	d3.2-3	hl	. . . .	. . . . .	. . . . . .	. + 1 + . . . m	. m 1 . . . . + 1 1 . . . . . . m . 1 1	. . . . . .
Pentaschistis curvifolia	d3.2-3	hl	. . . .	. . . . .	. . . . . .	. . . . 1 . + .	+ . 1 . . . m . . . 1 1 . . . . m	. . . . . .
Erica intervallaris	d3.2-3	hl	. . . .	. . . . .	. . . . . .	. . . . . 1 . 1	. 3 . . . . . . 3 3	. . . . . .
Nevillea obtusissima	d3.2-3	hl	. . . .	. . . . .	. . . . . .	. . . . m 3 . .	. a 1	. . . . . .

Isolepis digitata	d3.2-3	hl	. . . .	. . . . a . . . . a . m 3	. . . . . .
Chondropetalum mucronatum	d3.2-3	hl	. . . .	. . . . + ... 1 . . . . +	. . . . . .
Schizaea tenella	d3	hl	+ . . . . + ...	m + m m m 3 m m . + + . . 1 m m m . . + 1 m 1 . 1 . 1 1 . 1 1 . + 1	. . . . . .
Disa tripetaloides	d3	hl	. . . .	. . . m a . b 3 1 a a a . . a . 1 1 . + + + b . 1 . . . 1 a m 1 1 +	. . . . . .
Sphagnum capense	d3	ml	. . . . a	. . . . m . b a . . m 5 . m . . m . . m 1 a a . 1 . 1 3 . + m . 1 .	+ . . . . .
Campylopus stenopelma	d3	ml	. m	. . m b . b b . . . a . 1 . 1 . m . . m 1 a a . m . 1 3	. . . . . .
Utricularia bisquamata	d3	hl	. . . .	. . . . . 1 . . . . + ... + ...	. 1 . . . .
Juncus lomatophyllus	d4	hl	. . . . . r . r	. . . . + ...	a 1 4 1 1 3
Juncus capensis	d4	hl	. . . .	. . . .	1 m . 1 1 1
Pentameris thuarii	d4	hl	. . . .	. . . .	. 1 . + + +
Calopsis paniculata	d4	hl	. . . . . + ...	. . . .	1 + . + . a
Isolepis prolifer	d4	hl	. . . .	. . . .	1 . a 1 . +
Pennisetum macrourum	d4	hl	. . . . a 1	. . . . m . . . . r	3 a . . . 3
Paspalum urvillei	d4	hl	. . . .	. . . .	. + . + r
Morella serrata	d4	jl,s2	. . . .	. . . . a . . . . 1 b	1 + + r . 1
Wimmerella bifida	d4	hl	. . . .	. . . .	1 1 + . . m
Helichrysum cymosum	d4	hl	. . . .	. . . .	. 1 . . + .
Laurembergia repens	d4	hl	. . . .	. . . .	. . 1 . . +
Plecostachys polifolia	d4	hl	. . . .	. . . .	. + . . . 1
Symphyogyna podophylla	d2.1	ml	. 1 1 . 1 . . a . b . m 1	. . m b m b . . . . m . . . . a	. . 1 1 . .
Sematophyllum dregei	d2.1	ml	m . . . . m . a 1	. 1 . b . . . a . m . . . m . . . . a	. . . . . .
Fissidens plumosus	d2.1	ml	. . m . . . . a	b . m . . . . a 1	. . . . . .
Fissidens glaucescens	d2.1	ml	. . . m . . . . m b	. . . . m . a	. . . . . .
Riccardia species	d2.1	ml	. . . . a . . . m	. . . . m	. . . . . .
Brachylaena neriifolia	d2.2	jl	. . . . + . r + .	. . . . r + ... 1 . . . . + ...	. + + . . +
Brabejum stellatifolium	d2.2	jl	. . . . + ...	. . . . + ... r	+ . + . . +
Metrosideros angustifolia	d2.2	jl	+ . . . . 1 1 . 1 .	. . . .	. + . . . 1
Platycaulos callistachyus	d2.2	hl	. . . . + . . 1 a	. . . . 1 . . .	. 1 + . . .
Todea barbara		hl	r . . + + + r r . . a	. + . 1 . . r + ... + . 1 + . . + 1 + . . . 1 . . + . +	. . . . + .
Erica caffra		s1,s2,hl	a . + r 1 + ...	. + + + . 1 . . . . . . r . a a . . . . + 1 1 + ... 1 . . .	. + . + . .
Ischyrolepis subverticillata		hl	1 r . . m	. . . . + ... m . m 1 . b . a + ... 1 1 a	. + ...
Podalyria calyptrata		jl	r . . . . + ... r . . . r	. . . . + ... r . . . . r .	1 1 . . . +
Cunonia capensis		jl	. . . . + . . r .	. 1 . 1 . + . . r . . . . r . . r . . + ...	. . . . . .
Hymenophyllum peltatum		ml	. . . . 1 . . m	. . . b . . . . a	. . . . . .
Gleichenia polypodioides		hl	. + ... +	. . . . 1 . . . . + ...	. . . . . .
Ficinia ramosissima		hl	. . . .	. . . . m . . . . m . .	. + + . . .
Aristea africana		hl	. . . . r	. . . . r . . . . r	. . . . . .
Leucadendron xanthoconus		jl	. . . .	. . . . r	. r . . . r
Campylopus pyriformis		ml	. . . . a	. . . . m	. . 1 . . .

Rare species with the relevés in which they occur and their abundance between brackets:

Acacia mearnsii 146(r), 147(+), Aristea bakeri 16(+), 195(r), Aristea major 157(r), 236 (+), Askidiosperma chartaceum 79(1), 236(2m), Blechnum attenuatum 141(r), Cuscuta nitida 155(2a), 157(2m), Diospyros glabra 239(r), 249(r), Drosera aliciae 6(2b), 133(+), Ehrharta erecta 16(r), 117(1), Elegia thyrsifera 157(+), 215(1), Ficinia distans 145(2a), 212(+), Hypochaeris radicata 32(r), 249(1), Pinus pinaster 186(+), 249(1), Platycaulos cascadensis 185(1), 188(1), Platyhypnidium macowania 61(2m), 69(2m), Schoenoxiphium lanceum 137(+), 141(1), Ursinia scariosa 236(+), 239(r), Villarsia capensis 25(1), 157(+), Agrostis avenacea 161(+), Anthochortus laxiflorus 186(+), Anthoxanthum tongo 147(1), Asparagus rubicundus 195(r), Argyrolobium lanceolatum 93(+), Aristea latifolia 137(+), Berzelia lanuginosa 81(r), Briza maxima 147(+), Carpacoce spermacocea 236(1), Carpha glomerata 93(+), Centella eriantha 236(1), Cliffortia odorata 147(r), Cliffortia pedunculata 5(2m), Cliffortia strobilifera 147(r), Conyza scabrida 93(r), Cyperus denudatus 117(1), Cyperus fastigiatus 195(+), Dicranoloma billardieri 89(2a), Ditrichum species 268(2m), Edmondia pinifolia 58(r), Elegia asperiflora 247(1), Elegia persistens 58(1), Elaphoglossum conforme 61(+), Epischoenus villosus 185(2m), Euryops abrotanifolius 247(r), Felicia hyssopifolia 154(2m), Ficinia nigrescens 81(1), Fissidens marginatus 268(2m), Fumaria muralis 117(+), Gamochaeta subfalcata 195(+), Halleria elliptica 66(+), Heterolepis aliena 81(+), Holothrix villosa 81(1), Hypnum cupressiforme 81(1), Ischyrolepis gaudichaudiana 2(r), Isolepis fluitans 147(1), Juncus cephalotes 147(1), Juncus effusus 146(r), Lycopodium clavatum 247(1), Monopsis lutea 147(1), Oxalis corniculata 195(+), Oxalis lanata 117(+), Oxalis purpurea 117(1), Panicum maximum 159(+), Pelargonium tomentosum 117(1), Penaea mucronata 157(r), Pentaschistis densifolia 147(1), Pentaschistis malouinensis 157(+), Plagiochila species 63(2b), Platylophus trifoliatus 154(+), Plecostachys polifolia 93(r), Psoralea aculeata 236(r), Pteridium aquilinum 195(+), Pyrrhobryum spiniforme 16(2m), Restio burchellii 79(2m), Restio corneolus 224(1), Restio debilis 79(1), Restio intermedius 236(2m), Restio echinatus 236(1), Restio ejuncidus 236(2m), Restio nuwebergensis 79(1), Restio occultus 224(2m), Rubus rigidus 159(r), Senecio pterophorus 195(r), Sphagnum truncatum 137(2b), Staberoha cernua 76(1), Stachys aethiopica 117(+), Struthiola martiana 157(r), Tephrosia capensis 146(r), Capeobolus brevicaulis 157(1), Tetraria bromoides 224(+), Virgilia oroboides 249(r), Wachendorfia thyrsiflora 249(r), Widdringtonia nodiflora 186(+).

Table 4: Ericaceous Fynbos (Community Groups 5 and 6)

Community Group 5: Ericaceous Fynbos
- Ass. 5.1: Ischyrolepis triflora-Protea grandiceps Closed Shrubland
- Ass. 5.2: Nebelia fragarioides-Staberoha cernua Short Closed Shrubland
- Ass. 5.3: Erico longifoliae-Tetrarietum crassae
- Ass. 5.4: Cliffortio atratae-Restionetum purpurascentis
  - Subass. 5.4a: typicum
  - Subass. 5.4b: centelletosum erianthae
- Ass. 5.5: Restio purpurascenti-Cliffortietum hirsutae

Community Group 6: Transitional Fynbos
- Ass. 6.1: Elegia capensis-Cliffortia hirsuta Tall Closed Shrubland
- Ass. 6.2: Muraltio heisteriae-Ericetum pineae
- Ass. 6.3: Haplocarpha lanata-Euryops abrotanifolius Closed Shrubland

Community type			5.1		5.2				5.3							5.4a							
Relevé number			190	191	73	74	77	78	125	126	184	216	219	237	263	14	15	27	28	59	80	82	153
Transect no			79	80	19	19	20	20	43	43	75	95	96	108	129	4	4	7	7	14	21	22	57
River name			L	L	P	P	P	P	P	P	P	P	P	R	R	R	R	R	R	R	P	P	R
Environment			Southern, rainfall summer < 9.5%													Central, r							
			steep slope		river bank											no s							
					MAP < 1500				MAP >2000							xeric, well-draine							
Protea grandiceps	d5.1	s2	1	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cliffortia integerrima	d5.1	hl	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Struthiola martiana	d5.1	hl	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Willdenowia sulcata	d5.1	hl	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thamnochortus lucens	d5.1	hl	+	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Ischyrolepis triflora	d5.1	hl	a	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Watsonia borbonica	d5.1	hl	1	1	.	.	.	.	.	.	r	.	.	.	r	.	.	.	.	.	.	.	.
Psoralea asarina	d5.1	hl	1	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Geissorhiza species	d5.1	hl	r	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tetraria capillacea	d5.2	hl	.	.	m	m	m	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leucadendron xanthoconus	d5.2	hl	.	.	1	+	+	1	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Nebelia fragarioides	d5.2	hl	.	.	+	+	+	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.
Chironia jasminoides	d5.2	hl	.	.	+	+	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Nevillea obtusissima	d5.2	hl	.	.	3	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pentaschistis species	d5.2	hl	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Staberoha cernua	d5.2	hl	.	.	a	.	1	.	.	.	.	.	.	.	.	.	.	m	.	.	.	.	.
Tetraria crassa	d5.3	hl	.	.	.	.	.	.	a	m	+	m	.	1	1	.	.	.	.	.	.	.	.
Erica plukenetii	d5.3	hl	.	.	.	.	.	.	.	r	+	r	r	r	.	.	.	.	.	.	.	.	.
Staberoha vaginata	d5.3	hl	.	.	.	.	.	.	1	a	.	1	.	.	1	.	.	.	.	.	.	.	.
Restio aff. versatilis	d5.3	hl	.	.	.	.	.	.	a	3	.	.	.	.	b	.	.	.	.	.	.	.	.
Pentaschistis malouinensis	d5.3	hl	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	.	.	.	.	.
Erica sessiliflora	d5.3	hl	.	.	.	.	.	.	.	.	r	+	.	.	+	.	1	.	.	.	.	.	.
Gnidia galpinii	d5.3	hl	.	a	.	.	.	.	.	1	+	.	r	.	.	.	.	.	.	.	.	.	.
Tetraria pillansii	d5.3	hl	.	.	.	.	.	.	1	a	1	.	.	.	.	.	.	.	.	.	.	.	.
Restio subtilis	d5.3	hl	.	.	.	.	.	.	a	.	.	m	.	.	.	.	.	.	.	.	.	.	.
Erica fastigiata	d5.3	hl	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Grubbia rosmarinifolia	d5.3	hl	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Podalyria montana	d5.3	s2	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Restio corneolus	d5.1-3	hl	m	1	.	a	1	.	a	m	1	1	1	+	.	.	.	.	.	1	.	.	.

Brunia alopecuroides	d5.1-3	hl	.	.	+	3	4	4	.	+	+	+	r	.	a	.	.	.	.	.	.	.	.
Restio bifidus	d5.1-3	hl	.	.	m	.	a	.	m	1	+	m	1	1	b	.	.	.	.	.	.	.	.
Restio bifarius	d5.4a	hl	.	a	.	.	.	.	.	r	.	r	a	.	.	.	.	a	a	a	.	.	.
Restio burchellii	d5.4a	hl	1	.	.	.	.	.	m	1	.	m	.	.	.	.	.	m	a	.	m	1	.
Ceratocaryum argenteum	d5.4a	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.
Pentameris macrocalycina	d5.4a	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.
Pseudobaeckea africana	d5.4a	s2	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	r	+
Carpacoce spermacocea	d5.4b	hl	.	+	.	b	+	.	.	.	1	.	.	+	.	.	.	.	.	.	.	.	.
Centella eriantha	d5.4b	hl	.	.	+	.	.	.	.	.	1	.	.	r	.	.	.	.	.	.	.	.	.
Ficinia oligantha	d5.4b	hl	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Cliffortia atrata	d5.4	hl	1	3	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	1	1	1	.
Askidiosperma esterhuyseniae	d5.4	hl	.	.	.	.	.	.	.	.	.	+	.	.	.	3	m	m	1	.	.	.	m
Coleonema juniperinum	d5.4	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	+	.
Chrysithrix capensis	d5.4	hl	.	.	.	.	.	.	.	.	.	.	.	1	.	.	m	.	1	.	.	.	.
Erica lutea	d5.3-4	hl	.	.	.	.	.	.	1	1	1	a	a	b	.	1	.	a	.	3	1	1	.
Capeobolus brevicaulis	d5.3-4	hl	1	.	.	.	.	.	1	+	a	+	.	1	.	.	.	.	1	.	.	.	.
Elegia neesii	d5.3-4	hl	.	.	.	.	.	.	+	1	.	1	1	.	.	.	m	.	.	.	.	.	.
Restio intermedius	d5.3-4	hl	.	.	.	.	.	.	.	.	+	.	.	1	.	.	.	.	.	3	.	.	.
Erica tegulifolia	d5.3-4	hl	.	.	.	r	.	.	.	+	.	+	.	.	.	.	.	+	.	.	r	.	.
Elegia grandis	d5.3-4	hl	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	1	.	.	.	.	.
Tetraria thermalis	d5.3-4	hl	.	.	.	.	.	.	.	a	.	.	.	.	r	.	.	.	.	.	.	.	.
Stoebe incana	d5.3-4	hl	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.
Metalasia densa	d5.3-4	hl	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Erica longifolia		hl	a	1	.	.	.	.	.	r	.	1	+	r	a	.	.	.	.	.	r	.	.
Chondropetalum deustum		hl	m	.	.	.	m	.	1	.	a	m	m	1	m	.	.	1	.	.	m	.	.
Pentaschistis curvifolia		hl	1	1	.	.	.	.	.	.	1	a	+	.	.	.	.	.	.	.	m	.	.
Restio occultus		hl	.	.	1	.	1	+	.	1	.	.	.	.	1	.	.	m	m	.	.	1	.
Elegia spathacea		hl	m	.	a	.	1	.	.	+	.	1	.	.	a	.	.	+	.	.	.	.	.
Elegia racemosa		hl	a	m	.	.	.	.	.	.	+	.	.	.	r	.	.	.	.	.	.	.	.
Corymbium cymosum		hl	1	1	.	.	.	.	.	.	1	1	.	.	.	.	.	.	r	.	r	1	.
Erica curviflora	d5.5	hl	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.
Elegia thyrsifera	d5.5	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Neesenbeckia punctoria	d5.5	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Disa tripetaloides	d5.5	hl	.	.	.	.	.	.	a	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Schizaea tenella	d5.5	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brunia alopecuroides		s2	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	+	+	+	.	.	.
Sympieza labialis		hl	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	1	.	.	.	.
Ficinia ramosissima		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	m	.	.	.	+
Restio purpurascens	d5	hl	m	a	m	+	a	1	a	m	a	m	1	1	.	m	m	1	1	3	.	1	4
Berzelia squarrosa	d5	hl	a	a	.	b	+	.	+	1	+	+	1	1	.	.	3	.	.	+	+	.	.
Penaea cneorum	d5	s2	.	.	.	.	.	.	.	+	1	a	1	a	.	4	.	1	1	b	r	.	1
Erica equisetifolia	d5	hl	.	.	.	1	.	.	.	.	+	1	1	.	.	1	.	.	.	.	.	.	.
Chondropetalum mucronatum	d5	hl	.	.	+	b	m	3	a	.	+	1	1	.	+	.	1	+	.	.	.	.	.
Erica intervallaris	d5	hl	.	.	a	b	3	3	+	.	.	.	.	.	.	.	+	+	.	.	.	.	3
Villarsia capensis	d5	hl	.	.	.	1	.	.	1	.	.	.	.	1	.	.	.	1	+	.	.	.	.
Gleichenia polypodioides	d5	hl	.	.	.	.	.	.	.	.	m	.	+	.	+	.	.	.	.	.	.	.	1
Drosera aliciae	d5	hl	.	.	.	.	1	.	.	.	m	.	.	.	+	.	.	.	.	.	.	.	+
Prionium serratum	d5	hl	1	+	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.
Epischoenus villosus	d5	hl	1	1	.	.	.	.	m	.	.	.	.	m	.	.	.	.	.	.	.	.	.
Psoralea pinnata	d5	s1	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.
Grubbia rosmarinifolia	d5	s2	.	.	.	.	.	.	.	.	.	.	+	.	.	1	.	.	.	.	.	.	4
Psoralea aff. fleta	d6.1	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Elegia capensis	d6.1	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1

Cliffortia hirsuta	d5.5, d6.1	hl	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.	.	.	.	.	.	.
Brabejum stellatifolium	d6.2	s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cliffortia grandifolia	d6.2	jl,s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Liparia capitata	d6.2	s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hakea sericea	d6.2	s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Erica pinea	d6.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Restio dispar	d6.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Elegia asperiflora	d6.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pelargonium patulum	d6.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyperaceae spec.	d6.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Bobartia indica	d6.2	hl	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Erica nudiflora	d6.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Penaea mucronata	d6.2	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cassine schinoides	d6.3	t3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Haplocarpha lanata	d6.3	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cliffortia ruscifolia	d6.3	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helichrysum cymosum	d6.3	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thesium strictum	d6.3	s2	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	r	.	.
Widdringtonia nodiflora	d6.3	t3,s1,s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Gibbaria ilicifolia	d5.1, d6.3	hl	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Othonna quinquedentata	d5.1, d6.3	hl	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Galium tomentosum	d5.1, d6.3	hl	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Metrosideros angustifolia		s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Muraltia heisteria		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Platycaulos callistachyus		hl	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.
Stoebe cinerea		hl	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.
Diospyros glabra		s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Ficinia trichodes		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pteridium aquilinum		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cannomois virgata		hl	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Cliffortia polygonifolia		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tetraria cuspidata	d5, d6	hl	+	1	.	.	1	.	.	.	1	m	1	.	.	.	m	m	.	a	1	.	m
Leucadendron xanthoconus	d5, d6	s2	.	.	.	.	.	.	.	.	+	+	a	.	.	.	.	4	.	.	.	.	.
Metalasia cephalotes	d5, d6	hl	1	+	1	.	.	.	.	.	.	+	.	+	.	.	.	.	+	1	.	+	.
Tetraria bromoides	d5, d6	hl	.	.	.	.	.	.	.	.	.	1	+	.	.	.	m	1	.	1	1	r	.
Euryops abrotanifolius	d5, d6	hl	.	.	.	.	.	.	.	.	+	r	.	.	.	.	.	.	.	.	.	+	.
Erica curvirostris	d5, d6	hl	1	+	.	.	.	.	.	.	1	1	1	1	.	.	.	.	+	.	+	.	.
Helichrysum felinum	d5, d6	hl	+	r	.	.	.	.	.	.	+	.	1	.	.	.	+	.	.	1	.	.	.
Restio perplexus	d5, d6	hl	.	.	.	m	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Erica hispidula		s2,hl	m	3	1	m	1	.	+	1	a	1	+	1	a	1	a	a	1	4	1	1	.
Cassytha ciliolata		-	.	.	1	.	1	+	.	.	1	m	1	1	+	1	.	.	+	m	.	r	1
Aristea major		hl	+	1	.	+	.	.	.	+	+	.	.	1	.	.	1	.	.	1	.	.	.
Ischyrolepis subverticillata		hl	.	.	m	.	.	.	.	.	1	a	a	b	.	4	4	+	a	m	m	m	.
Ehrharta rehmannii		hl	m	1	.	.	.	.	1	.	1	1	.	.	+	.	+	.	.	.	.	.	.
Brachylaena neriifolia		s2	.	.	.	.	+	.	.	.	4	b	3	4	.	1	.	.	.	.	b	a	a
Agathosma crenulata		hl,s2	.	+	.	.	.	.	.	.	r	.	.	+	.	+	a	.	.	1	.	.	1
Podalyria calyptrata		s1	.	.	.	.	.	.	.	.	.	.	.	.	.	b	.	+	.	.	.	.	r
Struthiola myrsinites		hl	.	.	1	.	+	.	.	.	.	+	.	r	.	.	.	.	.	.	r	.	.
Stoebe plumosa		hl	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.
Diospyros glabra		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.
Pennisetum macrourum		hl	.	.	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Centella macrocarpa		hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Osmitopsis afra		hl	.	+	.	.	.	.	.	.	+	.	.	1	.	.	.	.	.	.	.	.	.
Asteraceae spec.		hl	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1	.	.	.
Berzelia lanuginosa		s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Widdringtonia nodiflora		jl	.	.	.	.	.	.	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.

Anthospermum galioides	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Oxalis truncatula	hl	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.
Tritoniopsis lata	hl	r	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.
Protea cynaroides	hl,s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Psoralea aculeata	s2	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Cliffortia complanata	hl	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.
Hypodiscus aristatus	hl	a	.	.	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	.	.	.
Askidiosperma chartaceum	hl	.	.	.	.	.	.	.	.	+	.	.	a	.	.	.	.	.	.	.	.	.
Restio egregius	hl	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.
Pentaschistis pallida	hl	1	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.
Bobartia gladiata	hl	.	+	.	.	.	.	.	.	1	.	.	.	+	.	.	+	.	.	.	.	.
Clutia polygonoides	hl	r	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.
Cunonia capensis	jl	.	.	.	.	.	.	.	.	1	.	r	.	.	.	.	.	.	.	.	.	.
Podalyria calyptrata	jl	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.
Protea repens	h1,s2	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	a	.
Empleurum unicapsulare	s2	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Restio echinatus	hl	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	m	.	.	.	.	.
Restio debilis	hl	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	m	.	.
Phylica ericoides	hl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Phaenocoma prolifera	hl	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.
Tritoniopsis dodii	hl	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	+	r	.
Cullumia setosa	hl	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pentaschistis holciformis	hl	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	+	.
Pentameris thuarii	hl	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.
Anaxeton asperum	hl	.	1	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Aristea bakeri	hl	.	.	.	.	1	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.
Centella difformis	hl	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Erica caffra	hl,s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Rare species with the relevés in which they occur and their abundance between brackets:

Cliffortia dodecandra 84(1), 85(+), Drosera glabripes 158(+), 220(+), Elegia persistens 27(1), 28(1), Erica imbricata 85(+), 263(2a), Gnidia o
Ischyrolepis gaudichaudiana 214(+), Isolepis fluitans 217(+), 240(+), Leucadendron laureolum 7(2a), 246(+), Lycopodiella carolinianum 7(+
240(r), 246(2a), Schizaea pectinata 15(1), 191(1), 238(+), Scyphogyne micrantha 172(+), 238(4), Thesium capituliflorum 217(+), 220(1), Th
Ursinia scariosa 210(+), 237(+), Adenandra acuta 126(2m), Anthochortus ecklonii 225(+), Anthochortus laxiflorus 3(2a), Anthospermum aet
ciliaris 172(r), Asplenium aethiopicum 31(2m), Berkheya herbacea 36(+), Blechnum punctulatum 210(1), Brachylaena neriifolia-jl 10(2b), Ca
210(+), Chondropetalum ebracteatum 190(2a), Cliffortia apiculata 59(+), Cliffortia odorata 184(1),

Cliffortia ovalis 191(1), Cliffortia sericea 11(+), Clutia alaternoides 210(1), Corymbium villosum 214(+), Crassula dejecta 31(1), Crassula nuc
Diosma cf. hirsuta 172(r), Diosma thyrsiphora 191(r), Ehrharta setacea s. uniflora 91(1), Elytropappus longifolius 7(1), Epischoenus quadrar
sitiens 184(+), Erica strigosa 172(+), Erica triflora 85(+), Euryops rupestris 80(+), Ficinia acuminata 214(+), Ficinia brevifolia 31(2m), Ficinia
11(r), Glia prolifera 210(+), Gnidia cf. anomala 36(+), Helichrysum species 248(2a), Heterolepis aliena 82(+), Hymenophyllum peltatum 59(2
Laurembergia repens 213(+), Leucadendron gandogeri 77(r), Leucadendron microcephalum 190(+), Leucadendron xanthoconus-jl 15(r), Lo
bodkinii 263(+), Morella serrata 153(+), Myrsine

africana 210(1), Othonna quinquedentatus 15(r), Oxalis nidulans 36(+), Oxalis species 246(+), Passerina vulgaris 246(1), Pellaea pteroides
Phylica imberbis 225(r), Polygala cf. nematocaulis 10(r), Protea amplexicaulis 246(+), Pseudopentameris obtusifolia 216(1), Psoralea aphyl
Restio stokoei 190(1), Rhus angustifolia 31(r), Rhus tomentosa 35(r), Roella dregeana 184(r), Stoebe prostata 246(1), Struthiola ciliata 36(+
fruticosus 85(1), Thesium carinatum 238(1), Thesium viridifolium 190(+), Trachyandra tabularis 190(+), Unknown species 172(1), Ursinia qu
schlechteri 216(+).

				5.4b								5.5				6.1		6.2							6.3	
158	187	217	225	10	11	83	84	85	91	220	238	3	7	223	240	19	210	35	36	213	214	246	248	258	31	172
59	76	95	98	3	3	23	23	23	26	96	108	1	2	97	109	5B	92	9	9	94	94	114	115	123	8	69
R	P	P	R	R	R	R	R	R	R	P	R	P	R	R	P	R	B	R	R	R	R	R	R	L	B	B
ainfall summer between 9.5 and 10 %																Northern, rainfall summer > 10%										
eepage from slope												Seepage from sides				pH < 4		pH > 4								
ed				mesic, poorly drained														MAP < 1000							MAP >	
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b . . b . . . 1 . . . 1 . . . . | . . . . 1 . 1 . . . .
. . . 1 . . . . . . + . . . . . | . . . . . . . . . . .
. a 1 . . . . . . . . . . . . . | . . . . . . . . . . .
. . a + . . . . . . . . . . . . | . . . . . . . . . . .
. 1 . . . . . . . . . . . . a . | . . . . . . . . . . .
. . . . . 1 r 1 + m 1 . . . . . | . . . . . . . . . . .
. . . . m . + 3 a 1 . . . . . . | . . . . . . . . . . 1
. . . . . . m 1 m . 1 . . . . . | . . . . . . . . . . .
+ . 1 1 . + . r . 1 1 . . . . a | . . . . . 1 1 . . . .
1 . . . m a . . . . 1 . a . . . | . . . . . . . . . . .
. . a . . . . . . 1 . . . . . . | . . . . . . . . . . .
. . . . . . . + . . . 1 . . . . | . . . . . . . . . . .
1 b . 1 . . . . . . 1 . + . . b | . . . . . . . . . . .
. . . r . 1 . . a . 1 . . . . . | . . . . . . . . . . .
1 . . . . . . . . . m . . 1 . . | . . . . . . . . . . .
. . . . a . . . . m . a . . . 1 | . . . . . . . . . . .
. . . . . . . . . . 1 . . . . . | . . . . . . . . . . .
. . . + . . . . . . . 1 . . . . | . . . . . . . . . . .
r . . + . . . . . . . . . . . . | . . . . . . . . . . .
. . . . . . . . . . . r . . . . | . . . . . . . . . . .
. . . . . . . . + . . . . . . . | . . . . . . . . . . .
. . a . . . . . . . + . . . . + | . . . . . . . . . . .
1 . . 1 . . . . . . m . . . . . | . . . . . . . . . . .
. . . . . 1 . 1 . . . . . . . . | . . . . . . . . . . .
. . 1 . . . . . . . a . . . . . | . . . . . . . . . . .
. . . . . . . . . . + . . . . . | . . . . . . . . . . .
. + . . . . . . . . 1 1 . . . . | . . . . . . . . . . .
. . . + . r . + + . 1 . . . . r | . . . . . + . . . . 1
. . . . . . . . . . . 1 1 . + r | . . . . . . . . . . .
. . . . . . . . . m . . b . . 1 | . . . . . . . . . . .
. . . . . . . . . . . . . a a . | . . . . . . . . . . .
. . . . . . . . . . . . . . b + | . . . . . . . . . . .
. . . . . . . . . . . . m . m . | . . . . . . . . . . .
. . + . . . . . . . + . + + 1 . | . . . . . . . . . . .
. . 3 + . . . . . . 1 . 1 . . 1 | . . . . . . . + . . .
. . . . . . . . . 3 . . . . 4 . | . . . . . . . . . . .
. . a 3 a a 1 4 b a . . b a a a | . . m . . . . . a . .
1 . r + b + . . . + . + a + 1 a | . . . . . . . . . . .
a . a a . 1 . + . + + . 1 1 1 a | . . . . . . . . . . .
. 3 . . . 1 . + . . a . . 1 . + | . . . . . . . . . . .
1 . . . . . . . . . . 1 m . 1 . | . . . . . . . . . . .
. . . . . . . 1 1 . . 1 . m . . | . . . . . . . . . . .
. . . 1 + . . . . . a . + . 1 . | . . . . . . . . . . .
a + . . . . + . 1 . . . . . 1 1 | . . . . . . . . . . .
. . . . . . . + . . . . . 1 + . | . . . . . . . . . . .
. . . . . . . . . . . . b 1 . . | . . . . . . . . . . .
. . . . . . . . . . . 1 . . . 1 | . . . . . . . . . . .
r . . . a . . . . . . . r . . . | . . . . . . . . . . .
. . . . . . . . . . . . . . b . | . . . . . . . . . . .
. . . . . . . . . . . . . . . . | a b . . . . . . . . .
. . . . . . . . . . . . . . . . | 1 b . . . . . . . . .
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. . . . . . . . . . . . 3 a b a | 5 5 . . . . . . . . .

. . . . . . . . . . . . . . . . | . . . . . a a b 1 . .
. . . . . . . . . . . r . . . . | . . a . . . a 1 1 . .
. . . . . . . . . . . . . . . . | . . . . . a + + . . .
. . . . . . . . . . . . . . . . | . . . . . + r + . . .
. . . . . . . . . . . . . . . . | . . . . . 4 a b 1 . .
. . . . . . . . . . . . . . . . | . . . . 1 1 1 b . . .
. . . . . . . . . . . . . . . . | . . 1 . + . + . + . .
. . . . . . . . . . . . . . . . | . . . . . + 1 + . . .
. . . . . . . . . . . . . . . . | . . . + . 1 + . . . .
. . . . . . . . . . . . . . . . | . . 1 . . + . + . . .
. . . . . . . . . . . . . . . . | . . . a . . . 1 . . .
. . . . . . . . . . . . . . . . | . . . a . . . 1 . . .

. . . . . . . . . . . . . . . . | . . . . . . . . . a r
. . . . . . . . . . . . . . . . | . . . . . . . . . 1 +
. . . . . . . . . . . . . . . . | . . . . . . . . . 1 +
. . . . . . . . . . . . . . . . | . . . . . . . . . 1 1
. . . . . . . . . r . . . . . . | . . . . . . 1 . . + +
a . . . . + . . . . . . . . . . | . . . . . . . . . r +

. . . . . . . + . 1 . . . . . . | . . . . . . . . . 1 +
. . . . . . . . . . . . . . . . | . . . . . . . . . 1 r
. . . . . . . . . 1 . . . . . . | . 1 . . . . . . . . +

. . . . . . . . . . . . . . . . | . b b . 3 a . . b a +
. . . . . . . . . + . . . . . . | . . + 1 . + + + . r +
. . . . . . . . . . . . . . . . | b . . . 3 . a a 3 . .
. . . . . . . . . . . . . . . . | . + + 1 . + . . r . .
. . . . . . . . . . . . . . . . | . . . . 1 + + . . a .
. . . . . 1 . . . . . . . . . . | a m m . . . . . . . m
. . . . . . . . . . . . . . . . | 1 . . . + a a . . . .
. . . . . . . . . . . 1 . . . . | . . b b . . . a . . r
. . . . . . . . . . . . . . . . | . . . . + . + . . . +

. . m . m . 1 m m m 1 . . m a m | m . m . . 1 . . . . .
. . . + + . . a . . + . + a + 3 | 1 . 3 . . a + 3 b . .
. + 1 r . r . . . a 1 1 . . + . | . . . . . 1 . . r 3 b
. . . . . . . 1 . . 1 a . . . . | . . a a . a 1 1 . . .
. . . . . . . . r 1 + . r . . . | . . 1 1 . 1 . 1 . a a
. . . . . + . . . . 1 + . . . r | . . . . + . . . . + +
. . . . . . . . . . r . r . . . | . . 1 . . + . + . . .
. . . . 3 3 . . . . . 5 . . . m | . . . . . . a 1 . . .

1 . . 1 b b + 3 3 3 a 4 . m 1 1 | . + 1 1 1 1 1 1 m . b
. 1 . 1 m m + m m 1 . 1 . m m 1 | m 1 m m . 1 1 m m . 1
+ . . + 1 1 . r + r . . . . . . | . 1 . r + + + 1 1 . 1
1 a . 1 1 b 1 1 . . b . . m . . | + . m 3 . a b . 1 a a
. . . + 1 . + . . m + . . . 1 . | . . 1 . 1 m . . 1 + a
+ + . a . . . a + . . . . . . 3 | . . . . a . . a 3 . .
a . . . m . . . . 1 r . . + . + | . . . . r . + . . m 1
. . . . r a . . . 1 . . . . + . | . . . a + + a + . r r
. . . . + . . . . . 1 . r + . 1 | . . 1 . . 1 1 . 1 1 1
. . . . . . . . . . r + . . . + | . r . . . . . 1 . 3 1
. 1 . . . . . r . . . . . . . + | . . . + . . . . + . .
. . . . . . m a + . . . . . . . | . . r . 1 . . . a . .
. . . + . . . r + . . . . . . . | . . . . . 1 1 . 1 . .
. . . . . . . 1 1 . . . . . . . | . . . . . . . 1 . . .
+ . . . . 1 . . . . . . . . . . | . . . 1 . 1 . . . . .
. . . . . . . . . . . . + a . . | . . 1 . . . r 1 . . .
. . . . . . . . . . . a . . r . | . . . . . + . . . . .
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ppositifolia 77(+), 84(1), Hippia frutescens 59(+), 84(+), Ischyrolepis cincinnata 27(2a), 28(2b),
-), 77(+), Phylica strigulosa 246(2a), 258(+), Protea lacticolor 80(+), 216(r), Protea neriifolia
nesium spicatum 172(+), 214(+), Todea barbara 184(+), 263(r), Ursinia eckloniana 91(r), 238(+),
hiopicum 214(+), Anthospermum spathulatum 172(+), Arctopus species 191(r), Aspalathus
alopsis hyalina 263(1), Carpha glomerata 59(r), Centella caespitosa 125(+), Chironia baccifera

dicaulis 172(+), Cuscuta nitida 158(2m), Cyathocoma hexandra 263(1), Dilatris viscosa 190(r),
ngularis 184(1), Erica autumnalis 126(r), Erica coccinea 238(1), Erica corifolia 220(+), Erica
nigrescens 82(+), Geissorhiza umbrosa 125(r), Gladiolus carneus 191(+), Gladiolus species
2a), Hypochaeris radicata 213(r), Ischyrolepis curviramis 225(1), Ischyrolepis helenae 190(1),
obelia jasionoides 225(+), Mastersiella digitata 216(+), Maytenus oleoides 172(r), Metalasia

31(1), Peucedanum galbanum 31(r), Peucedanum cf. strictum 31(1), Phylica gracilis 36(1),
la 84(2a), Raspalia microphylla 187(1), Restio nuwebergensis 80(+), Restio quadratus 210(2a),
+), Struthiola myrsinites 91(2m), Tetraria bolusii 35(1), Tetraria fasciata 217(2a), Thamnochortus
uinquedentata 77(r), Utricularia bisquamata 125(1), Wahlenbergia procumbens 190(1), Watsonia

Table 6: Forest and Scrub (Community groups 9 and 10)

Community Group 9: Afromontane Forests
- Ass. 9.1: Platylophus trifoliatus-Cunonia capensis Forest
- Ass. 9.2: Platylophietum trifoliati
- Ass. 9.3: Curtisio dentatae-Diospyretum whyteanae
- Ass. 9.4: Todeo barbarae-Cunonietum capensis
  - Subass. 9.4a: typicum
  - Subass. 9.4b: hymenophylletosum peltatae

Community Group 10: Riparian Scrub
- Ass. 10.1: Ischyrolepido subverticillatae-Metrosiderotetum angustifoliae
  - Subass. 10.1a: podalyrietosum calyptratae
  - Subass. 10.1b: typicum

Community type			9.1	9.2				9.3					9.4a													9.4b												10.1a									10.1b								
Relevé number			20	192	197	255	256	193	194	198	199	200	18	46	70	108	109	112	142	149	150	168	170	174	179	62	64	102	104	110	116	138	140	143	173	209	211	38	42	50	54	90	94	114	148	162	22	30	97	166	169	171	176	206	265
Transect no			6	81	84	120	121	81	82	84	85	86	5B	11	18	32	32	35	52	55	56	66	68	71	73	15	16	29	30	33	38	50	51	53	70	92	93	10A	10B	12	13	26	27	37	54	61	6	8	28	65	67	69	72	91	131
River name			R	L	L	L	L	L	L	L	L	L	R	E	E	B	B	E	E	E	E	B	B	B	B	R	R	B	B	P	E	R	R	E	B	B	B	E	E	E	B	R	E	E	R	R	R	B	E	B	B	B	B	B	Br
Environment			?	Scree									Low stream power, well-developed substrate																									High stream power, poor substrate																	
				Wet Bank				Back Dynamic					Dry soils													Moist soils												Poor soil development									Very rocky substrate								
Tree layer:																																																							
Platylophus trifoliatus	d9.1-2	t3	3	4	4	5	4	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Diospyros whyteana	d9.3	t3	.	.	.	.	.	3	1	+	3	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Curtisia dentata	d9.3	t3	.	.	.	.	.	a	.	a	3	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Podocarpus latifolius	d9.3	t3	.	.	.	.	.	.	.	a	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Olinia ventosa	d9.3	t3	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Olea capensis	d9.2-3	t3,s1,s2	.	.	.	+	a	b	+	3	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brabejum stellatifolium	d9.1, d9.4a	t3	3	.	.	.	.	.	.	.	.	.	.	.	b	.	.	4	.	3	3	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	3	.	.	.	.
Ilex mitis	d9.2-4a	t3	.	.	.	.	.	.	+	b	b	.	4	a	.	.	.	.	.	a	a	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Maytenus acuminata	d9.2-4a	t3	.	a	b	.	.	.	3	3	b	4	.	a	3	.	.	r	.	a	.	.	.	.	3	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rapanea melanophloeos	d9.2-4a	t3	.	+	.	.	.	1	a	a	b	b	.	a	.	+	a	.	.	a	.	a	.	.	.	.	+	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cunonia capensis	d9	t3	4	.	a	.	.	.	a	.	b	b	.	3	4	.	4	.	5	a	4	a	.	.	.	4	4	.	b	4	5	a	.	.	a	3	3	1	.	a	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.
Cassine schinoides	d9	t3	.	.	.	r	a	.	b	.	a	a	.	3	.	.	3	.	.	.	.	.	.	.	3	.	1	b	b	.	a	.	4	+	m	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brachylaena neriifolia	d9	t3	a	.	.	.	.	.	a	.	.	.	a	a	.	.	.	.	.	.	.	3	.	.	.	.	3	.	.	.	b	b	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.
Metrosideros angustifolia	d9	t3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	4	.	.	.	.	.	.	.	.	.	.	3	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	.	.	.
Kiggelaria africana	d9	t3	.	.	.	.	.	.	a	.	a	.	.	a	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Shrub layer:																																																							
Apodytes dimidiata	d9	s1	.	.	.	.	.	.	+	r	.	+	.	.	.	.	a	.	.	.	.	.	r	.	.	1	1	.	+	3	.	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cassine schinoides	d9	s2,s1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	b	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a
Ilex mitis	d9	s1	.	r	.	.	.	.	.	.	.	b	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rapanea melanophloeos	d9	s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Erica caffra	d10	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	b	b	.	b	.	.	.	.	1	+	.	b	.	.	.	b	.	a
Acacia saligna	d10	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	a	.	b	.	.	.	.	.	.	.	.
Podalyria calyptrata	d10.1a	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	a	+	.	.	+	.	b	b	.	.	.	.	.	.	.	.	.	.	4	3	+	.	a	a	+	a	+	.	.	.	.	1	.	.	.	.
Brabejum stellatifolium	d10.1a	s1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	a	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	a	.	.	a	3	+	.	.	.	.	.	.	.	.	a
Metrosideros angustifolius		s1	.	.	.	.	.	.	.	.	.	.	4	.	.	b	+	.	.	.	.	.	.	.	b	.	.	3	4	.	.	.	.	3	.	+	.	.	.	.	3	.	a	3	4	5	5	3	3	4	.	.	b	4	3
Brachylaena neriifolia		s1	.	.	.	.	.	.	.	.	.	a	.	.	.	+	a	.	+	a	.	.	.	1	b	+	.	b	.	.	.	.	.	b	3	3	.	b	5	4	4	3	b	b	.	a	.	a	+	.	.	.	a	.	b
Diospyros glabra		s1,s2	.	.	.	.	.	.	.	.	+	.	.	+	.	a	.	.	.	1	+	r	+	+	.	.	.	.	1	.	+	.	.	+	.	.	.	.	.	.	.	.	+	.	.	r	.	.	.	+	r	.	.	.	a
Rhus angustifolia		s1,s2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	r	.	.	.	.	.	.	+	.	.	.	.	a	.	.	.	.	r	.	.	.	.
Rhus tomentosa		hl,s2,s1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	r	.	.	.	.	.	.	.	.	.	.

Halleria lucida		s1,s2	. . . . a . . . . + ...	. . . .
Maytenus acuminata		s2	. . . . . 4 . . . . + ...	. . . . r . . . . .
Herb layer:				
Oxalis livida var. altior	d9.4a	hl	. . . . 1 . . . . . . m m . . . m 1 . 1 + ...	. . . .
Chasmanthe aethiopica	d9.4a	hl	. . . . + + . a + ...	. . . .
Restio cf. perplexus	d9.4a	hl	. . . . + r + ...	. . . . m
Dolichos decumbens	d9.4a	-	. . . . 1 + ...	. . . .
Unknown species	d9.4a	hl	. . . . + + ...	. . . .
Asplenium aethiopicum	d9.2-4a	hl	. + . + ... + . . 1 + + . . . 1 . . + ... 1	. . . .
Ehrharta erecta	d9.2-4a	hl	. 1 . . . 1 + . . + . . 1 . . . + ...	. . . .
Hymenophyllum peltatum	d9.4b	ml	. . . . . . m . . . . m . . m . . . . a 4 . . a a 4 3 m m . .	. . . .
Aristea major	d9.4b	hl	. . . . 1 . + 1 1 r m + ...	. . . . + ... + r . . .
Elaphoglossum angustatum	d9.4b	hl	. . . . m . + + 1 . . .	. . . . + . . .
Agathosma crenulata	d9.4b	hl,s2	. . . . r . . r r a . 1	. . . . + ...
Ursinia scariosa	d9.4b	hl	. . . . + 1	. . . .
Unknown geophyte	d9.4b	hl	. . . . 1 . . . m	. . . .
Restio intermedius	d9.4b	hl	. . . . 3 . . . a	. . . .
Asparagus rubicundus	d9.4b	hl	. . . . r + . . .	. . . .
Restio quadratus	d9.4b	hl	. . . . + 1	. . . .
Blechnum capense	d10.1a	hl	. . . . b 1 . . 4 . . . . . + . 1 . . . m 1 . . . . 4 4	a 5 a . . . a . 1 . . . .
Cassytha ciliolata	d10.1a	-	. . . . m . . . r r . + ... + ...	. . . 1 m 1 . . . .
Centella eriantha	d10.1a	hl	. . . . + ... 1	r . . . 1 . . a a . . . .
Stoebe plumosa	d10.1a	hl	. . . . + ... 1	. . . m . 1 . + ...
Pteridium aquilinum		hl	. . . . 1 . . . . . . + ...	. . . 1 . 1 . . b 1 . . . 1 . . . .
Pennisetum macrourum		hl	. . . .	. . . . 1 + a . . . .
Ischyrolepis subverticillata		hl	. . . . + . . . a 1 . . 1 . 1 . . . 1 a b + b 1 + 3 a . . .	3 4 m m 4 3 . . . + a + a b 1 . . .
Ehrharta rehmannii		hl	. . . . 1 . . 1 . . . 1 . . . . . m + 1 . 1 . . .	. 1 . m . . . . 1 . + . . . 1 . . 1
Myrsine africana		hl	. . . . + r . r . . . . 1 1 . . . . . + . .	. . . . + ...
Erica hispidula		hl	. . . . r . . . . r + . . + . . . + . . .	. . . . + ... +
Pellaea pteroides		hl	. . . . 1 . . + ... 1	. . . 1 . . . . . + . . 1 . . . . +
Elegia capensis		hl	. . . . + 3	. . . a . . . . . 1 . . . . a
Aristea bakeri		hl	. . . . + ... 1 . . .	+ + ... + ...
Schoenoxiphium lanceum	d9, d10	hl	. m + . a 1 1 4 1 m . m 3 . a . m a 1 b . 1 . . m . 1 . r a . + . . .	1 . 1 . . . + ... + + 1 . . .
Todea barbara	d9, d10	hl	b . . + . . + . . + . a . + a a . 1 . a + a + 4 3 . + m 1 b 1 . a b 3	. + b + a . . . . 1 1 . 1 . + . + .
Asparagus scandens	d9, d10	hl	. 1 + + + a 1 a 1 1 . m a + 1 1 b a + + 1 1 + . + 1 1 + . . + + + . .	. . . + . . . r . . . . . 1 . . . .
Blechnum punctulatum	d9, d10	hl	. . . + . + . . 1 . . . 1 . 1 . 1 1 a + r . . . . . . + ... 1 a .	. . . + ... r .
Knowltonia vesicatoria		hl	. . . . . 1 . . r . . . . + . + ...	. . . . + ...
Cunonia capensis		jl	. . . . . + ... r + ... + . . .	. . . . + ...
Kiggelaria africana		jl	. . . . . + . . . + ... + ...	. . . . r . . . . r . . . . .
Maytenus acuminata		jl	. . . . + ...	. . . . + ...
Podalyria calyptrata		jl	. . . . r . . . + . . .	. . . .
Erica caffra		jl	. . . . + ... a	. . . . r .
Pseudobaeckea africana		hl, s2	1 . . . . a . . . . a	. . . . 1 . . . .
Ischyrolepis gaudichaudiana		hl	. . . . + ... 1 . . .	. . . . . b . . m . . . .
Schizaea tenella		hl	m 1	. . . . . . + . . m . . . .
Ficinia brevifolia		hl	. . . . 1	. . . . + . . m . . . . . . a
Pentaschistis pallida		hl	. . . . 1 . . . 1 . . .	. . . . + . + . . .
Struthiola myrsinites		hl	. . . . 1 . . . . + . . .	. . . a . . . . + ...
Halleria elliptica		hl	. . . . . 1 . . . . . . + . . r	. . . . . a . . . .
Tetraria cuspidata		hl	1 . . . . a . . . 1	. . . . m . . . .
Pelargonium patulum		hl	. . . . 1	. . . 1 . . . . r . . . . .
Helichrysum cymosum		hl	. . . . 1 . . . . . . + ...	. . . . + ...
Pentameris thuarii		hl	. . . . 1	. . . . 1 . . . . r . . . . .
Cliffortia ruscifolia		hl	. . . . a	. . . . r + ...

Rare species with the relevés in which they occur and their abundance in brackets:
Asparagus volubilis 102(2), 114(2), Berzelia lanuginosa 162(1), 265(1), Blechnum attenuatum 138(5), 200(2), Blechnum tabulare 138(2), 149(3), Cliffortia hirsuta 18(3), 209(2), Cyathea capensis 138(1), 194(5), Dipogon lignosus 169(1), 170(1), Drosera capensis 20(3), 22(2), Empleurum unicapsulare 90(5), 148(1), Ficinia distans 112(4), 116(2), Gibbaria ilicifolia 90(3), 110(2), Gleichenia polypodioides 62(3)

162(3), Haplocarpha lanata 54(2), 174(2), Helichrysum helianthemiifolium 112(2), 192(1), Isolepis digitata 112(3), 116(4), Maytenus oleoides 70(5), 102(2), Morella serrata 162(2), 209(5), Olea europaea s. africana 142(2), 193(1), Oxalis truncatula 102(3), 109(2), Platycaulos callistachyus 22(7), 162(5), Podocarpus elongatus 143(7), 194(2), Prionium serratum 20(1), 97(3), Pterocelastrus rostratus 143(5), 174(1), Restio purpurascens 54(3), 110(4), Rubus rigidus 112(1), 148(7), Senecio coleophyllus 90(1), 110(2), Thesium strictum 54(3), 109(1), Tribolium brachystachyum 148(2), 265(2), Watsonia borbonica 143(1), 149(1), Zantedeschia aethiopica 97(r), 112(+), Acacia longifolia 162(r), Acacia mearnsii 148(r), Aloe plicatilis 102(2a), Anthoxanthum tongo 104(1), Apodytes dimidiata-jl 150(r), Argyrolobium lunare latifolia 138(2a), Asparagus retrofractus 94(+), Berzelia squarrosa 90(r), Brabejum stellatifolium-jl 30(r), Brachylaena neriifolia-jl 148(+), Briza maxima 148(1), Bulbine species 102(+), Calopsis paniculata 148(1), Cannomois virgata 140(1), Carpacoce spermacocea 90(2a), Carpha glomerata 22(2a), Cliffortia complanata 169(+), Cliffortia cuneata 150(r), Cliffortia polygonifolia 169(+), Cliffortia strobilifera 148(2a), Clutia laxa 54(r), Crassula dejecta 199(r), Crassula nudicaulis 166(+), Cullumia setosa 102(+), Ehrharta setacea s. uniflora 110(2m), Elegia thyrsifera 110(2m), Elytropappus longifolius 148(1), Erica hispidula-il 166(r), Erica hirta 54(+), Euphorbia epicyparissias 54(1), Euryops rupestris 102(1), Ficinia acuminata 143(+), Ficinia oligantha 265(+), Ficinia ramosissima 90(3), Ficinia trichodes 54(1), Geissorhiza Hippia frutescens 143(r), Histiopteris incisa 112(+), Holothrix villosa 108(+), Sphaerocionium aeruginosum 138(2m), Hypocalyptus sophoroides 112(2b), Hypolepis sparsisora 112(+), Ischyrolepis triflora 265(2m), Juncus lomatophyllus 138(2m), Knowltonia capensis 199(r), Merxmuellera stricta 265(1), Metalasia cephalotes 54(1), Neesenbeckia punctoria 20(1), Olinia ventosa -hl 192(1), Osteospermum ciliatum 54(1), Othonna quinquedentata 30(+), Oxalis lanata 114(1), Oxalis nidulans 54(r), Oxalis purpurea 102(2m), Penaea cneorum 62(+), Pentameris distichophylla 162(2m), Pentaschistis curvifolia 30(1), Pentaschistis densifolia 265(+), Peucedanum galbaniopse 149(+), Pinus pinaster 162(r), Pittosporum undulatum 70(3), Protea neriifolia 150(+), Psoralea aculeata 22(+), Psoralea aff. fleta 94(r), Psoralea pinnata 148(+), Restio dispar 265(1), Secamone alpini 173(r), Senecio cf. hastatus 148(r), Senecio vulgaris 148(+), Solanum retroflexum 192(r), Stachys aethiopica 149(+), Kogelbergia verticillata

Table 7: Synoptic Table for Riparian Communities including Seepages

(Presence classes: r = < 5%, + = 6-10 %, I = 11-20%, II = 21-40%, III = 41-60%, IV = 61-80%, V = 81-100%, additional numbers indicate averages of ordinal cover scales).

Category	Aquatic		Bogs and Mires						Wet Banks					Fynbos								Forest and Scrub				Other	
Table no.	2		1 (Seepage)						3					4					5			6				5	3
Community Group	1		Seepage 1			Seepage 2			2		3			5				6	7			9			10	8	4
Vegetation type	1.1	1.2	S1.3	S1.4	S1.5	S2.1	S2.3	S2.4	2.1	2.2	3.1	3.2	3.3	5.2	5.3	5.4	5.5	6.2	7.1	7.2	7.3	9.2	9.3	9.4	10.1	8.2	4.1
Number of relevés	26	6	4	6	4	3	3	9	13	5	6	9	19	4	7	20	4	7	5	18	5	4	5	25	18	5	6
Differential species of aquatic communities																											
Isolepis digitata	V^{6}	V^{6}	.	.	.	II^{4}	.	.	.	.	.	II^{5}	I^{6}	.	.	.	.	.	.	.	.	.	.	+^{4}	.	.	.
Fontinalis antipyretica	IV^{5}	IV^{5}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r^{7}	.	.	.
Differential species of Anthochorto crinalis-Elegietum intermediae and Ficinio argyropae-Epischoenetum villosi																											
Elegia intermedia	.	.	V^{9}	III^{5}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Differential species of Ficinio argyropae-Epischoenetum villosi																											
Ficinia argyropa	.	.	.	V^{5}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio umbellatus	.	.	.	V^{4}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I^{2}	.	.	.	.	.	.	.	.
Anthoxanthum tongo	.	.	.	II^{5}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r^{3}	.	.	I^{3}
Differential species of Restio bifurcus-Anthochortus crinalis Short Restioland																											
Restio bifurcus	.	.	.	.	IV^{3}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gladiolus carneus	.	.	.	I^{2}	IV^{2}	.	.	I^{1}	.	.	.	.	.	.	.	.	.	.	.	+^{3}	.	.	.	.	.	.	.
Differential species of Platycaulos depauperatus Short Herbland																											
Platycaulos depauperatus	.	.	.	.	.	V^{7}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pentameris hirtiglumis	.	.	.	.	.	IV^{3}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Kniphofia tabularis	.	.	.	.	.	IV^{3}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Differential species of Grubbia rosmarinifolia-Restio versatilis Riparian seepages																											
Clutia polygonoides	.	.	.	.	.	.	IV^{3}	.	.	.	.	.	.	.	I^{2}	r^{2}	.	I^{1}	.	.	.	.	.	.	.	.	.
Adenandra acuta	.	.	.	.	.	.	IV^{3}	.	.	.	.	.	.	.	I^{4}	.	.	.	.	.	.	.	.	.	.	.	.
Erica sitiens	.	.	.	.	.	.	IV^{3}	.	.	.	.	.	.	.	I^{2}	.	.	.	.	.	.	.	.	.	.	.	.
Erica coccinea	.	.	.	.	.	.	IV^{2}	.	.	.	.	.	.	.	.	r^{3}	.	.	.	.	.	.	.	.	.	.	.
Differential species of Tetrario capillaceae-Restionetum subtiis																											
Chrysithrix junciformis	.	.	.	.	.	II^{4}	.	III^{3}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chrysithrix dodii	.	.	.	.	.	.	.	II^{3}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Differential species of Bog communities and transitional community of Platycaulos depauperatus Short Herbland																											
Senecio crispus	.	.	IV^{2}	IV^{4}	V^{5}	V^{3}	.	I^{2}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cliffortia tricuspidata	.	.	II^{2}	IV^{5}	III^{7}	II^{5}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Differential species of Seepages																											
Anthochortus crinalis	.	.	V^{6}	V^{7}	V^{8}	.	II^{4}	IV^{7}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Epischoenus villosus	.	.	V^{4}	V^{7}	V^{6}	V^{4}	II^{4}	IV^{5}	.	.	.	.	+^{4}	.	II^{4}	r^{3}	II^{3}	.	.	.	.	.	.	.	.	.	.
Ehrharta setacea	.	.	.	V^{6}	V^{5}	V^{5}	II^{4}	IV^{3}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ursinia caledonica	.	.	.	II^{7}	III^{5}	II^{3}	II^{3}	III^{6}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Moss species differential for moss covered Pioneer Wet Banks and waterfalls																											
Symphyogyna podophylla	.	III^{6}	.	.	.	II^{4}	.	.	III^{5}	.	IV^{5}	.	I^{5}	.	I^{3}	.	.	.	.	.	.	.	.	r^{3}	+^{3}	.	II^{3}
Sematophyllum dregei	.	I^{4}	.	.	.	.	.	.	II^{5}	.	II^{5}	II^{5}	+^{5}	.	.	.	.	.	.	.	.	.	.	.	I^{3}	.	.

Differential species for erosion dominated Wet Banks Sphagno capensis-Disetum tripetaloidis and Pseudobaeckeo africanae-Prionietum serrati																											
Drosera capensis	.	.	.	.	.	.	.	.	.	I^{1}	.	IV^{4}	III^{4}	.	.	.	.	.	.	.	.	.	.	.	+^{2}	.	I^{1}
Lycopodiella caroliniana	.	.	.	.	.	.	.	I^{2}	.	.	.	III^{3}	III^{3}	II^{2}	.	.	II^{2}	.	.	.	.	.	.	.	.	.	.
Sphagnum capense	.	.	.	.	.	IV^{4}	.	II^{4}	+^{5}	.	I^{4}	IV^{6}	III^{5}	.	I^{3}	.	.	.	.	.	.	.	.	r^{4}	.	.	I^{2}
Differential species for erosion dominated Wet Banks also occurring in several other communities																											
Schizaea tenella	.	.	.	.	.	.	II^{3}	.	I^{2}	.	V^{5}	IV^{3}	IV^{3}	.	.	.	III^{4}	.	.	.	.	.	.	r^{3}	I^{3}	.	.
Disa tripetaloides	.	I^{2}	.	.	.	.	II^{5}	I^{4}	.	.	II^{5}	IV^{6}	IV^{5}	.	I^{5}	r^{3}	III^{5}	.	.	.	.	.	.	.	.	.	.
Campylopus stenopelma	.	I^{4}	III^{4}	.	.	.	II^{4}	II^{5}	+^{4}	.	III^{6}	III^{5}	III^{5}	.	I^{3}	r^{3}	.	.	.	.	.	II^{3}	.	r^{4}	.	.	.
Differential species of Nebelia fragarioides-Staberoha cernua Short Closed Shrubland																											
Staberoha cernua	.	.	.	.	.	.	.	I^{3}	.	.	.	I^{3}	.	III^{5}	.	r^{4}	.	.	.	.	.	.	.	.	.	.	.
Chironia jasminoides	.	.	.	.	.	.	.	.	.	.	.	.	.	III^{2}	.	r^{3}	.	.	.	.	.	.	.	.	.	.	.
Nevillea obtusissima	.	.	.	.	.	.	.	.	.	.	.	II^{6}	I^{5}	III^{6}	.	.	.	.	.	.	.	.	.	.	.	.	.
Differential species of Erico longifoliae-Tetrarietum crassae																											
Tetraria crassa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V^{4}	.	.	.	.	.	.	.	.	.	.	.	.
Erica plukenetii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV^{1}	r^{3}	.	.	.	.	.	.	.	.	.	.	.
Tetraria pillansii	.	.	.	I^{5}	II^{3}	.	.	.	.	.	.	.	.	.	III^{5}	.	.	.	.	.	.	.	.	.	.	.	.
Gnidia galpinii	.	.	.	.	.	.	IV^{3}	.	.	.	.	.	.	.	III^{2}	r^{2}	.	.	.	.	.	.	.	.	.	.	.
Staberoha vaginata	.	.	.	.	.	.	II^{2}	I^{2}	.	.	.	.	.	.	III^{4}	.	.	.	.	.	.	.	.	.	.	.	.
Podalyria montana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II^{2}	.	.	.	.	.	.	.	.	.	.	.	.
Pentaschistis malouinensis	.	.	.	.	.	.	.	.	.	.	.	.	+^{2}	.	III^{2}	r^{2}	.	I^{3}	.	.	.	.	.	.	.	.	.
Erica sessiliflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III^{2}	r^{3}	.	.	.	.	.	.	.	.	.	.	.
Watsonia borbonica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II^{1}	.	.	.	.	+^{1}	.	.	.	+^{1}	.	.	.
Differential species of Restio purpurascenti-Cliffortietum hirsutae																											
Cliffortia hirsuta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II^{1}	.	V^{6}	.	.	.	.	.	.	+^{3}	.	.	.
Neesenbeckia punctoria	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r^{2}	III^{5}	.	I^{3}	.	.	.	.	.	.	.	.
Differential species of Ericaceous Fynbos communities																											
Capeobolus brevicaulis	.	.	.	.	.	.	.	.	.	.	.	.	+^{3}	.	IV^{4}	II^{4}	.	.	.	.	.	.	.	.	.	.	.
Erica longifolia	.	.	.	.	.	.	.	I^{1}	.	.	.	.	.	.	IV^{3}	I^{4}	II^{2}	.	.	.	.	.	.	.	.	.	.
Erica equisetifolia	.	.	.	.	.	.	.	.	.	.	.	.	+^{5}	II^{3}	III^{3}	II^{5}	III^{3}	.	.	.	.	.	.	.	.	.	.
Carpacoce spermacocea	.	.	.	.	.	.	.	.	.	.	.	.	+^{3}	III^{5}	II^{3}	II^{3}	.	.	.	.	.	.	.	.	+^{5}	.	.
Restio occultus	.	.	.	.	.	.	.	.	.	.	.	.	+^{4}	IV^{3}	II^{3}	II^{4}	.	.	.	.	.	.	.	.	.	.	.
Gleichenia polypodioides	.	.	.	.	.	.	.	.	+^{2}	I^{2}	.	I^{3}	+^{2}	.	III^{3}	II^{4}	III^{3}	.	.	.	.	.	.	r^{3}	+^{3}	.	.
Restio intermedius	.	.	.	.	.	.	II^{7}	.	.	.	.	.	+^{4}	.	II^{3}	I^{6}	II^{3}	.	.	.	.	.	.	+^{6}	.	.	.
Elegia spathacea	.	.	.	I^{4}	.	.	.	II^{3}	.	.	.	.	.	III^{5}	III^{4}	+^{2}	.	.	.	+^{5}	.	.	.	.	.	.	.
Erica tegulifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	II^{1}	II^{2}	I^{2}	.	.	.	.	.	.	.	.	.	.	.
Differential species of Nebelia fragarioides-Staberoha cernua-Short Closed Shrubland also occurring in Restio marshlands																											
Tetraria capillacea	.	.	.	I^{6}	III^{3}	IV^{4}	II^{3}	IV^{5}	.	.	.	.	.	V^{5}	.	+^{3}	.	.	.	.	.	.	.	.	.	.	.
Nebelia fragarioides	.	.	.	.	II^{1}	.	II^{3}	I^{2}	.	.	.	.	.	IV^{2}	II^{2}	.	.	.	.	.	.	.	.	.	.	.	.
Differential species of Erico longifoliae-Tetrarietum crassae and Restio marshlands																											
Restio aff. versatilis	.	.	.	.	.	II^{4}	V^{5}	III^{5}	.	.	.	.	.	.	III^{6}	.	.	.	.	.	.	.	.	.	.	.	.
Restio subtilis	.	.	.	.	II^{8}	V^{7}	II^{7}	V^{8}	.	.	.	.	.	.	II^{5}	.	.	.	.	.	.	.	.	.	.	.	.
Erica fastigiata	.	.	.	.	II^{3}	.	V^{2}	II^{3}	.	.	.	.	.	.	II^{3}	.	.	.	.	.	.	.	.	.	.	.	.
Differential species of Erico longifoliae-Tetrarietum crassae also occurring in some seepage communities																											

Elegia grandis	.	.	.	II 5	III 2	.	.	.	.	.	.	.	.	.	II 3	I 3	.	.	.	.	.	.	.	.	.	.	.
Elegia racemosa	.	.	.	.	.	II 5	.	.	.	.	.	.	.	.	II 2	I 3	.	.	.	.	.	.	.	.	.	.	.
Restio echinatus	.	.	.	I 5	II 3	II 4	.	I 4	.	.	.	.	+ 3	.	I 3	r 4	.	.	.	.	.	.	.	.	.	.	.
Differential species of Ericaceous Fynbos and Restio Marshland communities																											
Restio corneolus	.	.	.	.	IV 3	.	IV 3	III 3	.	.	.	.	+ 3	III 5	V 4	I 3	.	.	.	.	.	.	.	.	.	.	.
Restio burchellii	.	.	.	.	II 2	.	II 2	III 4	.	.	.	.	+ 4	.	III 4	II 4	.	.	.	.	.	.	.	.	.	.	.
Elegia neesii	.	.	.	.	.	IV 4	IV 4	I 6	.	.	.	.	.	.	III 3	I 4	II 3	.	.	.	.	.	.	.	.	.	.
Gnidia oppositifolia	.	.	.	I 2	.	II 3	.	II 3	.	.	.	.	.	II 2	.	r 3	II 1	.	.	.	.	.	.	.	.	.	.
Drosera aliciae	.	.	.	II 2	.	II 2	IV 3	II 2	.	.	I 2	.	+ 6	II 3	II 3	+ 2	III 3	.	.	.	.	.	.	.	.	.	.
Differential species of Restio purpurascenti-Cliffortietum hirsutae and seepage communities																											
Elegia thyrsifera	.	.	.	.	.	II 5	II 3	I 5	.	.	.	.	I 3	.	.	+ 3	III 5	.	.	.	.	.	.	r 4	.	.	.
Differential species of Ericaceous Fynbos communities and Pseudobaeckeo africanae-Prionietum serrati																											
Penaea cneorum	.	.	.	.	.	.	.	.	.	.	.	I 2	III 5	.	IV 5	IV 5	V 4	.	.	.	.	.	.	r 2	.	.	.
Erica lutea	.	.	.	.	.	.	IV 3	.	.	.	.	I 2	III 5	.	V 5	III 5	III 5	.	.	.	.	.	.	.	.	.	.
Erica curvirostris	.	.	.	.	.	.	.	.	.	.	.	.	II 2	.	III 3	II 2	II 1	I 2	.	I 2	.	.	.	.	.	.	.
Askidiosperma esterhuysiana	.	.	.	.	II 2	.	.	I 6	.	.	.	.	II 5	.	I 2	III 5	II 5	.	.	.	.	.	.	.	.	.	.
Restio bifarius	.	.	.	.	.	.	.	.	.	.	.	.	II 5	.	III 3	II 5	.	II 3	.	.	.	.	.	.	.	.	.
Differential species of Ericaceous Fynbos communities, Sphagno capensis-Disetum tripetaloidis and Pseudobaeckeo africanae-Prionietum serrati																											
Tetraria cuspidata	.	.	.	.	.	.	.	.	+ 4	.	.	.	III 4	II 3	III 3	III 4	IV 5	II 4	I 2	.	.	.	.	+ 5	+ 4	.	.
Pseudobaeckea africana	.	.	.	.	.	.	.	.	+ 2	.	.	III 5	III 4	II 4	.	I 2	II 5	.	.	.	.	.	.	+ 5	+ 3	.	.
Pentaschistis curvifolia	.	.	.	.	.	.	.	.	.	.	.	II 3	II 3	.	III 4	I 3	.	.	.	+ 3	.	.	.	.	+ 3	.	.
Differential species of Restio marshlands, Ericaceous Fynbos and Pseudobaeckeo africanae-Prionietum serrati																											
Berzelia squarrosa	.	.	.	.	.	.	V 7	III 2	.	.	.	.	II 2	III 5	V 3	III 5	V 5	.	.	.	.	.	.	.	+ 1	.	.
Brunia alopecuroides	.	.	.	.	.	.	V 2	I 3	.	.	.	I 2	II 2	V 7	V 3	II 2	IV 2	.	.	.	.	.	.	.	.	.	I 1
Grubbia rosmarinifolia	.	.	.	.	.	II 5	V 7	IV 6	.	.	.	.	III 5	.	III 2	+ 7	II 6	.	.	.	.	.	.	.	.	.	.
Restio bifidus	.	.	.	.	.	.	V 3	I 2	.	.	.	.	I 5	III 5	V 5	.	.	.	.	.	.	.	.	.	.	.	.
Villarsia capensis	.	.	.	.	.	.	.	II 3	.	.	.	I 3	+ 2	II 3	II 3	II 4	III 3	.	.	.	.	.	.	.	.	.	.
Erica curviflora	.	.	.	.	.	.	IV 5	II 3	.	I 2	.	.	II 3	.	I 3	+ 3	IV 2	.	.	.	.	.	.	.	.	.	.
Differential species of Pseudobaeckeo africanae-Prionietum serrati also occuring in several other Wet Bank types, seepages and Ericaceous Fynbos																											
Prionium serratum	r 4	.	.	.	IV 2	.	.	.	I 5	II 5	.	III 5	V 6	.	II 3	.	III 5	.	.	.	.	.	.	.	+ 3	.	I 1
Differential species of seepages, Erosion dominated Wet Banks and Ericaceous Fynbos																											
Restio purpurascens	.	I 2	.	.	II 5	V 6	V 7	III 5	.	I 1	.	III 5	IV 5	V 4	V 5	IV 6	V 5	II 5	.	+ 4	.	.	.	r 4	+ 3	.	.
Chondropetalum mucronatum	.	.	.	.	III 7	IV 8	V 4	IV 6	.	.	.	I 2	I 3	V 6	IV 4	I 3	III 4	.	.	.	.	.	.	.	.	.	.
Erica intervallaris	.	.	.	III 5	II 6	V 5	II 2	IV 5	.	.	.	II 3	I 7	V 7	I 2	II 5	II 4	.	.	.	.	.	.	.	.	.	.
Chondropetalum deustum	.	.	.	.	II 3	.	IV 4	III 4	.	.	.	.	I 3	II 4	V 4	II 3	.	.	.	.	.	.	.	.	.	.	.
Differential species of Muraltio heisteriae-Ericetum pineae																											
Lipara capitata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III 4	.	.	.	.	.	.	.	.	.
Hakea sericea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III 2	.	.	.	.	.	.	.	.	.
Erica pinea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III 6	.	.	.	.	.	.	.	.	.
Restio dispar	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 2	.	.	III 5	.	.	.	.	.	.	+ 3	.	.
Bobartia indica	.	.	.	.	.	.	.	.	.	.	.	.	.	II 2	.	.	.	III 2	.	+ 3	.	.	.	.	.	.	.
Elegia asperiflora	.	.	.	.	.	.	.	.	.	I 3	.	.	.	.	.	.	.	III 2	.	.	.	.	.	.	.	.	.
Cliffortia grandifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+ 2	.	III 5	.	.	.	.	.	.	.	.	.

Centella macrocarpa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 2	.	III 3	.	.	.	.	.	.	.	.	.
Cyperaceae spec.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r 3	.	III 2	.	.	.	.	.	.	.	.	.
Pelargonium patulum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III 2	.	II 2	.	.	.	r 3	I 2	.	.
Platycaulos callistachyus	.	.	.	.	.	.	.	.	II 5	.	.	+ 3	.	I 5	.	.	.	III 6	.	+ 6	.	.	.	.	I 6	.	II 3
Penaea mucronata	.	.	.	.	.	.	.	.	.	.	.	+ 1	.	.	.	.	.	II 5	.	+ 5	.	.	.	.	.	.	.
Erica nudiflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 5	.	.	.	.	.	.	.	.	.
Differential species of Ericaceous Fynbos and Muraltio heisteriae-Ericetum pineae																											
Erica labialis	.	.	.	.	.	.	.	.	.	.	.	.	.	I 2	II 5	III 3	I 2	.	.	.	.	.	.	.	.	.	.
Cliffortia atrata	.	.	.	.	.	.	.	.	.	.	.	.	.	I 3	III 3	II 5	II 3	.	+ 2	.	.	.	.	.	.	.	.
Corymbium cymosum	.	.	.	.	.	.	.	.	.	.	.	.	.	II 3	II 2	II 1	I 2	.	+ 2	.	.	.	.	.	.	.	.
Tetraria bromoides	.	.	.	.	.	.	.	.	.	.	.	+ 2	.	II 3	II 4	.	IV 5	.	I 3	.	.	.	.	.	.	.	.
Euryops abrotanifolius	.	.	.	I 4	.	.	.	.	I 1	.	.	.	.	II 2	I 2	II 1	III 3	I 3	I 3	.	.	.	.	.	.	.	.
Helichrysum felinum	.	.	.	.	.	.	.	.	.	.	.	.	.	II 3	I 2	II 1	III 2	.	+ 2	.	.	.	.	.	.	.	.
Widdringtonia nodiflora	.	.	.	.	.	.	.	.	.	.	.	+ 1	.	I 4	I 5	II 1	I 2	.	+ 2	.	.	.	.	.	.	.	.
Differential species of Ericaceous Fynbos and Muraltio heisteriae-Ericetum pineae																											
Leucadendron xanthoconus	.	.	.	.	.	.	.	.	.	.	.	+ 1	V 3	III 4	II 6	V 6	IV 6	.	.	.	.	.	.	.	.	.	II 1
Restio perplexus	.	.	.	.	.	.	.	.	.	.	.	.	II 4	I 2	I 8	II 4	II 5	.	+ 5	.	.	.	I 2	+ 4	.	.	.
Differential species of Wahlenbergio parvifoliae-Pentameritetum thuarii																											
Pentameris thuarii	.	.	.	.	.	.	.	.	.	.	.	.	.	I 5	r 3	.	.	V 9	I 4	.	.	.	r 3	I 2	.	IV 2
Pseudoselago serrata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV 2	.	I 3	.	.	.	.	.	.	.
Othonna quinquedentata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r 1	.	.	II 3	.	.	.	.	.	+ 2	.	.	.
Helichrysum foetidum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 2	.	.	.	.	.	.	.	.	.
Differential species of Helichryso cymosi-Myrsinietum africanae																											
Cliffortia ruscifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 2	.	.	.	r 5	I 2	.	.	.
Species occurring in Wahlenbergio parvifoliae-Pentameritetum thuarii and Helichryso cymosi-Myrsinietum africanae																											
Ursinia scariosa	.	.	.	.	.	.	.	.	I 1	.	.	+ 2	.	I 2	.	.	.	II 2	I 4	.	.	.	+ 3	.	.	.	.
Helichrysum helianthemiifolium	.	.	.	.	.	.	.	+ 2	.	.	.	.	.	.	.	.	.	III 5	II 2	.	II 1	.	r 2	.	.	.	I 2
Ficinia acuminata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 2	I 3	II 4	.	.	.	r 2	.	.	.	.
Ficinia nigrescens	.	.	.	.	.	.	.	.	.	.	I 3	.	.	.	r 2	.	.	I 6	II 5	.	.	.	.	.	.	.	.
Differential species of Pelargonio tomentosi-Chasmanthetum aethiopicae																											
Rubus pinnatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III 5	.	.	.	.	.	.	.
Oxalis purpurea	.	.	.	.	.	.	.	+ 3	.	.	.	.	.	.	.	.	.	.	.	III 2	.	.	r 4	.	.	.	.
Helichrysum patulum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III 4	.	.	.	.	.	.	.
Chrysocoma spec.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 2	.	III 3	.	.	.	.	.	.	.
Senecio cf. hastatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 3	.	.	.	+ 1	.	.	.
Salvia chamelaeagnea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 3	.	IV 5	.	.	.	.	.	.	.
Fumaria muralis	.	.	.	.	.	.	.	+ 2	.	.	.	.	.	.	.	.	.	.	.	II 3	.	.	.	.	.	.	.
Zantedeschia aethiopica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 2	+ 1	III 2	.	.	r 2	+ 1	.	.	.
Pelargonium tomentosum	.	.	.	.	.	.	.	+ 3	.	.	.	.	.	.	.	.	.	I 2	+ 3	IV 5	.	.	.	.	.	.	.
Chasmanthe aethiopica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+ 2	IV 5	.	.	I 4	.	.	.	.
Asparagus rubicundus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 3	III 4	.	.	+ 2	.	.	.	I 1
Chrysanthemoides monilifera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 2	.	.	.	.	.	.	.
Viscum pauciflorum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 2	.	.	.	.	.	.	.

Cyperus denudatus	.	.	.	.	.	.	.	.	+ 3	.	.	.	.	.	.	.	.	.	.	.	II 4	.	.	.	.	II 2	.
Stachys aethiopica	.	.	.	.	.	.	.	.	+ 2	.	.	.	.	.	.	.	.	.	.	.	II 3	.	.	r 2	.	.	.
Clutia alaternoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 5	.	.	.	.	.	.
Pelargonium columbinum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 2	.	.	.	.	.	.
Differential species of Asteraceous Fynbos																											
Myrsine africana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 5	IV 5	IV 5	.	.	II 2	+ 2	.	.
Halleria elliptica	.	.	.	.	.	.	.	.	+ 2	.	.	.	.	.	.	.	.	.	II 5	II 6	IV 5	.	I 3	+ 2	+ 5	I 2	.
Ischyrolepis gaudichaudiana	.	.	.	.	.	.	.	.	.	.	.	.	+ 1	.	.	r 2	.	I 2	I 5	II 7	III 5	.	.	+ 3	I 5	.	.
Rhus tomentosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 1	II 2	I 2	II 4	.	.	r 1	I 2	.	.
Cliffortia polygonifolia	.	I 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 2	.	II 3	I 2	.	.	.	+ 2	.	.
Cliffortia cuneata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 2	II 6	II 3	.	.	r 1	.	.	.
Maytenus oleoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 2	II 3	II 5	.	.	+ 5	.	.	.
Erica hirta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV 2	II 5	II 3	.	.	.	+ 2	.	.
Oxalis livida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 4	II 4	III 3	.	.	.	.	.	.
Oxalis lanata	.	.	.	.	.	.	.	.	+ 2	.	.	.	.	.	.	.	.	.	I 4	I 3	II 4	.	.	.	+ 3	.	.
Wahlenbergia parvifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III 5	.	II 2	.	.	.	.	.	.
Species occurring in Muraltio heisteriae-Ericetum pineae and Asteraceous Fynbos																											
Ficinia trichodes	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r 3	.	I 4	II 6	II 6	III 5	.	.	.	+ 3	.	.
Muraltia heisteria	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r 2	.	IV 2	.	I 3	I 2	.	.	.	.	.	.
Cannomois virgata	.	.	.	.	.	.	.	.	.	I 2	.	.	.	.	I 2	r 3	.	III 6	I 2	II 6	.	.	.	r 3	.	.	.
Stoebe cinerea	.	.	.	.	.	.	IV 2	.	.	.	.	.	.	.	I 2	r 2	.	III 2	I 2	II 5	.	.	.	r 1	.	.	.
Differential species of Ericaceous and Asteraceous Fynbos																											
Struthiola myrsinites	.	.	.	.	.	.	.	.	.	.	.	.	.	III 3	II 2	I 3	IV 2	III 3	.	II 5	III 3	.	.	+ 3	I 5	I 3	.
Agathosma crenulata	.	.	.	.	.	.	.	.	.	.	.	.	II 2	.	II 2	III 4	III 2	II 2	.	III 3	.	.	.	I 3	+ 2	.	.
Metalasia cephalotes	.	.	.	.	.	.	.	.	.	.	.	.	.	II 3	II 2	III 3	II 2	II 2	.	II 5	.	.	.	.	+ 3	.	.
Psoralea pinnata	.	.	.	.	.	.	.	.	.	.	.	.	I 4	.	.	I 3	II 1	.	IV 5	+ 1	.	.	.	.	+ 2	.	.
Berzelia lanuginosa	.	.	.	.	.	.	.	I 2	.	.	.	I 1	.	.	.	.	III 5	III 3	.	I 2	II 5	.	.	.	I 1	I 1	.
Differential species of Platylophietum trifoliati																											
Platylophus trifoliatus	.	.	.	.	.	.	.	.	.	.	.	I 2	.	.	.	.	.	.	.	.	.	V 8	I 2	r 1	.	.	.
Differential species of Curtisio dentatae-Diospyretum whyteanae																											
Diospyros whyteana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V 6	.	.	.	.
Curtisia dentata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV 6	.	.	.	.
Kiggelaria africana	.	I 2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 2	.	.	IV 5	I 5	I 1	.	.
Podocarpus latifolius	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 6	.	.	.	.
Differential species of Afromontane Forests																											
Asplenium aethiopicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 2	III 2	I 2	II 3	.	.	.
Ehrharta erecta	.	.	.	.	.	.	.	.	I 2	.	.	.	.	.	.	.	.	.	.	.	.	II 3	III 2	+ 3	.	.	.
Ilex mitis	.	I 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+ 1	.	II 1	IV 6	II 6	.	.	.
Maytenus acuminata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+ 2	.	III 6	V 7	II 5	I 2	.	.
Rapanea melanophloeos	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 1	.	.	II 2	V 5	II 5	.	.	.
Oxalis livida var. altior	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 3	.	II 3	.	II 3	.	.	.
Apodytes dimidiata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III 2	II 5	.	.	.
Hymenophyllum peltatum	.	I 4	.	.	.	.	.	.	I 4	.	I 6	.	+ 5	.	.	r 5	.	.	.	.	.	.	I 4	II 6	.	.	.

Olea capensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+ 5	.	III 5	III 6	I 2	.	.	.
Differential species of Pteridio aquilini-Cliffortietum odoratae																											
Cliffortia odorata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 3	.	.	.	.	.	II 3	.	.	.	.	V 8	I 1
Differential species of Laurentio arabideae-Juncetum lomatophylli																											
Juncus lomatophyllus	.	II 2	.	.	.	.	.	.	I 1	.	.	.	+ 2	.	.	.	.	.	.	+ 2	.	.	.	r 4	.	.	V 6
Juncus capensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V 3
Morella serrata	.	.	.	.	.	.	.	.	.	.	.	I 5	I 5	.	.	r 2	.	.	.	.	.	.	.	r 5	+ 2	.	V 2
Wimmerella bifida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV 3
Isolepis prolifer	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV 4
Laurembergia repens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 2	.	.	.	.	.	.	.	.	II 3
Pennisetum macrourum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 2
Acacia mearnsii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+ 1	.	II 2
Differential species of Asteraceous Fynbos and Laurentio arabideae-Juncetum lomatophylli																											
Calopsis paniculata	.	.	.	.	.	.	.	.	+ 2	.	.	.	.	.	.	.	.	.	II 3	.	III 5	.	.	.	+ 3	II 3	IV 4
Helichrysum cymosum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 5	II 3	.	.	.	+ 3	+ 2	.	II 3
Differential species of Todeo barbari-Cunonietum capensis, Scrub and Pteridio aquilini-Cliffortietum odoratae																											
Blechnum capense	.	I 2	.	.	.	.	.	.	II 2	I 2	.	.	.	.	.	.	.	.	.	.	.	.	.	II 7	II 6	II 6	I 1
Differential species of Community Groups 4, 6, 7, 8, 10 and Todeo barbari-Cunonietum capensis																											
Metrosideros angustifolius	.	.	.	.	.	.	.	.	II 5	IV 5	.	.	.	.	.	.	.	IV 6	.	I 6	III 5	.	.	III 7	IV 7	III 4	IV 2
Brabejum stellatifolium	.	.	.	.	.	.	.	.	I 5	I 2	.	.	I 2	.	.	.	.	III 5	II 2	III 6	II 5	.	.	II 6	III 6	I 8	III 2
Pteridium aquilinum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III 5	IV 6	III 5	V 7	.	.	+ 3	II 5	V 6	I 2
Rhus angustifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 6	III 4	V 6	.	.	+ 2	I 4	II 6	.
Differential species of Restio purpurascenti-Cliffortietum hirsutae and Laurentio arabideae-Juncetum lomatophylli																											
Ficinia ramosissima	.	.	.	.	.	.	.	.	.	.	.	.	I 4	.	.	I 5	II 7	.	.	.	.	.	.	.	+ 7	.	II 2
Differential species of Asteraceous Fynbos, Afromontane Forest and Scrub communities																											
Asparagus scandens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 3	II 4	I 2	V 2	V 5	IV 4	I 2	.	.
Schoenoxiphium lanceum	.	.	.	.	.	.	.	.	I 3	.	.	.	.	.	.	.	.	.	I 2	I 3	.	IV 5	V 6	III 5	II 3	.	.
Blechnum punctulatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 3	II 4	III 3	II 2	II 3	II 4	I 2	.	.
Cassine schinoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II 2	III 5	I 2	III 5	IV 5	III 6	I 4	.	.
Pellaea pteroides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I 4	II 6	I 3	.	.	I 3	II 3	.	.
Elegia capensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r 3	.	.	II 6	I 3	I 5	.	.	+ 6	I 5	.	.
Common species occurring in Wetbanks, Ericaceous and Asteraceous Fynbos, Forest and Scrub																											
Podalyria calyptrata	.	.	.	.	.	.	.	.	I 2	II 1	.	.	II 5	.	I 2	II 5	II 2	V 4	II 5	III 6	II 5	.	.	II 5	III 6	I 1	III 3
Cassytha ciliolata	.	.	.	.	.	.	.	.	.	.	.	.	II 3	IV 3	IV 3	IV 3	IV 4	V 4	II 2	II 3	II 5	.	.	I 2	I 3	.	I 1
Aristea major	.	.	.	.	.	.	.	.	.	.	.	.	I 2	II 2	III 2	III 2	.	V 2	III 2	IV 4	III 2	.	.	II 3	I 2	.	.
Centella eriantha	.	.	.	.	.	II 3	.	.	.	.	.	.	+ 3	II 2	II 2	II 5	.	.	II 2	I 5	.	.	.	+ 3	II 5	.	.
Diospyros glabra	.	.	.	.	.	.	.	.	.	I 1	.	.	.	.	.	II 2	II 2	IV 2	III 2	IV 4	IV 2	.	I 2	II 3	II 3	.	I 1
Pennisetum macrourum	.	.	.	.	.	.	.	.	+ 5	I 3	.	I 4	+ 1	II 4	.	I 5	.	III 4	IV 4	.	I 4	.	.	.	I 4	.	III 7
Differential species of Erosion-dominated Wet Banks and Afromontane Forests and Scrub																											
Todea barbara	.	II 5	.	.	.	.	.	.	III 2	.	II 3	II 2	III 2	.	II 2	.	.	.	.	.	.	II 2	II 2	IV 6	III 5	.	I 2
Common species to all riparian communities excluding seepages																											
Ischyrolepis subverticillata	.	I 2	.	.	.	.	.	.	II 3	.	.	II 2	III 5	II 4	III 5	IV 6	II 4	IV 6	II 3	IV 6	III 5	.	I 2	III 5	IV 6	.	I 2
Cunonia capensis	.	II 2	.	.	.	.	.	.	.	II 2	III 3	I 1	I 1	.	II 2	r 1	.	I 2	II 1	.	.	II 5	IV 5	IV 7	II 5	.	.

Erica caffra	.	.	.	.	.	.	.	.	II^{3}	.	IV^{2}	I^{1}	II^{4}	.	.	.	II^{6}	I^{2}	.	I^{3}	.	.	.	I^{3}	III^{5}	I^{5}	II^{2}
Brachylaena neriifolia	.	III^{2}	.	.	.	.	.	.	II^{6}	IV^{2}	.	II^{2}	IV^{6}	II^{2}	III^{7}	III^{5}	II^{7}	III^{6}	.	III^{5}	II^{5}	.	II^{5}	IV^{6}	IV^{7}	.	IV^{2}
Pentaschistis pallida	.	V^{6}	.	.	.	II^{2}	.	.	+^{2}	.	I^{3}	.	II^{5}	.	II^{3}	.	II^{3}	.	.	I^{5}	.	.	.	+^{3}	I^{2}	.	.
Common species to all riparian and seepage communities excluding Wet Banks and Scree Forests																											
Erica hispidula	.	.	.	.	.	II^{3}	IV^{3}	II^{2}	.	.	.	I^{2}	III^{2}	IV^{3}	V^{4}	V^{6}	IV^{3}	V^{3}	.	II^{3}	.	.	.	I^{2}	I^{2}	.	.
Ehrharta rehmannii	.	.	.	I^{2}	.	II^{2}	IV^{3}	I^{3}	I^{4}	.	.	.	.	.	III^{3}	II^{3}	II^{3}	III^{3}	V^{5}	IV^{5}	II^{5}	.	.	II^{3}	II^{3}	.	I^{3}
Stoebe plumosa	.	.	.	III^{2}	IV^{2}	II^{2}	.	I^{2}	.	.	.	.	.	.	I^{2}	I^{2}	II^{2}	I^{3}	I^{3}	II^{6}	II^{5}	.	.	+^{3}	II^{3}	.	.
Oxalis truncatula	.	.	.	I^{2}	.	.	IV^{2}	.	.	.	.	.	.	.	I^{1}	+^{2}	.	II^{3}	.	+^{2}	.	.	.	+^{3}	.	.	.

Appendix F: Environmental variables at the sample sites

Community codes indicated with an S refer to seepage communities; soil types: Fw = Fernwood, Ch = Champagne, Ms = Mispah, Ma = Magwa, Oa = Oakleaf, Gs = Glenrosa

Community S1.1

Releve	Transect	Soil type	Soil colour	Altitude (in m)	Slope (in degrees)	pH (H_2O)	Resistance (in kilo-Ohms)	Gravel fraction (in %)	Coarse sand fraction (in %)	Medium sand fraction (in %)	Fine sand fraction (in %)	Silt fraction (in %)	Organic matter (in %)	Soil depth (in cm)
111	34	Fw	10YR 4/1	1365	20	4.09	1.91	0.10	0.80	77.30	10.50	11.40	3.82	60
233	106	Ma	10YR 3/2	1460	32	4.11	2.35	3.90	2.40	63.40	17.80	16.50	7.02	15
Average			Dark	1412.5	26.00	4.10	2.13	2.00	1.60	70.35	14.15	13.95	5.42	37.50

Community S1.2

241	110	Ma	10YR 3/1	1100	24	3.90	0.65	20.30	15.90	49.90	17.30	16.80	6.53	40
242	111	Fw	10YR 4/1	1100	24	3.96	1.91	11.90	16.90	55.70	14.50	12.90	2.81	60
Average			Dark	1100.0	24.00	3.93	1.28	16.10	16.40	52.80	15.90	14.85	4.67	50.00

Community S1.3

227	100	Ma	10YR 3/1	1200	0	4.13	1.17	8.30	27.90	65.10	4.00	3.00	5.97	60
228	101	Ch	10YR 2/2	1200	0	3.74	1.53	8.60	6.90	64.20	15.50	13.50	12.09	60
229	102	Ma	10YR 3/1	1200	0	3.90	2.52	3.50	23.20	70.20	4.70	1.90	5.34	60
230	103	Ma	10YR 3/1	1200	0	3.91	1.21	6.30	14.10	72.60	7.40	5.90	7.02	60
Average			Dark	1200.0	0.00	3.92	1.61	6.68	18.03	68.03	7.90	6.08	7.61	60.00

Community S1.4

226	99	Ma	10YR 3/1	1200	0	3.90	2.46	2.50	11.90	74.10	7.10	6.80	4.68	60
231	104	Ch	10YR 2/2	1370	0	3.74	1.52	2.60	0.20	47.10	22.20	30.50	19.89	60
232	105	Oa	10YR 3/1	1370	0	3.81	2.06	0.40	13.90	57.90	13.90	14.40	2.40	60
243	112	Ma	10YR 3/1	1125	0	4.04	1.83	3.70	10.20	76.90	8.70	4.20	5.58	60
244	113	Ma	10YR 3/1	1125	0	4.01	2.87	2.60	13.20	74.80	7.20	4.90	3.39	60
259	125	-	10YR 3/1	-	7	4.78	1.95	8.50	12.20	65.30	14.10	8.40	7.02	60
Average			Dark	1238.0	1.17	4.05	2.12	3.38	10.27	66.02	12.20	11.53	7.16	60.00

Community S1.5

188	77	Ma	10YR 3/1	1070	6	4.08	1.37	0.70	23.80	70.40	4.00	1.80	4.88	60
201	87	Ch	10YR 3/1	1280	7	4.02	1.61	2.10	4.90	71.30	12.70	11.10	10.34	60
202	88	Ch	10YR 3/1	1280	7	3.85	1.82	1.50	8.90	74.10	9.10	7.90	8.00	60
203	89	Ch	10YR 3/1	1270	7	3.96	1.96	2.60	7.00	78.00	8.40	6.60	8.87	60
Average			Dark	1225.0	6.75	3.98	1.69	1.73	11.15	73.45	8.55	6.85	8.02	60.00

Community S2.1

135	48	Fw	10YR 5/1	1180	0	3.73	1.82	0.70	11.20	81.30	4.00	3.50	2.63	-
136	49	Fw	10YR 3/3	1175	10	4.05	0.89	8.60	24.30	62.70	6.60	6.40	9.95	60
165	64	Ch	10YR 3/1	1170	-	4.08	1.58	0.70	15.40	78.10	3.10	3.30	10.34	50
Average			Brown	1175.0	5.00	3.95	1.43	3.33	16.97	74.03	4.57	4.40	7.64	55.00

Community S2.2

131	46	Oa	10YR 4/1	1160	18	3.94	1.21	5.80	24.50	69.60	3.60	2.30	5.77	60
134	47	Ms	10YR 4/1	1145	40	3.76	1.17	7.90	9.80	77.20	2.50	10.50	2.05	-
Average			Grey	1152.5	29.00	3.85	1.19	6.85	17.15	73.40	3.05	6.40	3.91	60.00

Community S2.3

124	42	Oa	10YR 3/1	1000	12	3.63	1.16	7.90	33.80	60.20	3.00	3.00	3.90	40
127	44	Ms	10YR 5/1	980	10	3.86	3.05	11.60	27.60	69.20	2.10	1.20	1.35	20
128	44	Ma	10YR 3/1	980	10	3.94	1.78	2.50	16.80	74.70	3.90	4.60	4.00	60
Average			Dark	986.7	10.67	3.81	2.00	7.33	26.07	68.03	3.00	2.93	3.08	40.00

Community S2.4

Releve	Transect	Soil type	Soil colour	Altitude (in m)	Slope (in degrees)	pH (H_2O)	Resistance (in kilo-Ohms)	Gravel fraction (in %)	Coarse sand fraction (in %)	Medium sand fraction (in %)	Fine sand fraction (in %)	Silt fraction (in %)	Organic matter (in %)	Soil depth (in cm)
86	24	Ch	10YR 2/1	1075	0	3.89	1.87	1.40	12.20	68.30	7.90	11.70	21.45	50
87	25	Ch	10YR 2/1	1060	0	4.22	1.29	1.70	12.30	75.70	6.40	5.70	11.08	50
123	42	Fw	10YR 6/1	1000	12	4.15	2.24	8.90	29.70	67.30	2.10	0.80	0.62	40
129	45	Oa	10YR 3/2	1060	0	3.49	1.77	16.40	36.70	57.70	2.80	2.90	6.20	30
163	62	Fw	10YR 5/1	1075	-	4.75	2.29	1.00	16.00	80.90	2.10	1.00	1.05	60
164	63	Ma	10YR 3/1	1075	-	3.81	1.26	1.50	15.20	70.20	6.80	7.70	4.58	60
189	78	Ch	10YR 2/1	1075	0	3.66	0.91	0.80	7.30	51.90	19.00	21.90	8.58	50
234	107	Ch	10YR 3/1	1060	0	3.95	1.63	1.40	16.90	66.30	9.90	7.00	8.78	40
262	128	-	10YR 4/1	-	5	4.55	2.83	2.40	55.20	40.90	2.00	1.90	4.91	60
Average			Dark / Grey	1060.0	2.43	4.05	1.79	3.94	22.39	64.36	6.56	6.73	7.47	48.89

Community 1.1

1	1	-	-	620	-	-	-	-	-	-	-	-	-	-
4	2	-	-	300	-	-	-	-	-	-	-	-	-	-
8	3	-	-	620	-	-	-	-	-	-	-	-	-	-
12	4	-	-	545	-	-	-	-	-	-	-	-	-	-
17	5	-	-	315	-	-	-	-	-	-	-	-	-	-
21	6	-	-	295	-	-	-	-	-	-	-	-	-	-
24	7	-	-	690	-	-	-	-	-	-	-	-	-	-
29	8	-	-	510	-	-	-	-	-	-	-	-	-	-
33	9	-	-	560	-	-	-	-	-	-	-	-	-	-
40	10	-	-	760	-	-	-	-	-	-	-	-	-	-
44	11	-	-	540	-	-	-	-	-	-	-	-	-	-
48	12	-	-	420	-	-	-	-	-	-	-	-	-	-
52	13	-	-	480	-	-	-	-	-	-	-	-	-	-
56	14	-	-	700	-	-	-	-	-	-	-	-	-	-
60	15	-	-	770	-	-	-	-	-	-	-	-	-	-
65	16	-	-	880	-	-	-	-	-	-	-	-	-	-
71	19	-	-	680	-	-	-	-	-	-	-	-	-	-
75	20	-	-	680	-	-	-	-	-	-	-	-	-	-
88	26	-	-	675	-	-	-	-	-	-	-	-	-	-
92	27	-	-	380	-	-	-	-	-	-	-	-	-	-
96	28	-	-	370	-	-	-	-	-	-	-	-	-	-
100	29	-	-	450	-	-	-	-	-	-	-	-	-	-
178	72	-	-	540	-	-	-	-	-	-	-	-	-	-
182	75	-	-	560	-	-	-	-	-	-	-	-	-	-
221	97	-	-	690	-	-	-	-	-	-	-	-	-	-
235	108	-	-	730	-	-	-	-	-	-	-	-	-	-
Average				567.7										

Community 1.2

130	46	-	-	1160	-	-	-	-	-	-	-	-	-	-
132	47	-	-	1145	-	-	-	-	-	-	-	-	-	-
167	66	-	-	580	-	-	-	-	-	-	-	-	-	1
204	90	-	-	540	70	-	-	-	-	-	-	-	-	-
205	90	-	-	540	80	-	-	-	-	-	-	-	-	-
250	50	-	-	860	-	-	-	-	-	-	-	-	-	-
Average				654.4	75.00									1.00

Releve	Transect	Soil type	Soil colour	Altitude (in m)	Slope (in degrees)	pH (H_2O)	Resistance (in kilo-Ohms)	Gravel fraction (in %)	Coarse sand fraction (in %)	Medium sand fraction (in %)	Fine sand fraction (in %)	Silt fraction (in %)	Organic matter (in %)	Soil depth (in cm)

Community 2.1

16	5A	-	-	315	40	-	-	-	-	-	-	-	-	10
34	9	-	10YR 6/1	560	20	5.04	7.38	91.30	65.30	33.50	0.60	0.70	0.45	1
41	10B	-	-	760	6	-	-	-	-	-	-	-	-	10
53	13	-	-	480	25	-	-	-	-	-	-	-	-	-
66	17	Ms	10YR 5/3	270	41	4.94	3.65	11.00	36.20	61.20	1.50	1.10	0.35	5
69	18	-	-	420	12	-	-	-	-	-	-	-	-	-
93	27	-	10YR 3/1	380	14	4.13	1.81	2.60	14.10	70.80	7.90	7.10	4.39	2
117	39	Ms	10YR 5/3	280	24	4.97	4.51	1.30	8.80	66.90	10.20	14.00	0.92	15
137	50	-	10YR 6/2	860	80	4.09	2.84	2.10	30.80	65.80	2.20	1.20	0.64	1
139	51	-	10YR 5/1	880	25	3.91	5.87	65.60	63.90	34.50	0.90	0.70	0.39	1
141	52	Gs	10YR 4/3	470	15	4.87	5.76	65.30	52.10	43.60	2.00	2.30	1.77	3
268	65	-	-	540	28	-	-	-	-	-	-	-	-	-
269	72	-	10YR 4/2	540	8	-	-	58.80	33.10	57.00	6.30	3.70	2.73	1
Average			Pale	519.6	26.00	4.56	4.55	37.25	38.04	54.16	3.95	3.85	1.46	4.90

Community 2.2

32	9	-	-	560	20	-	-	-	-	-	-	-	-	1
212	94	-	-	560	21	-	-	-	-	-	-	-	-	1
239	109	-	10YR 6/2	670	10	5.65	5.57	0.20	23.70	74.60	1.20	0.50	0.33	1
245	114	-	10YR 5/1	560	15	4.69	4.62	99.90	58.70	39.70	1.10	0.50	0.60	1
247	115	-	10YR 6/1	560	22	5.58	4.90	93.90	53.60	44.50	1.30	0.60	0.20	1
Average			Pale	582.0	17.60	5.31	5.03	64.67	45.33	52.93	1.20	0.53	0.38	1.00

Community 3.1

39	10A	-	-	760	6	-	-	-	-	-	-	-	-	1
45	11	-	-	540	30	-	-	-	-	-	-	-	-	15
49	12	Ms	10YR 4/2	420	5	4.06	0.89	36.10	42.00	54.50	2.20	1.40	1.89	15
63	16	Ms	10YR 4/1	880	34	3.92	0.95	9.00	38.30	54.70	4.00	3.00	2.26	3
133	47	Ma	10YR 3/2	1145	40	4.69	0.59	28.10	38.40	57.00	2.20	2.40	8.19	-
145	53	Gs	10YR 5/2	440	20	4.14	1.63	22.20	19.20	70.90	6.10	3.80	1.76	5
Average			Brown	697.5	22.50	4.20	1.02	23.85	34.48	59.28	3.63	2.65	3.53	7.80

Community 3.2

5	2	Ms	10YR 6/2	300	16	5.17	4.59	2.00	48.40	51.60	0.00	0.10	0.16	-
9	3	Ms	10YR 4/1	620	8	3.94	1.18	10.40	15.30	77.90	3.20	3.60	1.87	30
25	7	Ms	10YR 5/1	690	11	4.20	1.33	21.40	35.70	61.40	1.90	1.00	0.74	25
57	14	-	-	700	14	-	-	-	-	-	-	-	-	1
72	19	Ms	10YR 5/1	680	12	4.45	4.69	5.90	47.30	50.90	0.80	0.90	0.47	15
76	20	Ms	10YR 4/1	670	11	3.83	2.98	5.40	24.30	71.80	1.90	2.00	1.95	30
81	22	Gs	10YR 5/2	670	30	4.39	3.55	33.20	48.90	48.50	1.40	1.30	0.57	3
154	58	Gs	10YR 5/3	350	6	5.08	4.90	34.80	84.70	15.10	0.10	0.00	0.14	10
183	75	Gs	10YR 6/2	560	15	6.04	2.61	61.40	73.30	26.40	0.20	0.10	0.06	5
Average			Pale	582.22	13.67	4.64	3.23	21.81	47.24	50.45	1.19	1.13	0.75	14.88

Releve	Transect	Soil type	Soil colour	Altitude (in m)	Slope (in degrees)	pH (H_2O)	Resistance (in kilo-Ohms)	Gravel fraction (in %)	Coarse sand fraction (in %)	Medium sand fraction (in %)	Fine sand fraction (in %)	Silt fraction (in %)	Organic matter (in %)	Soil depth (in cm)
Community 3.3														
2	1	Ms	10YR 6/2	620	11	4.99	6.30	1.20	57.50	42.10	0.10	0.20	0.00	20
6	2	Oa	10YR 3/2	300	16	3.85	1.16	14.60	27.70	62.70	4.30	5.40	3.49	-

13	4	Ms	10YR 5/1	545	13	4.14	2.22	88.40	35.10	60.70	1.30	2.90	0.99	-
26	7	Ms	10YR 5/1	690	11	4.44	2.42	57.40	69.30	27.80	1.70	1.20	1.33	5
58	14	-	-	700	14	-	-	-	-	-	-	-	-	1
61	15	-	-	770	70	-	-	-	-	-	-	-	-	1
79	21	Gs	10YR 6/2	635	14	5.57	4.87	26.50	76.70	23.00	0.10	0.10	0.00	3
89	26	-	10YR 5/1	675	28	4.17	1.29	4.00	29.40	64.50	3.50	2.60	2.42	-
152	57	Ms	10YR 5/1	335	35	3.74	1.32	4.10	19.30	69.10	6.00	5.60	0.53	10
155	58	Fw	10YR 5/1	350	6	3.99	2.03	10.90	46.50	50.10	2.50	1.00	1.21	40
156	59	-	10YR 7/1	680	14	4.58	2.92	44.60	58.10	41.40	0.40	0.10	0.23	2
157	59	Gs	10YR 6/2	680	14	4.44	7.86	16.30	27.30	68.40	2.50	1.70	0.57	5
185	76	Ms	10YR 5/1	520	15	5.12	2.14	25.30	42.00	56.60	1.10	0.30	0.41	25
186	76	Fw	10YR 6/1	520	15	3.83	3.22	10.90	37.90	59.10	2.00	1.10	0.59	55
215	95	Ms	10YR 5/1	770	14	4.48	1.81	25.40	35.20	60.00	3.10	1.70	1.70	5
218	96	Ms	10YR 5/1	760	13	4.67	2.72	87.90	66.50	31.50	1.50	0.60	0.90	5
222	97	Ms	10YR 7/1	690	23	4.70	4.74	47.80	73.80	25.90	0.20	0.10	1.25	15
224	98	Ms	10YR 4/1	650	13	4.14	1.05	21.80	30.10	59.10	5.80	4.90	4.33	1
236	108	-	10YR 6/1	730	10	5.32	2.36	24.70	56.20	42.80	0.70	0.20	0.47	2
Average			Pale	611.58	18.37	4.48	2.97	30.11	46.39	49.69	2.16	1.75	1.20	12.19

Community 4.1

146	54	Gs	10YR 6/2	360	8	5.20	5.58	1.90	25.10	74.40	0.30	0.20	0.16	3
147	54	Ms	10YR 7/2	360	8	5.28	14.02	0.10	12.80	86.50	0.60	0.20	0.12	5
159	60	Gs	10YR 4/3	360	28	4.25	2.15	34.50	17.80	77.00	3.30	2.00	1.33	40
161	61	Gs	10YR 6/2	360	32	3.81	2.28	0.70	26.00	71.60	1.60	0.90	0.25	10
195	83	-	10YR 5/3	380	14	5.46	4.36	99.90	64.80	34.40	0.50	0.30	0.43	2
249	116	Gs	10YR 6/2	360	1	6.01	7.89	99.90	74.80	24.20	0.70	0.30	0.10	15
Average			Yellow	363.33	15.17	5.00	6.05	39.50	36.88	61.35	1.17	0.65	0.40	12.50

Community 5.1

190	79	Oa	10YR 3/1	570	20	4.09	1.65	4.60	24.60	66.60	5.20	3.60	3.35	30
191	80	Ma	10YR 3/1	540	15	3.99	1.67	5.10	21.00	70.50	4.80	3.80	5.93	25
Average			Dark	555.00	17.50	4.04	1.66	4.85	22.80	68.55	5.00	3.70	4.64	27.50

Community 5.2

73	19	Ms	10YR 6/1	680	12	3.99	3.00	1.60	14.30	82.40	1.90	1.40	0.53	35
74	19	Oa	10YR 3/1	680	12	3.82	1.90	2.50	10.10	76.40	6.50	7.00	3.00	30
77	20	Fw	10YR 5/1	670	11	4.19	1.42	3.20	20.10	76.00	2.40	1.50	2.98	40
78	20	Ms	10YR 3/1	670	11	3.57	1.51	2.30	18.10	73.30	4.30	4.20	4.52	30
Average			Variable	675.00	11.50	3.89	1.96	2.40	15.65	77.03	3.78	3.53	2.76	33.75

Community 5.3

125	43	Ms	10YR 6/1	995	30	4.09	3.17	16.40	37.20	61.00	1.20	0.70	0.43	15
126	43	Ms	10YR 4/1	995	30	3.78	1.88	6.00	21.00	67.60	5.30	6.20	2.13	25
184	75	Ms	10YR 4/1	560	15	4.00	3.73	2.40	12.80	80.40	4.90	1.90	1.62	15
216	95	Ms	10YR 6/1	770	14	5.07	10.72	99.90	69.70	29.20	0.70	0.30	0.31	3
219	96	Fw	10YR 4/1	760	13	4.06	1.80	1.90	12.00	79.00	5.60	3.40	4.91	40
237	108	Ms	10YR 6/1	730	10	5.19	3.45	21.60	41.90	57.10	0.90	0.20	0.82	35
263	129	-	10YR 5/1	700	15	3.94	1.98	27.30	41.80	56.20	1.40	0.60	1.01	2
Average			Pale, Grey	787.14	18.14	4.30	3.82	25.07	33.77	61.50	2.86	1.90	1.60	19.29

Community 5.4

Releve	Transect	Soil type	Soil colour	Altitude (in m)	Slope (in degrees)	pH (H_2O)	Resistance (in kilo-Ohms)	Gravel fraction (in %)	Coarse sand fraction (in %)	Medium sand fraction (in %)	Fine sand fraction (in %)	Silt fraction (in %)	Organic matter (in %)	Soil depth (in cm)
Community 5.4a														
14	4	-	-	545	13	-	-	-	-	-	-	-	-	-
15	4	Ma	10YR 3/1	545	13	3.86	2.28	15.70	20.30	69.10	5.40	5.30	6.98	-
27	7	Ms	10YR 5/1	690	11	4.36	4.34	2.70	33.80	63.20	2.10	1.00	0.78	30
28	7	Ms	10YR 5/1	690	11	4.65	5.00	37.30	19.90	71.80	5.10	3.30	1.05	5
59	14	-	-	700	14	-	-	-	-	-	-	-	-	10

80	21	Gs	10YR 5/3	635	14	5.34	5.10	6.70	30.60	67.70	1.10	0.70	0.51	3
82	22	Ms	10YR 4/1	670	30	4.38	3.27	4.30	26.80	62.90	4.40	5.90	2.34	3
153	57	Ms	10YR 5/1	335	35	3.58	1.10	20.50	34.30	60.10	3.60	2.10	2.67	35
158	59	Fw	10YR 4/1	680	14	3.81	2.29	14.80	13.70	78.90	4.80	2.70	3.30	40
187	76	Ms	10YR 6/1	520	15	4.52	7.19	5.70	29.70	65.80	2.90	1.60	0.33	25
217	95	Ms	10YR 4/1	770	14	4.62	4.51	8.70	21.90	69.10	6.10	2.90	1.95	25
225	98	Ms	10YR 5/1	650	13	4.78	7.31	2.70	33.80	63.50	1.90	0.90	1.09	-
Community 5.4b														
10	3	-	-	620	8	-	-	-	-	-	-	-	-	15
11	3	-	-	620	8	-	-	-	-	-	-	-	-	10
83	23	Ms	10YR 4/1	485	25	4.20	2.03	5.60	23.90	71.40	3.20	1.60	1.38	5
84	23	Ms	10YR 5/1	485	25	4.50	4.28	12.80	30.80	63.00	3.50	2.70	1.27	20
85	23	Ms	10YR 4/1	485	25	4.06	1.09	16.90	30.90	57.90	5.60	5.60	7.96	20
91	26	Oa	10YR 3/1	675	28	3.96	2.77	3.30	19.40	72.30	4.40	3.80	3.80	-
220	96	Oa	10YR 3/2	760	13	4.31	2.63	3.00	26.10	68.50	3.60	1.80	3.98	15
238	108	Fw	10YR 4/1	730	10	4.31	3.67	3.80	31.40	65.30	2.20	1.10	2.52	50
Average 5.4a				619.17	16.42	4.39	4.24	11.91	26.48	67.21	3.74	2.64	2.10	19.56
Average 5.4b				607.50	17.75	4.22	2.75	7.57	27.08	66.40	3.75	2.77	3.49	19.29
Average 5.4 tota			Grey, Pale	614.5	16.95	4.33	3.68	10.28	26.71	66.91	3.74	2.69	2.62	19.438

Community 5.5

3	1	Oa	10YR 4/1	620	11	4.28	2.55	26.50	14.70	67.50	6.30	11.50	5.89	20
7	2	Gs	10YR 6/1	300	16	3.81	2.07	5.60	27.40	68.20	2.80	1.70	2.09	-
223	97	Ms	10YR 4/1	690	23	4.10	2.26	6.50	44.50	51.90	2.10	1.50	2.15	25
240	109	-	-	670	10	-	-	-	-	-	-	-	-	40
Average			Grey, Pale	570.00	15.00	4.06	2.29	12.87	28.87	62.53	3.73	4.90	3.38	28.33

Community 6.1

19	5B	Ma	10YR 3/1	315	40	3.69	1.19	6.90	38.40	53.90	2.90	4.80	3.76	35
210	92	Ma	10YR 3/1	520	50	4.15	1.35	6.20	13.90	72.60	7.80	5.80	6.12	5
Average			Dark	417.5	45	3.92	1.27	6.55	26.15	63.25	5.35	5.30	4.94	20

Community 6.2

35	9	Oa	10YR 4/1	560	20	4.32	2.53	4.00	15.60	76.40	4.00	3.90	2.34	35
36	9	Oa	10YR 4/2	560	20	4.98	1.66	16.90	31.10	55.10	5.80	7.90	3.04	25
213	94	Ms	10YR 5/1	560	21	4.40	3.80	2.70	21.40	71.80	4.30	2.60	1.72	15
214	94	Ma	10YR 3/2	560	21	4.25	2.10	6.30	20.30	56.50	10.50	12.80	5.23	50
246	114	Fw	10YR 4/1	560	15	4.80	4.33	8.30	25.50	69.40	3.20	1.90	1.48	40
248	115	Ms	10YR 5/1	560	22	5.19	5.72	15.70	16.10	76.50	4.50	2.90	0.92	30
258	123	Ms	10YR 6/1	570	16	4.96	8.32	12.90	27.50	70.50	1.50	0.40	0.68	15
Average			Grey, Pale	561.43	19.29	4.70	4.07	9.54	22.50	68.03	4.83	4.63	2.20	30.00

Community 6.3

31	8	-	10YR 4/2	510	22	4.60	3.28	41.30	46.40	52.10	1.20	0.40	1.91	1
172	69	Ms	10YR 4/1	570	21	4.49	2.93	16.00	20.20	67.50	6.90	5.40	3.24	5
Average		Ms	Grey	540.00	21.50	4.55	3.11	28.65	33.30	59.80	4.05	2.90	2.58	3.00

Releve	Transect	Soil type	Soi colour	Altitude (in m)	Slope (in degrees)	pH (H_2O)	Resistance (in kilo-Ohms)	Gravel fraction (in %)	Coarse sand fraction (in %)	Medium sand fraction (in %)	Fine sand fraction (in %)	Silt fraction (in %)	Organic matter (in %)	Soil depth (in cm)
Community 7.1														
51	12	Oa	10YR 4/2	420	5	4.59	1.81	3.70	17.70	71.60	6.00	4.60	3.20	35
115	37	Ms	10YR 4/2	350	15	5.09	4.98	2.10	9.90	76.00	7.40	6.60	1.77	-
181	74	Ms	10YR 4/2	490	14	4.86	4.20	91.90	35.80	59.40	2.60	2.20	1.33	5
196	83	Ma	10YR 3/1	380	14	4.26	2.20	43.20	20.50	49.70	14.80	15.00	5.36	10
257	122	Oa	10YR 4/2	390	25	4.77	4.75	8.00	20.50	68.80	14.60	6.20	6.89	10
Average			Brown	406.00	14.60	4.71	3.59	29.78	20.88	65.10	9.08	6.92	3.71	15.00

Community 7.2

Community 7.2a														
55	13	Gs	10YR 3/3	480	25	5.05	1.65	9.10	16.40	69.40	6.60	7.70	3.08	40
95	27	Gs	10YR 4/3	380	14	4.82	2.78	9.70	18.10	67.10	6.20	8.60	3.32	25

99	28	Gs	10YR 4/3	370	16	4.61	2.90	68.90	34.10	59.70	2.80	3.50	2.61	5
103	29	Ms	10YR 5/1	450	13	4.38	3.32	11.40	33.00	63.30	2.00	1.80	1.03	10
106	31	-	10YR 6/3	405	28	4.57	4.98	21.70	59.10	40.20	0.50	0.30	0.35	2
107	31	Ms	10YR 4/1	405	28	3.93	4.35	2.50	21.00	64.30	5.80	9.00	3.28	-
144	53	Oa	10YR 2/2	440	20	4.73	2.42	26.60	28.40	62.00	4.60	5.00	5.15	10
175	71	Gs	10YR 5/3	590	15	4.22	4.77	8.80	12.30	80.80	4.90	2.10	0.96	10
177	72	Oa	10YR 4/2	540	8	4.08	3.37	1.70	23.20	67.00	6.00	3.80	2.77	-
Community 7.2b														
98	28	Oa	10YR 4/2	370	16	4.63	3.06	10.80	38.80	57.00	2.40	1.80	1.85	10
113	36	Gs	10YR 5/3	360	12	5.39	4.22	0.90	8.60	83.70	4.90	2.80	1.77	20
151	56	Oa	10YR 3/2	530	29	5.03	2.71	5.70	19.60	40.90	24.60	14.90	7.41	10
180	73	Ms	10YR 4/1	520	19	4.63	2.45	21.50	20.60	71.30	4.90	3.20	4.56	10
207	91	Gs	10YR 6/2	520	20	5.66	6.57	99.90	64.20	35.20	0.30	0.30	0.35	3
208	91	Fw	10YR 4/3	520	20	4.18	3.82	61.90	18.40	53.50	12.80	15.30	4.10	60
266	132	-	10YR 6/2	-	-	5.17	12.11	9.20	68.00	31.60	0.30	0.10	0.23	60
Community 7.2c														
37	10A	Ma	10YR 3/2	760	6	4.55	2.19	9.90	30.70	53.10	7.10	9.10	11.70	10
43	10B	Oa	10YR 3/2	760	6	4.73	2.56	11.00	26.40	65.70	3.60	4.40	3.08	40
Average 7.2a				451.11	18.56	4.49	3.39	17.82	27.29	63.76	4.38	4.64	2.51	14.57
Average 7.2b				470.00	19.33	4.96	4.99	29.99	34.03	53.31	7.17	5.49	2.90	24.71
Average 7.2c				760.00	6.00	4.64	2.38	10.45	28.55	59.40	5.35	6.75	7.39	25.00
Average 7.2 tota			Yellowish	494.12	17.35	4.69	3.90	21.73	30.05	59.21	5.57	5.21	3.20	20.31

Community 7.3

67	17	Oa	10YR 4/2	270	41	5.12	2.04	4.00	17.10	72.50	6.20	4.20	2.81	45
68	17	Ms	10YR 3/2	270	41	5.48	0.84	5.50	27.00	63.00	4.40	5.70	3.08	15
118	39	Ma	10YR 3/2	280	24	5.73	1.40	4.80	13.50	72.60	6.40	7.60	3.59	60
251	117	Oa	10YR 4/3	280	8	6.05	3.02	4.90	18.20	72.70	6.50	3.40	2.46	20
252	118	Oa	10YR 4/2	280	11	5.07	3.02	3.90	15.80	72.00	7.40	4.80	2.73	40
Average			Brown	276.00	25.00	5.49	2.06	4.62	18.32	70.56	6.18	5.14	2.93	36.00

Community 8.1

119	40	Oa	10YR 4/2	270	22	5.12	1.84	2.50	13.10	79.90	4.60	2.40	2.50	30
120	40	Gs	10YR 4/2	270	22	5.09	4.02	5.50	31.50	64.70	2.20	1.60	0.99	60
122	41	Oa	10YR 3/2	265	20	5.22	1.49	12.10	22.40	69.80	4.20	3.70	3.37	60
253	119	Gs	10YR 5/3	280	22	6.18	2.66	13.80	30.10	67.20	1.70	1.00	1.44	15
254	119	Gs	10YR 5/2	280	22	5.47	2.36	0.70	16.40	73.50	6.10	4.00	2.30	30
Average			Yellowish	273.00	21.60	5.42	2.47	6.92	22.70	71.02	3.76	2.54	2.12	39.00

Community 8.2

160	60	Gs	10YR 4/3	360	28	4.46	3.50	89.30	13.00	78.80	4.80	3.40	1.37	40

Community 9.1

20	6	-	-	295	22	-	-	-	-	-	-	-	-	20

Releve	Transect	Soil type	Soil colour	Altitude (in m)	Slope (in degrees)	pH (H_2O)	Resistance (in kilo-Ohms)	Gravel fraction (in %)	Coarse sand fraction (in %)	Medium sand fraction (in %)	Fine sand fraction (in %)	Silt fraction (in %)	Organic matter (in %)	Soil depth (in cm)
Community 9.2														
192	81	Oa	10YR 4/2	390	16	4.86	2.77	27.80	33.10	58.00	5.10	3.90	1.38	25
197	84	-	10YR 5/2	410	26	4.65	4.97	99.90	59.90	37.80	1.40	0.90	0.37	2
255	120	Ms	10YR 6/2	410	11	4.98	16.59	30.20	76.60	23.00	0.20	0.20	0.18	5
256	121	-	10YR 4/2	410	11	5.26	2.81	16.20	25.00	69.70	3.10	2.20	3.51	2
Average			Yellowish	405.00	16.00	4.94	6.79	43.53	48.65	47.13	2.45	1.80	1.36	8.50

Community 9.3

193	81	Ma	10YR 3/2	390	16	5.36	0.78	99.90	28.30	54.30	8.50	8.90	10.04	5
194	82	Oa	10YR 4/2	400	25	5.14	2.25	99.90	50.80	31.20	9.70	8.40	5.75	10
198	84	Ma	10YR 3/2	410	26	4.33	1.29	99.90	34.90	43.20	9.70	12.20	10.14	60
199	85	Ma	10YR 4/2	410	23	5.63	0.98	99.90	13.10	68.40	9.50	9.00	10.34	40
200	86	Ma	10YR 3/2	410	11	3.96	0.93	5.30	0.90	84.50	4.40	10.20	11.99	10
Average			Brown	404.00	20.20	4.88	1.25	80.98	25.60	56.32	8.36	9.74	9.65	25.00

Community 9.4

Community 9.4a														
18	5B	Gs	10YR 5/2	315	40	5.68	2.40	38.70	75.20	24.20	0.40	0.20	0.43	25
46	11	Ma	10YR 3/2	540	30	5.05	0.85	17.70	20.40	42.10	14.10	23.50	5.69	10
70	18	Oa	10YR 3/2	420	12	4.81	1.46	40.30	37.90	51.20	3.40	7.60	7.41	35
108	32	-	10YR 6/3	455	9	4.82	3.87	5.90	42.70	57.10	0.10	0.10	0.10	1
109	32	Gs	10YR 5/2	455	9	4.87	3.28	6.10	34.80	63.60	1.10	0.60	1.89	10
112	35	Oa	10YR 3/2	360	10	5.44	2.69	4.10	19.70	70.80	5.40	4.10	3.41	30
142	52	Oa	10YR 2/2	470	15	5.46	1.26	4.60	12.90	70.00	6.20	10.90	2.52	20
149	55	Oa	10YR 4/2	520	9	4.93	2.99	4.50	33.30	57.50	4.20	5.00	2.93	35
150	56	Ms	10YR 4/2	530	29	5.03	2.82	60.50	54.40	40.10	1.80	3.80	1.77	10
168	66	Oa	10YR 3/2	580	36	4.05	2.08	58.60	15.40	68.10	9.60	6.90	7.70	30
170	68	Gs	10YR 5/2	580	50	4.41	3.36	6.80	39.30	59.30	0.90	0.50	0.60	15
174	71	Ms	10YR 4/2	590	15	4.43	3.94	27.60	32.10	63.20	2.80	1.90	1.13	30
179	73	-	10YR 5/3	520	19	5.15	5.02	99.90	69.10	30.60	0.20	0.10	0.20	2
Community 9.4b														
62	15	-	-	770	70	-	-	-	-	-	-	-	-	40
64	16	Ms	10YR 4/1	880	34	4.25	2.20	9.00	31.70	64.50	2.40	1.50	1.11	3
102	29	Gs	10YR 4/2	450	13	5.27	2.11	6.70	23.10	69.40	3.80	3.70	2.63	25
104	30	Gs	10YR 3/3	470	25	4.70	1.27	6.30	21.10	55.10	8.90	14.90	11.31	10
110	33	Ma	10YR 2/1	1060	32	4.08	1.38	6.10	23.40	68.60	4.10	4.00	10.63	20
116	38	Ma	10YR 3/1	870	40	3.55	1.14	2.40	21.00	67.60	5.80	5.60	4.60	5
138	50	Fw	10YR 5/1	860	80	3.93	3.02	1.30	22.10	74.50	2.20	1.20	1.40	60
140	51	Ms	10YR 5/1	880	25	3.53	3.26	5.40	28.70	66.90	2.90	1.50	0.92	20
143	53	Gs	10YR 6/2	440	20	4.78	10.00	16.90	36.60	62.60	0.50	0.30	0.35	10
209	92	Ms	10YR 4/1	520	50	4.15	1.73	16.70	14.50	56.40	14.40	14.70	5.54	10
211	93	-	-	520	32	-	-	-	-	-	-	-	-	15
Average 9.4a				487.31	21.77	4.93	2.77	28.87	37.48	53.68	3.86	5.02	2.75	19.46
Average 9.4b				701.82	38.27	4.25	2.90	7.87	24.69	65.07	5.00	5.27	4.28	19.82
Average 9.4 total			Brown	577.4	28.6	4.71	2.93	23.74	33.53	57.42	4.17	4.91	3.24	18.92

Community 10.1

Releve	Transect	Soil type	Soil colour	Altitude (in m)	Slope (in degrees)	pH (H_2O)	Resistance (in kilo-Ohms)	Gravel fraction (in %)	Coarse sand fraction (in %)	Medium sand fraction (in %)	Fine sand fraction (in %)	Silt fraction (in %)	Organic matter (in %)	Soil depth (in cm)
Community 10.1a														
38	10A	Ma	10YR 3/2	760	6	5.03	1.60	8.80	26.70	60.20	7.20	6.00	8.09	10
42	10B	Ma	10YR 3/2	760	6	5.01	1.54	44.90	36.50	53.50	4.60	5.40	6.44	40
50	12	Ms	10YR 4/2	420	5	3.99	0.88	9.20	36.90	56.00	4.30	2.80	1.70	25
54	13	Gs	10YR 3/3	480	25	4.23	1.86	46.90	22.00	67.90	5.50	4.60	2.55	15
90	26	Oa	10YR 3/1	675	28	3.89	1.50	2.90	29.30	66.50	2.50	1.80	3.59	-
94	27	Oa	10YR 4/2	380	14	5.16	2.69	4.90	20.10	68.90	5.20	5.80	3.37	20
114	37	Ms	10YR 4/2	350	15	4.69	2.79	5.00	23.40	71.90	2.70	2.10	1.54	-
148	54	Gs	10YR 6/2	360	8	4.50	4.36	3.60	4.30	90.60	3.70	1.50	1.11	50
162	61	Oa	10YR 4/2	360	32	3.74	2.36	4.00	11.80	75.50	5.60	7.10	2.07	60
Community 10.1b														
22	6	Ms	10YR 4/1	295	22	3.70	1.44	3.00	25.00	71.60	2.10	1.30	1.42	20
30	8	-	10YR 4/2	510	22	4.30	3.95	9.20	31.60	66.00	1.50	0.90	1.40	1
97	28	Gs	10YR 3/3	370	16	4.46	3.42	4.60	26.80	64.50	3.60	5.20	3.20	25
166	65	-	10YR 5/2	540	28	4.45	4.61	1.10	17.10	74.60	5.60	2.80	0.82	1

169	67	-	10YR 4/2	570	18	4.96	2.50	99.90	51.10	47.60	0.80	0.40	0.72	1
171	69	-	10YR 4/2	570	21	4.15	4.07	99.90	48.70	48.10	1.80	1.50	1.03	1
176	72	-	10YR 4/2	540	8	4.12	2.97	58.80	33.10	57.00	6.30	3.70	2.73	1
206	91	Gs	10YR 6/3	520	20	4.51	2.63	7.30	36.30	60.60	2.20	0.90	0.29	3
265	131	-	10YR 6/2	-	-	4.48	5.02	14.20	28.30	65.20	4.80	1.70	1.60	2
Average 10.1a				505.00	15.44	4.47	2.18	14.47	23.44	67.89	4.59	4.12	3.38	31.43
Average 10.1b				489.38	19.38	4.35	3.40	33.11	33.11	61.69	3.19	2.04	1.47	6.11
Average 10.1 tot.			Brown	497.65	17.29	4.41	2.79	23.79	28.28	64.79	3.89	3.08	2.43	17.19

Releve	Strat	Soil	Zone	River	Colour	Aspect	Area	Altitude
S1.1	Sha	Fw,Ma	Slope-seep	RSE	Dark	N/E	100.00	1412.50
S1.2	San	Fw,Ma	Slope-seep	Lourensrivi	Dark	S	40.00	1100.00
S1.3	San	Ma, Ch	Seepage	Bergrivier	Dark	no	100.00	1200.00
S1.4	San	mainly Ma	Seepage	All	Dark	no	100.00	1238.00
S1.5	San	Mainly Ch	Seepage	Eerste Rivi	Dark	Mainly S	100.00	1225.00
S2.1	San	Fw, Ch	Seepage	Palmiet Riv	Brown	no	100.00	1175.00
S2.2	San	Oa, Ms	Riparian	Palmiet Riv	Grey	no	24.00	1152.50
S2.3	San	Oa, Ma	Riparian	Palmiet Riv	Dark	South	75.67	986.67
S2.4	San	Ch and oth	Seepage	mainly Palr	Dark to Gre	no	89.22	1060.00
1.1	San, Gra		Aquatic	all		no	19.31	567.69
1.2	San		Aquatic	all		no	19.55	629.23
2.1	San/Gra	Rock	Wetbank	all	Pale	N,S, W	14.69	519.62
2.2	San		Lowerdyna	Riviersond	Pale	N/S	21.40	582.00
3.1	San/Gra	Ms	Wetbank	Eerste e.a.	Brown	N,E,W	2.25	697.50
3.2	San	Ms, Gs	Wetbank	RSE, Palm	Pale	no	12.33	582.22
3.3	San	Ms, Gs	Lowerdyna	RSE, Palm	Pale	W, S	29.21	611.58
4.1	San, All	Gs, Ms	Lowerdyna	Riviersond	Yellow	N,S,E	25.83	363.33
5.1	San	Oa, Ma	Riparian	Lourens Ri	Dark	W	100.00	555.00
5.2	San	Ms,Oa,Fw	Dynamic	Palmiet	Pale to Dar	N, E	27.25	675.00
5.3	San	Ms	Dynamic	Palmiet, RS	Pale, Grey	S,N	27.86	787.14
5.4	San, Til	Ms,Oa,Fw	Backdynan	RSE, Palm	Grey, Pale	no	26.30	614.50
5.5	San/Til	Ms,Gs,Oa	Backdynan	Palmiet, RS	Grey, Pale	no	27.25	570.00
6.1	San	Ma	Dynamic	Berg/RSE	Dark	N	32.50	417.50
6.2	San	Ms,Oa,Fw	Backdynan	RSE	Grey, Pale	S,N	25.43	561.43
6.3	San	Ms	Backdyn	Berg	Grey	N,E	22.50	540.00
7.1	Gra	Ma,Oa,Ms	Backdynan	Eerste, Lou	Brown	no	53.40	406.00
7.2	San/Gra	Oa,Gs,e.a.	Backdynan	Berg, Eerst	Brown, Yel	no	40.67	494.12
7.3	Shale	Oa, Ma	Backdynan	Eerste Rive	Brown	N,S	41.80	276.00
8.1	Sha	Gs, Oa	Backdynan	Eerste	Brown, Yel	N,S	26.00	273.00
8.2	San	Gs	Backdynan	Riviersond	10YR 4/3	50	27.00	360.00
9.1	Sha		Lowerdyna	Riviersonderend		195	20.00	295.00
9.2	Gra	Ms, Oa	Shrub	Lourens	Brown, Yel	S,N	27.50	405.00
9.3	Gra	Ma, Oa	Shrub	Lourens	Brown	S,N	72.00	404.00
9.4	San, Gra	Gs, Ms, Oa	Shrub	All	Brown, Yel	no	55.28	577.40
10.1	San,Gra	Ms,Gs	Shrub, LD	Eerste, Be	Brown, Yel	no	25.67	497.65
5.4a	San/Til	Ms	Backdyn	RSE, Palm	Pale, Grey	N,S,W	28.17	619.17
5.4b	San	Ms, Oa	Backdyn	RSE, Palm	Grey	S, W, E,	23.50	607.50
7.2a	San, Gra	Gs, Ms	Backdyn	Berg/Eerst	Brown, Yel	no	42.78	451.11
7.2b	San/Gra	Oa, Gs	Backdyn	Eerste/Ber	Brown, Yel	S/E	45.29	470.00
7.2c	Gra	Ma, Oa	Backdyn	Eerste	Brown	no	15.00	760.00
9.4a	San/Gra	Ms,Oa, Gs	Shrub	Eerste/Ber	Brown, Yel	no	35.52	508.68
9.4b	San	Ms, Gs, Ma	Shrub	RSE, Berg	Grey, Brow	no	48.64	701.82
10.1a	Gra (San)	Oa e.a	Shrub	RSE, ER	Brown	no	18.70	484.00
10.1b	San	Rock	Shrub	Berg, ER	Brown, Yel	no	32.00	489.38

Slope	Total cover	Trees	Shrubs	Herbs	Moss	High trees	Low trees	High shrub
26.00	100.00	0.00	55.00	90.00	1.50	0.00	0.00	3.50
24.00	95.00	0.00	0.00	95.00	0.00	0.00	0.00	0.00
0.00	97.50	0.00	0.00	97.50	0.00	0.00	0.00	0.00
1.17	92.50	0.00	0.00	92.50	0.00	0.00	0.00	0.00
6.75	98.75	0.00	0.00	98.75	0.00	0.00	0.00	0.00
5.00	96.67	0.00	0.00	96.67	0.00	0.00	0.00	0.00
29.00	90.00	0.00	0.00	90.00	0.00	0.00	0.00	0.00
10.67	73.33	0.00	30.00	70.00	0.00	0.00	0.00	0.50
2.43	95.56	0.00	2.22	95.00	0.00	0.00	0.00	0.22
19.12	15.77	0.00	0.00	10.50	0.85	0.00	0.00	0.00
29.19	26.54	0.00	0.00	20.49	5.11	0.00	0.00	0.00
26.00	23.46	0.00	6.92	7.69	11.15	0.00	0.00	0.88
17.60	13.00	0.00	6.00	10.00	0.00	0.00	0.00	0.80
22.50	53.17	0.00	0.00	7.83	52.83	0.00	0.00	0.00
13.67	48.11	0.00	2.78	32.22	22.33	0.00	0.00	0.06
18.37	65.53	0.00	18.42	47.89	12.11	0.00	0.00	1.45
15.17	38.33	0.00	0.00	38.33	0.00	0.00	0.00	0.00
17.50	90.00	0.00	20.00	90.00	0.00	0.00	0.00	2.00
11.50	95.00	0.00	1.25	95.00	0.00	0.00	0.00	0.38
18.14	71.43	0.00	25.71	61.43	0.00	0.00	0.00	1.57
16.95	81.50	0.50	18.50	68.25	0.05	0.25	0.20	1.83
15.00	95.00	0.00	25.00	90.00	0.00	0.00	0.00	1.88
45.00	100.00	0.00	17.50	100.00	0.00	0.00	0.00	5.00
19.29	89.29	0.00	31.43	73.57	0.00	0.00	0.00	2.29
21.50	75.00	0.00	12.50	75.00	0.00	0.00	0.00	2.50
14.60	97.00	0.00	2.00	95.00	0.00	0.00	0.00	0.40
17.35	83.33	8.61	31.39	68.61	0.28	0.83	0.44	2.22
25.00	96.80	2.00	18.00	48.00	0.00	1.60	0.00	2.30
21.60	87.00	32.00	6.00	57.00	0.00	1.60	0.00	0.60
28.00	95.00	0.00	0.00	95.00	0.00	0.00	0.00	0.00
22.00	100.00	80.00	30.00	10.00	0.00	5.00	2.00	2.00
16.00	82.50	82.50	0.00	7.50	7.50	4.75	2.50	0.00
20.20	90.00	88.00	4.00	23.00	0.00	7.00	3.60	1.00
28.60	87.40	57.40	17.40	32.40	16.60	4.76	2.44	1.88
17.29	77.22	21.11	47.78	31.39	0.00	1.67	0.78	2.44
16.42	85.83	0.83	23.33	64.58	0.00	0.42	0.33	1.75
17.75	75.00	0.00	11.25	73.75	0.13	0.00	0.00	1.94
18.56	80.00	1.11	22.78	72.22	0.00	0.44	0.33	2.06
19.33	82.86	20.71	34.29	56.43	0.71	1.57	0.71	2.21
6.00	100.00	0.00	60.00	95.00	0.00	0.00	0.00	3.00
18.21	86.08	35.17	25.08	46.63	2.49	2.56	1.27	1.83
38.27	86.82	43.64	20.45	44.09	33.64	3.55	1.73	2.00
14.40	84.00	18.00	49.00	45.20	0.00	1.30	0.60	2.50
19.38	65.56	22.22	41.11	12.78	0.00	1.89	0.89	2.11

Low shrubs	High herbs	Low herbs	Max herbs	pH	Resist	Gravel	Csand	Msand
2.00	75.00	50.00	80.00	4.10	2.13	2.00	1.60	70.35
0.00	100.00	50.00	80.00	3.93	1.28	16.10	16.40	52.80
0.00	125.00	30.00	0.00	3.92	1.61	6.68	18.03	68.03
0.00	51.67	20.83	35.00	4.05	2.12	3.38	10.27	66.02
0.00	47.50	7.50	100.00	3.98	1.69	1.73	11.15	73.45
0.00	100.00	33.33	100.00	3.95	1.43	3.33	16.97	74.03
0.00	100.00	25.00	150.00	3.85	1.19	6.85	17.15	73.40
0.33	70.00	20.00	50.00	3.81	2.00	7.33	26.07	68.03
0.17	55.56	18.33	91.11	4.05	1.79	3.94	22.39	64.36
0.00	17.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	19.02	1.00	4.00	0.00	0.00	0.00	0.00	0.00
0.35	40.00	8.85	0.00	4.56	4.55	37.25	38.04	54.16
0.40	23.40	2.00	0.00	5.31	5.03	64.67	45.33	52.93
0.00	12.50	0.00	3.33	4.20	1.02	23.85	34.48	59.28
0.00	45.00	7.22	15.56	4.64	3.23	21.81	47.24	50.45
0.84	57.89	22.37	18.42	4.48	2.97	30.11	46.39	49.69
0.00	63.33	18.33	75.00	5.00	6.05	39.50	36.88	61.35
1.50	100.00	50.00	0.00	4.04	1.66	4.85	22.80	68.55
0.00	72.50	22.50	62.50	3.89	1.96	2.40	15.65	77.03
1.00	68.57	27.86	47.14	4.30	3.82	25.07	33.77	61.50
0.85	62.50	21.50	51.00	4.33	3.68	10.28	26.71	66.91
1.13	87.50	45.00	75.00	4.06	2.29	12.87	28.87	62.53
2.00	150.00	70.00	200.00	3.92	1.27	6.55	26.15	63.25
1.29	95.71	39.29	85.71	4.70	4.07	9.54	22.50	68.03
1.00	90.00	35.00	50.00	4.55	3.11	28.65	33.30	59.80
0.30	120.00	38.00	136.00	4.71	3.59	29.78	20.88	65.10
1.31	83.33	36.67	32.22	4.69	3.90	21.73	30.05	59.21
1.24	62.00	56.00	44.00	5.49	2.06	4.62	18.32	70.56
0.30	110.00	20.00	0.00	5.42	2.47	6.92	22.70	71.02
0.00	100.00	50.00	150.00	4.46	3.50	89.30	13.00	78.80
1.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	40.00	0.00	0.00	4.94	6.79	43.53	48.65	47.13
0.40	46.00	16.00	30.00	4.88	1.25	80.98	25.60	56.32
0.94	86.00	29.60	40.00	4.71	2.93	23.74	33.53	57.42
1.25	76.11	30.56	45.56	4.41	2.79	23.79	28.28	64.79
0.88	58.33	21.67	43.33	4.39	4.24	11.91	26.48	67.21
0.81	68.75	21.25	62.50	4.22	2.75	7.57	27.08	66.40
1.28	80.00	31.11	36.67	4.49	3.39	17.82	27.29	63.76
1.43	90.00	44.29	21.43	4.96	4.99	29.99	34.03	53.31
1.00	75.00	35.00	50.00	4.64	2.38	10.45	28.55	59.40
0.90	64.02	22.95	32.95	4.16	3.15	24.98	27.95	53.57
0.95	98.18	31.82	68.18	4.25	2.90	7.87	24.69	65.07
1.20	82.00	36.00	47.00	4.39	2.05	13.13	21.53	65.86
1.17	63.33	21.11	38.89	4.35	3.40	33.11	33.11	61.69

Fsand	silt	Organic	Bedrock	Boulders	Lg Cobbles	Sm Cobble	Pebb	SOil depth
14.15	13.95	5.42	5.00	15.00	5.00	0.00	0.00	37.50
15.90	14.85	4.67	0.00	5.00	0.00	0.00	0.00	50.00
7.90	6.08	7.61	0.00	0.00	0.00	0.00	0.00	60.00
12.20	11.53	7.16	0.00	0.00	0.00	0.00	0.00	60.00
8.55	6.85	8.02	0.00	1.25	0.00	0.00	0.00	60.00
4.57	4.40	7.64	0.00	1.67	0.00	0.00	0.00	36.67
3.05	6.40	3.91	20.00	10.00	0.00	0.00	0.00	60.00
3.00	2.93	3.08	0.00	13.33	0.00	6.67	6.67	40.00
6.56	6.73	7.47	0.56	1.67	0.56	0.56	0.56	48.89
0.00	0.00	0.00	9.81	55.58	10.00	11.35	4.62	0.00
0.00	0.00	0.00	19.66	43.93	9.03	11.80	4.22	0.05
3.95	3.85	1.46	18.08	42.69	7.31	3.46	8.85	4.90
1.20	0.53	0.38	1.00	62.00	16.00	6.00	12.00	1.00
3.63	2.65	3.53	40.00	28.33	0.00	15.00	0.00	7.80
1.19	1.13	0.75	6.67	36.67	1.11	7.22	0.56	14.88
2.16	1.75	1.20	8.42	32.63	10.00	11.84	6.58	12.19
1.17	0.65	0.40	0.83	17.50	5.00	16.67	11.67	12.50
5.00	3.70	4.64	0.00	45.00	0.00	0.00	0.00	27.50
3.78	3.53	2.76	0.00	0.00	0.00	0.00	1.25	33.75
2.86	1.90	1.60	6.43	31.43	4.29	13.57	12.86	19.29
3.74	2.69	2.62	10.50	29.00	3.25	2.50	2.50	19.44
3.73	4.90	3.38	0.00	2.50	2.50	23.75	3.75	28.33
5.35	5.30	4.94	0.00	15.00	0.00	0.00	10.00	20.00
4.83	4.63	2.20	4.29	8.57	4.29	10.00	5.71	30.00
4.05	2.90	2.58	0.00	80.00	10.00	0.00	0.00	3.00
9.08	6.92	3.71	0.00	28.00	4.00	4.00	2.00	15.00
5.57	5.21	3.20	0.56	29.44	3.89	5.56	4.44	20.31
6.18	5.14	2.93	6.00	16.00	0.00	0.00	0.00	36.00
3.76	2.54	2.12	0.00	9.00	6.00	9.00	4.00	39.00
4.80	3.40	1.37	0.00	0.00	0.00	0.00	30.00	40.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00
2.45	1.80	1.36	0.00	73.75	3.75	10.00	7.50	8.50
8.36	9.74	9.65	0.00	54.00	10.00	4.00	0.00	25.00
4.17	4.91	3.24	10.00	47.00	3.00	3.20	3.80	18.92
3.89	3.08	2.43	1.67	39.17	5.83	7.78	5.00	17.19
3.74	2.64	2.10	2.50	37.08	5.00	4.17	4.17	19.56
3.75	2.77	3.49	22.50	16.88	0.63	0.00	0.00	19.29
4.38	4.64	2.51	0.00	27.78	3.33	5.00	4.44	14.57
7.17	5.49	2.90	1.43	34.29	5.71	7.86	4.29	24.71
5.35	6.75	7.39	0.00	20.00	0.00	0.00	5.00	25.00
4.33	4.18	3.51	3.81	34.99	3.73	4.20	3.42	19.27
5.00	5.27	4.28	19.09	41.36	0.00	2.27	1.36	19.82
4.21	3.75	3.08	2.00	22.00	0.50	5.00	2.00	27.63
3.19	2.04	1.47	1.11	53.89	11.11	10.00	7.78	6.11

MAP	Rjan	Rjuly	Rsummer	Ratio	Distance	Elev	Verval	No. Specie
3345.00	76.00	461.00	9.40	6.10	0.00	0.00	0.00	20.00
2976.00	67.00	412.00	9.40	6.10	0.00	0.00	0.00	15.50
3152.00	66.00	446.00	9.00	6.80	0.00	0.00	0.00	4.50
2752.00	61.60	381.60	9.36	6.16	0.00	0.00	0.00	11.83
2974.75	63.00	419.75	9.13	6.68	0.00	0.00	0.00	14.50
2333.00	53.67	322.00	9.60	6.00	0.00	0.00	0.00	18.67
2521.00	59.00	344.00	9.60	5.80	2.50	0.80	3.50	28.50
2292.00	50.00	326.00	9.60	6.50	7.73	1.47	0.53	24.67
2344.63	51.75	329.38	9.51	6.35	0.03	0.04	0.09	15.33
1928.54	40.65	271.12	9.19	6.82	0.69	0.07	0.64	1.58
2021.68	43.80	281.48	8.94	6.23	1.75	0.24	0.78	2.93
1739.73	38.18	240.45	9.27	6.50	1.23	0.88	1.17	7.62
1143.20	20.60	158.20	8.98	7.90	2.02	0.48	0.70	6.40
2160.17	49.00	299.50	9.43	6.12	0.25	0.38	1.47	6.50
1744.00	37.00	248.00	9.41	6.78	1.29	0.54	0.30	9.67
1958.21	39.68	281.58	9.21	7.17	3.36	0.82	0.34	17.53
1115.83	20.67	152.33	8.65	7.90	2.92	0.45	0.10	18.17
1943.00	45.00	263.00	9.50	5.80	0.00	0.00	1.75	45.50
1423.00	37.00	185.00	10.30	5.00	4.38	1.23	0.25	19.25
2149.00	46.50	307.00	9.58	6.58	5.08	1.3	0.4	40.57
1844.80	36.70	265.95	9.06	7.44	5.86	1.79	0.38	24.75
1854.50	36.25	271.50	9.10	7.55	6.75	1.60	0.25	26.50
1803.50	34.00	257.50	8.35	7.90	5.00	1.00	3.10	14.50
901.00	15.00	121.00	8.90	8.10	4.99	1.69	0.83	28.43
2328.50	46.00	332.00	8.75	7.20	4.00	1.85	1.75	35.50
1724.20	39.80	235.60	9.58	5.92	6.70	1.52	0.90	27.80
2141.88	47.24	298.47	9.16	6.34	6.26	1.76	1.03	24.78
1294.00	28.00	174.00	9.30	6.20	5.02	2.08	0.30	33.00
1294.00	28.00	174.00	9.30	6.20	2.60	1.32	0.80	5.60
914.00	15.00	125.00	8.50	8.30	2.00	2.10	0.00	35.00
1342.00	22.00	194.00	8.10	8.80	1.00	0.40	0.20	14.00
2277.25	52.75	311.50	9.48	5.90	4.13	1.40	1.25	8.75
2165.60	50.00	295.00	9.42	5.90	8.30	2.30	1.06	15.40
2110.80	44.96	296.52	9.10	6.63	5.40	1.88	1.64	16.76
1924.06	40.59	267.65	9.02	6.80	3.32	1.09	0.95	13.78
1945.42	39.08	282.50	9.18	7.28	6.35	1.891667	0.258333	23.16667
1693.88	33.13	241.13	8.88	7.68	5.13	1.625	0.5625	27.125
2192.11	47.89	306.00	9.12	6.41	6.56	1.944444	0.522222	26.33333
2041.50	44.67	284.67	9.13	6.37	6.92	1.7	0.8	23.42857
2217.00	52.00	306.00	9.40	5.90	3.00	1.15	4	22.5
1990.96	42.71	278.50	9.08	6.77	5.01	1.54	1.12	19.12
2315.36	49.36	325.55	9.15	6.62	4.56	1.56	2.35	17.64
1670.70	36.00	228.30	9.11	6.50	3.17	1.05	1.11	14.70
2114.50	43.13	299.00	8.80	7.06	3.10	1.01	0.63	11.56

S

Appendix G: calculation of hydraulic parameters

The following formulas were used to calculate R, n and Q

$$R = A / P$$

$$\frac{1}{n} = \left\{ 1.11 \cdot \sqrt{g} \cdot \left(\frac{R}{d_{84}} \right)^{0.46} \cdot \left(\frac{d_{84}}{d_{50}} \right) \cdot s^{-0.39} \right\} \Bigg/ R^{1/6}$$

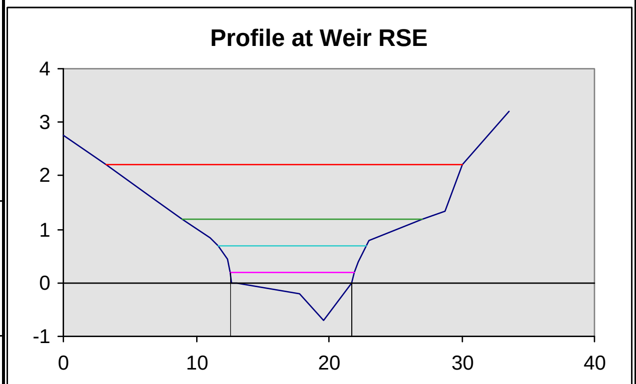
$$Q = \frac{A \cdot R^{2/3} \cdot \sqrt{s}}{n}$$

All distance and surface parameters measured in m and m², Q in m³/s and slope is expressed as a tangent

Weir Riviersonderend (H6H008)

Raw data of profile	
Horizontal	Vertical
0.00	2.75
3.20	2.20
6.80	1.55
8.95	1.20
11.10	0.85
11.68	0.70
12.40	0.45
12.57	0.20
12.70	0.00
13.10	0.00
17.80	-0.20
19.60	-0.70
21.70	0.00
21.95	0.20
22.20	0.40
22.80	0.70
23.00	0.80
27.00	1.20
28.70	1.35
30.10	2.20
33.60	3.20

Level 1	Level 2	Level 3	Level 4
0.20	0.70	1.20	2.20



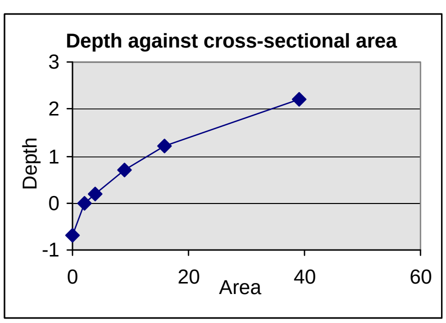
Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	9.19	2.02
Level 1		
Zone 1	0.00	0.00
Zone 2	9.42	3.83
Zone 3	0.32	0.03
Total	9.74	3.85
Level 2		
Zone 1	1.06	0.15
Zone 2	9.42	8.39
Zone 3	1.31	0.34
Total	11.80	8.89
Level 3		
Zone 1	3.84	1.22
Zone 2	9.42	12.96
Zone 3	5.55	1.78
Total	18.82	15.96
Level 4		
Zone 1	9.68	7.79
Zone 2	9.42	22.09
Zone 3	8.90	9.25
Total	28.00	39.12

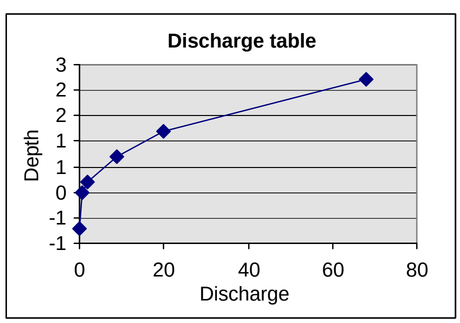
Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.00	0.00	0.00
Zone 2	0.41	0.20	1.96
Zone 3	0.08	0.20	0.00
Total			1.97
Level 2			
	R	n	Q
Zone 1	0.14	0.20	0.04
Zone 2	0.89	0.17	8.77
Zone 3	0.26	0.20	0.13
Total			8.94
Level 3			
	R	n	Q
Zone 1	0.32	0.20	0.53
Zone 2	1.37	0.16	18.72
Zone 3	0.32	0.20	0.78
Total			20.03
Level 4			
	R	n	Q
Zone 1	0.80	0.20	6.29
Zone 2	2.34	0.14	52.72
Zone 3	1.04	0.20	8.86
Total			67.87

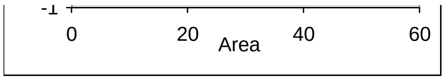
Parameters for normal water level (level 0)	
s	0.03
R	0.22
d_{84}	1.20
d_{50}	0.60
n	0.24
Q	0.58

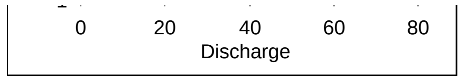
Vertical zonation is indicated in the graph as vertical lines and in the raw data as horizontal lines. In the calculations they are referred to as Zone 1, Zone 2 and Zone 3.

Return periods and their floods	
Interval (Y)	Discharge (m³/s)
1	44
2	50
5	54
10	56
20	58
50	60





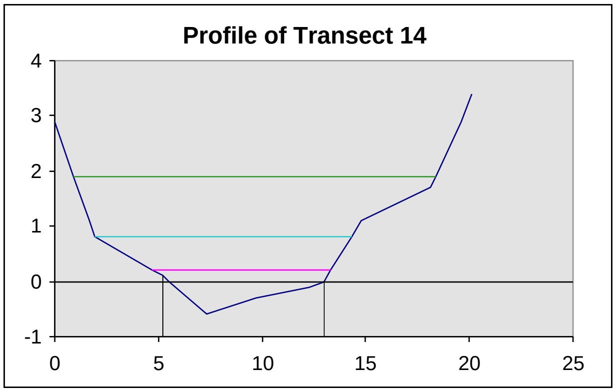




Transect 14

Raw data of profile	
Horizontal	Vertical
0.00	2.90
0.90	1.90
1.70	1.10
1.90	0.80
4.70	0.20
5.20	0.10
5.50	0.00
7.30	-0.60
9.70	-0.30
12.30	-0.10
13.00	0.00
13.32	0.20
14.31	0.80
14.80	1.10
18.10	1.70
18.36	1.90
19.57	2.90
20.10	3.40

Level 1	Level 2	Level 3
0.20	0.80	1.90

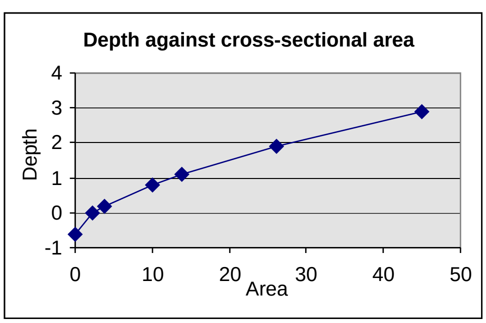


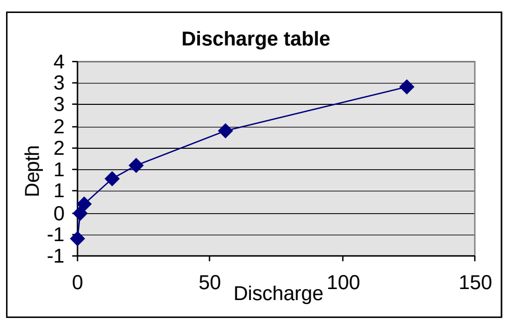
Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	7.63	2.17
Level 1		
Zone 1	0.51	0.03
Zone 2	7.95	3.72
Zone 3	0.38	0.03
Total	8.83	3.78
Level 2		
Zone 1	3.37	1.16
Zone 2	7.95	8.40
Zone 3	1.53	0.52
Total	12.86	10.09
Level 3		
Zone 1	3.73	4.99
Zone 2	7.95	16.98
Zone 3	5.79	4.10
Total	17.47	26.07

Parameters for normal water level (level 0)	
s	0.03
R	0.28
d_{84}	0.50
d_{50}	0.20
n	0.18
Q	0.99

Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.05	0.20	0.00
Zone 2	0.47	0.16	2.65
Zone 3	0.08	0.20	0.01
Total			2.66
Level 2			
	R	n	Q
Zone 1	0.35	0.20	0.54
Zone 2	1.06	0.13	12.32
Zone 3	0.34	0.20	0.24
Total			13.09
Level 3			
	R	n	Q
Zone 1	1.10	0.20	5.32
Zone 2	2.14	0.11	47.38
Zone 3	0.71	0.20	3.05
Total			55.75

Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	23.33
2	26.51
5	28.63
10	29.69
20	30.75
50	31.82

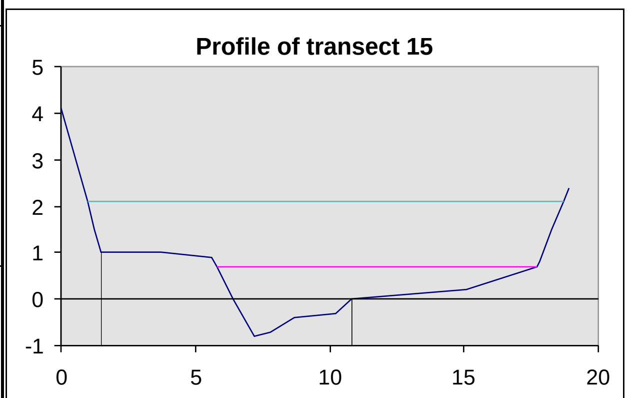




Transect 15

Raw data of profile	
Horizontal	Vertical
0.00	4.10
1.00	2.10
1.26	1.50
1.50	1.00
3.70	1.00
5.60	0.90
5.80	0.70
6.40	0.00
7.20	-0.80
7.80	-0.70
8.70	-0.40
10.20	-0.30
10.80	0.00
15.10	0.20
17.70	0.70
17.80	0.80
18.28	1.50
18.70	2.10
18.90	2.40

Level 1	Level 2
0.70	2.10

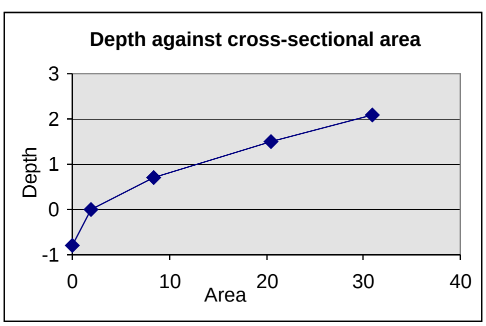


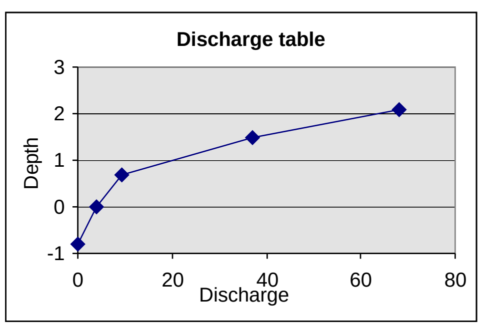
Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	4.86	1.88
Level 1		
Zone 1	0.00	0.00
Zone 2	5.78	5.17
Zone 3	6.95	3.23
Total	12.74	8.40
Level 2		
Zone 1	1.21	0.28
Zone 2	10.17	17.03
Zone 3	8.67	13.61
Total	20.05	30.92

Parameters for normal water level (level 0)	
s	0.08
R	0.51
d_{84}	1.50
d_{50}	1.00
n	0.22
Q	3.99

Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.00	0.00	0.00
Zone 2	0.89	0.21	6.56
Zone 3	0.46	0.21	2.65
Total			9.21
Level 2			
	R	n	Q
Zone 1	0.23	0.20	0.14
Zone 2	1.68	0.16	42.16
Zone 3	1.57	0.20	25.78
Total			68.08

Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	21.02
2	23.89
5	25.80
10	26.76
20	27.71
50	28.67

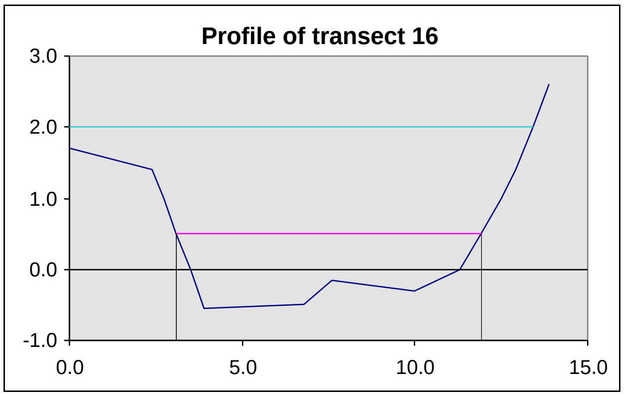




Transect 16

Raw data of profile	
Horizontal	Vertical
0.00	2.00
0.00	1.70
2.40	1.40
2.73	1.00
3.10	0.50
3.50	0.00
3.90	-0.55
6.80	-0.50
7.60	-0.15
10.00	-0.30
11.30	0.00
11.90	0.50
12.50	1.00
12.90	1.40
13.40	2.00
13.90	2.60

Level 1	Level 2
0.50	2.00

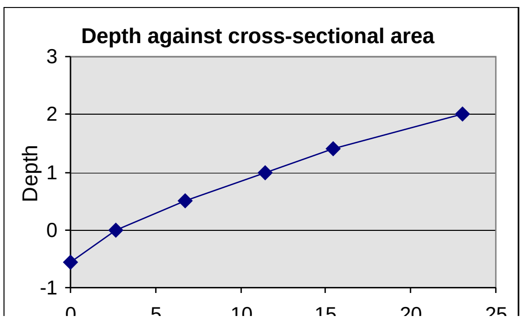


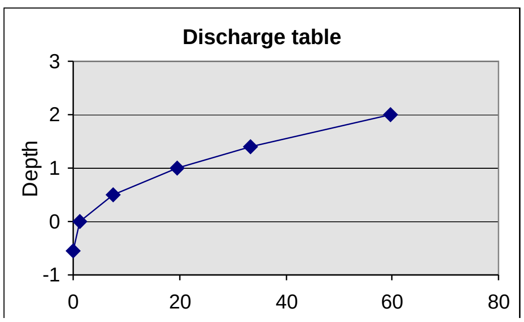
Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	8.19	2.63
Level 1		
Zone 1	0.00	0.00
Zone 2	9.61	6.78
Zone 3	0.00	0.00
Total	9.61	6.78
Level 2		
Zone 1	3.86	1.81
Zone 2	9.61	19.98
Zone 3	2.13	1.22
Total	15.60	23.00

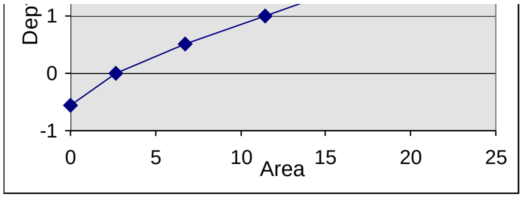
Parameters for normal water level (level 0)	
s	0.09
R	0.32
d_{84}	1.50
d_{50}	0.80
n	0.32
Q	1.14

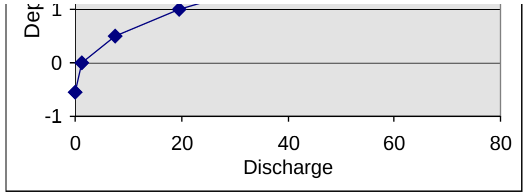
Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.00	0.00	0.00
Zone 2	0.70	0.25	6.27
Zone 3	0.00	0.00	0.00
Total			6.27
Level 2			
	R	n	Q
Zone 1	0.47	0.20	1.62
Zone 2	2.08	0.20	47.15
Zone 3	0.56	0.20	1.21
Total			49.98

Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	14.27
2	16.22
5	17.52
10	18.17
20	18.82
50	19.46





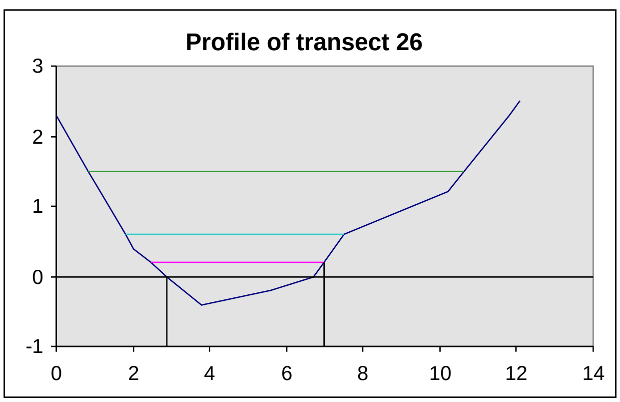




Transect 26

Level 1	Level 2	Level 3
0.20	0.60	1.50

Raw data of profile	
Horizontal	Vertical
0.00	2.30
0.84	1.50
1.15	1.20
1.79	0.60
2.00	0.40
2.45	0.20
2.90	0.00
3.80	-0.40
5.60	-0.20
6.70	0.00
6.97	0.20
7.50	0.60
10.20	1.20
10.64	1.50
11.80	2.30
12.10	2.50



Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	3.91	0.83
Level 1		
Zone 1	0.49	0.05
Zone 2	4.25	1.62
Zone 3	0.00	0.00
Total	4.74	1.66
Level 2		
Zone 1	1.27	0.38
Zone 2	4.25	3.24
Zone 3	0.66	0.11
Total	6.19	3.73
Level 3		
Zone 1	2.58	1.81
Zone 2	4.25	6.91
Zone 3	3.96	2.27
Total	10.80	10.99

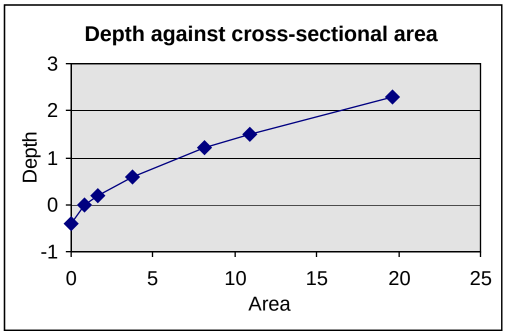
Parameters for normal water level (level 0)	
s	0.07
R	0.21
d_{84}	1.00
d_{50}	0.40
n	0.35
Q	0.22

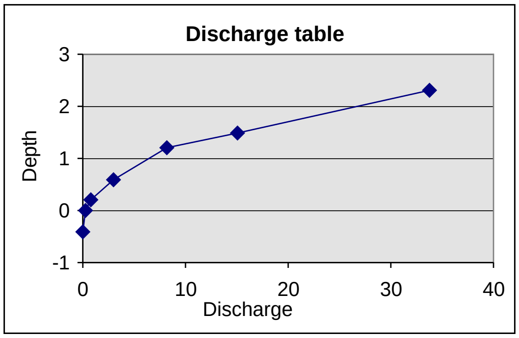
Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.09	0.30	0.01
Zone 2	0.38	0.30	0.74
Zone 3	0.00	0.00	0.00
Total			0.75
Level 2			
	R	n	Q
Zone 1	0.30	0.26	0.17
Zone 2	0.76	0.26	2.78

Return periods and their floods	
Interval (Y)	Discharge (m^3/s)

Zone 3	0.16	0.26	0.03
Total			2.99
Level 3			
	R	n	Q
Zone 1	0.70	0.22	1.70
Zone 2	1.63	0.22	11.43
Zone 3	0.57	0.22	1.87
Total			15.01

1	11.62
2	13.21
5	14.26
10	14.79
20	15.32
50	15.85

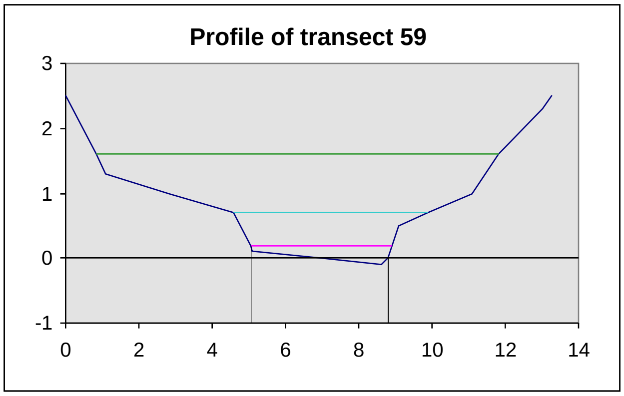




Transect 59

Level 1	Level 2	Level 3
0.20	0.70	1.60

Raw data of profile	
Horizontal	Vertical
0.00	2.50
0.83	1.60
1.10	1.30
2.85	1.00
4.60	0.70
5.04	0.20
5.10	0.10
6.90	0.00
8.60	-0.10
8.80	0.00
8.92	0.20
9.10	0.50
9.90	0.70
11.10	1.00
11.80	1.60
13.00	2.30
13.28	2.50



Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	1.93	0.09
Level 1		
Zone 1	0.00	0.00
Zone 2	3.85	0.75
Zone 3	0.23	0.01
Total	4.08	0.76
Level 2		
Zone 1	0.67	0.11
Zone 2	3.85	2.63
Zone 3	1.41	0.22
Total	5.92	2.95
Level 3		
Zone 1	4.62	2.65
Zone 2	3.85	6.01
Zone 3	3.57	2.31

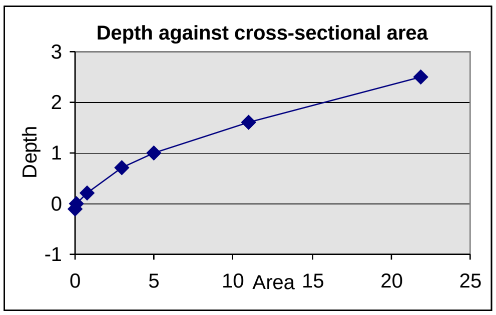
Parameters for all other water levels
Level 1

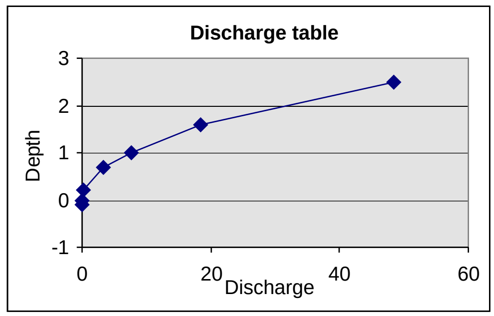
Parameters for normal water level (level 0)	
s	0.03
R	0.05
d_{84}	0.40
d_{50}	0.20
n	0.20
Q	0.01

	R	n	Q
Zone 1	0.00	0.00	0.00
Zone 2	0.19	0.13	0.30
Zone 3	0.05	0.20	0.00
Total			0.30
Level 2			
	R	n	Q
Zone 1	0.17	0.20	0.03
Zone 2	0.68	0.10	3.27
Zone 3	0.15	0.20	0.05
Total			3.35
Level 3			
	R	n	Q
Zone 1	0.57	0.20	1.48
Zone 2	1.56	0.08	15.52
Zone 3	0.65	0.20	1.40
Total			18.40

Total	12.03	10.97

Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	18.56
2	21.09
5	22.78
10	23.63
20	24.47
50	25.31

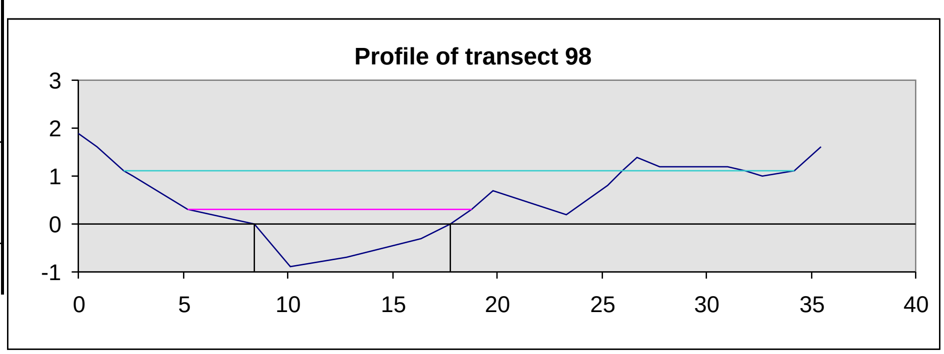




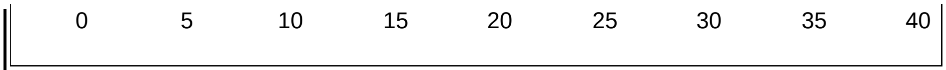
Transect 98

Raw data of profile	
Horizontal	Vertical
0.00	1.90
0.90	1.60
2.18	1.10
2.60	1.00
5.20	0.30
8.40	0.00
10.10	-0.90
12.80	-0.70
16.40	-0.30
17.80	0.00
18.80	0.30
19.80	0.70

Level 1	Level 2
0.30	1.10



23.30	0.20
25.30	0.80
26.00	1.10
26.70	1.40
27.80	1.20
31.00	1.20
31.85	1.10
32.70	1.00
34.20	1.10
35.50	1.60

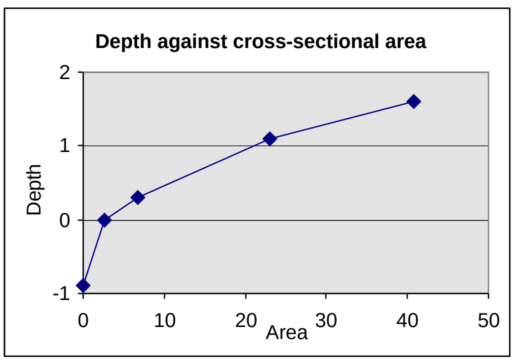


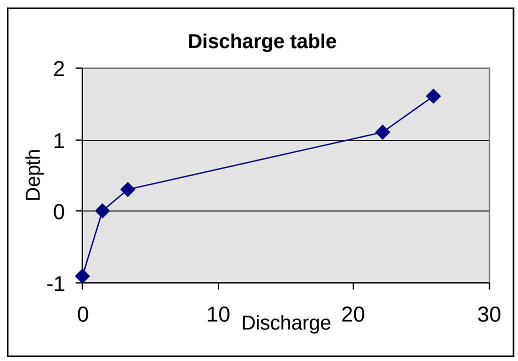
Parameters for normal water level (level 0)	
s	0.11
R	0.51
d_{84}	1.50
d_{50}	0.30
n	0.69
Q	1.48

Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.15	0.22	0.20
Zone 2	0.80	0.66	3.30
Zone 3	0.14	0.22	0.06
Total			3.36
Level 2			
	R	n	Q
Zone 1	0.47	0.17	2.11
Zone 2	2.08	0.50	20.90
Zone 3	0.56	0.17	1.57
Total			24.58

Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	9.69	4.94
Level 1		
Zone 1	3.21	0.48
Zone 2	9.69	7.76
Zone 3	1.04	0.15
Total	13.94	8.39
Level 2		
Zone 1	6.34	4.23
Zone 2	9.69	15.28
Zone 3	10.87	5.25
Total	26.89	24.75

Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	20.28
2	23.05
5	24.89
10	25.81
20	26.73
50	27.66

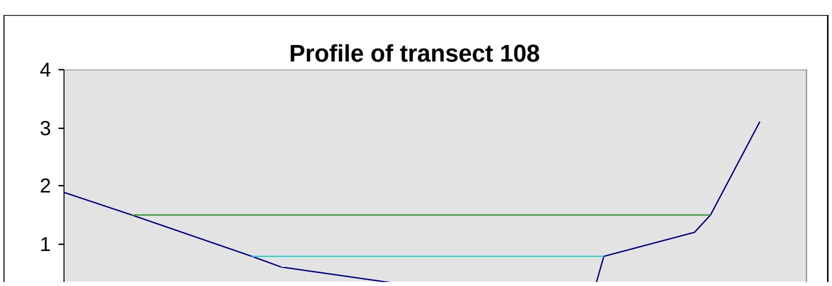




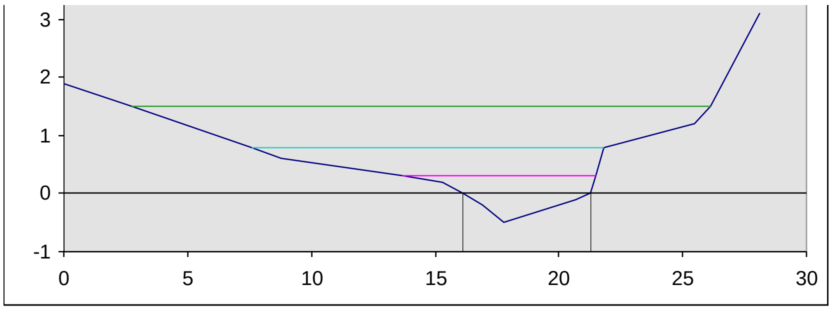
Transect 108

Raw data of profile	
Horizontal	Vertical
0.00	1.90
2.75	1.50
7.60	0.80
8.80	0.60
13.70	0.30

Level 1	Level 2	Level 3
0.30	0.80	1.50



15.30	0.20
16.10	0.00
16.90	-0.20
17.80	-0.50
20.70	-0.10
21.30	0.00
21.48	0.30
21.80	0.80
25.50	1.20
26.10	1.50
26.60	1.90
28.10	3.10

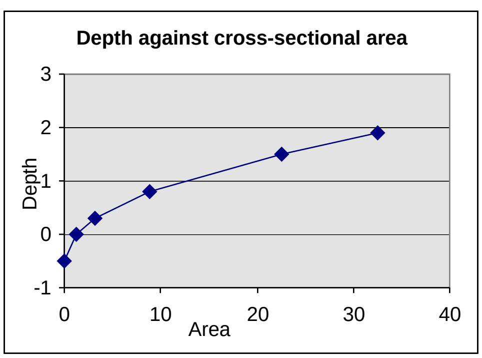


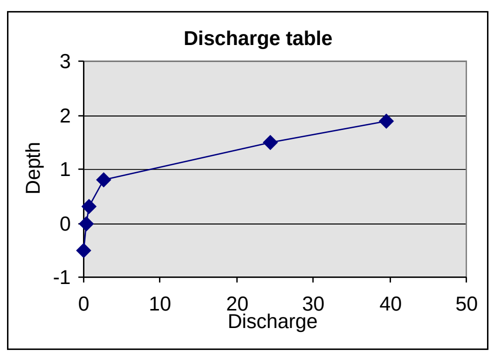
Parameters for normal water level (level 0)	
s	0.06
R	0.24
d_{84}	0.70
d_{50}	0.20
n	0.36
Q	0.35

Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.09	0.32	0.01
Zone 2	0.38	0.32	0.65
Zone 3	0.00	0.00	0.00
Total			0.66
Level 2			
	R	n	Q
Zone 1	0.30	0.28	0.15
Zone 2	0.76	0.28	2.43
Zone 3	0.16	0.28	0.03
Total			2.61
Level 3			
	R	n	Q
Zone 1	0.81	0.24	9.68
Zone 2	1.71	0.24	13.26
Zone 3	0.47	0.24	1.52
Total			24.45

Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	5.31	1.29
Level 1		
Zone 1	2.43	0.24
Zone 2	5.31	2.85
Zone 3	0.35	0.03
Total	8.09	3.12
Level 2		
Zone 1	8.55	3.28
Zone 2	5.31	5.45
Zone 3	0.94	0.20
Total	14.81	8.93
Level 3		
Zone 1	13.45	10.92
Zone 2	5.31	9.09
Zone 3	5.34	2.49
Total	24.10	22.50

Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	21.74
2	24.71
5	26.68
10	27.67
20	28.66
50	29.65

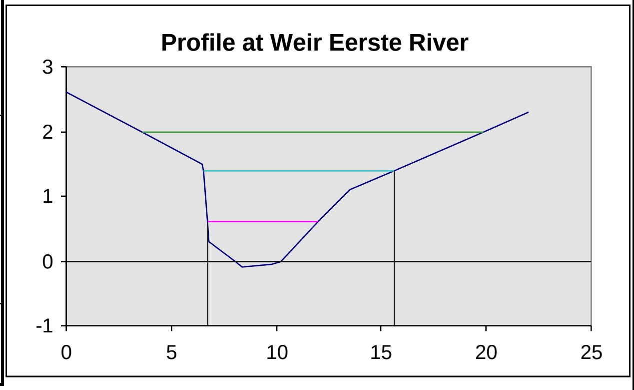




Weir Eerste River (G2H008)

Raw data of profile	
Horizontal	Vertical
0.00	2.60
3.60	2.00
6.50	1.50
6.52	1.40
6.72	0.60
6.80	0.30
8.05	0.00
8.40	-0.10
9.80	-0.05
10.20	0.00
12.00	0.60
13.50	1.10
15.61	1.40
19.89	2.00
22.00	2.30

Level 1	Level 2	Level 3
0.60	1.40	2.00

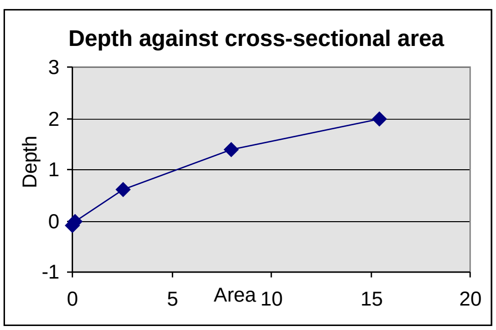


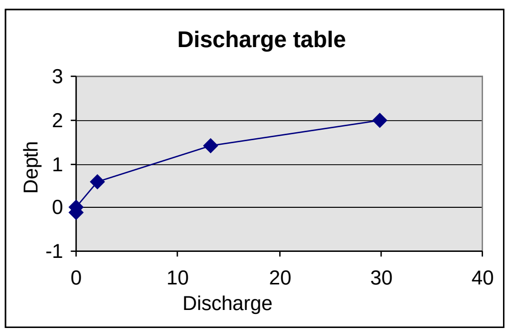
Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	2.17	0.13
Level 1		
Zone 1	0.00	0.00
Zone 2	5.66	2.54
Zone 3	0.00	0.00
Total	5.66	2.54
Level 2		
Zone 1	0.82	0.08
Zone 2	7.24	7.59
Zone 3	2.13	0.32
Total	10.20	7.98
Level 3		
Zone 1	3.87	0.94
Zone 2	7.24	11.65
Zone 3	6.45	2.87
Total	17.56	15.46

Parameters for normal water level (level 0)	
s	0.04
R	0.06
d_{84}	0.70
d_{50}	0.40
n	0.26
Q	0.02

Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.00	0.00	0.00
Zone 2	0.45	0.15	2.12
Zone 3	0.00	0.00	0.00
Total			2.12
Level 2			
	R	n	Q
Zone 1	0.10	0.20	0.02
Zone 2	1.05	0.12	13.14
Zone 3	0.15	0.20	0.09
Total			13.25
Level 3			
	R	n	Q
Zone 1	0.24	0.20	0.38
Zone 2	1.61	0.12	27.81
Zone 3	0.44	0.20	1.74
Total			29.93

Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	30.00
2	37.50
5	50.00
10	56.50
20	64.00
50	73.00

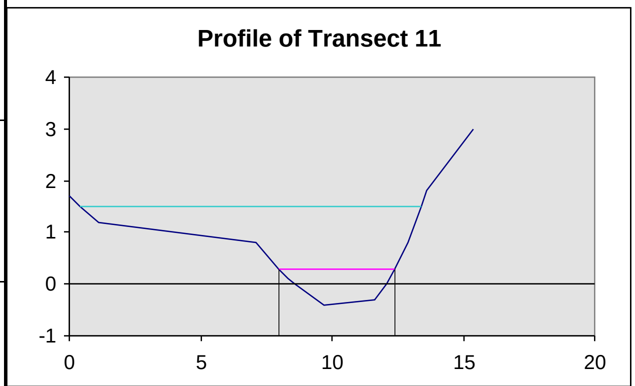




Transect 11

Raw data of profile	
Horizontal	Vertical
0.00	1.70
0.43	1.50
1.10	1.20
7.10	0.80
7.96	0.30
8.30	0.10
8.58	0.00
9.70	-0.40
11.60	-0.30
12.10	0.00
12.40	0.30
12.80	0.70
12.89	0.80
13.38	1.50
13.60	1.80
15.40	3.00

Level 1	Level 2
0.30	1.50

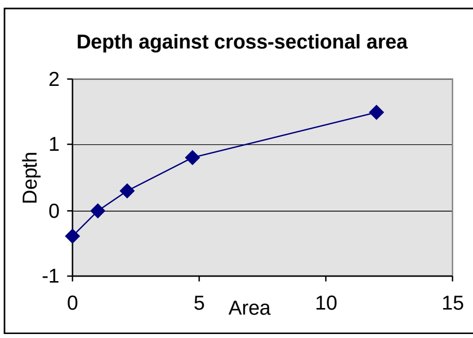


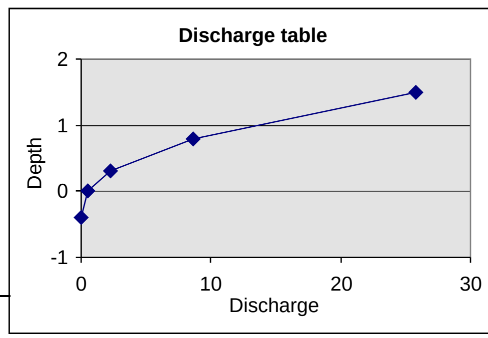
Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	4.37	1.01
Level 1		
Zone 1	0.00	0.00
Zone 2	4.79	2.17
Zone 3	0.00	0.00
Total	4.79	2.17
Level 2		
Zone 1	8.22	3.87
Zone 2	4.79	7.50
Zone 3	1.55	0.64
Total	14.56	12.01

Parameters for normal water level (level 0)	
s	0.11
R	0.23
d_{84}	1.00
d_{50}	0.80
n	0.22
Q	0.56

Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.00	0.00	0.00
Zone 2	0.45	0.18	2.28
Zone 3	0.00	0.00	0.00
Total			2.28
Level 2			
	R	n	Q
Zone 1	0.42	0.20	2.79
Zone 2	1.44	0.15	22.46
Zone 3	0.41	0.20	0.56
Total			25.81

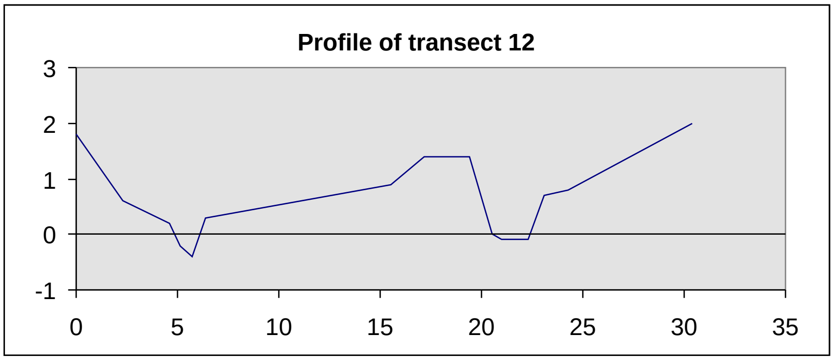
Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	8.00
2	10.33
5	12.00
10	13.33
20	14.66
50	16.00





Transect 12

Raw data of profile	
Horizontal	Vertical
0.00	1.80
2.30	0.60
4.60	0.20
5.10	-0.20
5.70	-0.40
6.40	0.30
15.50	0.90
17.20	1.40
19.40	1.40
20.50	0.00
21.00	-0.10
22.30	-0.10
23.10	0.70
24.30	0.80
30.40	2.00

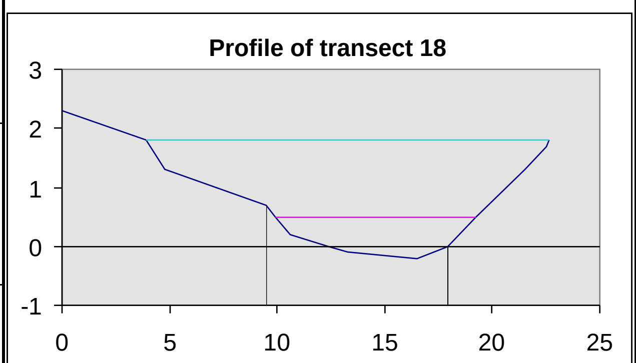


Transect 12 was abandoned due to the complexity of the profile of the riverbed.

Transect 18

Raw data of profile	
Horizontal	Vertical
0.00	2.30
3.90	1.80
4.80	1.30
9.50	0.70
9.90	0.50
10.60	0.20
12.40	0.00
13.30	-0.10
16.50	-0.20
17.90	0.00
19.25	0.50
21.55	1.30
22.50	1.70
22.64	1.80

Level 1	Level 2
0.50	1.80



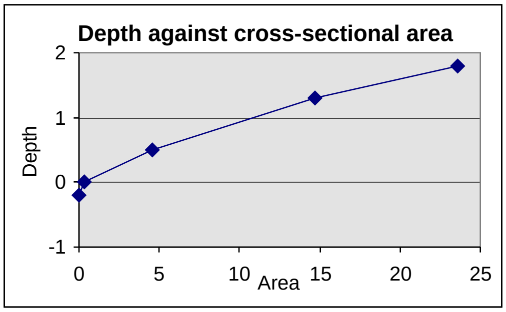
Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	5.52	0.35
Level 1		
Zone 1	0.00	0.00
Zone 2	8.09	4.24
Zone 3	1.44	0.34
Total	9.53	4.58
Level 2		
Zone 1	5.77	3.98
Zone 2	8.54	15.12
Zone 3	5.08	4.45
Total	19.39	23.56

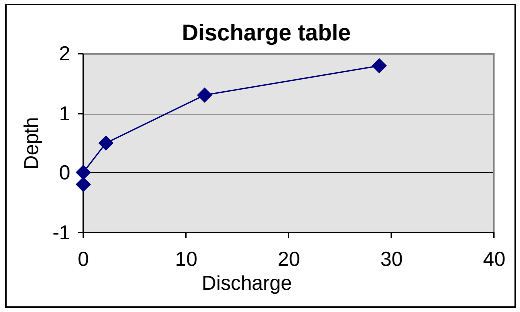
Parameters for normal water level (level 0)	
s	0.17
R	0.06
d_{84}	1.50
d_{50}	0.50
n	0.99
Q	0.02

Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.00	0.00	0.00
Zone 2	0.52	0.54	2.07
Zone 3	0.23	0.54	0.10
Total			2.17
Level 2			
	R	n	Q
Zone 1	0.69	0.42	3.07

Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	8.35
2	10.78
5	12.52
10	13.91
20	15.30
50	16.70

Zone 2	1.77	0.42	21.80
Zone 3	0.86	0.42	3.90
Total			28.78



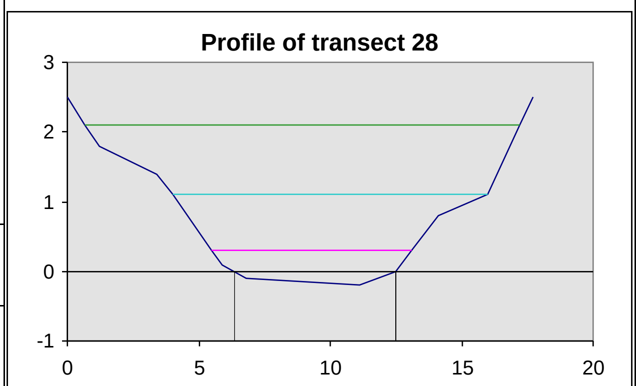


Transect 28

Level 1	Level 2	Level 3
0.30	1.10	2.10

Raw data of profile

Horizontal	Vertical
0.00	2.50
0.68	2.10
1.20	1.80
3.40	1.40
4.00	1.10
5.50	0.30
5.90	0.10
6.35	0.00
6.80	-0.10
11.10	-0.20
12.50	0.00
13.10	0.30
14.10	0.80
16.00	1.10
17.21	2.10
17.70	2.50



Calculation of wetted perimeter (P) and cross-sectional area (A)

	P	A
Level 0	6.18	0.81
Level 1		
Zone 1	0.91	0.15
Zone 2	6.18	2.65
Zone 3	0.67	0.09
Total	7.76	2.89
Level 2		
Zone 1	2.61	1.43
Zone 2	6.18	7.57
Zone 3	3.71	1.40
Total	12.50	10.41
Level 3		
Zone 1	6.12	5.47
Zone 2	6.18	13.72
Zone 3	5.28	5.51
Total	17.57	24.70

Parameters for normal water level (level 0)

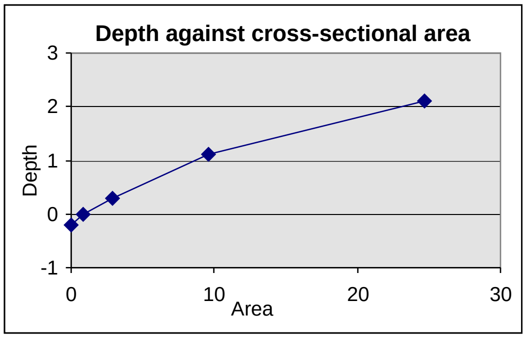
s	0.07
R	0.13
d_{84}	0.50
d_{50}	0.10
n	0.53
Q	0.10

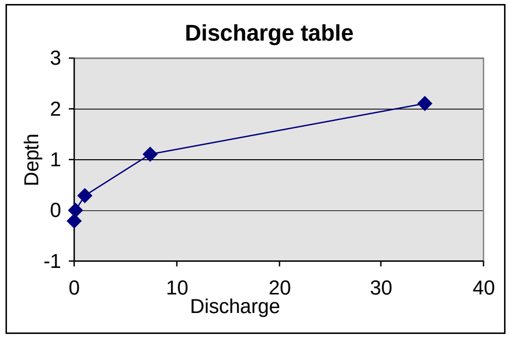
Parameters for all other water levels

	R	n	Q
Level 1			
Zone 1	0.00	0.00	0.00
Zone 2	0.43	0.39	1.03
Zone 3	0.13	0.39	0.02
Total			1.04
Level 2			
Zone 1	0.55	0.31	0.81
Zone 2	1.23	0.31	7.47
Zone 3	0.38	0.31	0.62
Total			8.90
Level 3			
Zone 1	0.89	0.26	5.10
Zone 2	2.22	0.26	23.46
Zone 3	1.04	0.26	5.69
Total			34.25

Return periods and their floods

Interval (Y)	Discharge (m^3/s)
1	17.26
2	22.29
5	25.88
10	28.76
20	31.63
50	34.51



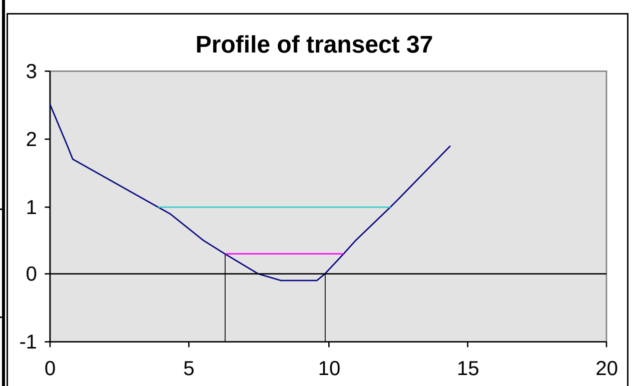


Transect 37

Level 1	Level 2
0.30	1.00

Raw data of profile

Horizontal	Vertical
0.00	2.50
0.60	1.90
0.80	1.70
3.87	1.00
4.30	0.90
5.50	0.50
6.30	0.30
7.50	0.00
8.30	-0.10
9.60	-0.10
9.90	0.00
10.55	0.30
11.00	0.50
12.25	1.00
12.50	1.10
14.40	1.90



Calculation of wetted perimeter (P) and cross-sectional area (A)

	P	A
Level 0	2.42	0.05
Level 1		
Zone 1	0.00	0.00
Zone 2	3.66	1.08
Zone 3	0.72	0.10
Total	4.38	1.18
Level 2		
Zone 1	2.53	0.86
Zone 2	3.66	3.60
Zone 3	2.55	1.14
Total	8.75	5.60

Parameters for normal water level (level 0)

s	0.05
R	0.02
d_{84}	0.50
d_{50}	0.30
n	0.31
Q	0.00

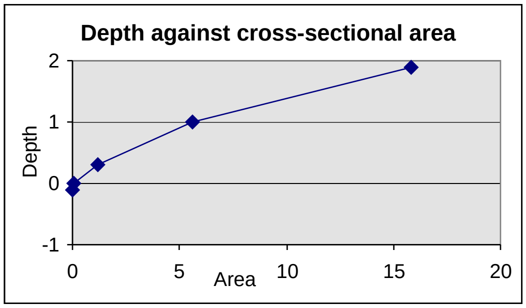
Parameters for all other water level:

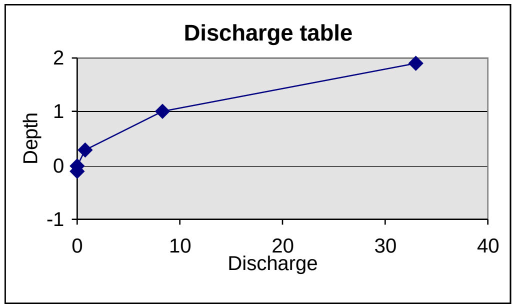
	R	n	Q
Level 1			
Zone 1	0.00	0.00	0.00
Zone 2	0.30	0.15	0.74
Zone 3	0.14	0.20	0.03
Total			0.77
Level 2			
Zone 1	0.34	0.20	0.48
Zone 2	0.99	0.12	7.01
Zone 3	0.44	0.20	0.76

Return periods and their flood:

Interval (Y)	Discharge (m^3/s)
1	8.10
2	10.47
5	12.16
10	13.51
20	14.86
50	16.21

Total	8.25

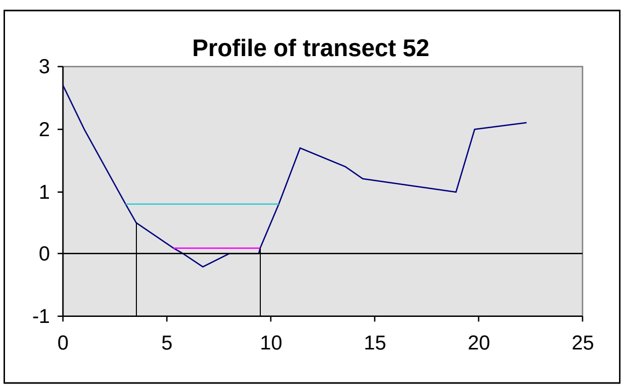




Transect 52

Level 1	Level 2
0.10	0.80

Raw data of profile	
Horizontal	Vertical
0.00	2.70
1.03	2.00
3.00	0.80
3.50	0.50
5.35	0.10
5.80	0.00
6.70	-0.20
8.00	0.00
9.40	0.00
9.48	0.10
10.38	0.80
11.40	1.70
13.60	1.40
14.40	1.20
18.90	1.00
19.80	2.00
22.30	2.10



Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	3.64	0.22
Level 1		
Zone 1	0.00	0.00
Zone 2	4.23	0.61
Zone 3	0.00	0.00
Total	4.23	0.61
Level 2		
Zone 1	0.58	0.07
Zone 2	6.12	4.42
Zone 3	1.14	0.32
Total	7.84	4.81

Parameters for normal water level (level 0)

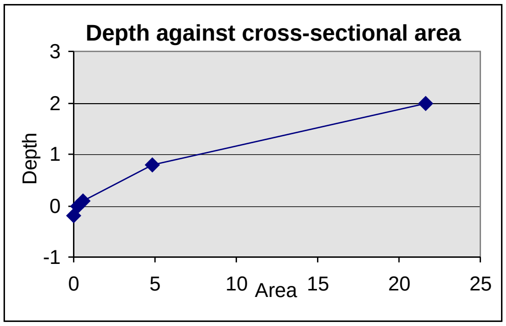
Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.00	0.00	0.00
Zone 2	0.14	0.70	0.11

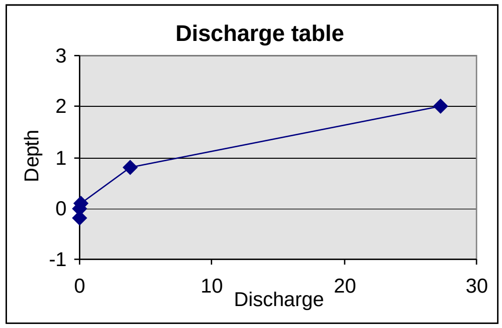
Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	7.87
2	10.16

s	0.22
R	0.06
d_{84}	2.00
d_{50}	1.00
n	0.90
Q	0.02

Zone 3	0.00	0.00	0.00
Total			0.11
Level 2			
	R	n	Q
Zone 1	0.13	0.46	0.02
Zone 2	0.72	0.46	3.67
Zone 3	0.28	0.46	0.14
Total			3.82

5	11.80
10	13.11
20	14.42
50	15.73

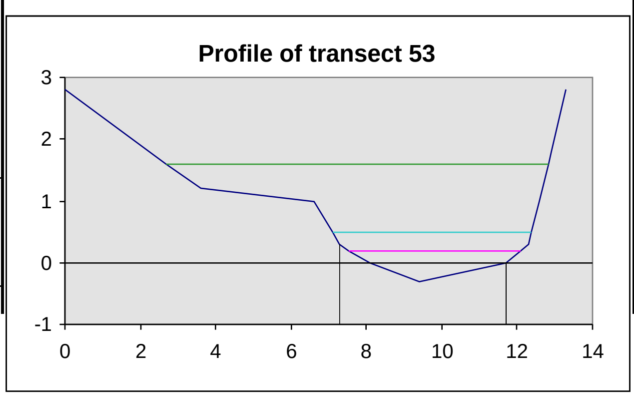




Transect 53

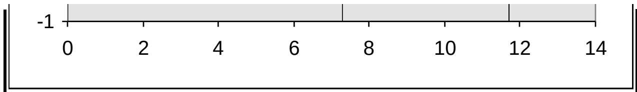
Level 1	Level 2	Level 3
0.20	0.50	1.60

Raw data of profile	
Horizontal	Vertical
0.00	2.80
2.70	1.60
3.60	1.20
6.60	1.00
7.10	0.50
7.30	0.30
7.53	0.20
8.10	0.00
9.40	-0.30
11.70	0.00
12.10	0.20



Calculation of wetted perimeter (P) and cross-sectional area (A)		
	P	A
Level 0	3.65	0.54
Level 1		
Zone 1	0.00	0.00
Zone 2	4.26	1.32
Zone 3	0.45	0.04
Total	4.70	1.36
Level 2		
Zone 1	0.28	0.02

12.30	0.30
12.38	0.50
12.59	1.00
12.82	1.60
12.90	1.80
13.30	2.80

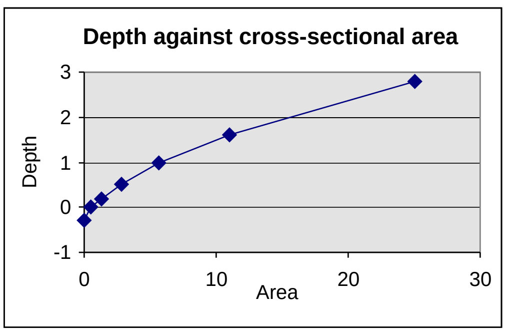


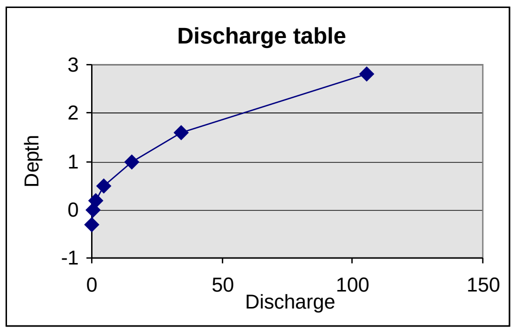
Zone 2	4.51	2.63
Zone 3	0.89	0.22
Total	5.68	2.86
Level 3		
Zone 1	4.98	2.34
Zone 2	4.51	7.47
Zone 3	2.07	1.21
Total	11.56	11.02

Parameters for normal water level (level 0)	
s	0.05
R	0.15
d_{84}	0.30
d_{50}	0.20
n	0.13
Q	0.27

Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.00	0.00	0.00
Zone 2	0.31	0.11	1.30
Zone 3	0.09	0.20	0.01
Total			1.31
Level 2			
	R	n	Q
Zone 1	0.07	0.20	0.00
Zone 2	0.58	0.09	4.64
Zone 3	0.25	0.20	0.10
Total			4.74
Level 3			
	R	n	Q
Zone 1	0.47	0.20	1.62
Zone 2	1.66	0.07	31.92
Zone 3	0.58	0.20	0.97
Total			34.51

Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	14.28
2	18.45
5	21.42
10	23.80
20	26.19
50	28.57



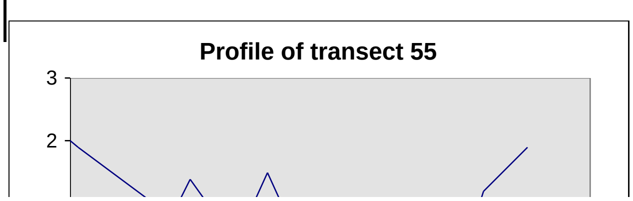


Transect 55

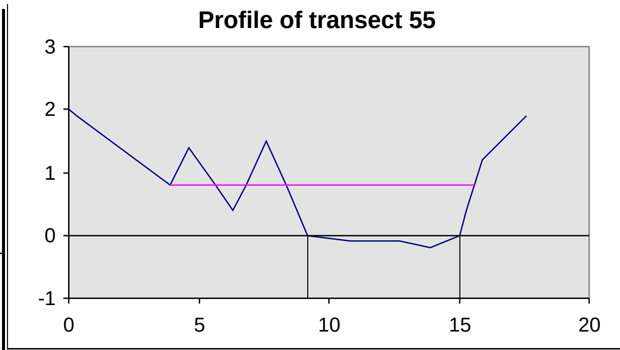
Raw data of profile	
Horizontal	Vertical
0.00	2.00
0.30	1.90

Level 1
0.80

Calculation of wetted perimeter (P) and cross-sectional area (A)



3.90	0.80
4.60	1.40
5.62	0.80
6.30	0.40
6.80	0.80
7.60	1.50
8.35	0.80
8.77	0.40
9.20	0.00
10.80	-0.10
12.70	-0.10
13.90	-0.20
15.00	0.00
15.30	0.40
15.60	0.80
15.90	1.20
17.60	1.90

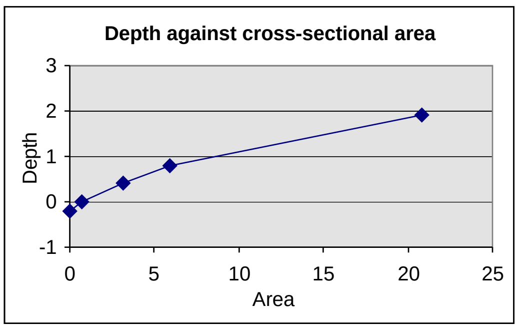


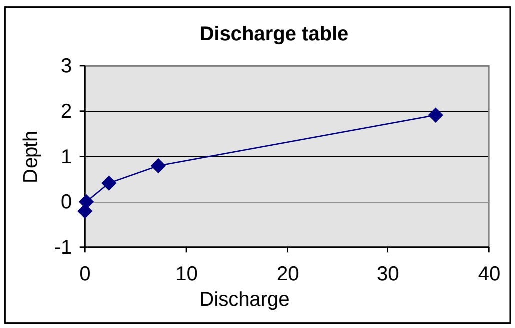
	P	A
Level 0	5.82	0.71
Level 1		
Zone 1	2.60	0.58
Zone 2	5.82	5.35
Zone 3	1.00	0.24
Total	9.42	6.17

Parameters for normal water level (level 0)	
s	0.10
R	0.12
d_{84}	1.50
d_{50}	1.00
n	0.36
Q	0.15

Parameters for all other water levels			
Level 1			
	R	n	Q
Zone 1	0.22	0.22	0.29
Zone 2	0.92	0.22	7.07
Zone 3	0.24	0.22	0.13
Total			7.20

Return periods and their floods	
Interval (Y)	Discharge (m^3/s)
1	11.02
2	14.24
5	16.53
10	18.37
20	20.20
50	22.04



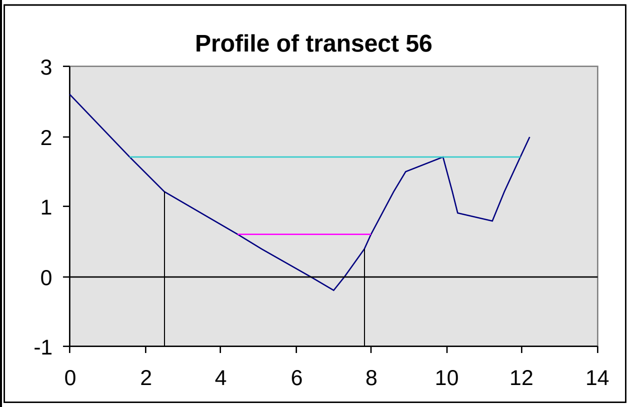


Transect 56

Level 1	Level 2
0.60	1.70

Raw data of profile

Horizontal	Vertical
0.00	2.60
1.60	1.70
2.50	1.20
4.45	0.60
5.10	0.40
6.40	0.00
7.00	-0.20
7.30	0.00
7.80	0.40
8.00	0.60
8.60	1.20
8.90	1.50
9.90	1.70
10.15	1.20
10.30	0.90
11.20	0.80
11.53	1.20
11.95	1.70
12.20	2.00



Calculation of wetted perimeter (P) and cross-sectional area (A)

	P	A
Level 0	0.99	0.09
Level 1		
Zone 1	0.00	0.00
Zone 2	2.99	1.35
Zone 3	0.28	0.02
Total	3.28	1.37
Level 2		
Zone 1	1.03	0.23
Zone 2	5.71	6.66
Zone 3	5.55	2.19
Total	12.29	9.07

Parameters for normal water level (level 0)

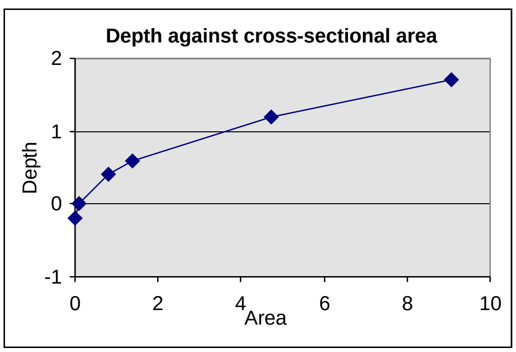
s	0.11
R	0.09
d_{84}	1.50
d_{50}	1.00
n	0.42
Q	0.01

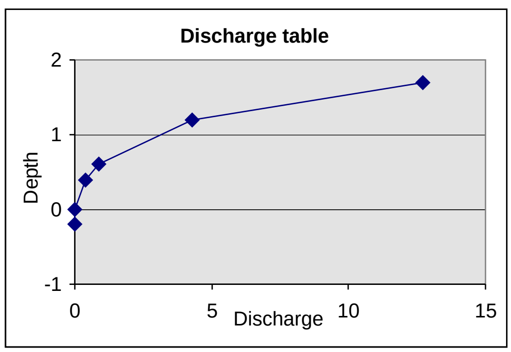
Parameters for all other water levels

	R	n	Q
Level 1			
Zone 1	0.00	0.00	0.00
Zone 2	0.39	0.28	0.90
Zone 3	0.07	0.28	0.00
Total			0.90
Level 2			
Zone 1	0.22	0.23	0.12
Zone 2	1.17	0.23	10.86
Zone 3	0.39	0.23	1.73
Total			12.71

Return periods and their floods

Interval (Y)	Discharge (m^3/s)
1	8.47
2	10.94
5	12.71
10	14.12
20	15.53
50	16.94





Calculations at control sections

In the control section the following equations are valid:

1) $$\frac{Q^2 \cdot B_{top}}{g \cdot A^3} = 1$$

2) $$z_1 + y_1 + \frac{Q^2}{2 \cdot g \cdot A_1^2} = z_2 + y_2 + \frac{Q^2}{2 \cdot g \cdot A_2^2}$$

The left-hand side of Equation 2) is referred to below as LH, and the right-hand side as RH. By iteration of the value y_2 the right value of Q can be found. It appears that this method is very sensitive to the value of z_1, which could not be detemined sufficiently accurate. The method is abandoned at a later stage because of this reason.

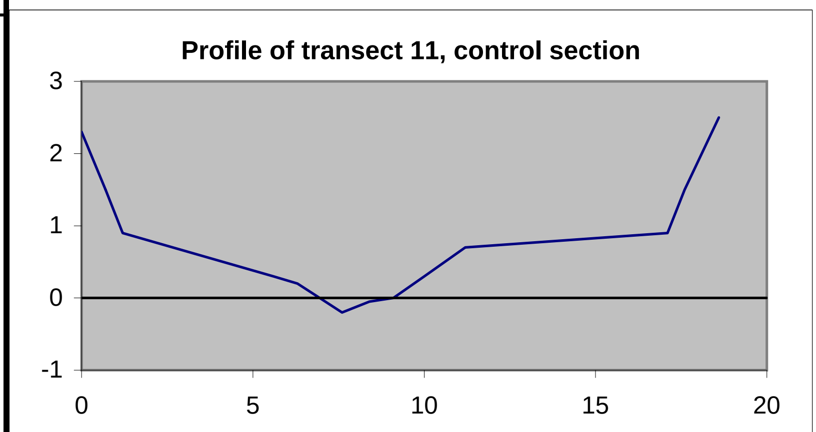
Transect 11, control section

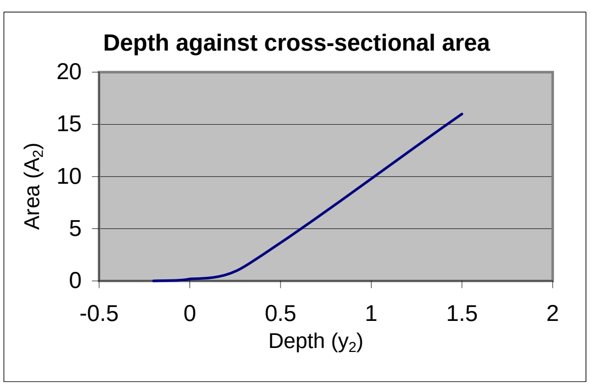
Values of y_1	Level 1	Level 2
	0.30	1.50

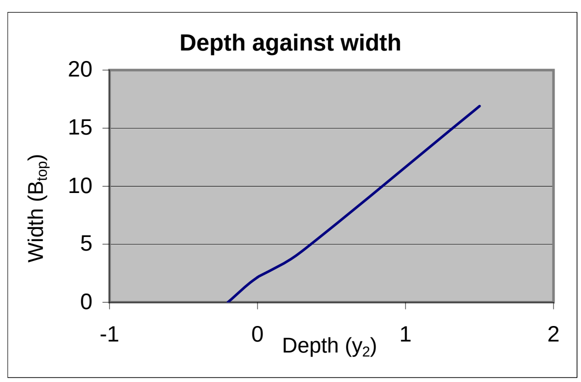
Value of z_1	Value of z_2
0.30	0.00

Raw data of profile

horizontal	vertical
0.00	2.30
0.70	1.50
1.20	0.90
5.60	0.30
6.30	0.20
6.95	0.00
7.60	-0.20
8.40	-0.05
9.10	0.00
10.00	0.30
11.20	0.70
17.10	0.90
17.60	1.50
18.60	2.50







	Level 1	Level 2
A_1	3.19	20.33
y_2	0.38	2.91
y_1	0.30	1.50
Q	5.06	106.42
Equation (2):		
LH	4.73	7.20
RH	0.61	3.49

difference	4.12	3.71

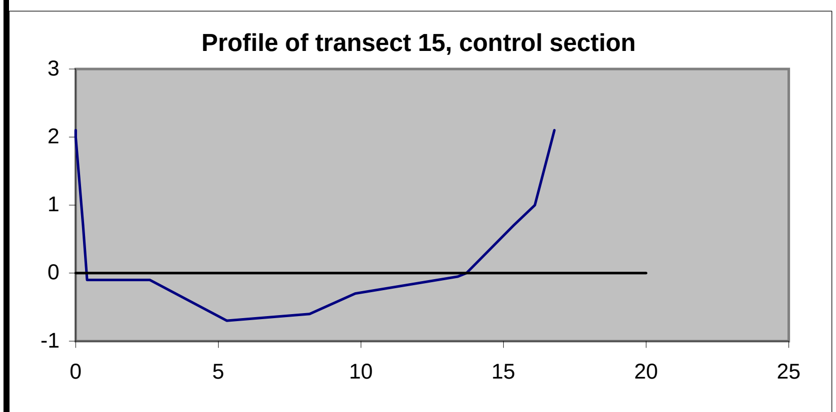
In this case the value of RH and LH could not be matched; this shows how sensitive the equation is to the value of z_1. The control section was abandoned at transect 11.

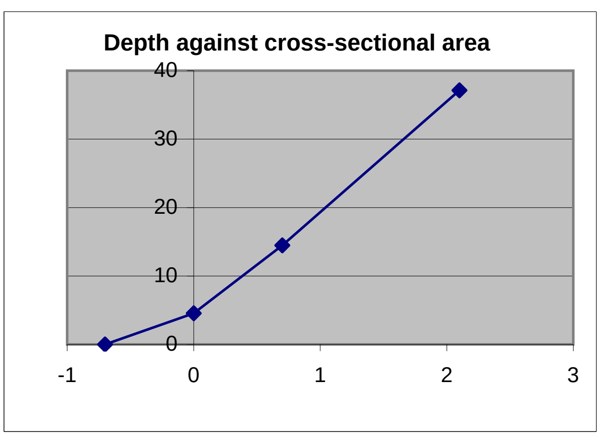
Transect 15, control section

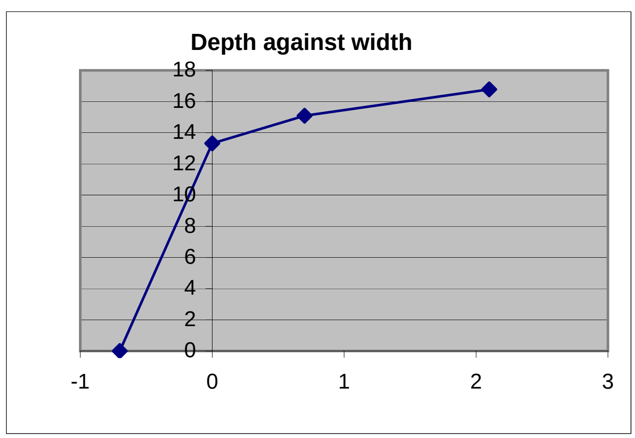
Raw data of profile	
horizontal	vertical
0.00	2.10
0.00	2.00
0.26	0.70
0.38	0.00
0.40	-0.10
2.60	-0.10
5.30	-0.70
8.20	-0.60
9.80	-0.30
13.40	-0.05
13.70	0.00
15.35	0.70
16.10	1.00
16.60	1.80
16.78	2.10

Values of y_1	Level 1	Level 2
	0.70	2.10

Value of z_1	Value of z_2
0.20	0.00







	Level 1	Level 2

A_1	17.48	43.08
y_2	0.70	7.03
y_1	0.70	2.10
Q	44.01	1582.40
Equation (2):		
LH	1.22	71.08
RH	1.17	10.44
difference	0.05	60.64

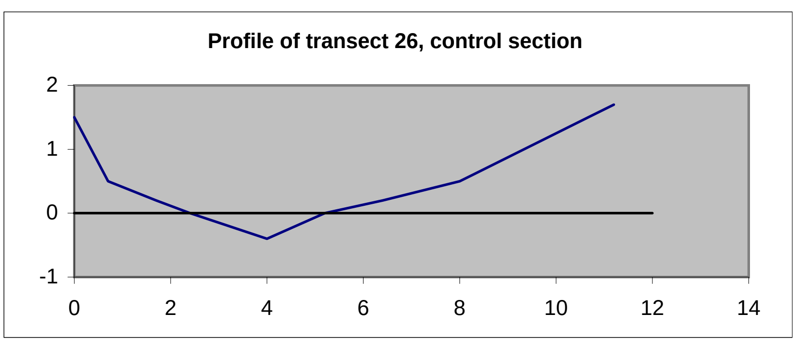
In this case, too, LH and RH could not be matched, so this control section was also abandoned

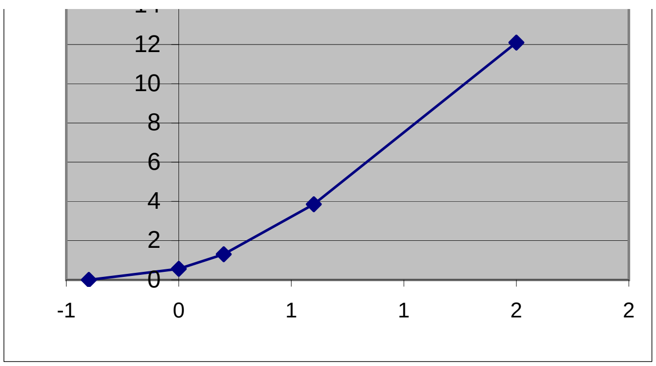
Transect 26, control section

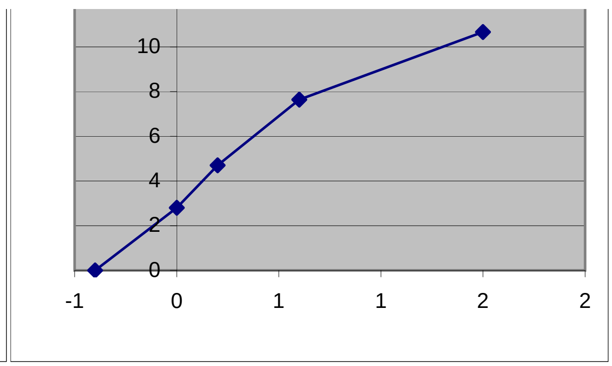
Raw data of profile	
horizontal	vertical
0.00	1.50
0.63	0.60
0.70	0.50
1.70	0.20
2.40	0.00
4.00	-0.40
5.20	0.00
6.40	0.20
8.00	0.50
8.27	0.60
10.67	1.50
11.20	1.70

Values of y_1	Level 1	Level 2	Level 3
	0.20	0.60	1.50

Value of z_1	Value of z_2
0.01	0.00







	Level 1	Level 2	Level 3
A_2	2.70	5.21	18.54
y_2	0.12	0.47	1.15
y_1	0.20	0.60	1.50
Q	1.12	5.16	26.93
Equation (2):			
LH	0.22	0.66	1.62
RH	0.22	0.66	1.62
difference	0.00	0.00	0.00

In this control section, the values of RH and LH could be matched, but only with a very small value of z_1. The discharge values are slightly higher than the ones calculated with Manning's n. The old values have been used for comparison and the values presented here have been abandoned.

Transect 28, control section

Raw data of profile

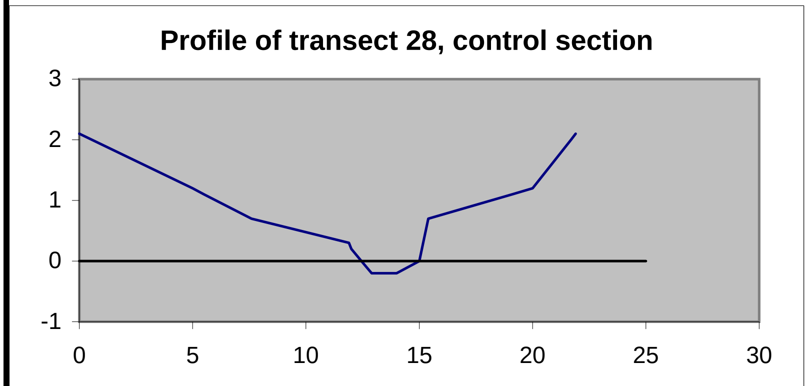
Values of	Level 1	Level 2	Level 3

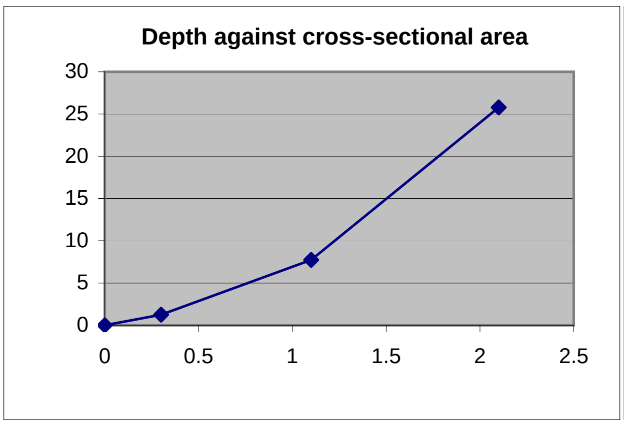
Value of z_1	Value of z_2

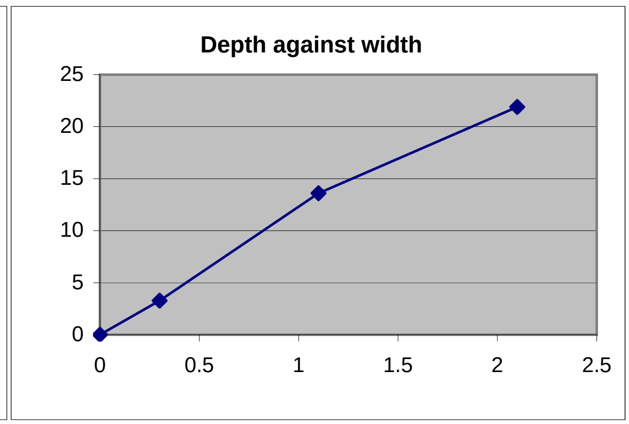
horizontal	vertical
0.00	2.10
5.00	1.20
5.50	1.10
7.60	0.70
11.90	0.30
12.00	0.20
12.45	0.00
12.90	-0.20
14.00	-0.20
15.00	0.00
15.17	0.30
15.40	0.70
19.10	1.10
20.00	1.20
21.70	2.00
21.90	2.10

y_1	0.30	1.10	2.10

0.20	0.00







	Level 1	Level 2	Level 3
A_1	2.89	9.56	24.70
y_2	0.11	0.88	-0.93
y_1	0.30	1.10	2.10
Q	0.54	7.23	477.53
Equation (2):			
LH	0.30	1.13	21.15
RH	0.30	1.13	21.15
difference	0.00	0.00	0.00

In this case, the values of RH and LH could be matched but result in negative values for y_2 and extremely high values for Q in the highest level. Because of this, the control section was abandoned.