

THE EFFECT OF CATCHMENT
LAND USE ON SEDIMENT INPUT
TO SWARTVLEI

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NOTE ON NOMENCLATURE

In this report suspended sediment concentration has been referred to as sediment load. The method of determination is described on page 10. Thus throughout this report references to sediment load neglect river flow rates and any reference to bed load.

ABSTRACT

The littoral aquatic plant community of Swartvlei declined after 1978, apparently as a result of increased lake water turbidity. To investigate the causes of this, land use and land management of the Swartvlei catchment area have been studied. Possible causes and the extent of accelerated runoff and sediment loss in different rainfall conditions were determined.

Rainfall, water flow, Secchi disc and sediment load data are reviewed and the apparent relationship between them noted. Water samples were collected at 32 different sample sites to determine sediment loads. Samples were vacuum filtered through coarse and fine glass fibre filters and the results recorded in milligrams of sediment per litre of water. The quantity and duration of rainfall in the immediate pre-sampling period were recorded. Secchi disc transparency of Swartvlei water was recorded.

Catchment land use and land management are described in four areas based on land use and geographical location. The naturally vegetated montane upper catchment area, the foothill plantation area, the agricultural areas on the tertiary plateau and the road reconstruction and recreation areas are considered separately.

Land use and land management information was obtained from a literature

review and study of topographical maps, orthophotographs, geological survey maps and aerial photographs. Flights over the area enabled confirmation of observations. Informal interviews with persons involved in catchment management, property-owners and roads authorities were conducted. Areas of accelerated sediment loss were determined and the magnitude of the problem noted.

Results show that rainfall duration, intensity, quantity and distribution determine the effect of sediment-laden runoff on river and vlei water quality. Small storm events (< 50 mm) influence the water quality of tributaries particularly in the lower catchment area. Storm events of > 50 mm influence the main catchment rivers and light penetration in Swartvlei at the river inflow points. Long-duration flood rainfalls bring about massive soil loss in the catchment and cause reduced light penetration over the entire surface area of Swartvlei. Most sediment originates from the lower sections of the catchment area where human activities are most intense. Natural vegetation acts as a protective barrier against soil loss and its removal and the lack of suitable runoff channels leads to greater sediment loss. Recommendations to reduce sediment loss are made.

The topographical and soil characteristics of the area make it sensitive to soil loss, the significance of which has only been recognised recently. The socio-economic circumstances in the region and the present economic recession are limiting amelioration of the situation in this beautiful natural area.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND INFORMATION AND STATEMENT OF AIM

The Wilderness Lakes of the southern Cape coast consist of five bodies of water, namely Groenvlei, Rondevlei, Langvlei, Eilandvlei and Swartvlei (Fig. 3.4). The subject of this report is the effects of catchment land use on sediment input to Swartvlei, a lake and estuarine system which supports a rich flora and fauna. Swartvlei is a popular tourist attraction on the Garden Route, and the lake system has lent itself to varied and detailed research.

The municipality of Sedgefield is situated on the estuarine section of Swartvlei. This village is developing rapidly and the seasonal influx of tourists is increasing. In season, the utilisation levels of the estuary have reached the overcrowded stage and there will be increased spill-over into the lake portion of the system. The increase in tourist industry has been predicted, and various management recommendations have been made in reports on the Swartvlei system. The catchment area of the lake, however, has received relatively little attention.

The reasons for this lack of emphasis are perhaps because a large proportion of the catchment area is under forestry and agriculture.

Neither of these activities is seen to be as potentially expansive as the tourist industry (Knysna-Wilderness-Plettenberg Bay Guide Plan, 1983, p.32). The tourist industry and its economic and environmental consequences have thus received more attention than agriculture or forestry. Secondly, before 1979 there was no reason to believe that catchment land-use activities were having any effect on the lake.

Howard-Williams and Allanson (1979), in their recommendations to the Water Research Commission, stated that the results of a four-year study, completed in June 1978, showed that there was no significant input of sediment from the rivers flowing into the lake. This was attributed to correct agricultural practices in the uplands. A series of events after 1978, which culminated in the loss of the lake's littoral plant community, led to speculation that increased development in the catchment areas was contributing towards decreased transparency in the lake.

The most significant of the above mentioned events was a series of high rainfalls which brought considerable quantities of sediment into the lake. During a feasibility study for this research, interviews with the several authorities involved in management and research in the area revealed that there was little agreement or certainty on the sources of this sediment or the circumstances under which it affected the lake.

It has been the aim of this research to collect the necessary information to answer the above questions and, in so doing, determine whether the ecological health of the Swartvlei system could be threatened in

any way, and what implications there are for future management of the catchment area.

1.2 PREVIOUS RESEARCH

Elements of the Swartvlei system (34°S, 22°45'E) have been extensively studied:

Hydrology: The Department of Water Affairs.

Hydrographic surveys: The Coastal Engineering and Hydraulics Division of the National Research Institute for Oceanology, Stellenbosch.

Geological and geophysical investigations: The University of Cape Town Marine Geoscience Unit.

Trace metal studies: The National Physical Research Laboratory of the Council for Scientific and Industrial Research (CSIR).

Zoological and ecological studies: The Department of Nature and Environmental Conservation of the Cape Provincial Administration (CPA), which has a laboratory complex at Rondevlei.

The physico-chemical limnology and biology of the Swartvlei system:

The Institute for Freshwater Studies of Rhodes University, whose Swartvlei Project research station is situated on the western shore of Swartvlei.

As a result a considerable fund of knowledge has been built up about the Swartvlei system. Only that information relevant to the topic of this report will be reviewed here. The following publications discuss the characteristics and functioning of the system:

CSIR Research Report 421, December 1983. Estuaries of the Cape. Part II. Synopsis of available information of individual systems Report No. 22 Swartvlei.

Howard-Williams, B. and Allanson, B.R. 1979. The ecology of Swartvlei: Research for planning and future management. Water Research Commission. Institute for Freshwater Studies, Rhodes University (CSIR Research Report 421, Report No. 22, 1983).

1.3 THE EFFECT OF THE LIGHT REGIME AND SALINITY ON THE LITTORAL ZONE AND INTERACTIONS BETWEEN THE LAKE AND ITS LITTORAL

A series of events from about 1979 led to the decline of the littoral plant community of Swartvlei. The series of events affecting the phenology of the plants was according to Whitfield (1985), as follows:

Between January and April 1979 Potamogeton pectinatus formed a typical dense canopy which eliminated almost all the light beneath it. Leaves below the canopy died and benthic algae were absent as there was virtually no penetration of photosynthetically active radiation (PAR) below 50 cm water depth. At the beginning of May 1979 the canopy began to senesce, but, contrary to the normal growth pattern, spring shoots did not develop. The reasons for the failure of the 1979 spring regrowth were not determined but the September 1979 flood, which caused littoral water transparencies to decline, would have prevented light from reaching the growing plants for at least 10 days. By January 1980, when the Secchi disc again exceeded 3 m, a dense filamentous mat had formed in the 1,5 - 3 m depth zone. The algal mat (Polysiphonia/

Chaetomorpha spp.) may have smothered Potamageton shoots. During the spring of 1980 water transparency was good (Secchi disc +3 m) but salinities exceeded 17‰, and Potamageton plants did not show signs of recovery until late 1980 when salinities declined below 15‰. The regrowth of the Potamageton beds received a setback at the end of January 1981 when the first of a series of heavy rains brought turbid waters flooding into Swartvlei. The plants failed to form a canopy and by April 1981 the senescence of the macrophytes had commenced. The poor 1981 spring growth of Potamageton may have resulted from the low water transparencies which prevailed for most of the year. During 1982 conditions appeared ideal for the recovery of the Potamageton beds, with low salinities and Secchi disc values exceeding 2 m for most of the year. However, most of the Swartvlei littoral zone comprised bare sand and even the epipsammic algal mat was absent, possibly as a result of the low salinities during 1981/82. According to Allanson and Howard-Williams (1984) Potamageton pectinatus has a dependence on the concentration of calcium in the water column, and rivers flowing into Swartvlei are low in Ca.^{**} Therefore the persistent flooding during 1981 may have reduced calcium concentrations in the littoral zone to lethal limits and prevented the regrowth of Potamageton in 1982. Plant growth in 1984 remains poor. This is due to the high salinities (18 - 20‰) occurring in the lake at present. These salinities are the combined result of a year of below-average rainfall and the mouth of the estuary remaining open for a longer than normal period (the latter the result of the 1981 high rainfall period).

From the above, one may conclude that decreased lake transparencies are

not the sole reason for poor plant growth. Decreased light penetration is, however, a significant factor influencing macrophytic regeneration and production. Alone, or in combination with other disadvantageous conditions (such as high salinities), it can make the difference between the presence or absence of a healthy, productive littoral zone.

The ecological necessity of a productive littoral zone becomes clear when the results of a decline in primary productivity are noted. The CSIR synopsis of available information on Swartvlei (1983) gives a summary of the effects of reduced primary production. Total primary productivity declined by approximately 60% between December 1975 and December 1980 because of a reduction in Potamogeton and Charophyta standing stocks (Taylor 1983). Associated with the senescence of the above plants was a 74% drop in invertebrate biomass (Davies 1982), a 69% decline in littoral fish populations (Whitfield 1983), and a 58% drop in the number of Red-knobbed Coot (Palmer, pers. comm.). The ecological health of the entire lake system is affected. This has implications not only for the flora and fauna of the region but also for research and recreation.

1.4 THE CATCHMENT AREA AND ITS RIVERS

The total area of the Swartvlei catchment is 340 km². Three major rivers enter the lake. The Diep-Wolwe river, draining an area of 125 km², enters through reed-covered levees on the north-western corner

of the lake. On the north-east side of the lake, the Hoëkraal and Karatara rivers, draining areas of 109 km² and 106 km² respectively, join at the edge of a small shallow stretch of water called Karatara Vlei, and then flow into Swartvlei. A fourth minor river, the Klein Wolwe, enters the same basin as the Diep-Wolwe river (CSIR Research Report 421, 1983).

The drainage pattern of the rivers may be described as dense dendritic. The three major rivers have their source on the southern slopes of the Outeniqua Mountains at elevations of between 1000 - 1400 m a.m.s.l. The upper slopes are covered with fynbos vegetation, with patches of indigenous forest remaining in the kloof areas. Further south, indigenous forest is found only in the steep, deep kloofs where forestry and agriculture have not penetrated. A considerable proportion of the catchment is under pine and Eucalyptus plantations. Agricultural land occurs south of the plantations.

The largest proportion of this area is under pastures (dairy farming) with a small percentage being cultivated for vegetable production. The Klein Wolwe river has its source in the southern borders of the forested area and in the agricultural area at elevations of 240 - 400 m above mean sea level.

The three catchments contribute similar amounts of water to Swartvlei, the mean annual run-off from the Diep-Wolwe river amounting to 19,8 x 10⁶ m³; the Hoëkraal river 24,8 x 10⁶ m³, and the Karatara river 20,1 x 10⁶ m³. An extra 1 x 10⁶ m³ can be added from minor

streams and direct precipitation, resulting in an average total fresh-water input of $66 \times 10^6 \text{ m}^3$ from the catchment each year (Hidraliese studie van die Swartvlei estarium, 1978, cited in CSIR Report No. 421, 1983). Due to the year-round rainfall pattern, there is no distinct seasonality in river flow. Occasional floods cause short-lived peak inflow periods.

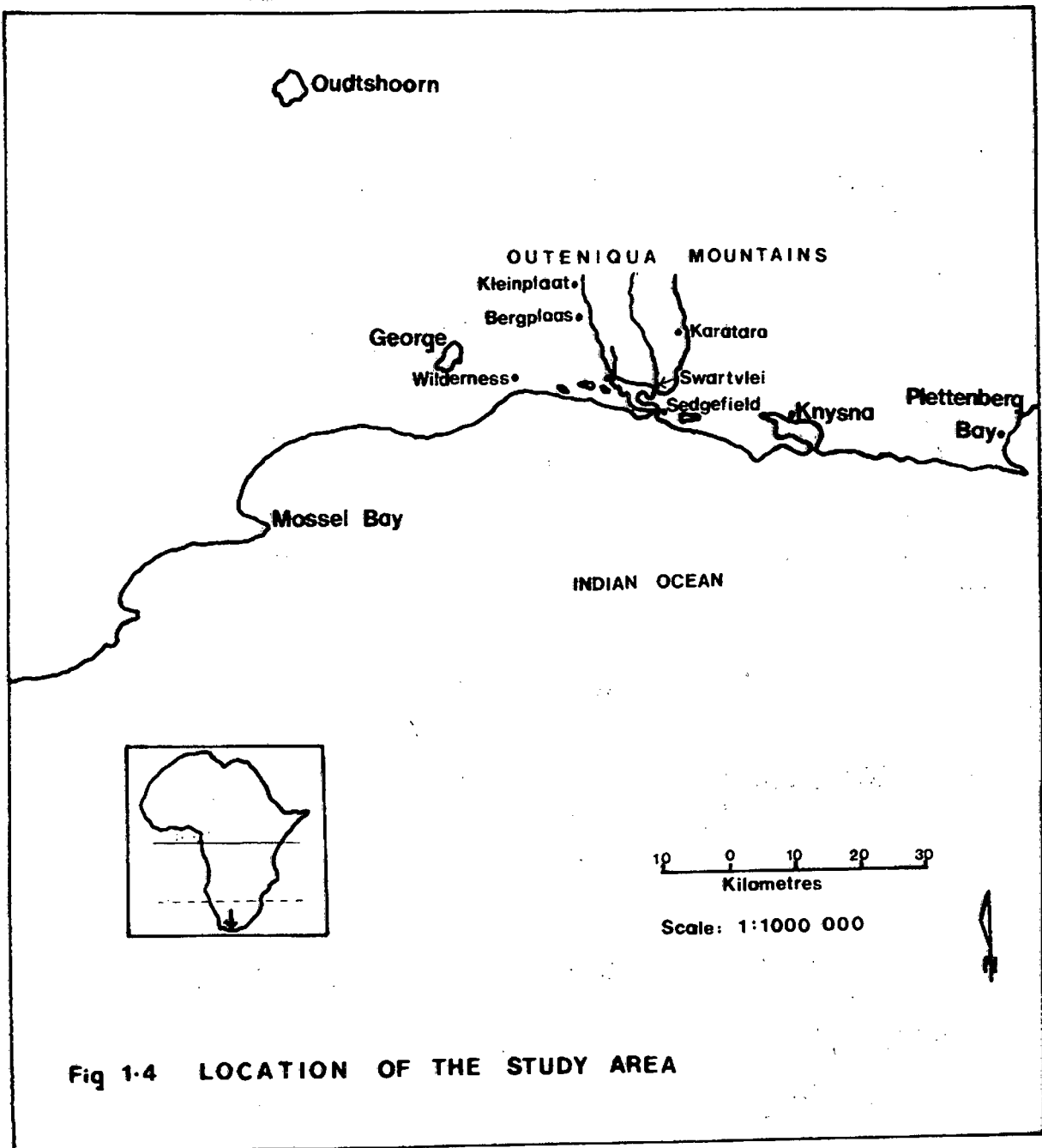


Fig 1.4 LOCATION OF THE STUDY AREA

CHAPTER 2

METHODS

2.1 METHODS

The methods used to gather the required information have been as follows.

A literature search was conducted. Information was collected from:

- general and subject-related libraries,
- the South African Water Information Centre in Pretoria,
- research bodies,
- authorities involved in management and land-use activities in the area,
- relevant Government departments.

Records of rainfall patterns, river flows, Secchi disc transparencies, suspended concentrations and sediment in the area for the period between 1974 - 1984 were accumulated and reviewed. Factors regulating and influencing the catchment area of Swartvlei were investigated in the field by a variety of methods including interviews and studies of all available information including maps and air photographs.

Sediment loads of the catchment rivers had not been taken until 1982. A series of sediment load records was collected, under differing rainfall conditions, at approximately 32 different sampling sites. Some

sites were sampled more regularly than others, depending on their relative importance. The time of sample collection after rainfall abatement as well as quantity and duration of rainfall were noted. The sample sites are referred to in the text and marked on Fig.6.2.

The method of sediment load sampling was as follows:

- (i) A sample of a litre, or less where little water was flowing, was collected at each sample site.
- (ii) This was vacuum-filtered through
 - a) a GF/C(glass fibre, coarse) Whatman filter
 - b) a GF/F (glass fibre, fine) Whatman filter.
- (iii) The sediment load was determined in milligrams of sediment per litre of water.

Secchi disc transparency readings of the lake were taken on a less regular basis. The standard 140 mm diameter Secchi disc was used. The low rainfall of 1984 ensured that dramatic changes in lake water transparency did not occur. The investigations of factors regulating the catchment area of Swartvlei have been divided into four subsections based on the differing land-uses and their geographical locations, as follows:

- (i) Upper catchment areas (natural fynbos vegetated fire protection zone)
- (ii) Forestry plantation areas (Foothill zone)
- (iii) Agricultural areas (Tertiary plateau)

(iv) Roads and Roadworks (Tertiary plateau and Recent sands)

Information for these chapters was obtained from available literature sources including those mentioned previously, as well as the

- 1:50 000 topographical maps of the area, numbers 3322 DC and 3422 BA Wilderness, 3422 BB Sedgefield, and 3322 DD Karatara,
- 1:250 000 Geology Map, 3322 Oudtshoorn,
- 1:10 000 Orthophotos of the area, i.e. 3322 DD 22 Ruigtevlei, 3322 DD 17 Karatara, 3322 DD 23 Homtini, 3322 DD 16 Beervleibos and 3322 DD 21 Hoogekraal,
- 1:30 000 aerial photographs of the area, flown in 1968, 1974, and 1980.
- Informal interviews with relevant personnel in the Knysna Directorate of Forestry. (See question framework in appendix.)
- Interviews with landowners in the area. (See question framework in appendix)
- Interviews with the Outeniqua Divisional Council Roads Authority.

These investigations were aimed at determining how catchment management and land utilisation practices may accelerate erosion and sediment runoff into the watercourses of the Swartvlei catchment area.

CHAPTER 3

RAINFALL, RIVER FLOW, SEDIMENT LOADS

AND SECCHI DISC TRANSPARENCIES

A substantial quantity of data is available as a great deal has been written about the hydrology of these catchments (Hughes & Görgens 1979 - 1983), and information on the ecology of Swartvlei has been produced by the Rhodes University research group (Howard-Williams & Allanson 1979, 1984; Whitfield 1985).

A statistical analysis of the available numerical data will provide relationships relevant to the water quality and light regime of Swartvlei, but this has not been attempted in this study. This study concentrates on the role of catchment land-use in relation to possible causes of sediment input to Swartvlei.

Information on records of rainfall, monthly flow volumes of the rivers, and Secchi disc readings of Swartvlei water transparency are presented in this section, together with some notes on the interrelationships between these data. The effects of humic acids and suspended sediments on Swartvlei's light regime provide the information base which generated the need for this study.

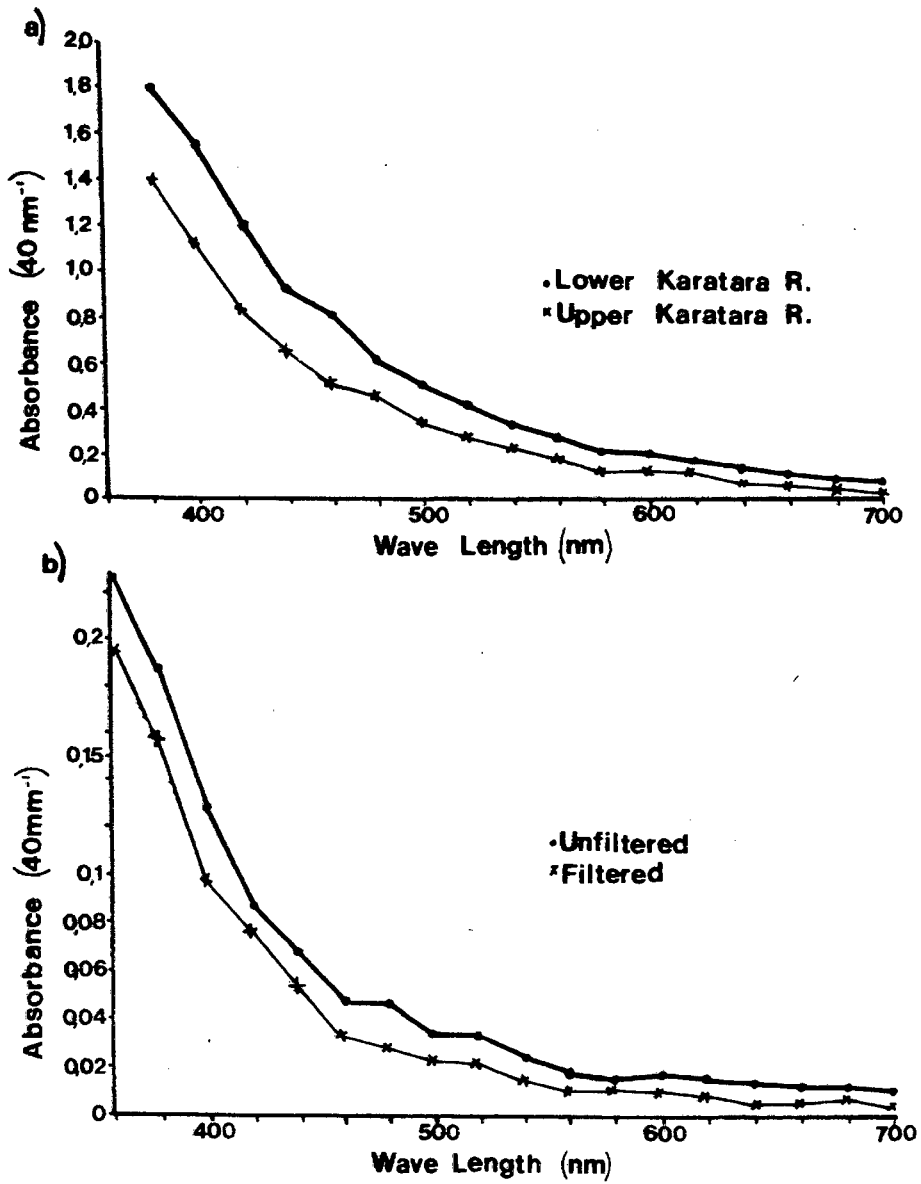


Fig 3-1 ABSORPTION SPECTRA FOR SWARTVLEI WATERS

a) INFLOWING RIVER WATER

b) LAKE WATER FILTERED AND UNFILTERED

(Howard-Williams, Allanson 1984)

3.1 THE INFLUENCE OF HUMIC ACIDS AND SUSPENDED PARTICULATE MATTER ON SWARTVLEI'S LIGHT REGIME

This discussion is based on B.R. Allanson's and C. Howard-Williams's report titled 'A contribution to the physico-chemical limnology of Swartvlei', published in 1984.

It is important to note that the rivers flowing into Swartvlei (Diep-Wolwe, Hoëkraal and Karatara rivers) are stained with dissolved organic matter which makes the lake water appear dark brown, despite some dilution from estuarine water. This brown colour may be only a surface phenomenon, extending down two or three metres with clear saline water below. Humic matter (60 - 80 mg per litre) precipitates out in the estuary at salinities above 17,5 parts per thousand provided the pH value is above 8,0. Such conditions are usually present during tidal phases when the estuary mouth is open (CSIR Research Report 22, 1983, p23). Allanson and Howard-Williams (1984) carried out spectroscopic analysis of Karatara river water to determine the absorption spectrum and the E_4/E_6 ratio (i.e. the absorbance ratio at 465 nm/665 nm) which distinguishes the relative importance of humic and fulvic acids. The absorption spectra for inflowing river water and lake water (unfiltered and filtered) is shown in Fig 3.1. From these spectra, the contribution of suspended particulate matter to light absorption at different wavelengths was calculated. The contribution to light attenuation by suspended matter was calculated from selected wavelengths from the absorption spectra by subtracting the absorbance of unfiltered water from that of filtered water and expressing this as a percentage of the value for unfiltered water. The results are shown in Table 3.1. It

Table 3.1 Absorption coefficients (g) for filtered and unfiltered water and the contribution of particulate matter to light absorbance in Swartvlei water at different wavelengths

Wave length nm	Absorption coefficient Unfiltered	Filtered	Contribution to absorbance by particulate matter %
400	7,31	5,64	21
435	4,26	3,45	25
500	1,90	1,26	33
530	1,61	1,04	38
600	1,04	0,58	44
630	0,81	0,35	46
675	0,69	0,23	60

Source: Allanson and Howard-Williams 1984

Table 3.2 Depth (m) to which light of given wavelengths is reduced to given fractions of its surface intensity after passage through unfiltered and filtered Swartvlei water collected in January 1978

		Wavelength nm						
		400	435	500	530	600	630	675
Unfiltered	% of surface light intensity							
	50	0,10	0,17	0,37	0,42	0,67	0,80	1,00
	10	0,32	0,56	1,21	1,40	2,22	2,67	3,33
	5	0,42	0,72	1,58	1,82	2,89	3,46	4,34
	1	0,65	1,11	2,42	2,80	4,45	5,33	6,67
Filtered	50	0,12	0,21	0,55	0,68	1,20	1,49	2,51
	10	0,41	0,67	1,82	2,26	4,00	4,95	8,33
	5	0,53	0,87	2,36	2,94	5,21	6,41	10,84
	1	0,82	1,33	3,63	4,52	8,00	9,88	16,60

Source: Allanson and Howard-Williams 1984

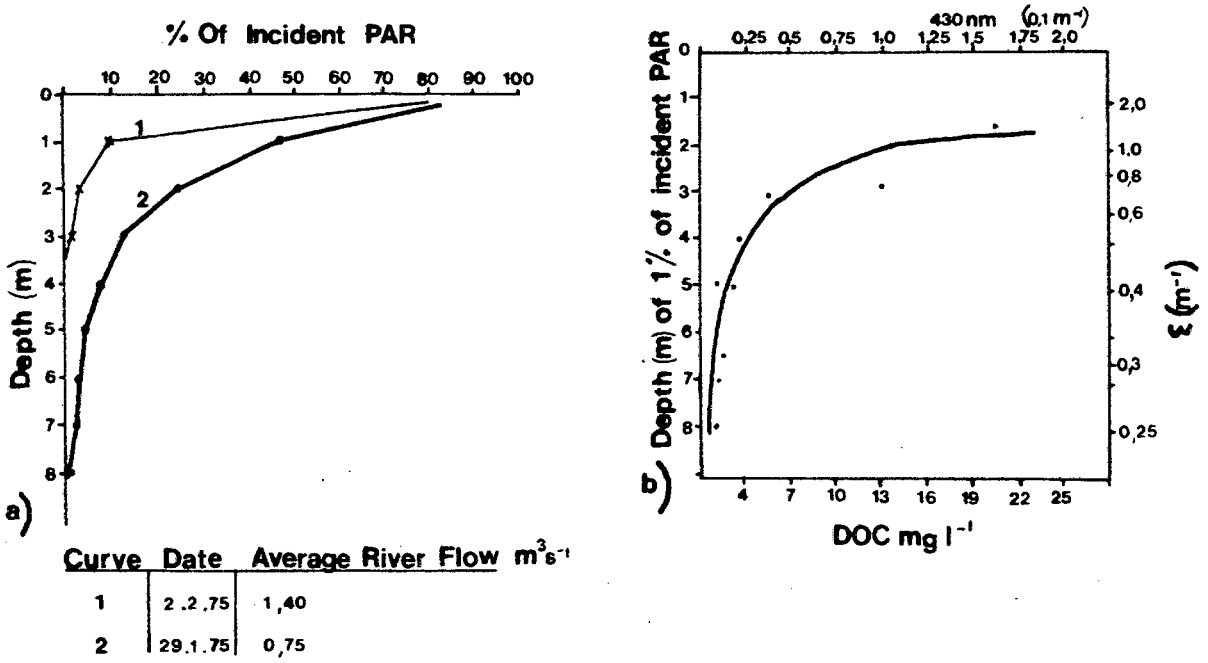


Fig 3-2 a) PENETRATION OF PAR INTO SWARTVLEI ON TWO DIFFERENT OCCASIONS SHOWING THE INFLUENCE OF RIVER WATER

b) THE EFFECT OF ABSORBANCE (upper axis) ON THE DEPTH OF THE 1% LEVEL OF PAR AND ON THE VERTICAL ATTENUATION COEFFICIENT

PAR Photosynthetically Active Radiation
 DOC Dissolved Organic Carbon

(Howard-Williams, Allanson 1984)

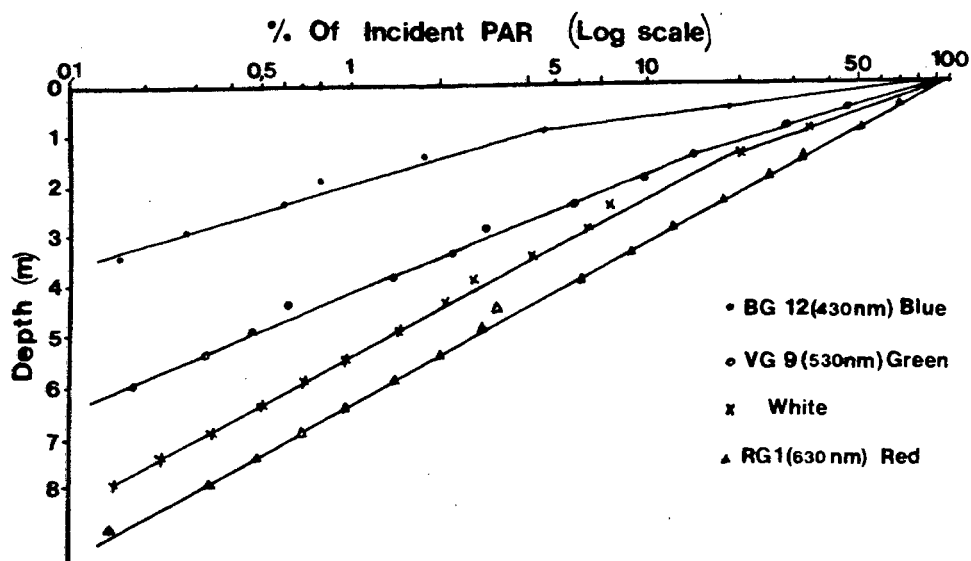


Fig 3-3 PENETRATION OF PAR INTO SWARTVLEI WATER AT DIFFERENT WAVELENGTHS IN THE 400-700 nm SPECTRUM

PAR Photosynthetically Active Radiation

(Howard Williams, Allanson, 1984)

is clear that at the lower wavelengths the water colour absorbs strongly and so the relative importance of suspended matter is small. The reverse is true at higher wavelengths.

The following equation was used to determine the depth to which light of given wavelengths would penetrate

$$Z' = \frac{I_0}{I_z \epsilon}$$

where Z' is the depth to which light of selected wavelengths is reduced to given fractions of its surface intensity
 I_0 is 1,0
 I_z is given fraction (i.e. 0,5; 0,25 etc.)
 ϵ is the attenuation coefficient for PAR (photosynthetically active radiation).

The results are shown in Table 3.2. The 1% level of light intensity of wavelengths corresponding with the chlorophyll-a absorption peaks of 435 nm and 675 nm are 1,1 and 6,6 m respectively in unfiltered Swartvlei water. Thus red light is the most penetrating wavelength in Swartvlei. The absorption spectrum of Karatara river water, with an absorbance scale 10x higher than that of Swartvlei, shows that light penetration in Swartvlei will depend on river inflow rates. Following high rainfall periods, the penetration of photosynthetically active radiation is reduced. Figure 3.2 shows this clearly. The maximum recorded level for 1% PAR in Swartvlei is 8 m and the minimum 1,5 m. A given increase in the amount of brown water (i.e. an increase in inflowing dissolved organic carbon (DOC)) has a larger effect on light penetration at the lower end of the concentration range (Fig. 3.3). Small river inflows

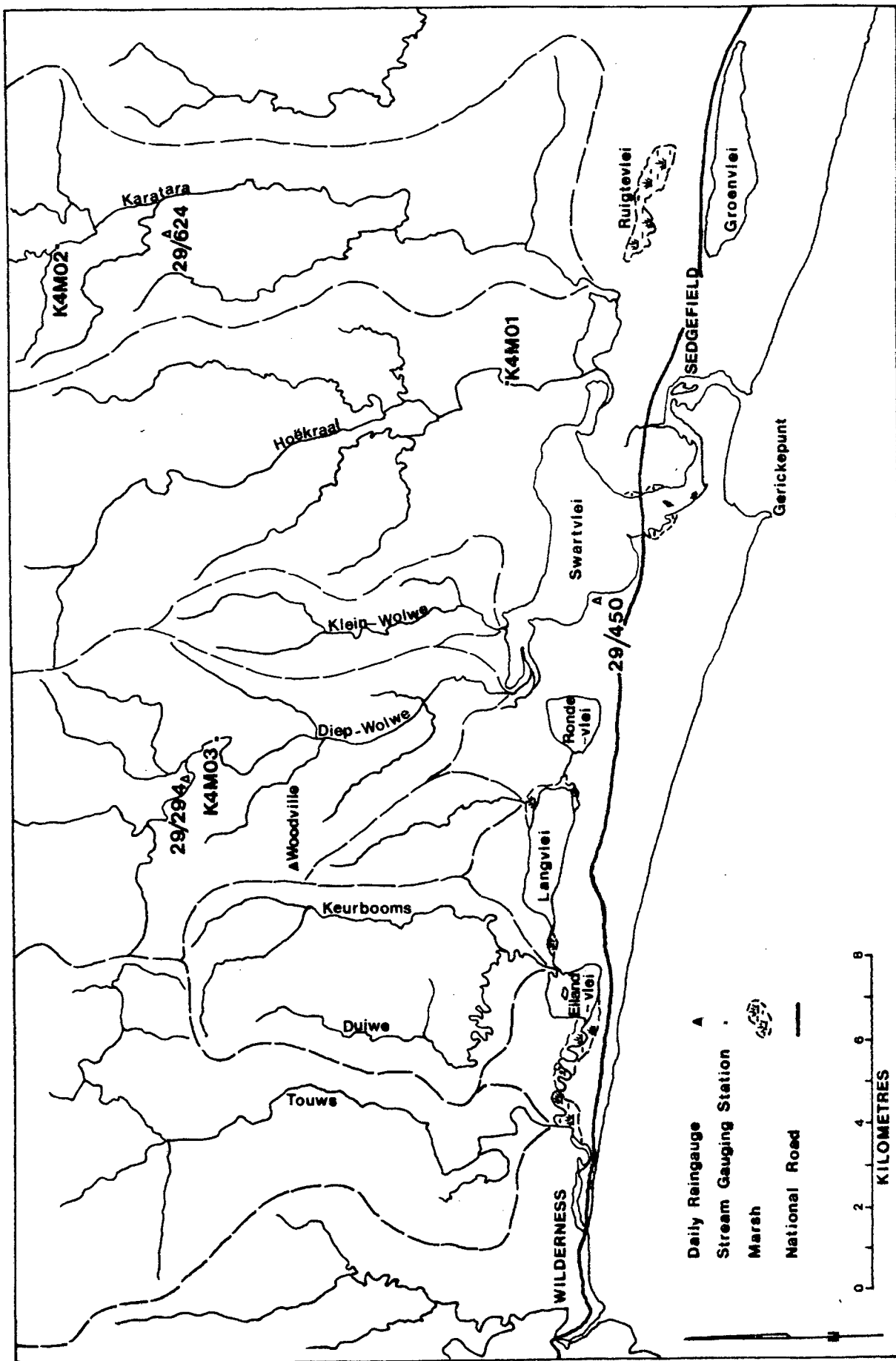


Fig 3-4 THE WILDERNESS LAKES: RAINGAUGES AND STREAM GAUGING STATIONS

can maintain 1% PAR at 3 - 5 m. Expressed in terms of dissolved organic carbon, mainly fulvic acid, an increase from 2 - 4 mg C.l⁻¹ reduces the 1% depth of PAR from 8 - 3,5 m, whereas an increase from 10 - 20 mg C. l⁻¹ DOC reduces 1% PAR from 2,5 - 1,5 m (Allanson & Howard-Williams 1984).

The limited light penetration into Swartvlei's dark water results in the restricted distribution of aquatic macrophytes to areas of water shallower than 3 m (CSIR Report No. 22, 1983, p25).

3.2 RAINFALL, SEDIMENT LOAD, FLOW VOLUME AND SECCHI DISC DATA

3.2.1 Rainfall

Rainfall data is based on information collected from stations 29/294, 29/624 and 29/450 (Fig.3.4). These stations provide rainfall data up to 1985. Two rainfall stations, namely 29/416 on the Diep-Wolwe River and 29/534 near the Hoëkraal River are no longer in operation. New rainfall stations at Kleinplaat, Woodville and Corneliskop have been established in 1983/84 by D.A. Hughes of the Rhodes University Hydrological Research Unit. Some preliminary data from these stations was obtained and studied, but, due to the relatively short period of collection and missing data, no definite statements on the nature of the data could be made. There were no major differences between these data and the data from stations 29/294, 29/624 and 29/450. Daily rainfall at these stations has been written out in such a manner as to

facilitate comparison of rainfalls between the stations. This has been done for the years between 1974 - 1984. These data are available at the Institute of Freshwater Studies at Swartvlei.

General rainfall characteristics of the area are as follows. Station 29/450 (Swartvlei area) receives an annual rainfall of between 570 - 850 mm. At stations 29/294 and 29/624 (Bergplaas and Karatara) there is a slight increase to between 600 - 900 mm per annum. Higher areas are expected to receive up to 1200 mm per annum. The absence of rain gauges in these areas prevents confirmation of this figure.

The area is characterised by rain shadows, and rainfall fluctuates vastly over comparatively small areas. There is a slight increase in rainfall as one travels east towards Karatara. Rainfall occurs throughout the year. More specific information on rainfall is given in individual sections, namely 4.1.2, 5.1.1 and 6.1.2 (Hughes & Görgens 1981; Weather Bureau, Pretoria).

An analysis of medium and long-duration extreme rainfalls in the southern Cape coastal lakes region by Görgens and Hughes (1982), revealed the influence of area on the depth-duration-frequency in this area. Graphs have been drawn which allow the user to find correction factors for any sub-area, such as a particular river catchment. These can then be applied to a table of extreme rainfalls for the whole area to determine design rainfalls, taking into account the mean annual precipitation of the sub-area or catchment. Extreme rainfalls can be established on the basis of percentages of mean annual precipitation

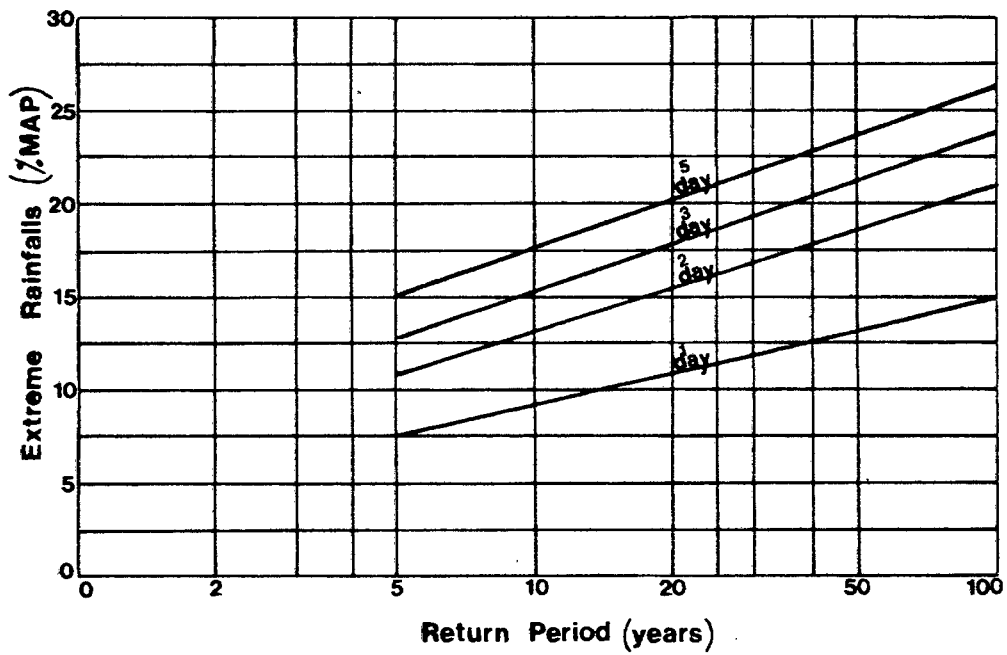
TABLE 3.3 Extreme rainfalls (1 - 5 day durations) for the southern Cape (values given are percent MAP)

Duration (days)	Return period (years)				
	5	10	20	50	100
1	7,53	9,24	10,99	13,41	15,35
2	10,97	13,27	15,55	18,61	20,99
3	12,90	15,48	17,98	21,25	23,71
5	15,10	17,83	20,43	23,78	26,29

Görgens, Hughes, 1982

TABLE 3.5 Monthly rainfall, flow and Secchi disc transparency

DATE	Secchi disc transparency (m)		Total monthly rainfall (mm)	Monthly flow volume in millions m ³			
	Max	Min		Diep-Wolwe	HoeKraal	Karatara	
October 1976	1,8	0,4	112 - 190		3,93		
November 1976	1,5	0,5	102 - 119		4,15		2,14
February 1977	3,1	1,0	122 - 170		3,58		2,45
March 1977	2,6	1,1	52 - 86		1,56		1,08
May 1977	2,8	0,2	146 - 179		3,46		2,8
October 1980	3,4	1,3	105 - 112	0,88	4,07		1,82
December 1980	2,1	1,1	77 - 114	0,91	1,79		1,41
April 1981	2,0	0,8	125 - 170	6,34	2,84		2,12
June 1981	0,6	0,4	59 - 620	3,64	5,07		1,01
July 1981	0,8	0,8	29 - 42	1,36	1,11		0,26
August 1981	1,6	0,6	183 - 195,7	3,68	3,91		2,73
September 1981	1,3	0,2	32 - 59	3,36	3,55		0,79
October 1981	1,7	0,5	99 - 119	1,83	2,71		1,56
April 1982	3,4	0,6	176 - 206	2,34	4,02		3,73
May 1982	1,3	0,7	12 - 17	1,27	1,64		0,58
August 1983	0,7	0,5	17 - 21	0,82	0,73		0,17
September 1983	2,8	0,2	53 - 94	0,62	1,22		0,89
October 1983	0,6	0,3	83 - 96	2,74	2,75		1,52



**Fig 3-5 DEPTH-DURATION-FREQUENCY FOR THE SOUTHERN CAPE
COASTAL LAKES REGION**

(Görgens, Hughes, 1982)

for the area concerned. Extreme values with rainfalls of duration 1, 2, 3 and 5 days and return periods of between 5 and 100 years can be established on the basis of a graph or a table in Gørgens and Hughes (1982) (See Fig. 3.5 and Table 3.3).

3.2.2 Sediment Loads

Individual graphs showing sediment loads at the most important sample sites are presented as Figs 3.6a-m (Appendix 1A). Most discussion of these sediment loads occurs in Chapters 6 - 7. Sediment load appears to be directly dependent on the quantity and duration of rainfall.

3.2.3 Monthly Flow Volumes

Monthly flow volumes (1977 - 1984) are given in millions of cubic metres for the following stations: K4M01 Hoëkraal River, K4M02 Karatara River and K4M03 Diep-Wolwe River (see appendix 1B). Table 3.5 shows flow volumes of selected months which were characterised by periods of high rainfall and low Secchi disc transparency. The maximum and minimum Secchi disc transparencies are given, rather than the average which can be misleading. The variation in rainfall is due to different rainfalls at each station. The Secchi disc transparency decreased after storm events. From Table 3.5 it can be seen that - a monthly runoff volume exceeding 1 million cubic metres is a good indicator of high rainfall and low water transparency.

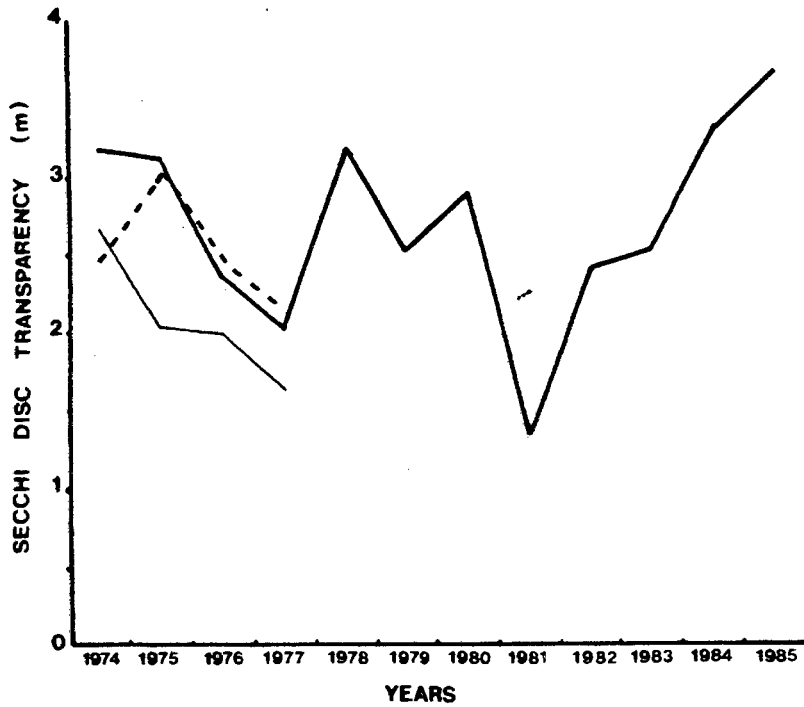


Fig 3.7 AVERAGE ANNUAL SECCHI DISC TRANSPARENCY

Deep Station ———
 Diep-Wolwe Basin ——— } Incomplete Records
 Karatara Basin - - - - - }

Note: 1984 and 1985 transparencies based on 7 and 6 months data respectively

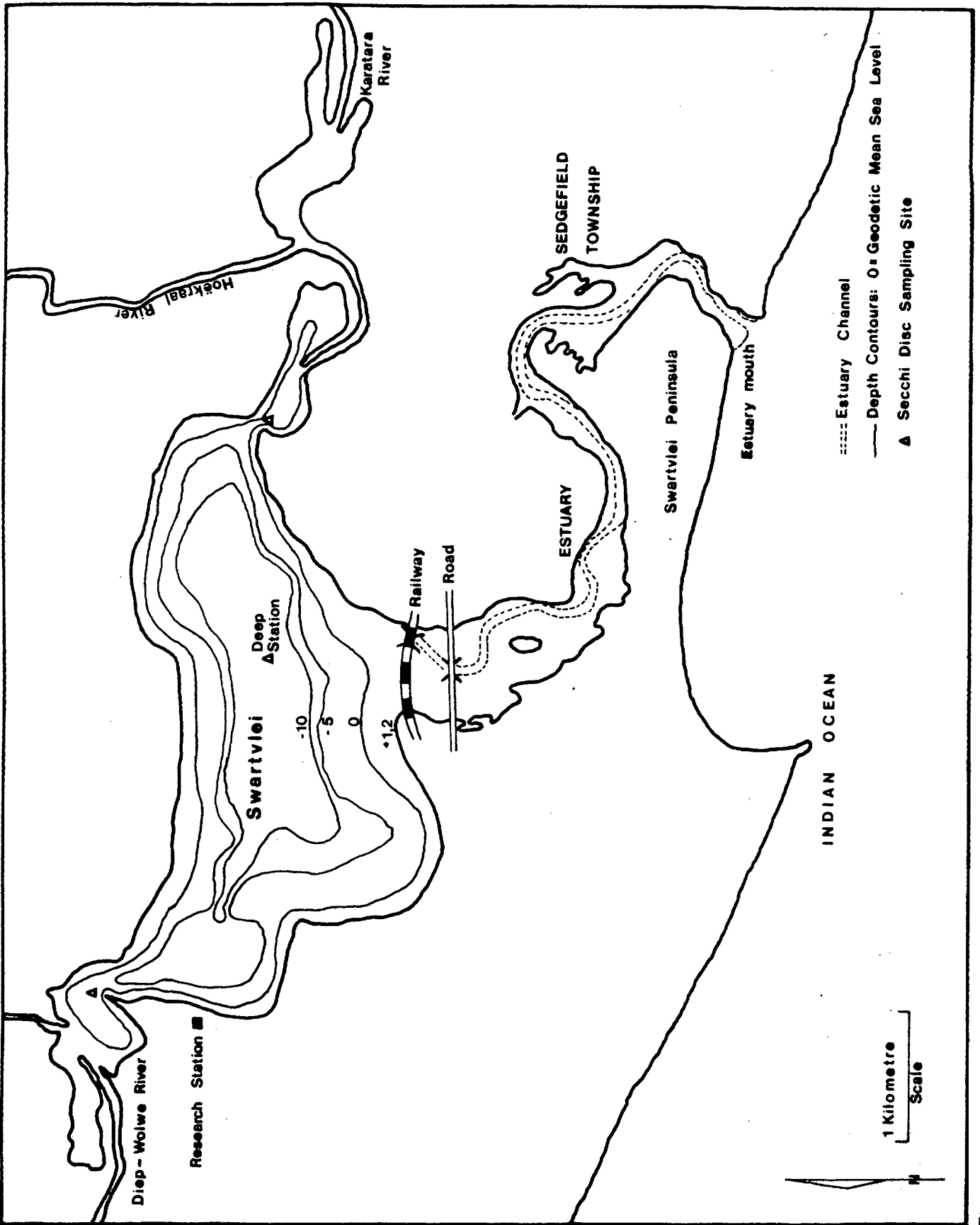


Fig 3-6 THE SWARTVLEI SYSTEM: SECCHI DISC SAMPLING SITES and SELECTED DEPTH CONTOURS

- During high rainfall periods, the Hoëkraal river yields the highest volume of runoff, followed by the Diep-Wolwe and Karatara rivers.
- Runoff volumes vary considerably between the three runoff recording stations.

3.2.4 Secchi Disc Transparency

Annual averaged Secchi disc transparencies 1974-1984 are shown in Fig. 3.7

From Fig. 3.7 it can be seen that:

- There is no overall decline in Secchi disc transparency between 1974 - 1984.
- Secchi disc transparencies in 1984 are relatively high due to below-average rainfall. Transparencies are comparable to other low rainfall years such as 1974 and 1978.
- The sharpest drop in Secchi disc transparency occurs in 1981 (flood year). This low average was recorded at Deep Station (towards centre of lake), which shows that a large proportion of the lake was affected. Deep station usually has the highest Secchi disc transparency. The Hoëkraal/Karatara basin and the Diep-Wolwe/Klein Wolwe basin have lower Secchi disc transparencies as they are nearer the inflow points of the rivers (see Fig. 3.8 for basin location).

It is possible that runoff volumes, catchment activities and fluctuating

humic content of the river water influence the changing Secchi disc trends.

3.3 INTERRELATIONSHIPS BETWEEN RAINFALL, SEDIMENT LOADS AND SECCHI DISC TRANSPARENCIES

3.3.1 Table 3.5 shows the interrelationship between average monthly inflow and Secchi disc depth. According to Allanson and Howard-Williams (1984), there is a significant negative correlation between transparency and total river inflow. Pearson's correlation matrix was $r = 0,68$, $n = 81$ and, highly significant, $P = 0,05$.

3.3.2 The relationship between Sediment loads and Secchi disc Transparency

The following tables show sediment load and Secchi disc transparency on two different occasions in 1984:

Table a April 3, 1984 - Dry conditions

Total rainfall for month of April 21 - 28 mm

Rainfall in week prior to sampling date: 0,2 mm

	<u>Sediment Load</u> mg/l GFF	<u>Secchi disc</u> <u>transparency (m)</u>
Deep Station	17,6	3,5
Hoëkraal/Karatara Basin	8,8	2,1
Diep-Wolwe Basin	14,3	2,0 - 2,3

Table b October 7, 1984 - 43-50 mm in 2 days (no increase in lake level) (according to A. Whitfield, pers. comm.)

Total rainfall for October 86 - 108 mm

Rainfall in week prior to sampling date 58 - 66 mm

	<u>Sediment Load</u> mg/l GF/F	<u>Secchi disc</u> <u>reading</u> <u>transparency (m)</u>
Deep Station	44,6	2,5
Hoëkraal/Karatara Basin	46,2	2,2
Diep-Wolwe Basin	49,4	2,1

One can draw the following conclusions from the given data:

- During dry conditions sediment loads in the lake are low and Secchi disc transparencies are fairly high, indicating reasonable transparency.
- The dark humic stained water of the Hoëkraal/Karatara basin probably accounts for the relatively low Secchi disc transparency for the small quantity of sediment present, shown in Table a. The influence of this dark water is reduced at Deep station, where there is likely to be a degree of mixing with clearer estuarine water, and where some flocculation and settling of humic matter may have occurred.
- A relatively small amount of rain in two days after a dry period results in an increase in sediment loads at all stations, but relatively little change in turbidity. Although sediment loads increased by up to 38 mg per litre at all stations, turbidity increased only at Deep station with a drop in

Secchi disc transparency of 1 m. Rainfalls of up to 40 - 50 mm are unlikely to have any serious or long-lasting effect on Swartvlei's turbidity, particularly after dry periods.

Tables in appendix 1C show Swartvlei Sediment loads and Secchi disc transparencies recorded between July 1982 and September 1983. The previous observations made on tables a and b (1984) are also applicable to these data. Two further observations are of interest when comparisons are made between the data. If one compares the data of 13 October 1982 with that of 7 October 1984 some clear differences emerge.

Table 3.6 Relationship between Swartvlei Sediment loads and Secchi disc transparency

	<u>13 October 1982</u>	<u>7 October 1984</u>		
Rainfall: Month's total	70 - 107 mm	86 - 108 mm		
Rainfall in week prior to sampling date	40 - 71 mm	58 - 66 mm		
	<u>Sediment Load</u>	<u>Secchi disc</u>	<u>Sediment load</u>	<u>Secchi disc</u>
Deep Station	9,9 mg/l	2,4 m	44,6	2,5
Hoëkraal/Karatara basin	11,8 mg/l	1,2 m	46,2	2,2
Diep-Wolwe river basin	45,1 mg/l	0,15 m	49,4	2,1

The most obvious difference is that sediment loads in 1984 are far higher than those of 1982 at Deep Station and the Hoëkraal/Karatara basin in particular. This phenomenon also occurs (to a lesser extent) on several other occasions such as:

4 February 1983 versus 21 March 1984

3 March 1983 versus 21 March 1984, and

18 May 1983 versus 21 March 1984

(see Tables: July 1982 - June 1984 in appendix 1C).

The higher sediment loads, however, have not made a significant change to the Secchi disc transparency. In fact, Secchi disc transparencies in 1984 have improved on those of 1982. There are two possible explanations for this occurrence:

- i) The September rainfall of 1982 was higher than that of September 1984, which implies that Secchi disc transparencies for 1982 may have declined from a lower level than the September 1984 transparencies. Unfortunately the Secchi disc readings for September 1982 were not taken late enough in the month to be comparable.
- ii) The very dry year of 1984 may have resulted in reduced humic input to Swartvlei which might allow effects of sediment input to be lessened. In addition, the high salinities of the lake during 1984 will have facilitated flocculation and settling of humic matter.

The large increase in sediment load input at the Hoëkraal/Karatara basin suggests that there may have been some catchment activities in mid-1983 - 1984 which have allowed increased sediment input. As will be shown later in the report the Karatara river is contributing considerable volumes of sediment to Swartvlei with rainfalls of over 65 mm (in this case, falling over 2 days).

Study of the Sediment loads and Secchi disc transparencies between 18 July and 3 September 1983 also reveals some points of interest (Appendix 1C).

The high rainfalls of late July result in the expected sharp drop in water transparency. The transparency of the water remains low throughout August and September, despite relatively low rainfalls in these two months. It appears that the effects of a heavy concentrated rainfall can continue for some time.

There is also a sudden increase in sediment load in the Hoëkraal/Karatara and Diep-Wolwe basins in September 1983. This appears to be the first time that sediment loads reach levels similar to those of 1984. The Secchi disc transparency is, however, very different to that of 1984.

Some additional Secchi disc transparencies were taken at Deep Station, as follows:

Table 3.7 1984 Deep Station Secchi disc transparencies

<u>Date</u>	<u>Secchi disc transparency</u>	<u>Rainfall</u>
10.1.84	2,7 m	Nil. Last rainfalls on 30.12.83 11-13 mm 2.1.84 14-15 mm
2.2.84	4,8 m	Nil. Last rainfalls 26-30 Jan < 4,6 mm
21.3.84	2,5 (Diep-Wolwe 1,5m)	8-15 mm on 20-21 March 1984
22.11.84	3,6 m	6-8 mm on 19-20 November 1984
12.12.84	3,9 m	6-19 mm on 3-6 December 1984

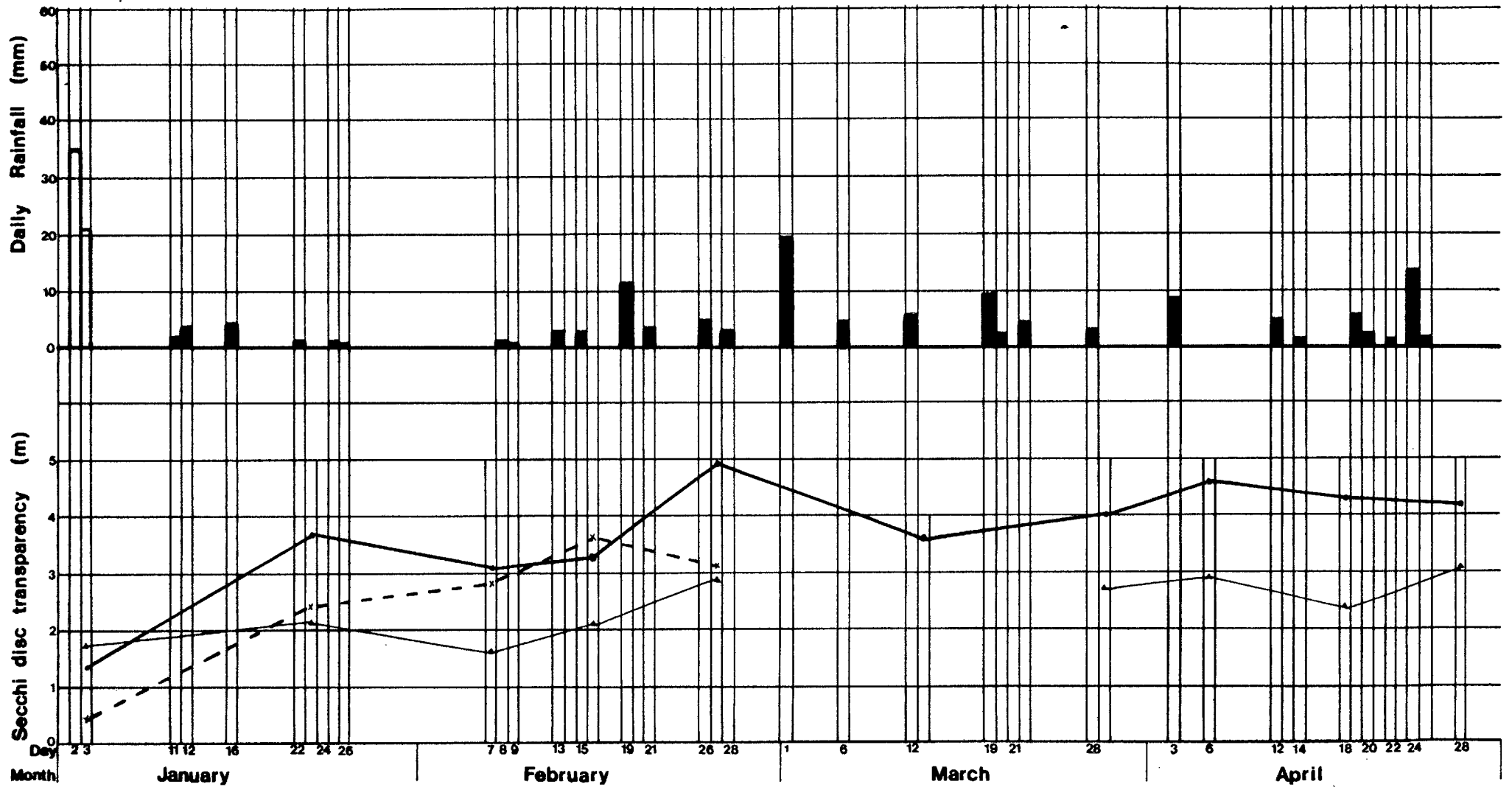


Fig 3-9a THE RELATIONSHIP BETWEEN RAINFALL AND SECCHI DISC TRANSPARENCY: 1979

DEEP STATION —●— Diep-WOLWE BASIN —▲— HOËKRAAL BASIN —x---x

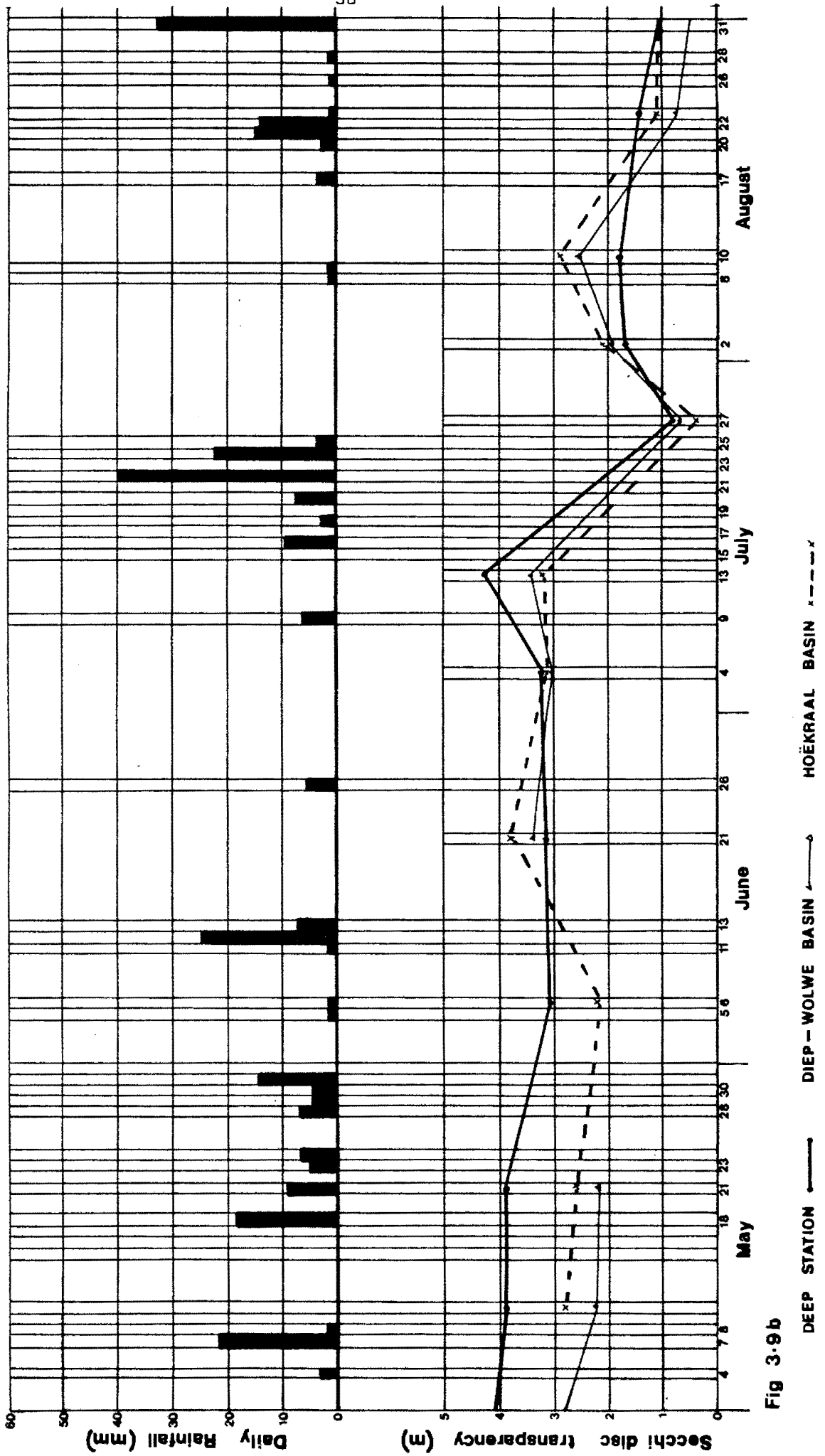


Fig 3-9b

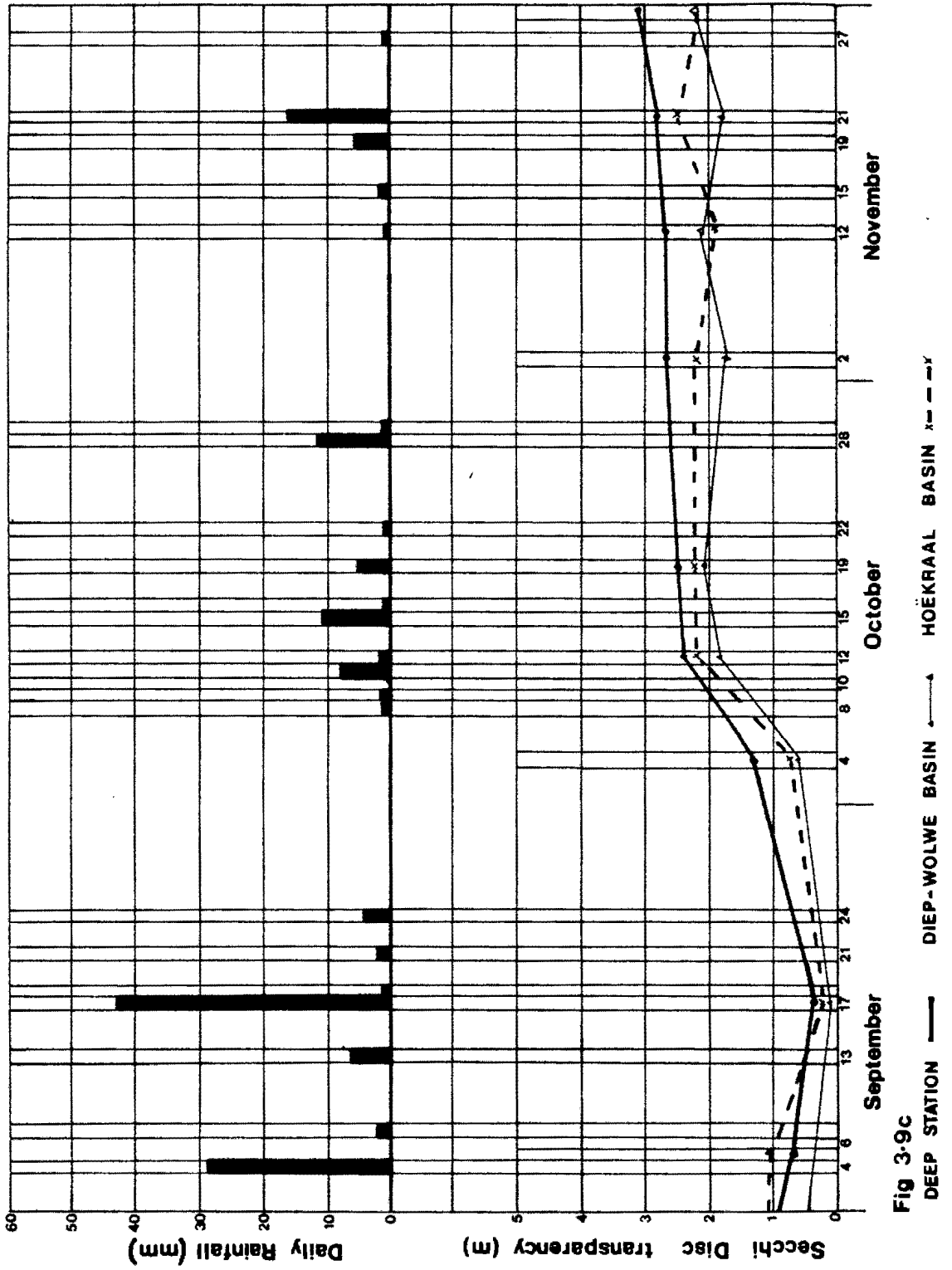


Fig 3-9c

The low rainfalls allow maintenance of clear lake water. Time of sampling influences results, i.e. a lower Secchi disc transparency is obtained if taken long enough after rainfall for water to flow into Swartvlei but before any settling has occurred. The Deep Station transparencies could be regarded as typical for low rainfall periods.

3.3.3 To show the direct relationship between rainfall and Secchi disc transparency, a graph plotting daily rainfall against Secchi disc transparency has been drawn up for January to November 1979 (Fig. 3.9a,b,c).

It appears that:

- The Secchi disc transparency is directly related to amount and duration of rainfall.
- A rainfall of approximately 40 - 70 mm or over in 1 - 3 days can bring about an immediate decline in Secchi disc transparency, as shown between 22 - 24 July 1979. Secchi disc transparency declines from approximately 3,5 - 4,5 m to 0,4 - 0,9 m. Lowest Secchi disc transparencies occur 2 - 5 days after maximum rainfall. Recovery rate is fairly rapid if there is no subsequent rainfall. In this example Secchi disc transparencies increased to 1,8 - 2,9 m by 8 - 10 August 1979 (i.e. approximately 12 days later). A relatively low rainfall of 31 mm, in 2 days on 21/22 August 1979, brings about a deterioration in Secchi disc transparency once again. If one studies the rainfalls between February - June 1979, similar rainfalls have little effect on Secchi disc transparencies which are maintained at between

2 - 4,5 m. This is due to slightly lower rainfalls and the large proportion of 1-day rainfalls. There is some suggestion that a relatively low and evenly distributed 2-day rainfall (as of 21/22 August) may have more detrimental effect on Secchi disc transparencies if it follows a period of high concentrated rainfall (22 - 24 July), as opposed to a period of evenly spread 1-day rainfalls. In addition, the Secchi disc transparency recovery rate is much delayed by the occurrence of 3 single high rainfall days on 31 August (23 mm), 4 September (28,5 mm) and 17 September (42,4 mm). Secchi disc transparencies are down to between 0,1 - 1,3 m between 23 August and 4 October 1979 (i.e. nearly one and a half months).

3.4 CONCLUSIONS

Swartvlei's light regime will fluctuate widely according to weather conditions. The unpredictability of the weather conditions in the southern Cape makes it difficult to determine whether Swartvlei's light regime will ever be so detrimentally affected over such a long period that recovery potential is lowered.

There is no doubt that abnormally high sediment loads are originating in the catchment area. Only under certain rainfall conditions will this sediment affect Swartvlei's light regime. The clarity of Swartvlei water during 1984 has been good due to below-average rainfalls and high salinities. In 1984 it has been the high salinities that have jeopardised

macrophytic recovery and reproduction rather than poor light penetration. This situation can change rapidly and dramatically as occurred in 1981 and even in years of average rainfall when Secchi disc transparencies can be kept low for periods between 10 days to 2 months. If the light regime is affected at a critical period of the year, such as at plant regeneration periods (September to Nov.) macrophytic production will be seriously reduced. The naturally-dark humic waters of the catchment do reduce penetration of PAR, which, in turn, limits plant distribution. However, a healthy littoral community exists under these conditions as PAR penetration is sufficient in the shallower areas. It is the addition of sediment which threatens macrophyte survival. It is possible that there has always been, and will continue to be, a cycle of deterioration and recovery in Swartvlei's littoral community. Man's activities, particularly in the lower parts of the catchment, have the capability to threaten the recovery potential of the community. The large quantities of sediment entering Swartvlei (although sporadic) have the ability to lower the thresholds which determine whether Swartvlei will continue to be a productive ecological system, supporting a wide variety of life forms, or a relatively lifeless stretch of water.

CHAPTER 4

THE UPPER CATCHMENT AREA OF SWARTVLEI

According to Hulett (1980, p3), a drainage basin or catchment is a watershed that collects and discharges surface streamflow through one outlet or mouth. Kruger and Van der Zel (1979, p19) define mountain catchments as the mountain lands exceeding 300 m elevation in the constant and winter rainfall zones, 600 m in the summer rainfall zone, and with runoff exceeding about 100 mm per year, or the equivalent of 1000 cubic metres per hectare per year.

4.1 UPPER CATCHMENT CHARACTERISTICS

Mountain catchments are characterised by steep topography and unstable landscapes and soil forms. These characteristics, together with a high rainfall, can make them vulnerable to erosion. Catchment areas are sensitive to changes in vegetation and to human activities. The flora and fauna of catchments are often diverse and uniquely adapted to their environment. These ecosystems require protection and management.

4.1.1 Topography

The relief of this area is dominated by the intensively folded, east-west trending Outeniqua Mountains. The headwaters of the rivers lie in the contorted (Ordovician) Table Mountain sandstones of the mountains, which are characterised by steep, long slopes, thinly mantled with talus. Ridge tops are narrowly convex (Shafer 1980). According to Tyson (1971), the accordance of the ridge tops suggests a possible bevel or erosion surface at about 220 m. Elevations of the Diep-Wolwe, Hoëkraal and Karatara catchment areas vary between 610 - 1403 m.

4.1.2 Climate

The Outeniqua catchment area lies east of the South Western Cape winter rainfall region and west of the summer rainfall area and experiences an all-year-round rainfall regime. There is a slight summer maximum (October to March), with June/July the driest months. Weather patterns are dominated by the passage of cold fronts along the southern coast of South Africa, which originate in the South Atlantic. Pre-frontal conditions and warm berg winds have a northerly component blowing from the interior, while colder weather results from post-frontal outbursts of cold polar or sub-polar air from the south-west.

Precipitation is predominantly cyclonic or orographic and increases slightly with altitude. The many rainshadow areas, caused by topographical features, result in dramatic differences in the quantity of rain received in different areas. The absence of rainfall gauges in the highest parts of the Swartvlei catchment area has prevented

collection of data. Rainfalls in the high areas, where no rainshadow effects occur, may increase to 1200 mm per annum.

Snowfalls are rare and limited to the highest peaks. Maximum temperatures range between 25°C (January) and 19,4°C (June). Minimum temperatures range between 13°C (January) and 7°C (June). With berg winds (autumn and winter) temperatures can soar to between 38 - 40°C. On the peaks temperatures can drop to -4°C. Frost is rare. During summer, south and south-easterly winds prevail, whereas north-westerlies are predominant in winter (Tyson 1971; Hughes & Görgens 1981; Southwood, A.J. 1983).

4.1.3 Geology

Refer to Fig 4.1. The upper catchment areas of the coastal streams are underlain by sedimentary rocks of Ordovician and Silurian age (ca. 500 - 440 Ma B.P.), which are collectively referred to as the Table Mountain Group and form part of the Cape Super-Group. Lithologically these rocks consist of various quartz sandstones with bands of shale. The broad east-west trend of the mountain ranges and the steep southward dip of the formation is due to folding which took place during the Cape Orogeny (over a period of ca. 50 Ma from the Perma-Triassic period). Outcrops of Cape Granite (Proterozoic) occur in the Woodville vicinity (Diep-Wolwe River area) (Tyson 1971; Southwood, A.J. 1983; Thompson 1983).

Table 4.1 Stratigraphy of the Table Mountain Group in the southern Cape

GROUP	FORMATION	LITHOLOGY
Table Mountain	Baviaanskloof	Sandstone with subordinate shale
	Kouga	Light grey siliceous medium-coarse grained ultra quartzose sandstone with subordinate shale. Cross-bedding is characteristic. It is whiter and more resistant to weathering than the Tchando formation
	Tchando	A fine to medium grained, siliceous, slightly feldspathic sandstone. Not as pure as peninsula sandstone, containing subordinate shale bands
	Cedarberg	A shale band, 25 - 100 m thick, overlying peninsula sandstones and often intermixed with them. It usually forms areas of negative relief due to more rapid weathering
	Peninsula	Pure white to blue-grey, mainly coarse to medium grained, siliceous, ultra quartzose sandstone. Cross-bedding is indistinct and shale bands less than a metre thick occur at wide intervals.

(Shafer, 1980)

4.1.4 Soils

The geological formations influence the soils of the area. Morphological and chemical properties such as deep weathering, soil texture, drainage, structural development and chemical deficiencies are dependent on type of parent material. Other soil-forming factors are climate, time, topography and biological processes.

Quartzites and sandstones of the Table Mountain Group produce shallow soils with a sandy to sandy-loam texture. These soils are generally leached, acidic and infertile.

Quartz particle sizes vary, but remain fine or very fine within the pale grey brown A horizons.

The shales and shale bands within the sandstone formations weather deeply, producing clay-like soils with much deeper weathered parent material. Shale-derived soils have developed strong blocky to prismatic structure as a result of the fine-grained and silty argillaceous textures (Thwaites 1984; Taylor 1984).

Researchers at the Saasveld Forestry research station have completed numerous soil transects in the southern Cape, one of which passes through a portion of the Karatara catchment area. Their descriptions of some typical soil profiles are reproduced in Appendix **2B** (Schafer 1980).

4.1.5 Vegetation

The distribution of plants is related to local differences in climate. The southern mesic upper catchment slopes are dominated by moist mountain fynbos and patches of indigenous forest, the latter restricted almost entirely to river kloof areas. In rainshadow areas, such as found on north, north-east slopes at Kleinplaat, some succulents and aloes occur.

According to dot planimeter calculations (1:50 000 topographical map) there is 2390,6 ha of natural vegetation in the Karatara catchment area, 3178,1 ha in the Diep-Wolwe catchment area and 4015,6 ha in the Hoëkraal catchment area. Natural vegetation here refers to both fynbos and forest.

The indigenous forest can reach heights of 18 - 30 m in favourable moist conditions, and is dominated by Podocarpus falcatus (Yellow-wood), Nuxia floribunda (Wild Elder), Olea capensis sub sp., macrocarpa (Iron-wood) with some Ocotea bullata (Stinkwood). Beneath the high canopy, young trees of the same species occur, and below them, at heights up to 6m, trees such as Ilex mitis (Cape Holly) and smaller shrubs such as Trichocladus crinitus (Witch hazel/Onderbos). Wetter forest floors are densely covered with ferns and herbs. As rainfall decreases so does canopy height (Tyson 1971).

Shafer (1980) describes the mountain fynbos occurring on the Karatara transect. The highest elevations of the transect support a waist-high shrub-restio veld with Berzelia commutata, Erica

arachnoidea, Restio compressus on moderately deep soils rich in organic matter. At similar elevations, more in fairly incised drainage lines, a Leucadendron conicum community occurs with associated Penaea myrtoides, Peyrausea umbellata, Ursinia spp., Gleichenia polypodioides, Blechnum sylvaticum, Senecio lineatus and Restio spp. Indicators of relatively moist soil appear to be Cliffortia odorata, Pteridium aquilinum, and Blechnum sylvaticum.

Figure 4.2 gives an indication of the plant communities occurring in the catchment areas. Refer to fynbos community description in Table 4.2

Problem Plants

None of the catchment areas is completely free of alien invaders. Refer to Table 4.3 for a list of the problem plants.

Rare and Endangered Plant Species

Identification and monitoring of rare and endangered species in these catchment areas is incomplete. Those that have been identified are shown in Table 4.4.

TABLE 4.2 Plant communities in the Upper Catchment area (Refer to Fig.4.2) Plant communities in the Outeniqua Upper Catchment area.

COMMUNITY	SYMBOL	HABITAT	DIAGNOSTIC FEATURES
<u>1. Heathlands</u>			
Wet heathland	H1s	Wet south slopes 600 m to mountain crests	Dense small-leaved shrubland 0,5 - 1,0 m high. Restoid cover more than 50%
Graminoid Heathland	H2	Steep, rocky north aspects: 380 - 1060 m	Tall open canopy of <u>Seimocheilus multiflorus</u> and <u>Erica viridescens</u>
<u>2. Proteoid Shrublands</u>			
Proteoid shrublands with a heath understorey. Medium tall, mid-dense <u>Leucadendron eucalyptifolium</u> ; <u>P. neriifolia</u> shrubland	P1a	Mesic south aspects: 400 - 1160 m	Closed canopy formed by these species. Dense under-storey of restoids, graminoids and small-leaved shrubs
Tall, sparse to mid-dense <u>Leucadendron uliginosum</u> shrubland	P1b	Gravelly soils on N and NE aspects: 370 - 1240 m	<u>Leucadendron uliginosum</u> visual dominant in the canopy. Under-storey varies from a closed to an open heath
Tall, mid-dense <u>Leucadendron eucalyptifolium</u> , <u>Berzelia intermedia</u> shrubland	P1c	Steep mesic south aspects: 300 - 1230 m	Dense canopy of broad sclerophyll proteoid leaves, 1,5 - 2,0 m, overlies a small-leaved ericoid under-storey

Source: Forestry Branch, Knysna, 1983. Policy Memorandum: Southern Cape and Tsitsikamma Forest Region

TABLE 4.3 Principal problem plants in the Outeniqua catchment area

WEED SPECIES	METHOD OF SPREAD	NOTES
<u>Alien plant invaders</u>		
1. Pines		
<u>Pinus pinaster</u>	a) Seed (wind dispersed) b) Baboons	Wind dispersal is highly effective in spreading seeds: seedlings are regularly found 1000 m from nearest adult trees. Seedlings can become established in 12-18 yr-old fynbos
2. Wattles		
<u>Acacia mearnsii</u>	a) Seed (birds)	Seed remains viable for over 50 years. Fire stimulates germination
<u>A. cyclops</u>		
<u>A. saligna</u>	b) Construction of road and railway embankments	Stream beds are easily infested with black wattle
3. <u>Hakea sericea</u>	Seed (wind)	<u>Hakea</u> cannot establish itself in mature fynbos; infestation only occurs after fires. Winged seed can be blown several km.
<u>Indigenous species</u>		
4. Kystervaring		
<u>Gleichenia polypodioides</u>	a) Vegetatively b) Seed (gravity)	Colonises soils derived from sandstone and quartz low in phosphorus after soil disturbance, e.g. afforestation

Source: Southwood, A.J. 1984; Forestry Branch, Knysna; Policy Memorandum, Outeniqua Catchment area

Table 4.4 Rare and endangered plant species in the upper catchment area

<u>Species</u>	<u>Locality</u>	<u>Status</u>
<u>Leucospermum glabrum</u>	Karatara area	Rare
<u>Mimetes pauciflorus</u>	Scattered	Rare
<u>Acmadenia altenifolia</u>	Hoogekraal pass area	Rare
<u>Mimetes splendidus</u>	Karatara area	Vulnerable
<u>Penaea cneorum</u> spp. <u>cneorum</u>	Scattered	Rare
<u>Agathosma planifolia</u>	Hoogekraal area	Rare
<u>Amphithalea fourcadei</u>	Scattered	Rare
<u>Erica stylaris</u>	Wet mesic fynbos areas	Uncommon

Of those listed in Table 4.4 Mimetes splendidus is of greatest importance. It is believed to be one of the most beautiful and rare members of the protea family, occurring only on the wet southern slopes of the Langeberg, Outeniqua and Tsitsikamma mountains. According to J. Vlok (1984), in the last three years existing populations have declined, and regeneration is poor. Most of the populations are small, with seldom more than one to five plants. Two factors contributing to the decline of the species are incorrect burning practices, and flower-picking. A 12 - 15 year burning rotation, with burns occurring between January and March, is recommended.

4.2 UPPER CATCHMENT MANAGEMENT

The Bergplaas and Karatara catchment areas fall under the control of the Forestry Branch, Department of Environment Affairs. Until 1984 the Forest Act No. 72 of 1968 provided the statutory power for management of catchment areas on State land. This act was repealed in 1984 and is being replaced by Forest Act No. 122 of 1984. This act is discussed under Section 5.2.7. Associated legislative acts are the Water Act 54 of 1956 and the Mountain Catchment Areas Act 63 of 1970, the last-mentioned applying to management of private land.

Control of the Outeniqua mountain catchments is planned within a multi-purpose management framework. This multi-purpose framework aims to realise the various objectives under each land-use type according to resource capacity and use priorities. Not all the land-use types are mutually compatible so attempts are made to harmonise the land-use patterns either by spatial separation (zoning) or regulating the degree to which any particular land-use type is pursued.

The planning procedure by the relevant authorities is as follows:

The catchment planning team of the Knysna Forestry branch (made up of professional forest scientists) evaluates the management prescriptions and potential uses of the catchment area, based on collected ecological data, a catchment resources inventory and general assessment of information. This evaluation is written up in the form of a Policy Memorandum. The Policy Memorandum is reviewed by research personnel and policy-makers. After any necessary alteration, the memorandum is approved by the Forestry Branch head office in Pretoria. It is

returned to the regional planning section (Knysna Forestry Branch) where it is used as a framework for drafting a detailed management plan which embodies explicit prescriptions for each management unit within the area, together with the maps and supporting documentation. This management plan passes through the same review procedure as the policy memorandum before acceptance as the mandatory document for management in the area. Policy memorandum and management plan are reviewed once every five years.

A Policy Memorandum for the Outeniqua catchment area has been in existence since 1980. A detailed draft management plan was compiled in 1984/85. The management of the catchment areas involved has followed the general recommendations expressed in the Policy Memorandum. Burning activities have been completed according to the Annual Plan of Operation for the catchment concerned, under supervision of the District Forest Officer. (Policy memoranda, Tsitsikamma and Outeniqua regions 1983/84; Kruger, Van der Zel & Andrag 1979; Van der Zel 1981; A. Southwood, pers. comm. 1985.)

According to the Policy Memorandum, there are five land-use types applicable to the Outeniquas: namely, water conservation, nature conservation, agricultural utilization, fire protection and recreation. There are three basic management approaches. Areas subject to specific management approaches form a management zone. The three zones are the water conservation zone, the fire control zone and the restricted management zone. Any specific area may be allocated to an alternative zone during revision of management plans if this is warranted by

changed circumstances or additional information.

The Bergplaas and Karatara catchment areas fall into a fire control zone. This is due to the necessity of protecting the plantations south of the upper catchment areas. The entire area between the plantations and the watershed on the southern slopes of the Outeniquas is a fire control zone except for the small portion of the Millwood Nature Reserve occurring in the Karatara catchment area.

The primary management aim of firebelts within a fire control zone is fire protection of the plantations and prevention of wildfires entering the mountain catchment area and disrupting the burning regimes, as well as prevention of accidental fires which could damage neighbouring land.

Secondary management aims in these catchments are as follows: Water conservation, Nature conservation, Recreation and Research.

For management purposes, the area has been divided into compartments, as units of orientation, description, recording and treatment. Firebelts have been burnt along the southern boundary of the upper catchment area. Compartment size varies according to management requirements, and boundaries are usually located to facilitate burning, usually along ridges or streams.

Management of the area involves:

1. Extinguishing or restricting to the smallest possible size any

unscheduled fire which starts in the Outeniqua catchment area.

2. The creation of a mosaic of fynbos of different ages, by conducting a prescribed scheduled burning programme. The intention is to reduce the size and intensity of fires originating in this area.

The specific position of a compartment in the burning schedule is determined by the joint consideration of four factors, namely:

- Present veld age in relation to the relevant rotation. Any compartment is burnt as close to rotation age as possible, starting with those with the oldest veld.
- The creation of a mosaic of divergent veld ages to achieve habitat diversity and conditions favourable to veld fire control. When possible, adjacent compartments are burnt at intervals corresponding to half the rotation age.
- Long-term runoff stability. The complete catchment will not be burnt at a single point in time.
- Equalization of work load.

Compartments are to be burned between 1 January and 30 April on a 12-year rotation. (The Millwood Nature Reserve is burnt on a 15-year rotation.)

The secondary management aims in these catchments have not yet received much attention.

1. Water conservation

Water conservation activities (such as the clearing of pines and hakea) have occurred largely on the northern slopes of the Outeniquas.

2. Nature conservation

The Millwood Nature Reserve, located on Karatara and Goudveld State Forests, is the area selected specifically for nature conservation. Only a very small portion of the nature reserve falls within the study area. The whole reserve covers an area of 6032 hectares, and the management objectives of the reserve are to protect representatives of typical Outeniqua mesic fynbos and wet to very wet montane forest types. Due to the presence of some rare and valuable plant species (Table 4.4) nature conservation is of importance in the catchment area. A policy memorandum has been drawn up for the reserve and additional information may be obtained from it.

3. Research

Most research is initiated by the Saasveld Forestry Research Centre. No detailed research has been undertaken in these catchments apart from general information collected for use in the Policy Memorandum. The need for constant monitoring and research is recognised in the Outeniqua Policy Memorandum.

4. Recreation

The Outeniqua Hiking Trail is the only recreational facility offered in these catchments. The trail in the Bergplaas and Karatara catchment areas is approximately 54 km long, with huts at Kleinplaat, Langberg, Windmeulnek and Farleigh. No further recreational facilities are being planned.

No agricultural activities occur in the upper catchment area. A few cattle are maintained by forestry workers at forestry stations such as Bergplaas and Kleinplaat, but they are kept within the confines of the forestry village.

Catchment Management Activities

Bergplaas compartments (Fig. 4.3).

The Bergplaas catchment compartments were planned in February/March of 1981. Before this period, there were no compartments and the fynbos was not actively managed. The compartments are numbered Cla and b; C2a and b; C3; C4; C5; C6; C7; C8; C9. There are four more compartments (up to C13) in the Bergplaas catchment area, but they fall outside the study area. Some changes in compartment boundaries may occur in 1985/86.

Firebelts

These are burnt on a six-year rotation scheme.

Table 4.5 Management Schedule Bergplaas

Compartment	Prescribed-burns completed	Cut Hakea or Pinaster	Follow-up operations	Future prescribed burns
C1a/b	1985/86	1984/85	1986/87 1988/89	1997/98
C2a/b		1988/89	1990/91 1992/93	1989/90
C3		1986/87	1988/89 1990/91	1987/88
C4		1987/88	1989/90 1991/92	1988/89
C5		1985/86	1987/88 1989/90	1986/87
C6	1981/82			1993/94
C7	1981/82			1992/93
C8	1982/83		1983/84 1985/86	
C9	1982/83		1983/84 1985/86	1993/94

Note: The Planning/Financial year extends between April and March the following year.

Accidental Fires

There have been no accidental fires within the ^{Bergplaas} study area (Fire reports, Knysna Forestry Branch).

Control of Exotic Invaders

Hakea and Pinus species are cut 12 - 18 months in advance of controlled burning, and the removal of seedlings is done a year or two after such a burn. Attempts are made to integrate the burning programme and exotic invader control.

Future Afforestation

There is a possibility that a large section of the Bergplaas Upper Catchment area will be afforested in the near future. Some uncertainty was expressed as to exactly where and when, but this will probably occur in 1992/93 in the vicinity of the road passing through compartments C1a and C2a (pers. comm. District Forest Officers, Knysna Forestry branch).

Karatara Compartments

The Karatara catchment compartments were first planned in 1980. Since then, minor changes have been made in their boundaries and the labelling of the compartments has been altered (B_n to K_n . n = number of compartment). Compartments are currently labelled K2; K3; K4; K5; K6; K7; K8; K9.

Karatarra Management Schedule (past)

<u>Compartment</u>		
<u>Old number</u>	<u>New number</u>	<u>Year of burn</u>
B8	K9 (eastern half)	July 1975
B5a	K8	July 1975
B6 (western section)	K2 (eastern section)	July 1975/76
B6 (eastern section)	K1 (eastern section)	July 1974/75
B5b	K7	April 1976
B7	K7	April 1976
B7	K4 and K5	March 1976
B9	K3 and small western portion of K2	November 1978
B6 (middle section)	K1 (western section)	November 1979

Karatarra Management Schedule (present)

<u>Compartment</u>	<u>Cut Hakea/P. pinaster</u>	<u>Tracers; burn</u>
K7	1983/84	1984/85
K4	1985/86	1986/87
K8	1987/88	1988/89
K3	1988/89	1989/90
K5	1989/90	1990/91
K9 prt	1991/92	1992/93
K2	1993/94	1994/95
K6	1994/95	1995/96
K7	1995/96	1996/97

Source: Knysna Forestry Branch

Accidental fires

An accidental fire swept through compartments M10, M11, K2 and K1 in 1984. The fire swept further east out of the study area. A total of approximately 2000 hectares of fynbos was burnt within the study area. Due to this fire, the sequence of scheduled burning was disrupted and had to be replanned.

Control of Exotic Invaders

The same methods are used in the Karatara catchment area as in the Bergplaas catchment. Most activity has occurred in the following compartments:

B1a (now Eastern Section of M11) - slashed and burnt in 1980/81,

B5b (now K7) - western portion of B5b was slashed in 1983/84,
eastern portion of B5b is being slashed in 1984/85.

The two portions will be burnt together in 1984/85.

On average, up to, but usually less than, 500 ha of exotic vegetation can be cleared per annum.

In addition, a breeding colony of the Hakea snout beetle (Erytenna consputa) was established in compartment B2 in July 1984. This colony has not taken. A further attempt will be made during winter 1985 (District Forest Officers for Karatara and Bergplaas. Knysna Forestry Branch, 1984/85).

4.3 UPPER CATCHMENT MANAGEMENT POLICIES AND ACTIVITIES IN THE CONTEXT OF EROSION HAZARD AND WATER QUALITY

Erosion causes the physical and chemical degradation of the soil mantle and consequent losses in productive land area, losses of nutrients, high maintenance costs in respect of access systems, external damage due to sediment export and reduced aesthetic value. In addition, detached soil particles suspended in streams have a detrimental effect on water quality. It is this effect which will be discussed in this section.

Sedimentation is the deposition of soil particles in streams or stream-expansion areas where it is directly available for re-suspension in water. Sedimentation occurs as a result of surface water erosion and mass soil movement. These processes are enhanced by unsound management practices.

The energy required to detach, move and deposit soil particles in streams is largely derived from the rain drop and water velocity. The volume of soil dislodged for transport is directly related to the density of the soil cover. The size of an exposed area and its distance from the stream will determine whether a detached particle will reach the stream during a storm event. Management practices exposing large areas near streams would have a more serious effect on sedimentation than similar practices near the water divide (see Modified Soil Loss Equation in Appendix **2C**) (Bosch & Hewlett 1980, pp50-51).

Scheduled burning is the dominant management activity which has the potential to increase catchment erodability and decreased water quality.

4.3.1 Fire and Management of Riparian Zones

Water yield can be influenced by manipulation of vegetation, with increases or decreases in water yield being related to changes in plant biomass (Hibbertt 1967; Wicht 1971). Fire removes vegetal cover, and consequent changes in water yield can be expected. Bosch, Schulze and Kruger (1984) have researched this topic comprehensively and, in their article on the effect of fire on water yield, draw the following conclusions. They state that experimental results are not sufficient for conclusive expressions on the effects of short-lived relatively small biomass changes as caused by burning of grassland and fynbos. As a general rule, one can expect fire to have a relatively large effect on water yield when a vegetation type with a large biomass is burned during a period of vigorous growth and when sufficient amounts of water are available. In contrast, burning of dormant, low structure vegetation during cool rainless periods would have very little immediate effect on water yield. The extent to which water yield would be affected over a longer period (a year and longer) depends mainly on the rate of recovery of the vegetation and climatic conditions during the time of recovery. A review of studies on burning and protection in fynbos revealed that (with one exception), increases in water yield following a burn are short-lived or small. The magnitude of changes in vegetation type and composition need to be pronounced to have detectable influences on water yield.

When considering erosion potential, the question arises whether an increased water yield necessarily leads to increased erosion. Factors that need to be considered are time scale (long and short term), climatic conditions, overland flow, vegetal cover and type, soil type and topography.

One may first consider the general effects of a fire. The most obvious is removal of vegetation cover, which, in turn, decreases interception of rainfall. The erosive force of the raindrop becomes direct and immediate. Infiltration rates are influenced by frequent and intense fires. The rate at which rain infiltrates the soil is a function of surface factors such as initial wetness, texture and structure, hydraulic conductivity, uniformity and other physical characteristics of the soil profile. Fire destroys litter and organic matter and this tends to decrease the rate of infiltration through the surface. Bosch's reviewal of experiments brought him to the conclusion that, although experimental results varied considerably, most indicated that grassland and shrubland fires are not intense enough to change soil physical properties (Bosch cites Wells et al. 1978). Under certain conditions fires cause temporary repellancy in soils. Resistance to wetting and increased overland flow may be caused by residual ash dust. Heating of the surface layers in some soils may also result in the condensation of volatilized organic matter in underlying layers, promoting water repellancy. It is clear that the age and density of the fynbos and the corresponding intensity of the fire will be of influence here. Unfortunately no research has been undertaken in South Africa to investigate effects on streamflow components, or on erosion and sedimentation processes.

Fire does have the potential to increase the erodability of a catchment. What are the implications for the Bergplaas and Karatara catchment areas in their classification as fire control zones?

Firstly, one must consider the immediate as opposed to the long-term effects of fire. The immediate post-fire period is of greatest significance as regards sediment-laden runoff potential. According to Kruger and Bigalke (1981) fynbos recovers 80% of canopy cover in less than three years. The intensity of the fire will influence rate of recovery. In this study area the first 6 months after a fire would probably be the period when water quality could be affected by runoff. It would take up to another 18 months before adequate ground cover was established to act as a disperser and trapper of sediment in runoff. The intensity, frequency and duration of rainfall, the rate of overland flow, and proximity of burnt areas to water courses will determine whether water quality will be affected. Due to the all-year rainfall pattern and the potential for high rainfalls in the upper catchment areas, there are no 'safe' periods in which to burn. However, it has been found that, in general, humid catchments tend to have low response factors for stormflow volumes (Bosch et al. 1984).

In addition, some experiments have indicated that rate of overland flow does not change after slashing and burning of fynbos. Versfeld (1981) states that runoff from four small plots (0,08 ha) at Jonkershoek never exceeded 0,05% of rainfall, even with storms (125 mm) immediately after treatment. However, these experiments were conducted on slopes of 14 degrees, which is not comparable to upper catchment slopes

(15 - 40°), and the soils on the plots were of low bulk density, high porosity (loams to sandy loams) and deep, with no impermeable layer to a depth of at least several metres. In addition, hoeing, slashing and burning activities were carefully carried out, with no roads or compacted areas developing as accelerated runoff zones.

The soils in the upper catchment areas (see p.45) of Bergplaas and Karatara are also friable and permeable, if not as deep. This suggests that infiltration would be good although slopes are considerably steeper. The inherent erosion potential of the catchment soils may be regarded as moderate to low. The intensity and quantity of rainfall and rainfall period would dictate degree of erosion. A long period of high rainfall (> 80 mm, occurring over 2-4 days) would almost certainly bring increased quantities of eroded material into watercourses from bordering burn areas. However, there are factors which make the problem less serious. These are that burns occur in compartments and are controlled. The 12-year rotation will ensure that fires are not too intense and that recovery rates should be fairly rapid. The accidental burn which occurred in the Kaagiesberg area (Fig. 4.3) was fairly intense, yet approximately 3 weeks after the fire, the first shoots of green were much in evidence. These were mostly from geophytes whose underground bulbs had not been destroyed by the fire. The remaining burnt material and underground root systems play an important role in maintaining soil permeability and slowing runoff.

Burns near the watershed will not affect water courses as much as those directly above water courses. Riparian Zones are extremely vulnerable areas, usually having steeper slopes and fluctuating moisture content.

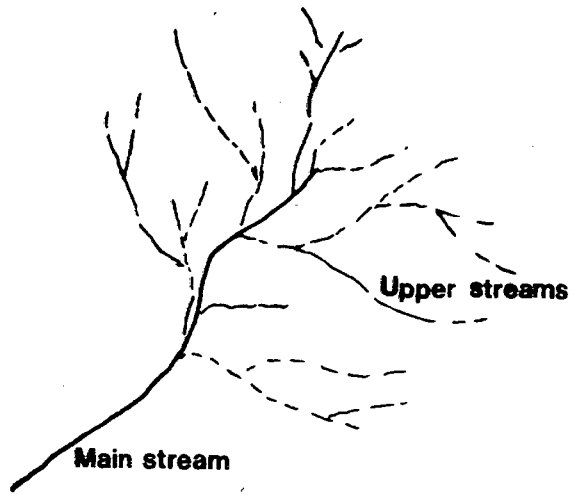


Fig 4-4 STREAM CONFIGURATION

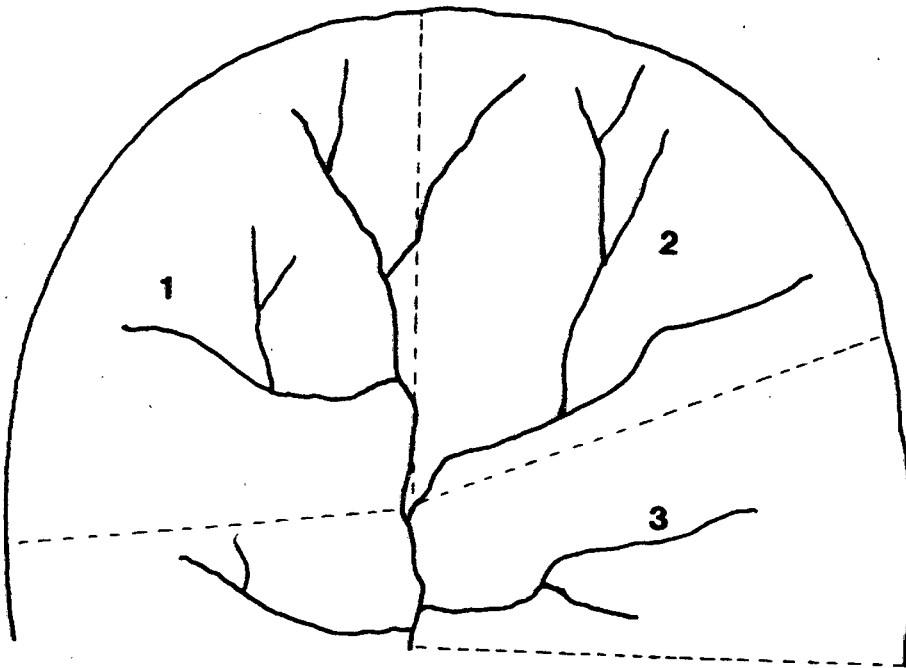


Fig 4-5 BLOCK BURNING

Catchment kloofs which are steep and densely vegetated with indigenous forest are usually safe from fire and may be regarded as traps for sediment originating on the mountain slopes. Some of the Bergplaas and Karatara kloof areas do have dense vegetation, but, in most areas, fynbos continues down to water level. According to the district forest officers involved in catchment management, this fynbos does sometimes burn, but often the riparian zones are too wet to burn. It is necessary to distinguish between the upper smaller kloofs, which do not have such rapid or constant water flow and the river courses into which these upper streams flow, which are generally wetter (Fig. 4.4). The upper stream areas are generally more susceptible to burning, and these areas are likely to produce greater volumes of sediment after heavy rain.

The ideal management recommendation as regards erosion in these areas would be to ensure that sufficient vegetative cover is left within at least 2 - 5 m of the upper streams, and possibly a wider area at the mainstreams. Width would depend on local topography and vegetation type. However, it is not always feasible to try to prevent fires from entering kloof areas, particularly in the upper stream areas. It is unlikely that any catchment fires will be prevented from crossing stream areas.

The only other alternative would be to avoid burning too large an area comprised of streams belonging to a single river catchment, so that the area vulnerable to erosion is decreased. According to catchment planning personnel at the Forestry Branch (Knysna), the ideal block-burning arrangement is as demonstrated in Fig. 4.5.

A burning rotation of 12 (fire control zone) or 15 (nature reserves) years would occur as follows in

	<u>12 years</u>	<u>15 years</u>
Block 1	1980 : 1992	1980 : 1995
2	1988 : 2000	1990 : 2005
3	1984 : 1996	1985 : 2000

The idea behind this arrangement of blocks is to facilitate safe, controllable burning. A catchment would be divided into 3 or, if possible, more blocks. Tracers are made, using natural barriers (usually ridges), and the fire burns inwards. The 3 or 4 block arrangement also allows some regulation of runoff and thus also of sediment removal and transportation.

This arrangement of blocks is visible in the Bergplaas and Karatara upper catchment areas. However, a large catchment stream area is still exposed to the effects of raindrop energy after burning. To some extent this is unavoidable, but, in most circumstances in this area, excessive damage is not likely to occur due to the rapid recovery of vegetation. A further safety factor would be the establishment of 'streamside management zones' (SMZ) as recommended by Bosch and Hewlett (1980). SMZs are areas that run parallel to the streams at distances which would depend largely on the topography and vegetation of the area. These areas would receive special management. In mountain catchments SMZs might comprise whole gorges or kloofs. Streamside management zones will be discussed further in section 5.2.

4.3.2 Sediment Loads in Upper Catchment Areas

Sediment loads in the Bergplaas and Karatara upper catchment areas have been negligible, varying between 0,1 and 10 mg/l. Very few samples were taken due to the obvious clarity of the water. Due to the very low rainfall of 1984 (the lowest in the last 10 years, excepting 1978), there were no occasions when increased sediment loads could be expected. General observation of the upper catchment areas showed no serious signs of erosion on the mountain slopes, with two exceptions discussed below.

4.3.3 Roads and Footpaths

The Outeniqua trail footpath passes through the upper catchment area. In most places the path is in fairly good condition, but on some of the steeper slopes erosion channels are developing. These are of no significance as regards water quality, as the paths are bounded by fynbos or plantation, and runoff would seldom reach watercourses directly. Places where footpaths cross streams are the most important. These areas are relatively vulnerable to erosion after storm events. The section of the trail between Karatara and Farleigh is particularly vulnerable at the moment because of the relative frequency of upper stream crossings and the accidental fire of 1984. Under present rainfall conditions these areas are not sediment sources, but are potentially erodable after large storm events. More serious are upper catchment roads. The Bergplaas catchment is the only one affected. A road has been bulldozed between Kleinplaat and Langberg (Fig. 4.3).

The uppermost sections of the road seem to have been bulldozed without concern for the erosion potential (or aesthetic devaluation) the road has brought about. Road material has been pushed aside at random, forming an unstable sediment source for a Diep-Wolwe River catchment stream. Although no sediment samples have been taken in this stream, there is very little doubt that storm events would bring abnormally large amounts of sediment into the stream. However, because most of the material is fairly coarse road material, most of it would probably settle out before having any serious long-term effect on water quality.

4.4 CONCLUSION

One may conclude that present upper catchment management activities are not contributing towards increased sediment loads under the relatively dry conditions of 1984. The potential for increased erosion exists, and care should be taken to monitor the streams in future. Additional research needs to be initiated to discover if there are increased runoff and sedimentation rates after burns, particularly in riparian zones. These observations may need confirmation or further assessment over a longer time period.

CHAPTER 5

THE PLANTATION AREA

(THE FOOTHILLS ZONE)

5.1 FOOTHILL ZONE CHARACTERISTICS

Topography

The foothills zone of the Outeniqua mountains occurs at elevations of between 310 and 550 m. The terrain is steeply rolling to hilly.

5.1.1 Climate

Refer to Figs 5.1 and 5.2. The rainfalls of the Diep, Hoëkraal and Karatara rivers can differ greatly on a daily basis. For example, on 22 December 1982, the Diep river area received 24,5 mm whereas the Karatara river received only 2,7 mm. Rainfall can also be restricted to one catchment area, as between 14 - 17 June 1981 when the Karatara river area received 450,4 mm of rain over four days whereas the Diep river area received only 8,0 mm on 14 June (assuming that rainfall was correctly recorded) (Daily rainfall data, Weather Bureau, Pretoria). There is a tendency for rainfall to increase towards the east. As can be seen from Fig. 5.1 the Karatara appears to have a higher rainfall

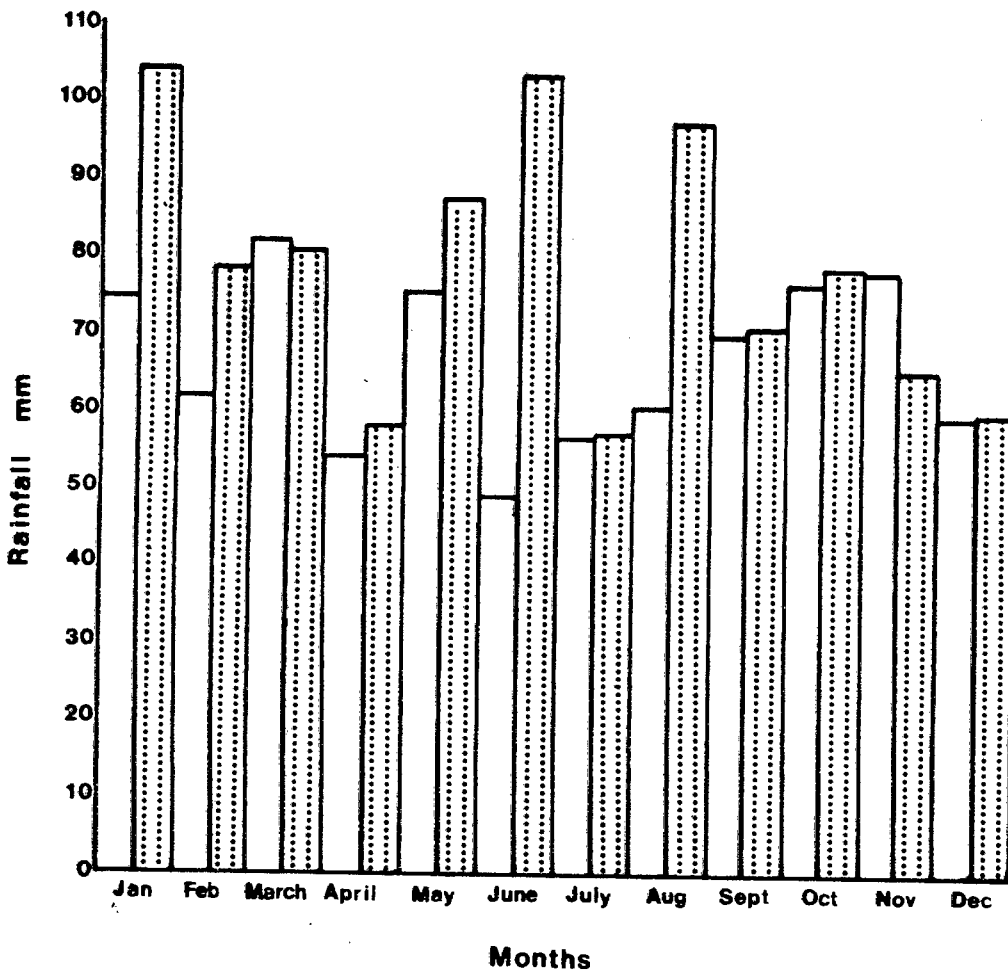


Fig 5-1 AVERAGE TOTAL MONTHLY RAINFALL AT BERGPLAAS
AND KARATARA 1974 - 1984

□ Bergplaas ▤ Karatara

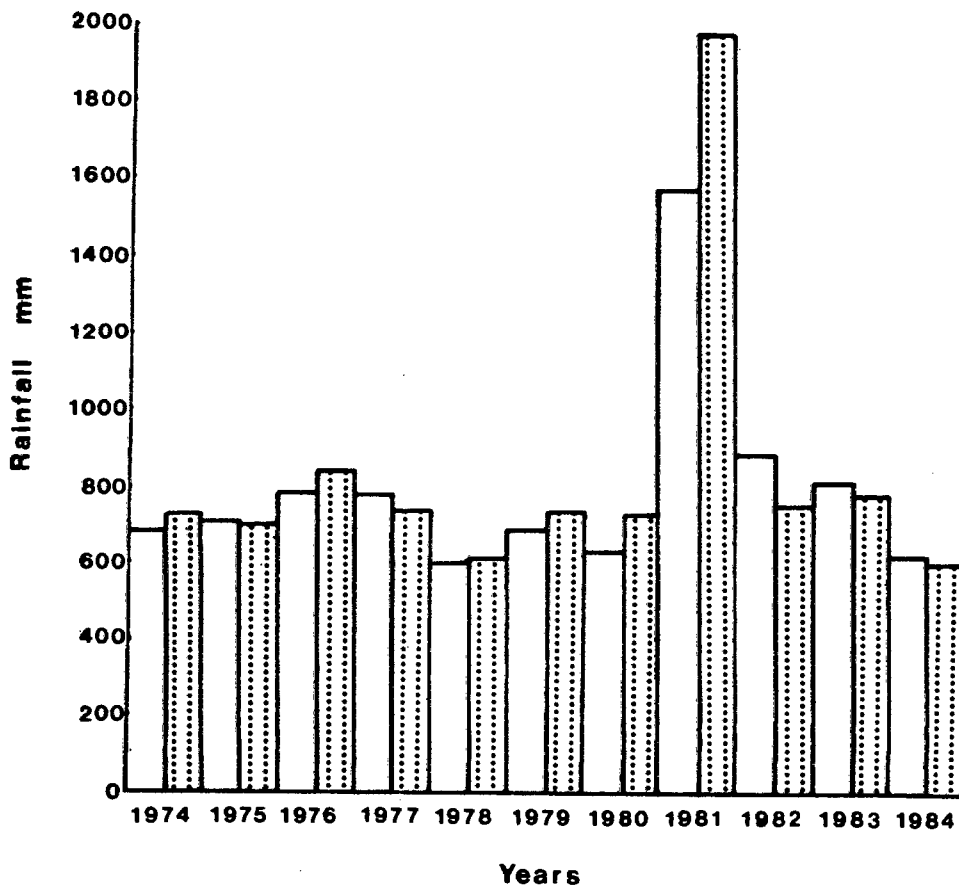


Fig 5-2 AVERAGE TOTAL ANNUAL RAINFALL AT BERGPLAAS
AND KARATARA 1974 - 1984

□ Bergplaas

⋯ Karatara

than the Diep-Wolwe and Hoëkraal rivers. This is largely because the Karatara area is relatively free of rainshadow effects, in contrast to the Diep and Hoëkraal rivers (Hughes, p20, 1983). There are insufficient raingauges in the area to allow accurate recording of rainfall. (See Fig. 3.4 for location and number of raingauges.)

5.1.2 Geology

The foothills zone is also comprised of Table Mountain Group formations, predominantly the Tchando and Peninsula formations, with a thin band of Cedarberg shale.

5.1.3 Soils

According to Schafer (pers. comm. 1984), the foothills zone consists dominantly of colluvial soils with more shallow lithosols on steep upper, upper mid and top slopes.

Gleysols are common, occurring dominantly on southern slopes. Gleying usually occurs lower down in the profile, indicating wet conditions in the lower subsoil or C material.

Many of the topsoils are fairly poorly drained; for example, ^{the soil forms} Pinedene, Kroonstad, Avalon and Westleigh. Examples of better drained top soils are Pinegrove, Clovelly and Oakleaf.

Deep Colluvial soils, also with gleyed subsoils occupy narrow bottomlands. The majority of the soils are medium textured, with a high percentage silt and fine sand.

Hydrophobia (water repellency) is common in upper topsoil, i.e. directly below the needle litter. This is common in southern Cape soils and is probably due to vegetable oils from the fynbos vegetation. Once the soils are moist, however, this feature becomes less noticeable and water infiltration is facilitated.

Podzolisation is common in the foothill zone as a contemporary soil-forming process. New soil forms, Pinegrove and Jonkersberg, are both podzols. Constantia form is usually podzolic and sometimes the Clovelly form shows weak podzol development.

Schafer has given the soil forms as follows (S.A. Binomial Soil Classification System):

<u>Dominant</u>	<u>Sub-dominant</u>
Clovelly	Lamotte
Constantia	Kroonstad
Pinedene	Swartland
Glenrosa	Klapmuts
Cartref	Pinegrove
Houwhoek	Westleigh
Jonkersberg	Oakleaf
Avalon	

Typical soil profile analyses across the foothill zone are given in Appendix **3A**. See Fig. 4.3 for location of soil pits.

5.1.4 Vegetation

The plantations are made up of Pinus and Eucalyptus species. In some plantations, trees have been planted down to water level in river courses, whereas in others patches of natural vegetation remain, such as indigenous forest, fynbos, and various types of riparian vegetation. Invasion of river courses by exotic species such as Acacia mearnsii (Black Wattle) has occurred to some extent, but not so seriously as has occurred in the agricultural area.

5.2 PLANTATION MANAGEMENT AND ACTIVITIES IN THE CONTEXT OF EROSION HAZARD AND WATER QUALITY

Information on plantation management was obtained by interviewing the District Forest Officers and Foresters responsible for the plantations in the study area. A general framework of the type of questions asked can be seen in Appendix **3B**.

Afforestation involves some activities which have the potential to increase erosion hazard. Whether accelerated erosion occurs or not depends almost entirely on planning and use of appropriate techniques for the environmental conditions of the area concerned.

An area selected for afforestation will be subjected to compartmentalisation, establishment of roads and firebreaks, clearing, planting, thinning and, finally, clearfelling. These activities occur over a period of 30 - 40 years with intensity of activity fluctuating widely.

Considerable research has been done on the effects of afforestation on water yield (Van der Zel 1970; Bosch & Hewlett 1981; Stodart 1975; and many others). Less research has been done on the actual extent or nature of erosion from afforested areas. The basic conclusions reached from water yield studies were as follows:

- a) Reduction of forest cover (thinning and clearfelling) increases water yield. Van der Zel (1970) found that thinning brought about a 50% increase in stream flow when 33% of the Pinus radiata trees in a fully afforested catchment (Jonkershoek) were removed 16 years after planting. The increase in stream flow was maintained for 3 years after thinning. Most of the increase in flow was due to decreased transpiration. Bosch and Hewlett (1981) stated that coniferous and eucalypt cover types cause an approximate 40 mm change in annual water yield per 10% change in forest cover.
- b) Establishment of forest cover on sparsely vegetated land decreases water yield.

Decreases in water yield following afforestation seem to be proportional to the growth rate of the stand, while gains in water yield after clearfelling diminish in proportion to the rate of recovery of the vegetation. Streamflow response to deforestation or afforestation depends both

on the region's Mean Annual Precipitation (MAP) and on the precipitation for the year under treatment. Yield changes, whether increases due to cutting or decreases due to planting, are greatest in high rainfall areas. The effect of clearcutting is, however, shorter-lived than in low-rainfall areas due to rapid regrowth of vegetation (Bosch & Hewlett 1981). In addition, Rycroft (1955), Banks (1961/62, and Nänni (1970) found that removal of indigenous riparian vegetation at Cathedral Peak and Jonkershoek resulted in reduced diurnal vapour losses and increased base flow (increased by 1,1 cubic metres p.d./100 m of stream bank cleared).

The above study conclusions all relate to water yield, i.e. the drainage basins' total yield of water during some period of time. Base flow refers to ground water outflow. Little reference is made to the origin of this increased water yield; for example, what percentage of the increased yield (from thinning and cutting) would result from surface stormflow as opposed to subsurface stormflow and baseflow? Surface stormflow is of the greatest relevance regarding surface erosion. An increased water yield need not necessarily bring about increased sediment loads, particularly if increased water yield is due to reduced transpiration. The relevance of increased water yield as regards erosion, is possibly the increased velocity of flow, with corresponding increased potential to lift and transport sediment deposited from surface stormflow, as well as sediment washed off river banks. One of the conclusions of this study was that water velocity was one of the more important factors determining whether sediment reached Swartvlei. Could an increased water yield, resulting from clearfelling (and burning

in the upper catchment area) be a significant factor in allowing more sediment-laden water to flow into Swartvlei? Once again (as stated in Section 4.3.1) there are many factors to be taken into account, such as time scale (i.e. how sudden is increase in water yield and for what period does the increase continue?), climatic conditions during and after clearing and proportion of surface versus subsurface flow, type of vegetation cover and its recovery rates, type and extent of riparian vegetation, soil types and topography.

The question of increased water yield has been adequately dealt with by Bosch and Versfeld (1983). It is felt by the writer that increased water yield through reduced transpiration and increased base flow in these catchments is not, on its own, a significant factor in accelerating erosion. An increased water yield is desirable as long as water quality is good. If, however, forestry infrastructure and operations bring about increased water yield in such a way as to increase sediment loads, some consideration will have to be given to the relative merits of increased water yield in contrast to the disadvantage of erosion and sedimentation.

It must be remembered that water quality will be most affected if forestry activities occur within the vicinity of water courses, be they perennial or ephemeral (definition in Appendix 3C). Most attention must be given to these areas.

It is necessary to note first how riparian zones have been managed in the past. The Department of Forestry's vigorous afforestation programme

from about 1920 onwards resulted in public anxiety about apparent decreases in water yield. In some cases it was claimed that previously perennial streams dried up or flowed only intermittently. This observation has been made by farmers in the Outeniqua areas. However, some doubt existed about the causes of this occurrence. In response to the claims of decreased water yield, the Department adopted a policy, in 1932, of prohibiting afforestation of the zone within 20 m (a convenient chain length) of both sides of perennial streams, vleis and other surface water. Private growers were not obligated to comply except in the case of some soil conservation district schemes. Only with the 1969 Soil Conservation Act and the introduction of afforestation permits with restrictions on riparian zone afforestation in 1972 did the reservation of 20 m strips assume universal application. The General Provisions of the Soil Conservation Act No. 76 of 1969 stipulated in this respect:

1. 'No vegetation, excepting proclaimed weeds and other noxious plants, shall be destroyed within ten (10) metres of the edges or banks of or in rivers, brooks, springs, vleis, marshes, dongas, water courses or earth channels.'
2. 'Within ninety (90) metres of the edges of marshy water sponges, under average rainfall conditions, and twenty (20) metres horizontally and vertically from the edges of water sponges, brooks and rivers, no plantations shall be planted or re-established for commercial purposes or regrowth allowed after existing plantations have been thinned out or completely felled.' (Bosch & Versfeld 1983)

Bosch and Versveld (1983) made an important observation about the above legislation, namely that, although it stated that vegetation 20 m from streambanks should not be destroyed, it did not state that the vegetation should not be managed - including management through burning. In other words, it did not enforce total protection. No mention was made in the Soil Conservation Act of the 'protection' of riparian zones.

The situation has now changed with the introduction of the Conservation of Agricultural Resources Act 43 of 1983 and the Forest Act 122 of 1984. This has resulted in the repeal of the Soil Conservation Act 76 of 1969 and the Forest Act 72 of 1968.

The utilisation of watercourse areas is now dealt with in the Conservation of Agricultural Resources Act (discussed in Section 6.3). In contrast to the previous arrangement, aspects relating to afforestation and plantation management will be covered by the 1984 Forest Act. Some of the relevant information in this Act is discussed on page 112.

Further attention has to be given to the forestry practices themselves. This has been done by Bosch and Hewlett (1980) in their article on sediment control in South African Forests and Mountain catchments, and more recently by D.C. Grey and E.D. Jacobs of the Saasveld Forestry Research Centre in George.

Bosch and Hewlett's recommendations for management of riparian zones are fully supported, as such recommendations provide some guarantee of reduced erosion rates in the Bergplaas and Karatara forestry areas. However, the foresters who knew something of Bosch and Hewlett's

recommendations stated that some of them were almost impossible to apply, in both the practical and economic sense. For example, it was not considered feasible to leave streamside zones unburnt where they fell into fire protection areas. The question was raised as to who would take the responsibility if a fire passed through a streamside zone due to the presence of riparian vegetation which had been left there for the purposes of stabilising stream banks, preventing erosion and trapping sediment. In addition, it was said that roads near the stream base were often more practical than ones higher up a long slope. On a long steep slope it would be more detrimental to have to slip logs up the entire length of the slope to an upper road than to allow the logs from the lower half of the compartment to be slipped downslope to a lower road. Both these examples are relevant, and it becomes clear that individual sites will have to be managed differently according to their characteristics. A balance will have to be created between what is environmentally ideal and practicably possible.

The situation in these catchment areas is described in the light of the above authors' recommendations. Primarily, the importance of riparian zones as buffer zones against upland disturbances cannot be overemphasized. In the light of observations made in the study catchments, appropriate management of the riparian zones would alleviate those examples of accelerated erosion that do occur. According to Bosch and Hewlett (1980), citing Cameron and Henderson (1979), it is common policy in Australia to leave protection strips of Eucalypt forest along streams when clearfelling catchments, and in the U.S.A. logging prescriptions for riparian zones are specified in detail. In contrast,

in South Africa, riparian zones have frequently been seen as ideal areas for roads, firebreaks and log-slipping trails. In studies abroad, roads, log-slipping trails and stream crossings have been found to be responsible for about 80% of sediment delivery to streams. Hewlett (1979) tested the effect of clearcutting, roller chopping and machine planting on sediment yields in a Piedmont forest and showed that 90% of the long-term mass export due to forest operations was directly attributable to bad road-building and unnecessary channel area damage by equipment.

Similar research, mostly concerned with harvesting impacts, is now being initiated in South Africa. A report titled 'The influence of catchment management on erosion and subsequent sediment and nutrient loads in South African Mountain Streams', is in preparation at the Jonkershoek Forestry Research Station. Some preliminary results have been presented. Care will have to be taken when assessing the relevance of South Western Cape information to the southern Cape.

Management techniques in the Bergplaas and Karatara catchment areas are as follows:

5.2.1 Clearing and Planting Operations

Clearing of previously unafforested areas is carried out by burning the vegetation. Burning usually occurs between October and March (excepting mid-December - mid-January). Approximately 50 - 100 ha are cleared per annum. Planting usually occurs between March to May,

or September to October, depending on rainfall, nursery plant availability and work load. Up to a month before planting occurs planting spots (termed 'spot preparation') are prepared by loosening the soil in an area of about 45 cm in diameter and 30 cm deep for each seedling. In the past, clearing and planting has occurred down to water level, even on steep slopes. Unfortunately there is no record of whether such operations, followed by storm events, brought about increased sedimentation rates. The potential for soil mass wastage is increased under such conditions.

Mass wastage usually occurs on steep slopes with inherently unstable soil conditions. Soil slippage occurs when shear resistance is exceeded by the shear stress along the failure line. Shear stress is a function of the effective mass of the soil and the inclination of the sliding surface, and shear resistance depends on soil particle cohesion and the angle of internal soil friction. Natural conditions thus govern mass soil movement but road-building, channel erosion and tree-cutting can enhance the process and hasten the damage. Disturbance of delicately balanced conditions occurs as a result of (1) increased soil mass caused by the addition of unusual rainfall or by unusual surface loading; (2) reduced shear resistance caused by the death of root systems and/or changing water flow pathways in the soil; and (3) undercutting of unstable slopes through construction or channel cutting (Bosch & Hewlett 1980). These conditions occur particularly after clearing, roadbuilding, burning and felling operations. Clearing and burning of vegetation reduces interception of water. The soil may become waterlogged more rapidly. Root systems, if destroyed, fail

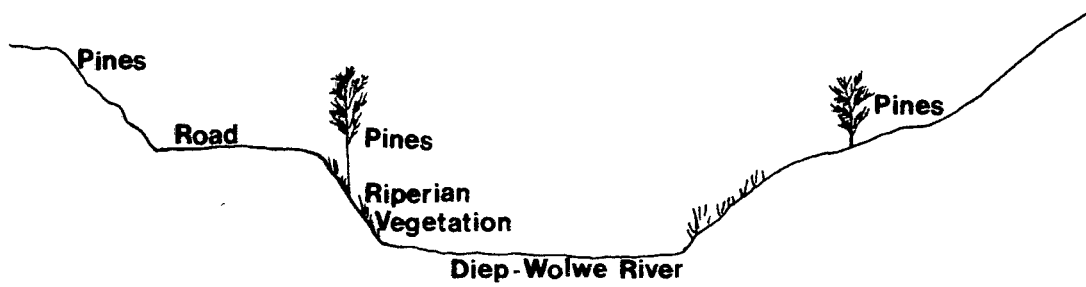


Fig 5.3 CROSS SECTION OF THE BERGPLAAS - KLEINPLAAT FORESTRY ROAD AND ADJACENT RIVER

to bind the soil. If the soil is not easily permeable overland flow is rapid, bringing about surface erosion. Examples of past occurrences of soil mass wastage on some steep slopes have been seen in the study area. They are not easily visible because, as the trees have regrown, slopes have stabilised and needle litter and other organic matter has filled in washaway areas. Once forest trees become established and litter accumulates, erosion after storm events is much reduced. The areas most susceptible to soil loss are river channels where trees are planted down to and sometimes through water courses. The presence of pine trees is known to discourage growth of other types of vegetation. Where other vegetation types (fynbos and riparian) have died out, mass wastage may occur. Because the water course has less needle litter, there is less protection of soil. The large roots of the pine trees fail to hold the sandy soil together as would the dense smaller root systems of fynbos, grass and riparian vegetation. It is only under these circumstances that visible active erosion occurs, even after fairly small storm events (20 - 40 mm). Where trees are planted far enough apart for other vegetation to survive, mass wastage rarely occurs and channel erosion is reduced. An example of an area where some natural vegetation has re-established itself is between Bergplaas and Kleinplaas where a forestry road runs parallel to the main channel of the Diep-Wolwe river (Fig. 5.3). Pine trees were planted on both sides of the Diep-Wolwe River before the Afforestation and Soil Conservation regulations became mandatory.

During clearing and planting operations in this vicinity it is possible that sediment loads increased, but there are no records of this period.

The trees are now reaching maturity and well established. Needle litter has accumulated and, because sufficient light reaches the river, ferns and other types of riparian vegetation have grown up on the river banks. During normal flow periods the water is free of sediment. Vegetation on the banks traps sediment from pine plantations and the road.

However, the Diep-Wolwe river between Kleinplaat and Bergplaas does have fluctuating sediment loads. On 11 March 1984, after approximately 27 mm of rain between 6 - 8 March 1984, sediment loads increased to 23,4 mg/l from the normal 0,1 - 2 mg/l. Sediment loads were probably higher immediately after the rain. The reading of 23,4 mg/l was obtained on the upper section of the river between Kleinplaat and Bergplaas. However, by the time the water reached the bridge at the section of river below Bergplaas itself, it was clear at 2,7 mg/l. There are two possible explanations for this change in sediment load: (1) En route to Bergplaas, sediment may have settled out or been trapped by vegetation. There are many areas where the river is bordered by dense fynbos and riparian vegetation; (2) insufficient time had elapsed for sediment-laden water to reach this point. This example could show the potential of riparian vegetation to act as a barrier against bank disturbance. Density and occurrence of riparian vegetation in the study catchments fluctuates, depending on factors such as density of tree-planting, type of water-course (perennial or ephemeral), bank slope and light penetration. From what could be observed during the study period, those streams bordered by dense riparian vegetation were almost always free of sediment (providing there was no serious upstream disturbance), whereas those which were bordered by pines or Acacia mearnsii alone were showing signs

of past bank erosion. Flow rates during 1984 were seldom fast enough to cause significant bank erosion.

Invasion of alien vegetation along water courses is common, particularly in the more southerly areas of the plantation zone and the agricultural areas. Alien vegetation types (predominantly Acacia spp.), like densely planted pine trees, tend to discourage growth of riparian vegetation. Water courses bordered by this vegetation also show signs of erosion.

The above observations show the necessity of managing riparian zones, rather than ignoring them or allowing invasion of alien vegetation which can have as much detrimental effect as pine trees on both water yield and erosion potential.

It has been stated by the Knysna Forestry Branch that watercourse zones being clearfelled at present, will (in most cases) not be replanted. This means that fairly large areas are going to need management in the near future.

5.2.2 Road Construction and maintenance

Another forest operation which increases sediment yield is road-building and maintenance. Most of the roads in the plantation areas are well established. Their contribution to sediment yield may have been higher at the time of construction than at present. Determination of road distances in the plantations is not easy as new roads (of varying

quality) are being constructed and maintained all the time, whereas others fall into disuse. The last given records state that in 1983 there were 310 km of roads in the Karatara plantations, and 550 km of roads in the Bergplaas plantations (Forestry Branch, Knysna, 1984).

The road which appears to contribute most sediment to a watercourse directly is the one, previously mentioned, running between Bergplaas and Kleinplaat. Its proximity to the Diep-Wolwe river makes a degree of sediment offload inevitable. The road crosses the river at an angle of approximately 45 degrees to the direction of flow. In places, the concrete crossings dip down towards water level. After rain, runoff from the dirt road on either side of the bridge runs downslope to the crossing and into the watercourse. Significant quantities of soil accumulate on the crossings themselves, deposited there by runoff and passing vehicles, whose tyres and undercarriage accumulate soil from travelling on dust roads. After rain this sediment runs into the water, and forestry vehicles, which cross the river at considerable speed, aid the process (forcing splashing and lateral movement of rain-water). This is the most visible source of sediment. Sediment also trickles off the road embankments, but as these are generally well-vegetated, it is not easily visible.

Wherever roads crossed streams at right angles to direction of flow (i.e. going straight in and straight out of the stream) and were built up to the correct contour level for the topography, few signs of runoff or erosion were seen. In many cases the foundation for the road at stream crossings consisted of packed boulders with a pipe or naturally

filtering waterway for streamflow. This method appeared fairly successful. In some cases where sediment was washed off the road, it was trapped in vegetation (such as ferns and moss) growing on or in the vicinity of the boulders. The rough rocky border of the crossing prevents water running straight over the edge of the road into the waterway, as it would on a concrete crossing. These stone-packed river crossings are not likely to be used in future due to comparative difficulty of construction and the strain imposed on the crossings by heavy logging trucks, particularly where the crossings occur on sharp corners. In some cases the earth component of the rock base of the bridge is washed away, leaving an uneven surface and unstable foundation. New concrete bridges will be strongly constructed but will have no natural silt-trapping mechanism. However, abnormal floods, such as occurred in 1981, still have the potential to damage relatively well-constructed roads and bridges, as can be seen in forestry reports for the period. The reports make frequent reference to bridges and roads (particularly on corners) which were washed away (Knysna Forestry Branch).

The maintenance process of grading the Bergplaas-Kleinplaat road also accelerates sediment offload. Grader vehicles push road material to the river side of the road (the other side being too steep - see Fig. 5.3). This loose accumulated soil gradually trickles down the river bank. Fortunately bank vegetation traps the largest proportion of this soil but, because it is relatively loose, any rise in water level and water movement easily lifts and transports the sediment. The increase in sediment load mentioned previously (0,1 - 23,7 mg/l)

was largely the result of road sediment. This section of forestry road seems to be the only one clearly contributing significant amounts of sediment directly into the Diep-Wolwe river. Other forestry roads in the study area showed signs of erosion downslope, but this is of no significance unless the water runs directly into a watercourse. In some cases, road runoff appeared to pass through plantations or riparian vegetation before reaching water courses. When this occurs water flow is reduced and dispersed and sediment is deposited.

One of the less obvious sources of silt from roads originates from side drains. These drains usually run parallel to the road, and are below road level. Water washes off the road and runs down the drain. These drains often run downhill and cross or empty into minor streams which are usually at the lowest point towards which water erodes. Because the drains are long and no cross drains deflect water into bordering vegetation, water velocity increases and erosion can occur. This occurs only in heavy rainfall conditions. Although sediment offload from these drains has not been monitored, their silt contribution is likely to be significant. An alleviating factor is that most silt deposited in streams is likely to settle out before seriously affecting downstream water quality. Only in flood conditions would their contributions become significant.

5.2.3 Firebreaks

Establishment of firebreaks can also lead to accelerated erosion.

In the catchments, the northern firebreaks are burnt on a 6 - 8 year

rotation. Southern firebreaks (on the southern boundary of the plantations) are ploughed and hoed annually. Additional areas are slashed. Some root material remains, but dies off. Waste material from clearing the southern firebreaks is pushed to one side, whereas material in the northern firebreaks is pushed into the area to be burnt.

In the study catchments concerned, firebreaks appeared to contribute little sediment to streams. It must be remembered that there were no heavy rainfalls during the study period. Those firebreaks that were seen did go straight into and out of streams as recommended. There was no apparent use of water bars on steep slopes. The limited width of the firebreaks, the permeability of the soil, and left-over root material are all factors which possibly reduce erosion in these areas. Near Knysna an example of a seriously eroded firebreak was found. A gully several feet deep had developed. The potential for erosion in these areas seems to exist.

5.2.4 Thinning

Thinning and clearfelling are forest operations of significance to erosion potential and water quality. As stated earlier, thinning does lead to increased water yields, though largely through reduced transpiration. However, the actual thinning process is unlikely to increase sedimentation rates. Thinning intervals have changed over the years as shown in the following table.

Table 5.1 Thinning intervals

	No. of stems planted per hectare	1st thinning Age of tree & stem number	2nd thinning Age of tree & stem number	3rd thinning Age of tree & stem number
<u>Past</u>	1300	10 yrs *850/*650	15 yrs 500/400	20 yrs 300/250
<u>Present</u>	1300	8 yrs 650	13 yrs 400	18 yrs 250

* Whether the stand was thinned to 850 or 650 stems per ha. depended on the plantation's quality.

Source: District Forest Officer, Knysna Forestry Branch.

From 1985 onwards, in most cases, 815 stems per hectare will be planted - due to the decreased demand for material obtained from the first thinning and the necessity of decreasing planting costs. In some selected cases, e.g. for pole production, the espacement of 2,7 m will still be adhered to.

That material which can be used is removed, and waste is usually spread over the ground. This activity should not increase erosion hazard as use of machines is limited, the compartment is not denuded of vegetation and, in fact, left-over thinned material can act as further ground surface protection against erosion.

5.2.5 Clearfelling

Clearfelling can lead to increased erosion potential if incorrect methods are used, and ground cover is removed or destroyed. According to Hewlett (1980, p140) approximately 1 metric ton of organic debris per hectare will absorb 98% of rainfall energy. Forest floors usually vary from one to five tons per hectare. However, a few hundred kilograms of debris, particularly fibrous materials such as pine straw, spread over a hectare of bare soil will reduce rainfall's erosion potential 75% or more. In addition, litter detention storage disperses water energy that otherwise would break the bonds between colloids and fine aggregates to produce a thin slurry of mud over the surface. Where exposed directly to raindrop energies, infiltration capacity is impaired as mud clogs surface pores. The removal of trees and the disturbance of soil cover make a cleared compartment susceptible to erosion. According to Schutz (1982, p4) erosion losses after logging steep slopes may be excessive. Citing Nutter and Douglas, 1978, as reference, he states that the choice of cropping practice can produce a 250-fold difference in soil loss.

Erosion hazard is further increased if slash disposal burning is carried out. Schutz (1982, p4) citing Germishuizen and Badenhorst, 1977, states that a slash disposal burn on a 10 degree slope after clearfelling Pinus patula in Swaziland resulted in a topsoil loss of about 16,5 t/ha within four months. Burning of slash in the southern Cape usually only occurs when the compartment has been invaded by the indigenous invasive Gleichenia polypodioides or other invasives. Gleichenia

TABLE 5.2 a ^{Forest} Harvesting impacts in southern Africa

Species	Age Years	Location	Impacted area	Soil form	Increase in bulk density	Reduction in height growth
<i>E. grandis</i>	1,1	Zululand	12%	Fernwood	16%	44%
<i>P. patula</i>	16	Swaziland	36%	Hutton	5%	66%
<i>P. elliottii</i>	9	S. Cape	18%	Estcourt	N.S.	26%
<i>P. radiata</i>	1,6	S. Cape	14%	Estcourt	11%	59%
<i>E. grandis</i>	4,8	Zululand	12%	Fernwood	-	28,3% (1)
<i>P. patula</i>	8	Swaziland	-	Hutton	-	19,3%(2)

N.S. - Not significant ($P > 0,1$)

(1) Annon 1984

(2) Germishuizen et al. 1977

Source: Grey 1985

TABLE 5.2b

Area impacted by ^{Forest} harvesting activities

Percentage of area impacted	Slopes	Type of operation and system	Author
11 - 30%	10°-20°	Thinning skidders	Murphy 1982
12%	< 1°-22°	Clearfelling skidders	Sidle et al. 1981
2%	16°-26°	Clearfelling helicopters	Clayton 1981
35%	-	Clearfelling skyline	Schwab et al. 1981
63%	-	Clearfelling crawler	Schwab et al. 1981
3%	-	Clearfelling skyline	Patric et al. 1978
4%	2°-26°	Clearfelling torsion bar suspension skidder	Froehlich 1978
11 - 18%	2°-7°	Clearfelling skidder	Own data S. Cape

Grey 1985

(a fern) has been seen in some compartments to grow to a height of 1 - 2 m. In addition, some experiments are being carried out on the possibility of burning undecomposed litter under standing trees. It is unlikely that the latter practice would increase runoff erosion seriously. Burning is avoided where possible because it encourages growth of invasives (Acacia spp.) and also a type of fungus (Rhizina). D.C. Grey of the Saasveld Forest Research Centre, George, has made observations and written articles on the effects of logging and clear-felling in the southern Cape forests. Problems that have been noted to occur include destruction of soil structure due to slipping wheels, and soil compaction due to heavy weights of machinery and logs. These processes, together with the development of skid trails, lead to increased erosion. D.C. Grey has written a detailed review of the impacts of mechanised harvesting systems on forest site quality. Some of the points made in this review are as follows:

'Ground-based extraction gives rise to skid trails which cover from 10 to 40 percent of the soil surface (see Table 5.2) Inadequate control of entry leads to the area being increased to more than 25% of the compartment in subsequent harvesting cycles. If skid roads are incorrectly situated and erosion potential is high (depending on topography, soils etc.) erosion on skid roads can continue for several years.'

'Measurements in the southern Cape area of South Africa show sediment production and active gully erosion, due to headwall and channel bank retreat, to be present 9 years after harvesting. Removal of leached

A and E horizons has exposed erodible subsoils during routine grading operations.' This leads to rapid side drain erosion on most duplex soils with dispersive lower clays.

'Other impacts apart from erosion are compaction, reduced infiltration, disturbance, soil crust formation and the dumping of forest debris into streams. Compaction decreases soil porosity, infiltration capacity and gaseous exchange. There is decreased wind erosion, but increased surface runoff and erosion.'

'In the southern Cape, compaction was measured by determining reduction in air-filled porosity. Air-filled porosity was reduced by 35 - 85% in silty loam topsoils following unusually high rainfalls. Bulk density increases varied from 14 to 19% during the same operations. Penetrometer readings showed significant increases in the top 25 cm of Estcourt, Kroonstad, Lamotte, Cartref and Westleigh soils with low organic matter and high (70% - 90%) fine sand contents.'

If clearfelling occurs within the immediate vicinity of a watercourse, it is inevitable that runoff after storm events will contain considerable amounts of eroded material. If there is no buffer zone for the watercourse concerned water quality will be affected. Of concern are those watercourses which are relatively small and through which pine (or Eucalyptus) trees have been planted. Although water flows only after rainfall in some of these streams (intermittent or ephemeral) (see definition in Appendix 3C), and there is no serious erosion at present due to interception and ground litter, clearfelling operations

can change these presently insignificant watercourses into potential sediment sources. Movement of machinery and logs across the watercourses has been seen to occur and seems unavoidable in plantations where trees are planted in watercourses. Disturbed and compacted soil will contribute sediment to these watercourses until such time as natural vegetation can reestablish itself in sufficient density to act as a trap, barrier and dispenser of runoff erosion. This is likely to be a period of 1 - 3 years.

Most damage presently encountered in the field could have been avoided with proper planning, training and working methods, virtually without any additional costs. The fact that recommendations on prevention of damage during logging operations are presented in soil science lectures at Saasveld Forestry College, and that they have also been presented to head office staff of the Forestry branch demonstrates that the decision-makers and planners are aware of the problems and their solutions. Practical application of such recommendations should now be a priority. The necessity for applying such measures in watercourse areas is clear when one considers the large areas, presently afforested and stable, which will be cleared in the next few years.

Whether the water quality of Swartvlei will be affected by such operations will depend on the techniques used, clearing area, clearing intervals and climatic conditions during and after clearing. Under the weather conditions of 1984 the amount of sediment originating from forested areas appeared negligible. However, it was not always possible to establish where sediment was originating. The potential

for increased erosion hazard is unquestionably present.

In the context of the above mentioned hazards, some recommendations are made based on the ideas of J.M. Bosch, J.D. Hewlett, D.C. Grey and D.E. Versfeld.

Of primary importance is a change in the laissez-faire approach to riparian zone management. Bosch and Versfeld (1983) recommend multiple use management of riparian zones, with selection of use dependent on local requirements and conditions. Conflicting interests should be arranged in order of priority, and optimum use determined. Bosch and Versfeld give the following possible objectives for riparian zone management:

- i) to increase water yield
- ii) to maintain water quality
- iii) to produce timber
- iv) to produce agricultural products (e.g. fruit trees, livestock)
- v) to maintain natural floral, faunal and aquatic communities
- vi) to provide zones for recreation.

On the Outeniqua southern slopes objectives (ii), (iii), (v) and (vi) are applicable. Objectives (iii) and (vi) must be carried out with particular care so as to maintain water quality.

The maintenance of water quality is of greater importance than normal due to the sensitivity of the lakes system into which the catchment rivers run.

As recommended by Bosch and Hewlett (1980) streamside management zones (SMZ) should be delineated in all management areas. This would involve identifying perennial, intermittent and ephemeral streams, and marking the SMZ on the ground and on maps. Width of the SMZ would depend on topography, type of vegetation and the degree of control over activities in the SMZ. If a high degree of control is possible, the zone may be narrower. The type of activity occurring on the adjoining slopes will also determine width of the zone. Activities which could bring about increased erosion hazard may necessitate a wider buffer zone.

It may be possible to further delineate the buffer zone by determining a primary and secondary buffer zone. The primary buffer zone would be relatively narrow (6 - 10 m), be situated adjacent to the water course and be subject to the strictest conservation controls. The secondary buffer zone would be wider (up to 40 - 50 m maximum), depending on slope, erosion potential and type of activity. Normal soil conservation controls would apply in this zone.

Bosch and Hewlett's (1980, p53) general recommendations for the SMZ are as follows:

- Keep wheeled and tracked vehicles out of these zones
- Keep roads and trails as far away from the SMZ as possible
- Carry out all silvicultural and logging operations by hand within the SMZ (where trees have been planted in the past)
- Avoid burning schedules that would leave the SMZ exposed to rain

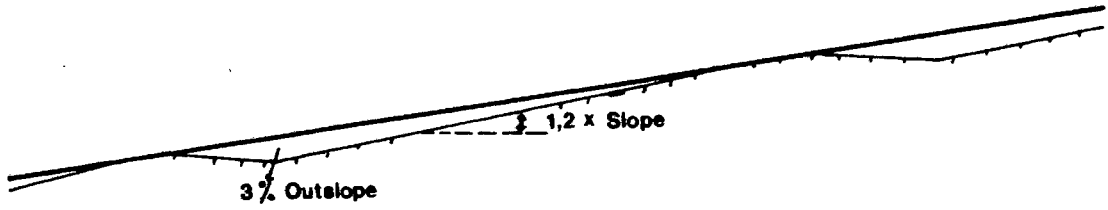


Fig 5-4 BROAD-BASED DIP

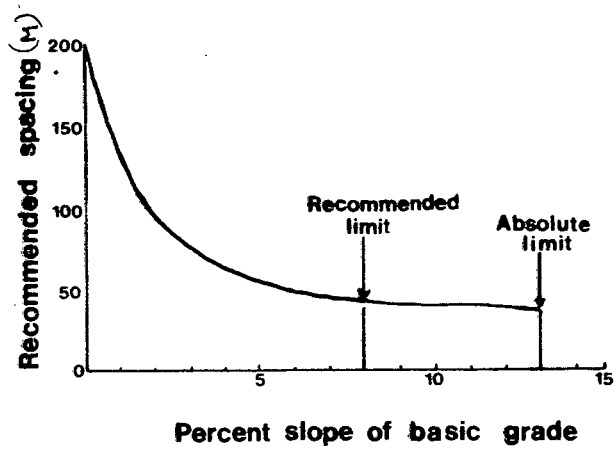


Fig 5-5 DIP SPACING

(Bosch, Hewlett, 1980)

- Keep tracers for firebreaks as far uphill as possible.

5.2.6 Specific Recommendations for Individual Forestry Operations

Clearing and planting previously unafforested areas:

- Planting should occur as soon as possible after clearing. In many cases in the past a year or more elapsed before planting occurred. Holes for transplants should not be prepared too soon before their insertion. (Immediate planting is not always possible due to practical difficulties such as climatic conditions.)
- The width of the buffer zone must be carefully calculated and should remain undisturbed.

Establishment of roads and firebreaks:

Bosch and Hewlett (1980) make detailed recommendations about construction of forestry roads based on the use of the broad-based dip. Broad-based dips have been described and recommended for mountain and piedmont roads in the U.S.A. (Cook & Hewlett 1979). The function of a broad-based dip is to prevent erosion by removing stormwater from the road efficiently, economically and without causing difficulty for the driver or his vehicle. Details of the features of a broad-based dip are given in Appendix 3D. When new forestry roads are built in the study area, it would be worthwhile to follow Bosch and Hewlett's recommendations of constructing the road several months before use, ensuring good topographic location, design features that remove water

from the road surface, and prompt revegetation of the road following intensive use. Pre-building also makes it possible to establish erosion-resisting vegetation on the road banks and shoulders, which will help reduce erosion before and during logging. Pre-building also allows observation of how the road reacts to storm events, and indicates where slash may have to be used to dissipate water energy. Such techniques could have been favourably employed on the new road built in the Bergplaas upper catchment area (referred to in Chapter 4, Fig.4.3).

Because most of the plantation roads are already well established, many of the above recommendations do not apply. Road activities are restricted largely to maintenance. Methods for reducing sediment off-load during maintenance would be as follows:

As regards the Diep-Wolwe river road, the pushing of road material towards and over the road embankment down towards the watercourse, by graders, should be lessened if possible. The same applies to any other roads parallel to watercourses. Existing bank vegetation must be encouraged to grow, possibly with the addition of grass seed. Placing of slash material or local stone material on the road embankments may also help dissipate flow. Those particularly vulnerable areas at bridge crossings should be improved, either by improving the bridge structure itself - a relatively major operation - or, more feasibly, by constructing frequently placed drainage structures, such as cross-ditches, culverts, broad-based dips and ditch turnouts. Spacing will depend on slope. These structures should be designed so as to drain

water off the road and into dense bank vegetation for some distance before the road water is allowed to drain into the river. This would allow opportunity for sediment deposition.

It has been shown that 'greenways' provide a vegetative filter which reduces the amount of pollutants and sediments entering watercourses. Filter efficiency is related to the length of the flow path. Schultz et al. (1982), writing on water quality control for the Meramec river, state that data from several researchers, primarily Wilson (1967) was reviewed. Most of the data provided fell close to a line described by the logarithmic relationship:

$$\% = 2,225D^{0,555}$$

where

% = percent of sediment removed by the filter

D = the distance of flow through the filter (feet)

In the above study, an average flow distance of 500 feet (151,5 m) was expected, giving a projected maximum sediment removal efficiency of 70%.

$$2,225(500)^{0,555} = 70\%$$

With careful planning, it should be possible to ensure that drainage water passes through vegetative filters for a sufficient distance to allow sediment to be trapped. It is also possible that some vegetation types (or combination of types) may be more efficient as filters than others. This may be worth researching. Water in side drains should be frequently deflected to avoid further erosion.

Primary concern is with those roads where runoff does reach a water-course.

It has been stated that main forestry roads are to be upgraded as funds become available in the next few years. Care must be taken, during upgrading, that excessive amounts of material are not dumped into streams, particularly where blasting occurs. The road going up to Bergplaas will be particularly vulnerable as blasting will occur next to the river.

Reasons given for the apparent lack of drainage structures (apart from side drains) on plantation roads were:

- financial constraints
- sediment from roads was not yet considered to be a problem.

From what could be seen, most funds are being directed towards construction of new roads and maintenance of most frequently used roads. New roads are constructed as economically as possible, repairs are carried out only when seen to be absolutely necessary, and a very small proportion of available finance is directed towards prevention of damage.

According to Mr D.C. Grey, of the Saasveld Forestry Research Centre, road maintenance costs are excessive. Gravelling alone costs approximately R441 480 per annum. It was stated that regravelling costs could be reduced by 80% if existing roads were redesigned, and new roads were correctly built with good quality road materials and the

necessary degree of drainage structures and compaction. It was suggested that costs of such operations could be recovered in about nine to ten years.

The above strategy, involving long-term planning, would be of benefit to the forestry department and to the environment. However, present economic constraints are likely to postpone any significant upgrading to some time in the future.

Firebreaks

Firebreaks should follow contours and water divides as far as possible, and when SMZs have to be crossed, firebreaks should go straight in and straight out of streams. Roads should be used as firebreaks where possible. If possible, some of the riparian vegetation, which grows on the wetter parts of river banks and which rarely burns, should be preserved. If signs of surface runoff are seen on tracer belts, they should be equipped with water bars (at intervals of ± 30 m) to throw surface water off the trace. (A water bar is a non-trafficable drainage structure installed to turn the water.)

Clearfelling

Recommendations for avoiding compaction, soil disturbance and erosion during logging operations are presented in soil science lectures at the Saasveld College for Foresters. These recommendations are reproduced in Appendix **3 E**.

The most important of the recommendations is that any clearfelling operation be preplanned, so that appropriate action can be taken to avoid disturbance of sensitive areas such as water channels.

Up until the present, the degree of preplanning felling activities has varied. In the last 3 - 5 years Karatara foresters have been instructed to preplan a felling operation as regards costs, method, logging route and machinery used. Each compartment must have a work file. At Bergplaas, a standard form has to be completed, giving details of equipment to be used, direction of felling, volume available as saw timber and its distribution and yield, roads and costs (see appendix **3 F**). In addition, a sketch of the compartment must be made giving visual details. If these forms are regularly and accurately completed they should provide some records for future research. Missing from these forms is any information on soil types or sensitivity, signs of erosion, compaction or other factors which might be detrimental to long-term productivity. These forms should act as a source of information for all levels of personnel involved in the clearfelling operation.

The clearfelling plan is largely the responsibility of the plantation forester (trained at Saasveld in most cases). . District Forest Officers make occasional spot checks on clearfelling operations. The work itself is carried out by a foreman and his team of labourers. The foreman receives his instructions on a daily basis from the plantation forester. The foreman receives in-service training as well as some training at the Concordia training centre. His training is largely practical, for example, how to operate and service his machinery.

When instructed about clearfelling operations, emphasis is laid on maximum productivity at minimum cost.

Responsibility for ensuring use of appropriate methods for the existing environmental conditions falls to the plantation forester in conjunction with the District Forest Officer. Is he concerned about long-term productivity and resource and environmental preservation? From what could be assessed, the answer to this question is yes - but he is far more concerned with the important task of meeting production deadlines and any delays inevitably cost money. In addition he demands proof that presently used methods may have long-term detrimental effects in the plantation under his control. Unfortunately, it often takes several years for such proof to be established. For example, variations in tree growth due to compaction may take up to four years to show in thinnings (Grey 1985).

The solution must lie in two directions, namely, research into the sensitivity of individual plantations to clearfelling operations, and education of all persons connected with the clearfelling operation, including the machinery operators.

These solutions are being initiated to some extent by the Saasveld Forestry Research Centre. Mr D.C. Grey's research involves preparing reports which give specific hazard ratings to specific areas (based on information derived from climatic patterns, soils, geology, topography). In addition, harvesting is scheduled appropriately. In effect, a land-planning package will be produced.

This research is currently being carried out in the Tsitsikamma forests and, unfortunately, the information is not applicable to the study area. Some of the information may be extrapolated to parts of the Karatara area by about 1987. It is unlikely that any significant work will be done in this study area until or beyond 1990 (pers. comm. D.C. Grey). It is unlikely that any changes will occur before this date. The present economic recession also slows progress.

One questions whether any changes are required in clearfelling techniques in the study area. This question could form the basis for an entire thesis and cannot be answered within the limits of this study. The general opinion of the foresters themselves was that there were no significant compaction problems in the study area and that skid trails rarely eroded or compacted. This opinion is not entirely supported by the professional managers. Occasional erosion was seen to occur but on a small and temporary scale under 1984 rainfall conditions. One must bear in mind that the general image of erosion is one of dongas and gullies on devegetated land. This type of erosion rarely occurs in the study area. Erosion and its concomitant sediment-laden runoff is of a subtler nature and often not visible unless one is looking for it.

The limited personal observation that was possible suggested that the potential for erosion exists for a period of about 6 months after felling and that it can be intensified by slip-paths and roads. However, it would take a considerable amount of rain (probably over 80 - 100 mm in 1 - 2 days) before water quality would be significantly affected. After

rain, cleared slopes did show water channels developing, which pushed remaining needle litter aside on their paths downslope. Very often, however, the path of the water was slowed or deflected by a leftover log or other vegetation and thus did not reach the watercourse at the base of the slope. The importance of leaving some heavier material behind, lying across the slope, and the importance of a barrier zone at the watercourse itself is emphasised. Material left behind does not need to be so big or in such quantity as to threaten seedlings. Waste logs strategically placed can, in fact, prevent channels from forming below seedlings and have a protective role. Care must be taken that remaining material does not concentrate water into channels.

It was suggested that it might be possible to thin rather than clear-fell sensitive water channel areas. Pine and Eucalyptus trees do have supportive root systems. Gradual thinning and removal of trees in these areas may be preferable to instantaneous and complete clearfelling. This more gradual process would allow reestablishment of natural vegetation to act as a barrier against erosion. Some of the thinned material could be left on the banks of the watercourse to act as temporary buffer material. This suggestion was rejected as being impractical. It was stated that it was uneconomical to return to a compartment a second time, the best trees often grew on watercourse banks, and it went against the foresters' sense of orderliness.

Large compartments, with many small intermittent streams leading into a perennial stream, are particularly vulnerable when being clearfelled. Although the effect of disturbance of one intermittent stream may have

little effect on sediment loads, the combined effect of sedimentation from several intermittent streams after a storm event may have significant effect on sediment loads of the perennial stream. Once again, whether sediment from the perennial stream ever reached the main branch of the river concerned and Swartvlei would depend much on downstream vegetation and water velocity. Having identified some of the problem areas, one may consider what legislation is applicable.

5.2.7 The Forest Act No. 122 of 1984

The 1984 Forest Act aims 'to provide for the protection, management and utilisation of forests; the protection of certain plant and animal life; the regulation of the trade in forest produce; the prevention and combating of veld, forest and mountain fires; the control and management of a national hiking way system and national botanic gardens; and matters connected therewith'.

Section 88 states that the provisions of this Act apply in addition to, and not in substitution for, the provisions of any other law which are not in conflict with or inconsistent with the provisions of this Act. The Act is applicable to State forests and also to private forests upon the written request of the owner.

Sections 7 and 8 cover the topics of the use of land for afforestation and protection of natural water resources. Section 7(1) states that 'without the prior written approval of the Director-General no land, including land in the possession of the State -

- a) which has not been used previously for the establishment and management of a commercial timber plantation; or
- b) which for a period of more than five years after the removal, harvesting or destruction of a commercial timber crop, has not been so used, may be used for the planting of trees to produce timber for commercial or industrial purposes.'

The provisions of this section should prevent uncontrolled afforestation.

Of greater relevance is Section 8 which states that

1. 'The Minister may in respect of land which in terms of this Act is being or may be used for the planting of trees to produce timber, by notice served on the owner of that land or by notice in the Gazette, prohibit the planting of trees within an area defined in the notice or the reafforestation of such an area after the harvesting or destruction of a timber crop or prohibit any other act or direct the owner to take any other steps which in the opinion of the Minister are necessary for the protection of any natural water source.'
2. 'An owner of land shall not permit the regeneration of a commercial timber plantation on any part of his land in respect of which a notice in terms of subsection (1) applies, after an existing timber crop has been harvested or destroyed.'

The implications of this wide-ranging and fairly general statement are not spelt out. For example, does protection of the natural water source

also imply protection of the water quality of that water source? Also, are all natural watercourses, including those which flow intermittently, included under the term 'natural water source'? What is clear is that the Minister of Environment Affairs and Fisheries has considerable powers to protect water source areas. It should be noted that in Part XI, section 75, it is stated that any person who

- i) contravenes a provision of Section 7(1) or 8(2)
- ii) fails to comply with a condition imposed under Section 7(2) or 7(3)
- iii) contravenes a prohibition in terms of a notice under Section 8(1) or fails to comply with a direction under the said section,

is guilty of an offence.

In this Section, there is no mention of prevention of excessive soil loss or erosion. Part X, Section 73 of the Act does, however, empower the Minister to make regulations on a wide variety of issues and activities. In particular, subsection (1) (a) (xiv) states that the Minister may make regulations with regard to State forests in general or a particular State forest or a part thereof relating to 'a prohibition for specified periods on the grazing of stock, or the cutting or taking of forest produce in, or the removal of forest produce from, any defined area for the purpose of regenerating a forest or of conserving forest produce or pasturage, or for the prevention of soil erosion or sand drift, or for the reclamation of soil or drift sand.'

Regulations under subsection (1) may provide for penalties for any contravention of, or any failure to comply with, its provisions not exceeding the penalties prescribed by Section 75(2). Sections 8 and 73 of this Act appear to be the most relevant as regards water source areas and erosion, but there appears to be no legislation applicable to general management of watercourses/riparian zones on an equivalent level to that provided in the Conservation of Agricultural Resources Act. Considerable leeway is given by the Forest Act and whether any forestry activities or utilisation of State forest areas will contribute to accelerated runoff and sediment loss will depend much on the 'conditions the Director-General deems fit'. Activities such as mining, grazing, clearing, ploughing or cultivation of land require authorisation from the director-general who issues a permit on such 'conditions'. Whether the 'conditions' will

- i) make provision for prevention of damage (particularly in watercourse zones) and
 - ii) restoration of damage (particularly in the case of mining)
- and whether the conditions will be adhered to, cannot be predicted at present.

According to J. Bosch (1985, pers. comm.) at the Jonkershoek Forestry Station, research is being carried out to formulate a model for determining management patterns in riparian zones. These management patterns (including possible use of a buffer zone of appropriate width) will be flexible and adapted to the environmental conditions of the catchment concerned. Research on this model is likely to continue for another 2 years. An interim model has been formulated but needs

refinement. This model will first be used only for new areas becoming afforested. Later it will be applied to areas already afforested. This model should in future provide guidance on management of riparian zones. It is possible that some changes to the 1984 Forest Act will become necessary when the model becomes practically applicable.

5.3 SUMMARY AND CONCLUSIONS

- Streamside management zones are extremely important for buffering erosion.
- There is no single source of sediment from the plantation areas. Most visible sources are the Diep-Wolwe river road, side drains and those streams with relatively steep banks and little to no vegetation apart from pine trees or invasive species.
- Specific research in the study area itself under differing climatic conditions and varying intensities and extent of forestry operations will become necessary, to establish whether any increased sediment loads are significantly affecting downstream water quality and for what period.
- Present (1984) levels of sediment contribution from forested areas is low. Increased levels are of a temporary nature. This is due to low rainfall and the relatively large proportion of the study area which is under established plantation. Potential for increased sediment contribution may increase as areas are clearfelled in the near future. Intensity of clearfelling

activities does fluctuate. The total area clearfelled in a year should not on its own result in massive increases in sediment loss, but together with sediment loss from other areas such as roads and drains, could determine the difference between low and high water quality in high rainfall conditions.

- Almost all potential increased sediment load could be decreased through well-planned clearfelling programmes and techniques and the use of buffer zones. Some consideration should be given to the area and time period over which a single river system is cleared. Greater attention should be paid to the proximity of afforested intermittent watercourses to perennial streams which transport sediment, and the potential for accelerated erosion.
- The directives for improved plantation management exist. Such directives would ensure long-term productivity and improved environmental quality. What remains to be done is practical application of these directives. Several changes may have to take place before practical steps are taken, namely:
 - Increased education and awareness of all personnel, particularly those involved directly in the plantations.
 - There should be greater feedback between researchers and foresters. Research results must be clearly and regularly communicated to the foresters.
 - An upswing in the economy, with a greater proportion of funds being allocated towards conservation of environmental resources, so ensuring long-term productivity.

CHAPTER 6

THE AGRICULTURAL AREA

Agricultural activities occur on the Tertiary plateau, with the largest proportion occurring south of Main Road number 14. A few farms extend north of the road, south of the area under plantations in the upper plateau and Outeniqua foothill region.

6.1 TERTIARY PLATEAU ZONE CHARACTERISTICS

6.1.1 Topography

Most farms are situated on the level or gently undulating portions of the plateau. The plateau is dissected by the four main rivers of the study area and their tributaries. The drainage system has a moderately dense open dendritic pattern. The bottomlands are narrow, widening prior to entering Swartvlei. Slopes are generally convex, and steep downcutting by the rivers for 60 - 100 m has taken place (Schafer 1980, and general observation in field and map interpretation).

6.1.2 Rainfall

As in the upper catchment and foothills areas, rainfall varies according to situation and rainshadow effects. Between 600 to 800 mm of rain occurs annually in this zone (Daily rainfall data, Weather Bureau, Pretoria).

6.1.3 Geology

The plateau area is made up of bands of pre-Cape rock, comprising various members of the Kaaiman's formation of Namibian age. Members found include Sandkraal, Skaapkop, Soetkraal, Victoria Bay and Homtini (see Fig. 6.1). Lithologically they consist of contorted bands of schist phyllites, feldspathic quartzites and schists. Within these series there are outcrops of intrusive gneissic granite and granodiorite (Hughes & Görgens 1981 and Geological Survey Map 1979. 1:250 000 Geol. Series 3322 Oudtshoorn).

The Homtini phyllites found in the Karatara river area consist of fine-grained slates, shales and phyllites with occasional thin intercalated bands of arenaceous material. They are usually a greenish-grey colour when fresh and weather to a pale grey clay.

The phyllites consist mostly of a fine-grained quartz and white mica.

Relatively coarse-grained Victoria Bay feldspathic quartzites occur in parts of the Hoëkraal, Karatara and Barrington areas. The feldspar usually weathers white, giving the rock a speckled surface. The

feldspar occurs in the form of microcline with plagioclase as an accessory mineral.

6.1.4 Soils on the Tertiary Plateau

Most of the tertiary plateau is covered by fluvial and aeolian deposits. The duplex nature of the soils gives rise to a typical Estcourt form soil. Wetter sites, down-slopes and depressions contain Kroonstad form soils. Sterkspruit and Swartland occur where the duplex nature of the soil is not so prominent and an 'E' development is minimal - usually on mid or lower slopes. These duplex soils have a calcium/magnesium imbalance in the B horizon (Schafer 1980).

A typical Estcourt profile shows apedal, friable, permeable loamy sands in the A horizon, changing to moderately permeable, firm sandy clay loams in the B1 horizon and, finally, in the B21 horizon there is a change to a strong, coarse, prismatic hard clay with slow permeability. The Barrington soil profile (see Appendix 4A) gives the characteristics (see Fig. 6.2 for location).

The clays are usually fine sandy clays or silty clays (up to 60% clay). These clay mantles cap the plateau and are found on the level to gently sloping top slopes. The deposits appear deepest towards the foothills of the Outeniqua mountains, tapering off southwards. Their distribution pattern is irregular. The clays rest unconformably on either fluvial deposits or on bedrock.

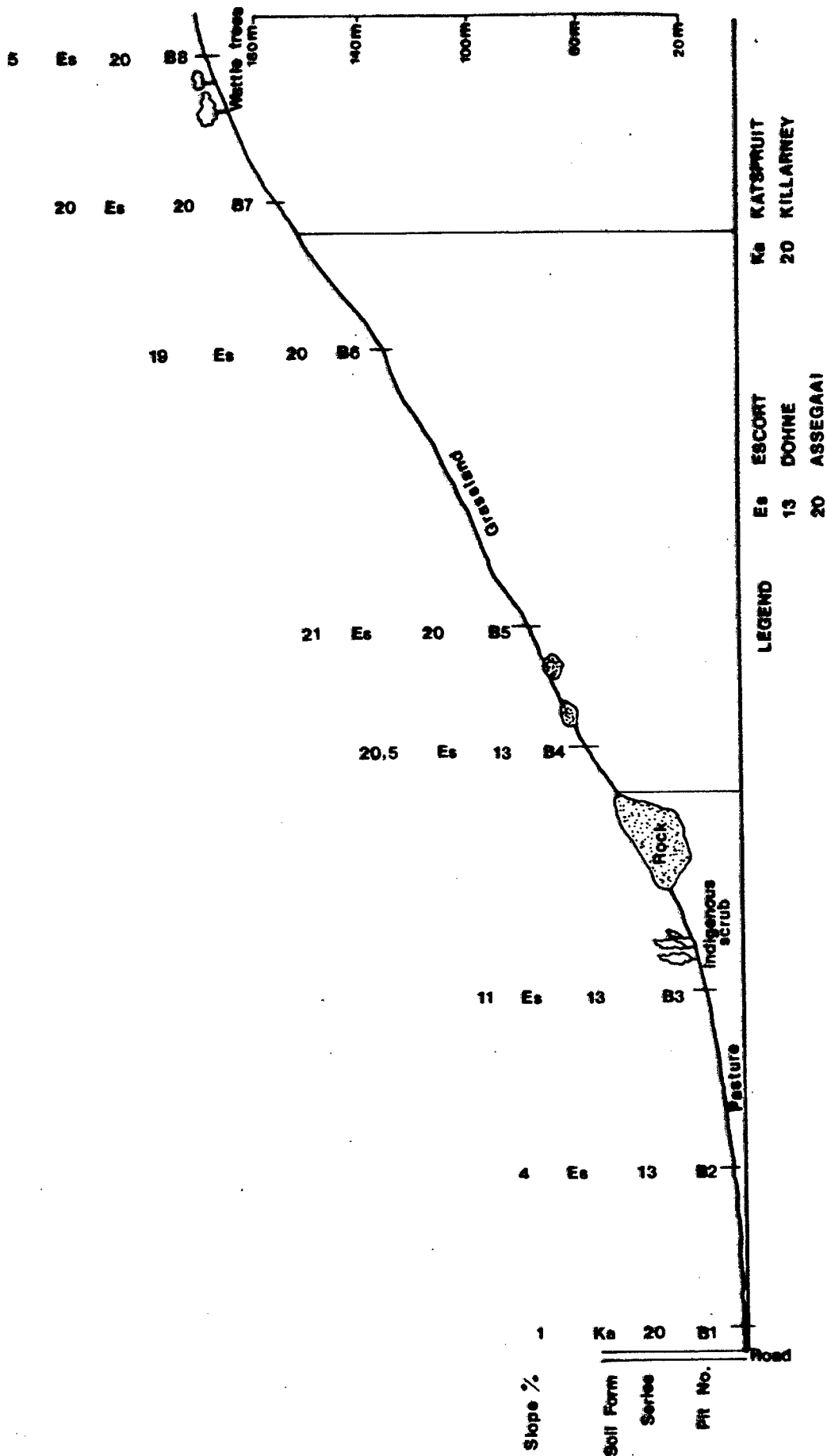


Fig 6.3 PROFILE TRANSECT B
(Thompson, 1983)

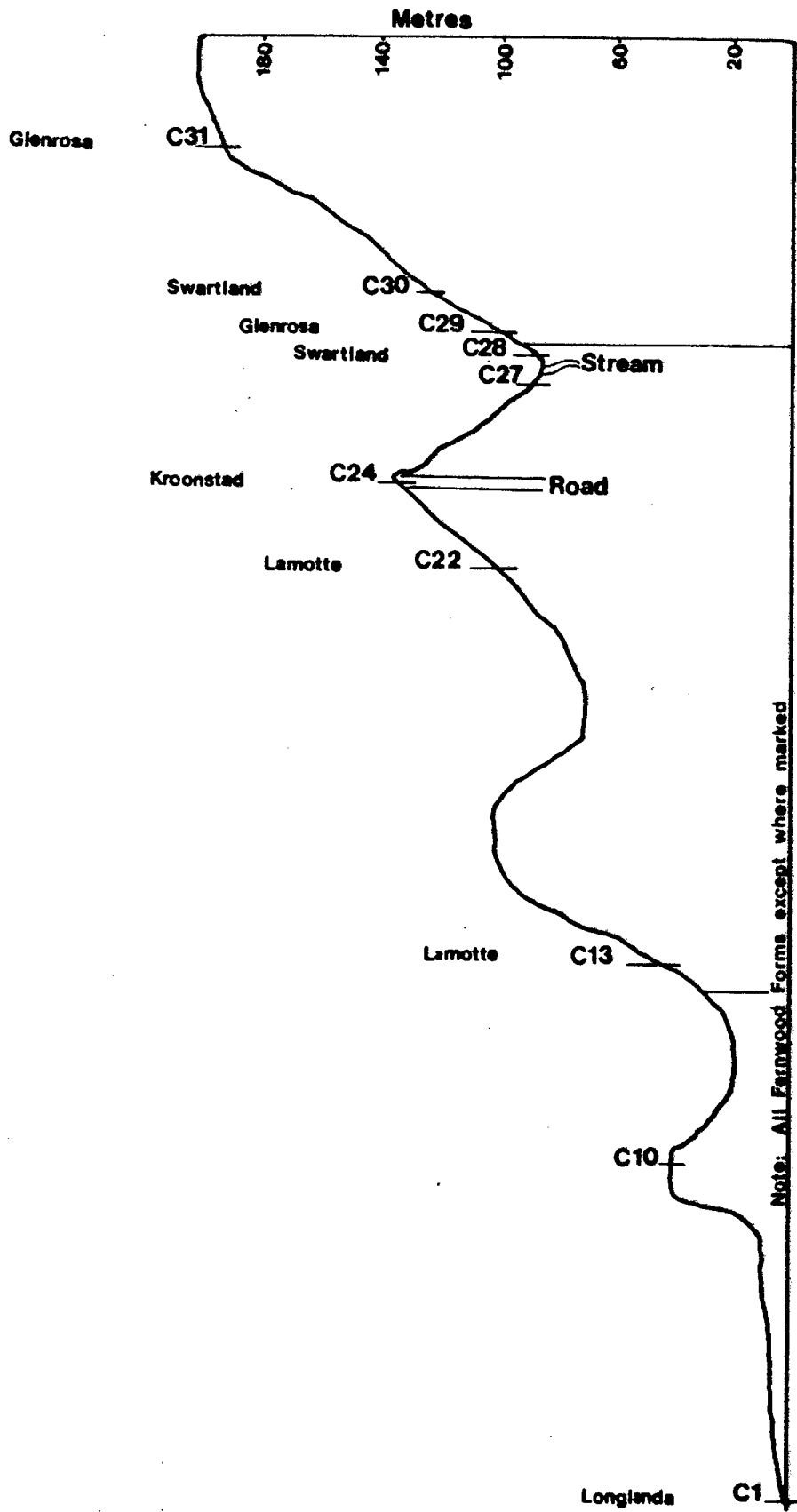


Fig 6.4 PROFILE TRANSECT C
(Thompson, 1983)

J.L. Thompson (1983) of the Saasveld Research Centre studied transects further south. Thompson's B transect showed the following soils (refer to Fig 6.3 - 6.4). From the top of the even slope in Fig. 6.3 all pits showed an Assegaai series of the Estcourt form in the upper midslope and topslope positions of pits B8, B7, B6 and B5. The lower mid and foot-slopes showed Estcourt form but of the Dohne series, having a higher clay content. The sand fraction was fine throughout the transect. Gravel occurred at pits B8 and B7 in the bottom of the pits, indicating in situ weathering of the Cape Granite. The midslope position was of a colluvial nature, and a light occurrence of gravel appeared in the bottom of pit B6.

A Katspruit form occurs in the bottomland position at pit B1. To the left of pit B3, facing uphill 50 m away, the remains of a relic sand dune are found, probably of aeolian origin. These relic dunes show Fernwood forms.

Thompson's transect C consisted of a steep slope down from the 200 m contour through material of the Kaaimans formation at pits C31 and C29, with an underlying parent material of shales. Two Swartland soil forms occur at pits C30 and C28. Aeolian sand dunes have formed up against and covered the Kaaimans formation as a consequence of the receding sea. This has occurred in two steps, creating an old aeolian and a younger aeolian dune. The soil of the older aeolian dunes was of Kroonstad Form at pit C24 and two Lamotte Forms on the steep southerly aspect in the midslope position at pits C22 and C13. The podzolic horizon is strongly coloured. The rest of the soil forms are Fernwoods of a fine sandy nature. The Longlands Form appears in the lower bottomland position at

pit C, having a definite E horizon and a sandy, gleyed, soft plinthic B horizon.

6.2 AGRICULTURAL CHARACTERISTICS, EROSION HAZARDS AND WATER QUALITY

Information for this section of the study was obtained by interviewing the farmers whose properties fall within the study area. The type of questions that were asked can be seen in Appendix 4B. The questions were adhered to in a fairly strict manner, but where additional information was volunteered or seemed necessary, this was noted. Information was also obtained from 1:50 000 topographical maps of the area, 1:10 000 Orthophotos and 1:30 000 aerial photographs (1980). Several flights over the study area supplemented map information. A reasonably detailed collection of information for most of the farms was obtained, but the information presented here will be of a generalised nature. (Note: not all the property-owners were able to answer all questions with complete certainty and in some cases, estimates were made of areas of pastures and number of livestock. Their estimates were checked as far as possible by ground observation and study of maps of the area.) Additional information was obtained from people connected with agriculture, such as extension officers, pesticide and weedicide distributors, and research personnel.

The farms in the area have been delineated on Fig. 6.5. Reference to the farms in the text will be according to each farm's allotted number. In addition, the farms have been grouped together into four subsections.

Each subsection is made up of farms which border on or are near one of the river systems under discussion, i.e. the Diep-Wolwe, the Klein Wolwe, the Hoëkraal and the Karatara. In some cases, farms fall into two river systems. In these cases, the farm has been placed into the river system which appears to cover the greater surface area of the property.

A limited degree of forestry also occurs in this section. These areas will be dealt with separately. Questions for foresters can be seen in Appendix **3B**.

First, some general idea of the total area under agriculture. In 1984 there is an estimated 7280 ha of land being farmed between the Diep-Wolwe and Karatara rivers (excluding the areas under forestry and numerous smallholdings used largely for recreational purposes). The farming may be described as mixed farming with pastures (planted and natural) forming the basis of the industry. While many farmers concentrate on pastures and dairy alone, others have diversified, in varying degrees and combinations, into pastures, vegetables, dairy, beef, sheep and pig farming. Further details will be given in each subsection. The subsections will give factual details on topics such as

- size of farms and area being cultivated,
- pastures and livestock and seasonal activities,
- use of machinery,
- changes in type of farming in the last 20 years,
- water sources and storage,
- use of fertilisers, herbicides and pesticides,
- soil type and depth.

pine trees has been occurring since mid-1984 and is likely to continue until the end of 1985. Approximately 50 ha of pine trees will remain.

c) Seasons

Preparation of fields, planting and harvesting occur throughout the year, with mid-July to mid-September being a relatively quiet period. This applies throughout the study area.

d) Livestock numbers (head)

Sheep: 1146 (will increase to about 1646 in next 2 - 3 years)

Cattle (mixed dairy and beef): 697 (at least 66 - 70% dairy)

e) Implements

Implements used for cultivation include tractors, plus mouldboard plough, disc, harrow, tiller and, to a lesser extent, rippers and subsoilers. All but two farmers are cultivating soils. On the vegetable farm in the area an instrument for making seed and seedling beds is used. The profile of the bed would be as in Fig. 6.6. Of the farmers who do plough and cultivate fields, 80% use the mouldboard plough, i.e. one which turns the soil.

f) Changes in type of farming and farms coming into production in the last 20 years (1964-1985)

An estimated 518 ha of land has come under production since 1965. This is on areas which were previously under a mixture of fynbos, pine trees

The above information will be used to assess erosion hazard and water quality in the area concerned.

6.2.1 The Diep-Wolwe River Area

6.2.1.1 Agricultural Characteristics:

a) Farms

The farms in this area have been numbered from 1 to 18. (Note: this does not signify 18 property-owners, as, in some cases, landowners hire or buy property apart from their own. In some cases, farms belonging to a single property-owner have been given two different numbers.)

The total agricultural area is 1528,6 ha. Of this, approximately 801 - 948 ha (52% - 62%) is being cultivated, i.e. ploughed or worked with tine implements. The rest of the area (580 - 727,6 ha) is either riverine bush or grassland which is used for grazing but not planted to pastures or other crops. Riverine bush makes up an estimated 16 - 18% of the area (118 ha) whereas grassland available for rough grazing covers about 82 - 84% of the area (476,1 ha).

b) Crops and pastures

These are as follows

Mixed vegetables: (including peas, broccoli, potatoes, cauliflower, sweetcorn, beetroot, beans, carrots, pumpkins) 202,5 ha.

Maize: 10 - 30 ha (the area under maize has increased in 1985)

Wheat: 199 - 254 ha

Pastures: 437 ha permanent and annual. Approximately 25 - 30% are semi-permanent or permanent pastures. (Note: the area under specified individual and mixed pastures is known but is not presented here as the combinations and area of certain pastures vary according to climatic conditions and other influencing factors.) Typical pastures planted are as follows:

Cocksfoot (Dactylis glomerata)

Tall fescue (Festuca arundinaceae) (perennial)

Italian Rye grass (Lolium multiflorum) (annual) and (Lolium Perenne) (perennial)

Midmar Rye grass

Kikuyu (Pennisetum clandestinum)

Lucerne (Medicago sativa)

Serradella (Ornithopus compressus)

Sainfoin (Onobrychis sativa)

Oats (Avena fatua)

Babala - Tennisetum americanum

Superdan Sorghum

Clovers (Trifolium sp.)

Trefoil (Trifolium sp.)

The area under pasture will increase as small stands of pine trees on the farms are being felled at present. Approximately another 115 - 130 ha of pastures will be planted within the 1985-86 period. Clearfelling of



Scale: 1cm = 0.5m

Fig 6-6 Cross section of Soil Bed

and various grasses which grow in the area when the bush is removed. Of the 518 ha, 222 ha have been cleared since 1974 and 80 ha since 1980. This has occurred on farms numbered 14 (1974), 7 (1967), 10 (1965), 6 (1981), 17 (1974), 18 (1980), and 13 (1974). A greater area is coming under cultivation due to the clearfelling of pine trees.

The only major change in farming type has been from vegetable to pasture farming on 50 ha of land in 1981/82. This occurred after the 1981 high rainfall period on farm number 10.

g) Water sources and storage

Most water is stored in kloof or earth dams. Kloof dams refer to those constructed on a tributary of one of the rivers, whereas earth dams refer to those constructed in a dip or other appropriate place on the farm. There are approximately 20 kloof and 15 earth dams in the area. Farms numbers 7, 10, and 15 have irrigation and farms numbers 10 and 1 have boreholes. Due to the steep gradient and deeply incised river courses, pumping water from the main rivers or larger tributaries is uneconomical. Most farmers rely on the smaller tributaries which pass through their farms, or on rainwater.

h) Soil type and depth

Soils vary from the deep sandy soils at farms 1 and 2 to sandy loams and clay loams on the plateau. Depth varies from 22 - 30 cm but is deeper on the slopes (38 - 50 cm) (see soil description p 120).

i) Use of fertilisers, herbicides and pesticides

Fertilisers:

Various fertilisers are used when establishing pastures and on all vegetable, wheat and maize crops. Quantities applied vary, but about 150 to 350 kg per hectare (per annum) is applied for pasture establishment. Certain vegetables require much greater amounts, for example, potatoes, 1450 kg per crop, and cabbages and cauliflower, 760 kg per crop. The largest quantities of fertiliser are used on the vegetable farm, number 7. About 86% of the farmers use fertilisers.

Herbicides:

Herbicides are used on both broadleaf and grass-type weeds. Commonly occurring plants regarded as weeds are:

'Ramnas' (Wild Radish) - Raphanua raphanistrum (European)

Wild Mustard - Sisymbrium thellingii (indigenous)

Cape Marigold - Arctotheca calendula (indigenous)

'Sprinkaan senecio' - Senecio ilicifolius (indigenous)

'Dissels' (Scotch thistle) - Cirsium vulgare

Dense-thorned bitter apple - Solanum sisymbriifolium (American)

'Oond bas' - Conyza podocephala (indigenous)

'Dubbeltjies' (Spiny emex) - Emex australis

'Olieboom' (Spiny Cockle Bur) - Xanthium spinosum (American) or

(Large Cockle Bur) - Xanthium strumarium (American)

and various types of ferns (Gleichenia spp.)

(Henderson 1966).

Pesticides:

Pesticides are used mainly on vegetable crops and on wheat and maize.

Common pesticides used are:

Orthomonitor

Sumicidin

Dithane (fungicide) and Sumisclex (fungicide)

Parathion or Malathion or Bexadust

Metasystox

Roxion - this is also used on pastures such as Lucerne for
protection against sand mites

Monocrotofos

Agrisulfan

Lannate

Various combinations of these pesticides are used on farms Nos. 7, 2, 4, 13, 14, 10 in the past and 1. Various dips for livestock are used, for example, Disnis or Bacdip.

6.2.1.2 The Diep-Wolwe River: Erosion Hazard and Water Quality:

There are several factors which determine whether water quality will be affected by agricultural activities. Firstly, the natural factors, such as climate, soil types, slope and topography, and secondly, factors determined by man's perceptions, decisions and activities. Observations in the Diep-Wolwe river area indicate that the following factors are important:

- the position of the farm, particularly in relation to watercourses;
- the area being cultivated and intensity, frequency and method of cultivation;
- the type of crops cultivated;
- dams and irrigation practices;
- livestock, in relation to control of movement, and carrying capacity;
- establishment of anti-erosion structures and techniques;
- use of herbicides, pesticides and fertilisers;
- riparian vegetation and proximity of cultivated and utilised farm land to riparian zones.

These factors will be discussed as set out above but, as many of the factors are interrelated and mutually influential, specific headings will not be adhered to.

All the farms in this area (Nos. 1 - 18) are traversed by either the main Diep-Wolwe river, or its many tributaries. As the main river progresses across the plateau and down towards Swartvlei, it becomes deeply incised and its steep banks are thickly covered in indigenous forest (and invasives such as Eucalyptus and Acacia spp.). The farms are situated on the upper gentler slopes of the plateau. Where the farms border steep forested slopes (such as the eastern borders of farms Nos. 4 and 6) there is no danger of any agricultural activities affecting water quality, even though erosion might occur. In contrast the tributaries are readily affected. Some of the tributaries originate in the vicinity of farms Nos. 3, 10, 7, 11, 12 and 18. These tributaries are incising slopes which are cultivable yet steep in places. Cultivation takes

place close to the banks of the watercourses. Where these banks are not cultivated they are used for grazing purposes. In addition, these tributaries contribute substantial sediment loads to the river as, in some cases, they have not yet incised down to bedrock level - in this case Granite. They are cutting across erodable duplex soils. The flow of the main Diep-Wolwe river, in contrast, is slowed by large deep pools bordered by granite rock outcrops. It is clear that considerable amounts of sediment settle in these pools.

Sediment loads, at the points marked 1 and 1a on Fig. 6.2 were consistently high even though flow rates were extremely slow. Table 6.1 gives the sediment loads on three different occasions.

TABLE 6.1 Sediment loads: Diep-Wolwe River

Raindays	1 day		1 day
Rainfall	8 - 13 mm	NIL	Samples taken immediately after rain ceases 28 - 28 mm
Date	25.3.84	3.4.84	13.6.84
Unit	mg/l GF/F	mg/l GF/F	mg/l GF/F
Sample site			
Point 1 on Fig. 6.2 Southern corner of Property 8 (tributary)	57,2	66,6	755
Dam site, Point 2 Further downstream on same tributary	77,5	-	-
Diep-Wolwe River Point 3	4,5	-	-

The readings show that:

- Sediment loads of this tributary are high, even during dry periods. The loads increase dramatically with only 20 - 28 mm of rain and immediate sample-taking (i.e. no settling period permitted).
- The main stream of the Diep-Wolwe river, at the sampling time, was unaffected by the sediment loads of the tributary. This is because the amount of rain (8 - 13 mm) was insufficient to bring enough sediment-laden water into the river to affect its turbidity. In addition, sediment-laden water was being trapped downstream at a newly constructed dam at point 2. It is possible that the sample of point 3 was taken too soon after the rain. A sample taken later in the day further downstream, at point *d on Fig. 6.2 gave a slightly increased sediment load of 10,8 mg/l. The degree of dilution and settling therefore prevents any serious effect on water turbidity in the mainstream. This is not the case with higher rainfalls over a longer period. For example, on 23 July 1984, after 50 - 55 mm of rain over 3 days, sediment loads at the same site (*d) rose to 30,9 mg/l. This is not an exceptionally high reading, but it is sufficient to visibly affect the clarity of the water.

This tributary's sediment loads (Points 1 and 2) are not likely to decrease in future as its banks are being intensively cultivated for vegetable farming. Under low rainfall conditions there are no serious sedimentation problems, but high rainfalls (35 - 60 mm) saturate the topsoil and there is considerable runoff which has high nutrient and

sediment levels. Presumably pesticide and herbicide levels would be high as well, but this has not been measured. There are at least 110 ha of land from which fertiliser, herbicide and pesticide- laden runoff will originate and have access to the tributary. By referring to the available application levels given in Appendix 4C one may obtain some idea of possible pesticide and herbicide levels in the water, although these levels will fluctuate with rainfall and runoff volumes, type of crop and extent thereof, type of herbicides and pesticides applied, soils, slope, cultivation techniques and riparian vegetation and many other factors.

Sediment levels in the tributary were also increased by dam construction activities at point 2. Bulldozer activity destabilised the tributary's banks and vegetation (indigenous and exotic) was unavoidably destroyed. The access road to the dam runs downhill into the water and, during high rainfalls, runoff from the road has direct access to the tributary. The dam has filled to some extent so some disturbed areas are being drowned. As vegetation becomes reestablished on the banks the area should stabilise to some extent. Unfortunately, it is mostly Acacias and a few pines that establish themselves in these conditions. Dam building and enlargement on this tributary have been occurring since about 1976/77 and the eroding embankments of the dams ensure the constantly high sediment levels of the water. The duplex soils with dispersive clays cannot resist even minor rainfalls when completely exposed. The recently built (1980/81) dam at point 1a is a typical example. The banks have become so deeply gullied that there is no chance of their becoming revegetated. The older dams upstream are not so seriously eroded and some grass has grown on their uncut banks. However, the

width of uncultivated area is insufficient to prevent runoff from adjoining lands entering the water. The natural filtering action of grassed 'greenways' has been shown to be effective (see Section 5.2.6) but the grassed area here is too small to act as a greenway.

Irrigation of duplex soils has to be carefully controlled. If the topsoil is permitted to become too wet, infiltration is reduced and excess water runs downslope.

Another detrimental factor is that the tributary is not fenced in any manner from livestock. Remaining vegetable matter is grazed and animals can trample paths and muddy waterholes. However, this problem is not so serious here as in some other tributaries, as the livestock are here for a limited period only.

It is difficult to assess whether the livestock-carrying capacity of the area is being exceeded. This is because the area available for grazing fluctuates with climatic conditions and seasons. Some pastures cannot be grazed after rain due to risk of trampling. The carrying-capacity for dryland pastures was estimated to be 2 large stock units per ha. or 15 small stock units per ha for a limited period only.

(Outeniqua Experimental Agricultural Station, George)

The removal of pine plantations on farms 8, 6 and 4 has led to temporarily devegetated slopes. The pines were planted down to water level and have been removed to within 0,5 - 5 m of the watercourse. If permanent pastures (such as Kikuyu) are planted in these areas, runoff

erosion will be prevented but the slopes will still be vulnerable to land slips if overgrazed or subjected to very high rainfalls which saturate the topsoil. The absence of a barrier zone along the tributary (5 - 10 m of undisturbed indigenous riparian vegetation) makes this area permanently subject to erosion and landslips.

Further problems can be caused by cultivation techniques. Cultivation of duplex soils involves some risks. The plateau soils in this area are sandy loams to clay loams, underlain by a clay layer. This clay layer varies in position and in places the topsoil is shallow. These clays have a strong structure and their high sodium and magnesium content makes them dispersive and erodable.

As stated earlier, 80% of the farmers are using the mouldboard plough for pasture establishment. This plough turns the soil over. It buries plant residues and, in addition, if the clay layer is disturbed and clay is brought to the surface, it can eventually reduce the soil's permeability through partial or complete crust formation. The farmers in the area do not adjust their ploughing depth to avoid this occurrence. It would be an almost impossible task due to the vastly and rapidly fluctuating clay depth. Tine implements which cut through the clay layer can also be damaging but not to the same degree as the mouldboard plough.

Another problem associated with the use of the mouldboard plough is compaction. This plough has three compacting actions. A plough pan or compacted layer is formed which reduces water infiltration and may

inhibit plant growth. After ploughing, considerable discing and harrowing has to be done to break up the soil sufficiently for seeding. The repeated pressure of tractor tyres also causes compaction. The answer would seem to lie in the establishment of semi-permanent and permanent pastures. Semi-permanent here refers to pastures which last for 3 to 6 years before needing reworking and reseeding. Permanent pastures refers to grasses such as Kikuyu which can last considerably longer if necessary. One of the arguments, expressed by farmers, against semi-permanent pastures, was that the clay loam soil was too hard for such pastures unless it was regularly ploughed. Unfortunately, it is this ploughing process which intensifies the problem in the long-term time scale.

An extension officer, based at the Outeniqua experimental farm, felt that semi-permanent and permanent pastures should not lead to compacted soil unless livestock-carrying capacity was exceeded. If overstocking did result in a hardened surface layer, this could be ripped to loosen it again. This suggestion seems reasonable and should prolong productivity, reduce costs and prevent soil from becoming increasingly impermeable and compacted. The benefits as regards erosion, runoff and sedimentation would be unquestionable. Ploughing frequency could be reduced from twice a year to once every three to five years. Only 3 - 4 farmers in this area expressed any intention to increase areas under semi-permanent and permanent pastures.

It is not suggested that entire farms be placed under semi-permanent or permanent pastures. Permanent pastures must be present on all

slopes above watercourses and the rest of the farm's pasture types can be planned according to soil, slope, clay depth and occurrence. An extension officer at Outeniqua experimental farm recommended that 25% of the farm be Rye grass (annual), 25% Kikuyu, and 50% either grass/clover or Lucerne/grass mixtures on a four-year rotation. The grass/clover mixture does, however, require irrigation, a facility not available on most of these farms. Individual assessment of each farm would be necessary.

Some research has been done on runoff and erosion as affected by various tillage practices (Mallet et al. 1981), but none has been done on the type of soils or climatic conditions of the study area. Studies at Cedara (Hutton form, Doveton series soil) showed that

- practices that left plant residue on the surface, such as ripping and no-tillage, proved the most effective in capturing applied moisture;
- the mouldboard plough, which buried plant residues, was the least effective;
- precipitation capture effectiveness proved dependent on percentage cover;
- soil loss was closely related to the runoff volume.

A considerable amount has been written about the method of minimum tillage (Borland, ¹⁹⁸⁰Snyman, 1982..). Minimum tillage has considerable advantages as regards erosion, runoff, compaction and wind erosion.

Details will not be discussed here, but it has been generally agreed that the advantages of such a method outweigh the disadvantages (the latter being diseases such as Diplodia and insect damage - problems which can be solved with judicious and correctly timed use of herbicides and pesticides).

The applicability of a similar method in the study area should be considered. What must be emphasised is the need for care when intensively cultivating soils which are more suitable for semi-permanent or permanent pastures.

Another problem in this area which is associated with frequent cultivation, is direction of ploughing. Many of the farms in this area should be contoured, but are not, as the upper slopes are sufficiently gentle not to warrant it. The slopes do, however, become steep as they dip down towards the watercourses. These slopes are just gentle enough to permit cultivation, but this is, usually, only possible by ploughing up and down hill. Where possible slopes are ploughed in the appropriate contour direction.

This downhill ploughing is leading to an acceleration of soil movement downslope. According to the farmers, soil depth on the lower slopes is greater than on the upper slopes. This movement downslope is a natural process but some suggestion of an accelerated movement is present. Farm number 6 (originally part of farm number 4), which has only recently come under cultivation (1980/81), has more shallow soils on its lower slopes, if the farmer's observations are correct. Permanent vegetation

(used for grazing) on this farm until recently may have prevented accelerated downslope soil movement. Accelerated soil movement could lead to underlying clays becoming increasingly exposed, which will intensify infiltration, compaction and erosion problems. If long-term productivity is to be maintained, it might be advisable to place vulnerable slopes under permanent pastures or to construct contour banks.

Some possible reasons for such measures not having been employed before are as follows. The farms are fairly small and intensity of farming varies considerably. Those farmers whose sole activity is farming and who are attempting to make their properties as productive as possible (such as farms 7 and 11) have to utilise as much of their property as possible. In addition, they often hire property. They have a high capital input and so have to obtain a high output. As far as could be assessed, the balance between input and output in this area is fairly delicate. These farmers are using every possible part of their properties for maximum output. Their opinion is that the risk associated with soil loss and erosion is low and does not warrant the expense of adapted farming techniques. Their risk assessment appears to be correct as vegetation regrowth after cultivation is rapid (4 - 8 weeks after planting), occurrences such as the 1981 rainfalls are relatively rare, there is no soil loss after short rainfalls and that which occurs after 2 to 3 days' consecutive rain is considered unavoidable. Indeed, massive soil loss is not clearly visible, although signs of finger erosion on newly cultivated slopes have been seen to occur.

The dramatic post-rainfall increases in sediment loads in tributaries suggest that at least some of the sediment loss is caused by agricultural activities on adjoining lands. The road reconstruction activities do not affect the tributary on which the sediment samples were taken. The loss to the farmer is not significant within his time scale. He is more likely to repair any damage that might occur, as it occurs, than to spend money on preventing possible damage. This applies particularly on hired property. Farmers have to obtain certain returns from the property, and are not likely to invest in improving its long-term productivity potential. They may also take greater risks on such a property in order to obtain high returns on a short-term basis. It has been noticed that crops such as maize are usually grown on hired land. The crop requires intensive clean cultivation and application of various herbicides and pesticides. This crop can exhaust the soil fairly rapidly. If production levels drop or it becomes uneconomical, the land can be hired to someone else. There may not be an intermediate rotation crop.

In contrast, there is the farmer with a small property (17 - 40 ha) which is not an economically viable unit. He farms on a more casual basis, and may have an external source of income or be prepared to live at a lower income level. His choice of where to cultivate is limited by the size of his property and its position, and if there is no option but downhill ploughing, this method is adopted.

The opinion that possible personal losses in farm productivity do not warrant changed methods is associated with traditional use of present

farming methods. Present methods have served well enough in the past, equipment such as the mouldboard plough, which is easy to use and can be used to eradicate weeds, has been passed from father to son, and the costs and effort of changing to different instruments or an increase in allocation of land to permanent pastures are seen as prohibitive. The partial loss of topsoil during high rainfall periods is regarded as unavoidable and accepted as one of the hazards of farming. Saturation and loss of topsoil may be unavoidable in some circumstances, but prevention of this topsoil's reaching watercourses and affecting water quality should be possible. The construction of grassed waterways and 'greenways' and protection and management of riparian zones would all contribute to decreased sediment loads in rivers. Riparian zones could be used for some crops, providing these allow a permanent ground cover.

Having reviewed agricultural patterns and techniques and associated problems, conservation practices which are employed in the area are considered. These include

- fencing off kloof areas (one farm only);
- formation of furrows at an angle to plough direction, running across slopes;
- use of contour walls (one farm only);
- in the case of the vegetable farm (number 7), the use of a plough which does not turn the soil; leaving organic trash in the soil, crop rotation and the use of a cultivator which forms a seed-bed which has the profile shown in Fig. 6.6. The V-shaped

channels trap water and aid soil moisture retention. The channels also direct excess water into runoff channels which disperse water over a wider area. Unfortunately, sometimes the runoff channels lead almost directly to watercourses, are inadequately grassed and poorly maintained. They become a source of sediment.

The above methods are used on only a few farms (about 4 - 5) and have been used either to repair damage or improve productivity. There are approximately two or three other property owners aware of the risks of downhill ploughing in particular, and who are in favour of semi-permanent and permanent pastures in vulnerable areas.

Erosion on the farms was not considered a problem except in certain places and under specific circumstances. This seems to be a reasonable assessment for particular circumstances and areas mentioned by the farmers.

The risk-producing circumstances and situations mentioned by the farmers follow

- Sediment runs off paths, roads and bridges adjacent to or crossing streams. Specific mention was made of some roads which were washed away in 1981 - as on property number 8.
- The vulnerability of kloof areas was acknowledged in some cases and denied in others. In some kloofs in 1981, Acacia trees and fences were said to have been washed away.

- Newly cultivated fields after rain were said to be subject to erosion.
- Downhill ploughing.

In addition, one could mention

- the free access of livestock to watercourse areas, and
- the cultivation of riparian zones.

Some farmers plant Kikuyu on river banks for grazing purposes. This is preferable to cultivation of the area. The Kikuyu traps and disperses runoff. Unfortunately, on its own, it is inadequate as river bank protection. Its root system seldom penetrates deep enough to prevent soil slippage if the topsoil becomes saturated. The situation is worsened if the area is overgrazed and livestock movement is uncontrolled. The possible solution would be to reestablish natural vegetation on the watercourse banks and fence these areas so as to allow livestock access to water in carefully selected and protected areas. The natural vegetation not only acts as a barrier to sediment originating upslope, but traps sediment being transported downstream. The root systems are deeper and no examples of soil slippage have been seen where this vegetation remains in sufficient quantity. The width of this zone, in most cases, does not need to be very great. Its determination would depend on upslope activities.

From the given information the following conclusions may be drawn:

- Some agricultural activities are affecting water quality, the most significant being downslope ploughing, riparian zone

cultivation and farm roads, paths and livestock tracks.

- Short duration, low rainfall events will not affect mainstream turbidity.
- Longer duration rainfall (2 - 3 days rain, 50 - 100 mm and over) will affect mainstream turbidity.
- Tributary sediment loads can increase dramatically with only small quantities of rain.
- Increased mainstream turbidity is due to the cumulative effects of agricultural and road reconstruction activities and, to a lesser extent, the natural characteristics of the area (e.g. duplex soils).
- In the long term the present situation is likely to deteriorate rather than improve. Agricultural productivity may drop and greater and less suitable areas may be cultivated in attempts to increase cash flow.
- Increases in livestock feed prices and other expenses may result in some farmers converting to vegetable farming (either partially or completely) or feed crops such as maize. There has been an increase in the area under maize in 1985.
- It is almost impossible to enforce soil conservation legislation. The extension officers are wary of making recommendations for change where traditional methods have been employed for several generations. Any accusations would make it difficult to work with the same property owners in future so conflict situations tend to be avoided. In addition the seriousness of the effects of sediment loss in this area have not been fully comprehended.

- The lack of perception about the consequences of sediment loss in the Lakes catchment area is possibly due to the fact that erosion and sedimentation levels in this area are not at present as serious as in other parts of the country (such as Kwazulu/Natal) and not so clearly visible. Awareness of the consequences of increased sedimentation rates on the Wilderness lakes is relatively recent and is, as yet, not of any significance to many of the catchment land-owners.
- Short-term rather than long-term productivity seems to be considered of greater importance at present.

The sedimentation rates and erosion hazards of farming in the Diep-Wolwe river area have been described in relative detail. The same problems recur in the three river systems of the study area still to be discussed, but in differing degrees of severity. The Diep-Wolwe river is the most vulnerable system in the study area, largely because of its topographical characteristics (cultivable slopes) and relative proximity to Swartvlei.

6.2.2 The Klein Wolwe River Area

6.2.2.1 Agricultural characteristics

a) Farm numbers and area:

This river system is relatively small. The river has its source in the Beervleibos region, which is under plantations. There are only four properties on this system, two of which cover a large area. The farm numbers are 19; 20; 21 and 22.

b) Crops and pastures:

Only two properties are purely agricultural, namely properties 20 and 22, making up an area of 651 ha, of which an estimated 514 ha (78%) is cultivated. Of the cultivated area, 240 ha are under pastures, of which 29% are semi-permanent or permanent. 270 ha are under maize, and 10 ha under cash crops such as potatoes or oats, which are rotated with a grass crop. There are also 4 ha of export plums. Of the remaining area (137 ha) 40% is available for rough grazing and 60% is natural bush.

Property 21 (67,13 ha) is a timber creosoting area and is made up of 25 ha of pine plantation, 25 ha of natural mixed bush, from which usable wood has been extracted, and 17,13 ha of clear ground used for stacking drying wood. Property 19 has three different land-uses, namely an estimated 501 ha of plantations, between which are 249 ha of rough grazing (grassland - not planted pastures), and on the southern borders of the property are 26 ha of Hops lands. There is also an estimated 128 ha of mixed natural bush on this property.

The total area is 1622 ha.

c) Livestock numbers (head)

Sheep: 1000

Cattle: Approximately 838 - 962 (41 - 47% dairy). (Note: number of livestock on property 19 was unknown. This was calculated according to the stated carrying capacity of the area, i.e. 1,5 - 2 large stock units per ha).

d) Implements:

Implements used include shallow and deep subsoilers and discs (Hop lands, property 19), mouldboard plough (property 20) and tine implements, tiller, harrow and discs (property 22).

e) Changes in type of agriculture and land use, and farms coming into production in the last 20 years (1964-1985):

There has been a change in land use on property 21. This used to be farmed (pastures, vegetables) but is now used for timber creosote processing, although some cattle are kept on the property. It is claimed that timber processing produces no wastes which would affect water quality.

Property 20 (60 - 70 ha) has been cultivated only since 1973. It was previously under a wheat/potato rotation but is now under a maize/pasture/potato rotation. The area under cash crops (vegetables) on property 22 has decreased in the last 10 years.

f) Water sources and storage:

There are approximately 6 kloof dams and 9 earth dams. Two of the kloof dams are on tributaries of the Klein Wolwe river. Farms numbers 19 (Hops area) and 22 are sprinkler irrigated.

g) Soil type and depth:

The southern portion of property 19 (Hops area), adjacent to the Diep-Wolwe and Klein Wolwe rivers has deep sandy alluvium with patches of clay. The plateau area (property 19) has sandy clay loam, approximately

45 cm deep, and properties 20 and 21 have sandy clay loams to clay loams, 30 - 40 cm deep.

h) Use of fertilisers, herbicides and pesticides:

Herbicides and pesticides are used on properties 20 and 22. Pesticide is used on the Hops fields on property 19. The list of herbicides and pesticides given under the Diep-Wolwe river area is also applicable here. Hoelon and MCPA are used on property 20.

Fertilisers are used on all properties under agriculture. Lime is also applied on these acidic soils, and the sandy alluvium of property 19 (hops area) is enriched with nitrogen, potash and superphosphates.

6.2.2.2 The Klein Wolwe River: Erosion Hazard and Water Quality

This river system is at present less vulnerable to runoff from agricultural land than the Diep-Wolwe river system. This is because the western border of the river is under established plantations, and the eastern border is edged by a fairly continuous strip of mixed vegetation. Although much of this is alien vegetation (particularly on the western border of property 22) or pine trees, and the strip is not wide, it does act as a protection zone for the stream area. In addition, property number 22, situated at the source of some of the river's tributaries, does use accepted conservation techniques, such as contour banks and tine implements. It is the only farm in the study area which has been effectively contoured. The tributaries on the farm are bordered to

some degree by riverine vegetation although in isolated places this is sparse. Two large dams on the property capture a considerable amount of water which would otherwise flow directly into the Klein Wolwe river. If there are very high rainfalls, sediment-laden water from the dams may be released into the river. Any increased sediment load would, however, be of a temporary nature.

The main sediment sources in this river system are farm roads, drainage ditches, road rerouting and reconstruction and, to a lesser degree, uncontrolled livestock movement across and alongside watercourses. The farm roads on property 22 tend to become a muddy morass after rain, and it is possible that water off these roads finds its way into watercourses or ditches leading to the Klein Wolwe river. This would probably affect the river only after high rainfalls over a period of 2 or more days.

The major source of sediment is the straightening and reconstruction of main road number 14, as described and illustrated in Section 7.2 p. 207. The area below the roadwork sites has consistently high sediment load readings, sometimes exceptionally high readings such as when, on 13 June 1984, a sediment load of 4590 mg per litre was obtained. Normal limits are between 50 - 90 mg per litre. Some of this sediment does settle or become diluted as it moves downstream. For example, on 3 April 1984, sediment load at the road reconstruction area (Point D, Fig. 6.2) was 25,5 mg/l, whereas downstream at Point *Kw (just before the river enters Swartvlei on property 19) it was 8,6 mg/l. On 13 June 1984, the sediment load at point *Kw was 53,3 mg/l. This is a high

sediment load for a mainstream area so close to Swartvlei, but is relatively low when compared to upstream sediment loads recorded on this date.

Slightly downstream of sample site *Kw is an area where livestock congregate to drink water. The river banks are badly trampled and any slight increase in water velocity results in sediment being lifted and transported downstream.

Another possible sediment source is from the western border of property 22 and eastern border of property 21 where river banks are too sparsely vegetated in places. Property 21 needs to be kept dry (for timber drying) and so is drained by ditches which lead through bordering vegetation to the Klein Wolwe river. Such ditches can be sediment sources if incorrectly designed.

Erosion and sediment loss did once occur off the Hops lands on property 19, adjacent to the Diep-Wolwe river. The construction of an earth dyke along the river on the southern border of the Hops lands has prevented runoff (from irrigation) entering the river. However, the dyke is being undermined by the river itself and, unless stabilised, may gradually collapse into the river. Increased river flow velocity after high rainfalls removes sediment from the dyke's banks. As the Hops lands are periodically deep subsoiled and irrigated it is advisable to maintain the dyke.

The effect of fertilisers, herbicides and pesticides on water quality

in this area should not be as direct as that occurring in the Diep-Wolwe river area. The degree of absorption and dilution should be better here. The decreased area under cash crops should have brought about a decline in quantities utilised.

The quantity of water contributed to Swartvlei by this river system is relatively small. However, the fact that sediment loads at point *Kw, just prior to entering Swartvlei, can be at least as high as 54 mg/l, suggests that its silt contribution to the lake could be more direct and possibly as severe as those contributions made by the Diep-Wolwe river. The Klein Wolwe river system is not diluted by large quantities of clear upper catchment area water, but its capacity to lift and transport sediment from disturbed areas is high after rainfall. Its mainstream sediment loads become as high as the sediment loads of tributaries in other river systems. The low rainfalls of 1984 have made its contribution relatively low, but this would change with higher rainfalls.

The area will become considerably more susceptible to runoff erosion when the plantations on property 19 are clearfelled (discussed under Plantations on the plateau, p. 191).

6.2.3 The Hoëkraal River Area

6.2.3.1 Agricultural Characteristics

The Hoëkraal river is deeply incised into the plateau along most of its course, and the terrain is more steeply rolling than in either of the two previously discussed river systems. The mainstream embankments are thickly covered in indigenous forest except for the last section

of the river, just before it enters Swartvlei. Except for this last section, there are no agricultural activities on the mainstream slopes of the river. Agriculture is limited to the tributary areas, west and east of the river.

a) Farm numbers and area:

The area under agriculture is 1667,7 ha. This excludes a large area under plantations, 2095,7 ha, and mixed forest, plantation and fynbos, 262 ha, giving a total area of 4025,4 ha.

The property numbers fall between numbers 23 to 49 (including plantation properties).

Of the 1667,7 ha under agriculture, 595 - 631 ha (33 - 37%) are cultivated. The area will increase to about 671 ha (40,2%) in the next 2 - 3 years.

b) Crops and pastures:

Cash crops (including potatoes, broccoli, green beans, pumpkins and pecan nuts) 59 ha.

Maize 92 ha

Pastures 479,3 ha, of which 42% are semi-permanent and 58% annual.

There is an additional 484,3 ha of rough grazing or grassland and 544,5 ha of indigenous bush.

c) Livestock numbers:

Sheep 531 - 756.

Cattle 764 - 825 (64 - 74% dairy).

d) Implements and machinery:

Implements used are the same as those utilised in the Diep-Wolwe area, with approximately 76% of the farmers making use of the mouldboard plough.

e) Changes in type of agriculture and land use, and farms coming into production in the last 20 years (1964-1985)

Property 43 has been farmed only in the last 5 years, and property 38 in the last 20 years. These areas were previously under fynbos and grasses. Clearing of additional portions of properties 32 and 45 has occurred for Kikuyu establishment.

Changes in land use include:

- a change from pine plantation to pastures on property 41 (an increase in area under pastures of about 30 ha per annum, from 1984 onwards),
- a change from pastures to pine plantations on property 36 since 1977/78,
- a change from vegetable to pasture farming on property 39 since 1982/83.

f) Water sources and storage:

There are approximately 14 kloof dams and 6 earth dams in the area. Some of the dams are partially fed by a canal which originates in the Vanderwattsbos plantation area, immediately north-west of Karatara village. The canal partially supplies Karatara with water and then

passes west of Karatara, flowing southwards along the western side of Divisional road number 54. It eventually crosses the road and that water which has not been tapped (small quantities) enters a tributary of the Karatara river.

There are also several springs in the area, two of which are tapped on properties 30 and 28. Over 400 litres per hour is yielded.

g) Soil types:

These vary from the relatively deep sandy soils (alluvium) on the southernmost bottomlands of the Hoëkraal river, and the recent Aeolian sands immediately north of Swartvlei, to the shallower sandy clay loams of the plateau area.

h) Use of fertilisers, herbicides and pesticides:

All the farmers use fertilisers in varying degrees of intensity. Farms where maize and vegetables are grown use pesticides and herbicides. Herbicides are used to kill weeds in some pasture areas. Fungicides are used on properties where potatoes are cultivated (in rotation), and also on proteas on property 31. Areas where herbicides and/or pesticides are used include properties 43, 30 in future, 41, 38, 35, 48, 50, 47 and 46.

6.2.3.2 The Hoëkraal River: Erosion Hazard and Water Quality

The mainstream of the Hoëkraal river is the only one in this study area which does not receive abnormally high sediment loads after rainfalls such as occurred in 1984 and the first three months of 1985 (up to 55 mm). The main reasons for this are the thick indigenous forest which borders the mainstream along most of its course, the dilution factor, the limited area on the tributaries which is subject to intensive cultivation and the fact that pastures and cash crops are usually established on the gentler slopes nearer the sources of the tributaries. The tributaries' embankments are bordered by indigenous forest prior to entering the mainstream, and this acts as a filter for upstream tributary water, which can have high sediment loads as recorded in the three other river systems of the area.

On 13 June 1984 two sediment samples were taken at points marked **4** and **5** on Fig. 62. There had been only 20 - 28 mm of rain and the flow of the sampled tributaries was not rapid. The sediment loads of the two tributaries showed a considerable contrast. Sediment load at point 4 was 20,2 mg/l, whereas at point 5 it was 109,5 mg/l. Some of the possible reasons for the contrast in sediment loads are listed:

- Tributary 4 is partially diluted with water originating in the forested area north of the sampling site, although much of this water is captured by a large dam before reaching the site. It is unlikely that this amount of rainfall will have affected the tributary.
- The slopes above sample site 4 are under permanent mixed grass

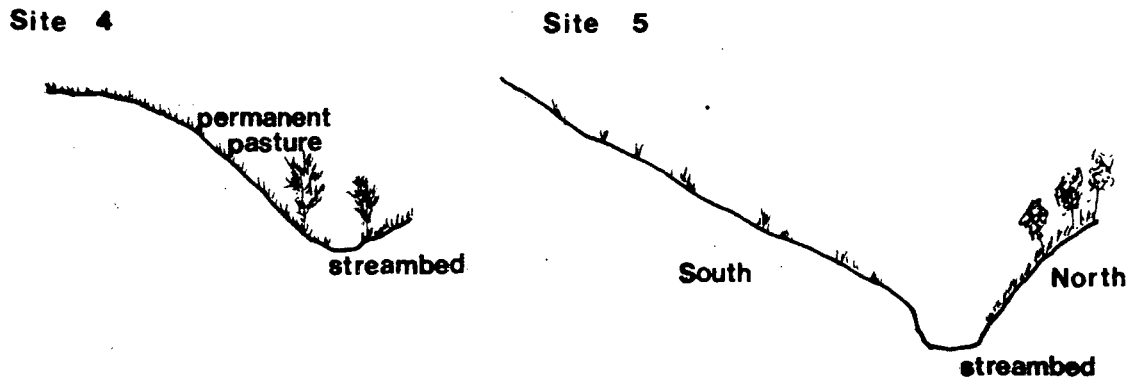


Fig 6-7 SLOPES AT SITES 4 and 5

cover. The cover continues down to water level. There are patches of Wattle trees (Acacia mearnsii) bordering the river.

- The slopes at sample site 5 are longer and slightly steeper than those at site 4. They are also under permanent (but shorter) grass cover, but this is not continuous down to water level. The tributary is more deeply incised here and one of its embankments has become too steep to allow grass to grow on it. Livestock movement has trampled the embankments, and so water running downstream is not prevented from lifting and transporting sediment. Because most of the riparian vegetation on the southern bank of the tributary has been removed, there is nothing to prevent it further incising the bank, and nothing to filter sediment carried by the water. There is no dilution and no dam to capture rainfall.
- Approximate profiles of the two slopes would be as in Fig. 6.7.
- In addition, the geology of the sites varies. Tributary 4 area is underlain by granite, whereas tributary 5 is underlain by Victoria Bay feldspathic quartzite.

The higher sediment load in tributary 5 is partially due to natural features, but is greatly intensified by man's activities. However, it is only under high rainfall conditions that the mainstream sediment load will be affected.

As in the Diep-Wolwe river system, downslope ploughing and use of the mouldboard plough does occur. Their effect here is limited as the steeper topography in most cases prevents cultivation of riparian zones.

Some problems have been experienced on properties 38 and 39. On property 38 some cultivation of riparian zones used to take place, but these areas are now, according to the farmer, largely under permanent grassveld. Property 39, under previous ownership, was used for vegetable farming. The downslope ploughing led to soil slippage and loss during the 1981 high rainfall period. The present owner states that he is trying to remedy the situation by ploughing across slope (to loosen compacted soil) and establishing pastures (largely annual). He says he has also built retaining walls.

The effect of fertilisers, pesticides and herbicides on water quality in this area should be limited due to the filtering role of the relatively large area of indigenous vegetation.

The Karatara canal should not be a sediment source except under high rainfall conditions. Its sediment load in 1984 varied between 6,2 mg/l in dry conditions to 24 mg/l on 7 October 1984, when there had been approximately 43 - 50 mm in two days' rainfall. The canal is bordered by various types of vegetation along its course. This vegetation occasionally grows thickly enough to reduce water flow. It is likely that under sustained heavy rainfalls the canal would overflow in some areas.

One sediment source which has been particularly severe in this area, and which has not yet occurred to the same degree in the two previously discussed river systems, is landslips. Most of these landslips occurred during the 1981 high rainfall period, although some have been said to have occurred more recently. These landslips probably contributed a

considerable amount of silt to the Hoëkraal river in 1981. Most of them are still eroding and enlarging but some are becoming partially covered by grasses and alien vegetation. They vary in size and situation. Those that could be seen were between an estimated 2 to 10 metres in width and length. They occurred in kloof areas where such an occurrence can be expected due to concentration of water in a relatively small area, as well as towards the bases of the relatively long and steep slopes characteristic of the area. They were, without exception, seen only where natural vegetation had been removed and replaced by pastures or cash crops. Even permanent pastures were unable to withstand the effects of high rainfall. The combination of a relatively shallow, saturated surface soil, a long fairly steep slope, in some cases an underlying impermeable clay layer, occasional presence of underground water, the movement of livestock and machinery and the absence of dense deeper-rooted natural vegetation, which would intercept, absorb and redistribute rainfall and help to anchor soil both at the crests and bases of the slopes, has led to these landslips. They will continue to occur in periods of sustained rainfall, and the existing ones will make progressively larger areas unstable. It is possible that reestablishment of indigenous riparian vegetation would prevent some of the sediment originating from these areas affecting water courses so severely. Strict control of numbers of livestock on vulnerable slopes (particularly in wet periods), and no cultivation of such slopes would go some way towards prevention of future landslips. Such steps are unlikely to be taken as the occurrence of high rainfalls is not frequent enough to worry farmers who are losing ground to landslips. Where possible, farmers are still clearing kloof areas to enlarge grazing areas and reduce tick infestation.

Landslips were said to have occurred on properties, 26, 29, 49, 32, 39, 35, 48 and 50. A flight over the area revealed more landslip areas, but the short flight period did not allow individual properties to be identified.

Although this river system has vulnerable areas as regards erosion potential, its water quality is the best in the study area. Its geological and topographical characteristics necessitate that care be taken when utilising slope areas for agriculture. Any future rainfall events similar in scope to those of 1981 will make the area more susceptible to sediment loss.

6.2.4 The Karatara River Area

6.2.4.1 Agricultural Characteristics

a) Farm numbers and area: Refer to Fig 6-5

Property numbers are from 50 to 89.

The total area under agriculture is approximately 3433 ha. Of this, approximately 950 - 1047 ha is cultivated (27 - 30% of the area).

1600 ha is rough grazing or grassland (46%) and 819,4 ha is indigenous bush (23%). There are also approximately 434 ha of mixed fynbos and plantations (property 58) and 1156,2 ha of plantations, giving a total area of 5023,2 ha.

b) Crops and pastures:

Cash crops 88 ha (including peas, potatoes, tomatoes, lettuce, cucumbers,

peppers, onions, watermelons, garlic, cabbages, beetroot, carrots, avocados and various fruits such as guavas). Many of these are being cultivated on a small-scale experimental basis.

Maize 129,5 ha

Pastures There are 826 - 830 ha of planted pastures, of which about 73% are annual and 27% semi-permanent.

c) Livestock numbers (head):

<u>Sheep</u>	<u>Cattle</u>	<u>Pigs</u>
900	2182 (90% dairy)	> 1013

d) Implements and machinery:

Implements used are similar to those used in the previously discussed river systems. Approximately 77% of the farmers use the mouldboard plough.

e) Changes in type of agriculture and land use and farms coming into production in the last 20 years (1964-1985)

The following properties have come into production relatively recently: properties 68 (1976 onwards), 55 (1968 onwards) and 57 (1979 onwards).

The following properties have undergone change in types of farming:

property 89 - vegetables to annual pastures (1978 onwards),

property 60 - poultry and cash crops to pastures (dairy),

properties 72 and 64 - an increase in area under pastures (previously pine plantation),

property 62 - a small area under sweet potatoes, now replaced by Kikuyu.

f) Water sources and storage:

There are approximately 27 kloof dams and 25 earth dams. Water is also obtained from the Karatara canal, the Karatara river and natural springs. Parts of farms numbers 60, 82 and 86 are irrigated, as well as small portions of other properties where cash crops are grown.

g) Soil types:

These are similar in type to those of the Hoëkraal river.

h) Use of fertilisers, herbicides and pesticides:

As in the other river systems, fertilisers are used on almost all the farms, but in varying intensities. Herbicides are used on weeds both in pastures and cash crop areas, and pesticides mostly on cash crops. Herbicides are used on the following properties: 83, 82, 59, 81, 55, 61, 86 and 88 (future).

Pesticides are used on properties 85, 76 and 86.

It is possible that herbicides and pesticides are used on other properties in the area.

Dips or tick sprays are used on farms with livestock.

6.2.4.2 The Karatara River System: Erosion Hazard and Water Quality

The Karatara river system is similar to the Hoëkraal river system. The terrain is steeply rolling, and, again, most agricultural activities are limited to tributary areas. The area utilised for agriculture extends further north than the agricultural area of the Hoëkraal river system,

with most intensive farming occurring west, east and south of Karatara village.

Like the Hoëkraal river system, most of the Karatara's mainstream embankments are covered in indigenous forest. As in the Hoëkraal system, one would expect this forest to have a protective role as regards water quality. However, unlike the Hoëkraal river, the Karatara river (mainstream and tributaries) has very high sediment loads after certain rainfall conditions. The reasons for this are varied and will emerge in the discussion.

Some examples of sediment loads obtained in the Karatara river system are shown in Table 6.2. A discussion of the sediment loads reveals several problem areas.

i) The Huis River

This river is a major tributary of the Karatara river. Its source area is north and west of Karatara village. The Huis river originates in two streams which join together south of main road number 14. Both of these streams contribute sediment to the river, largely because of removal of riparian vegetation and/or cultivation too close to the tributaries' embankments. The western stream (marked (i) on Fig. 6.2 of the Huis river is bordered by cash crops (for example, Property 84, Peas). Slope is gentle, but even so there is some runoff after rain on newly cultivated fields, particularly as ploughing direction is down-slope towards the watercourse. In addition, the turning circle of the tractor is at the point marked (ia) on Fig. 6.2 which

TABLE 6.2 Sediment loads: Karatara River

Raindays	1 day	1½ days		1 day	3 days	2 days	1½ days
Rainfall (mm) (time samples taken after rain ceased)	10-15 mm immed.	10-15 mm immed.	Nil	20-28 mm immed.	50-55 mm 2 days	43-50 mm immed.	41-50 mm 16 hrs
Date	12.3.84	20.3.84	3.4.84	13.6.84	23.7.84	7.10.84	8.4.85
Unit: mg/l							
Sample sites (see Fig.6.2)							
i) Huis River	20,9	-	30,8	38	19,5	101,0	67,0
ii) Upper Karatara R. bridge	1,3	-	3,2	-	7,5	159,0	20,5
iib) Tributary on property 88	-	-	-	-	-	-	248.0
iii) Tributary near road bend	-	8,4	7,1	-	19,0	-	-
iv) Tributary on property 55	-	-	-	61,5	-	-	-

is one of the source points of the stream. This area (in 1984) had been churned into muddy channels by the tractor wheels.

The eastern stream (ib) of the river runs through a grazing area immediately west of Karatara village. There is no riparian vegetation on the embankments and livestock have free access across the stream. This stream has consistently high sediment loads. The situation has been aggravated by the movement of earth-moving equipment in the Karatara area. The stream has been dammed recently with an earth wall.

The western bank of the Huis river, along the rest of its course down to the Karatara river, is largely under permanent grassveld, used for grazing. The eastern bank is under small areas of pine plantation, which are being removed on some properties (e.g. 82 and 83). As the pine trees have been planted down to water level, there is the increased risk of sediment-laden runoff after high rainfalls, until such time as permanent pastures have been established. Signs of past bank erosion were visible on this river, particularly where pine trees were planted to water level and erosion had made the banks too steep for other vegetation to grow in the area.

From the sediment loads obtained, one can see that there is a rapid increase in turbidity after two or more days of rain, but that this increase diminishes rapidly as sediment is washed downstream, water velocity decreases and water is trapped by dams.

The source areas of another tributary of the river (originating on the

eastern portion of property 82 (ic)), have also been cultivated very close to the watercourse embankments. However, indigenous riparian vegetation, situated downstream of this tributary, should act as a filter.

ii) The Upper Karatara River Bridge

These samples were collected just below the bridge at point I on Fig. 6.2. As most of the water in this area is clear catchment water, no high sediment loads were expected. However, on 7 October 1984 an abnormally high load of 159 mg/l was found. This is the highest sediment load obtained in the mainstream of any of the study area rivers at a point so high upstream. The most likely sources are two tributaries which enter the mainstream immediately upstream of the sampling area. It is unlikely that catchment water has a high sediment load. The two tributaries concerned are the tributary (iia), which originates immediately east of the eastern border of Karatara village, and (iib) Tributary 88 which originates in the vicinity of properties 87 and 88 (southern borders).

Tributary (iia) is not easily visible, due to vegetation, and a sample was not obtained from it. The tributary is bordered largely by young pine trees. It is possible that its sediment load has increased because of the installation of water reticulation and sewage works in Karatara settlement. (For information on the settlement see Appendix 4D). This has necessitated installation of pipelines and, consequently, considerable earth movement has occurred during 1984. Post rainfall periods reveal several areas where sediment-laden runoff could reach watercourses. The situation may improve once installation is

complete, but further problems could be created in future as this area is near a site selected for expansion of Karatara village. Further investigation may have to be initiated here to determine the nature and extent of the problem and whether anything can be done to reduce sediment loads.

Tributary (iib) has a low flow rate but high sediment load, as shown by the sample taken on 8 April 1985. As far as could be determined, sediment in this tributary is originating from:

- some sections of main road number 14 where rainwater cuts through road embankments and runs downslope to the stream, and
- the southeastern border of property 88, where the stream passes through an area of pine plantation.

Sediment appears to originate from the river embankments, a farm road which runs downslope to the watercourse and disturbance of the area by livestock movement.

Although both the above tributaries contribute relatively little sediment-laden water to the Karatara river under low rainfall conditions, sustained rainfall changes the situation dramatically.

(iii) In contrast to the above tributaries, this tributary ^(see Fig b-2) has relatively low sediment loads. The reasons for this are low flow rates, dense bank vegetation (indigenous forest and, further upslope, established pine plantations), fynbos in the area south of the bend in

road number 14 and no cultivation, roads, or livestock movement in the vicinity of the watercourse.

iv) Tributary (iv), on property 55, has high sediment loads. Sediment in this area probably originates from steep slopes (which are not sufficiently densely covered in natural vegetation) and landslip areas, similar sediment sources to those noted on property 49 (Hoëkraal river system).

It seems that the Karatara river contributes greater volumes of sediment to Swartvlei than the Hoëkraal river, although similar sediment source areas are found in both river systems. The sediment load of the Karatara river can remain high as far south as the Sedgefield Municipality waterworks at Ruigtevlei (see note on Table 7.1 Section 7.7). Although no sample was taken on 8 October 1984, water at this area had a high sediment load on this date (pers. comm. technician at Municipality waterworks). The relative contributions of the above mentioned sediment sources in comparison with the contribution from the road slip area further downstream, discussed in Section 7.6 (point L Melkhoutskraal on Fig. 6.2) could not be determined. It is likely that some of the sediment originating in the upstream area settles out before reaching the southern reaches of the river. It must be noted that the Karatara river contributes the greatest volume of water to Swartvlei. This may increase its capacity to transport sediment.

Similar sediment source areas, as discussed above, occur on other farms in this river system. For example, landslips also occurred on

properties 54, 81, 57 and 88. Problems of erosion and runoff associated with cultivation (including downslope ploughing) and/or overgrazing, long steep slopes devoid of natural riparian vegetation, pine trees in watercourse areas, and farm roads were either mentioned by property-owners specifically or observed by the writer. Some of the properties where such problems occur are numbers 86 (Karatara area), 71, 68, 72 and 64.

One other potential silt source occurs on property 60. A canal, which originates in a marshy area on property 61, continues through property 60 and drains into the Karatara river mainstream. This canal has to be cleared of vegetation (using a bulldozer) every 3 - 4 years. Rainfall after clearing operations or the operation itself could increase sediment loads of the river until such time as disturbed sediment settled in the canal, and the excavated material deposited on the canal's banks became more resistant to erosion. During the study period, the water flow rate in this canal was slow and it appeared fairly clear. It had been cleared in 1982/83. As the water hosts internal parasites harmful to livestock, such as liverfluke, it is (according to present landowners) going to be fenced. Portions of property 60 are flooded after high rainfall periods (as occurred in 1981), but, as the property is largely under permanent pastures and water infiltration and drainage is rapid, sediment contribution is likely to be low. The canal will only become a serious sediment source if water velocities become high enough to transport sediment into the Karatara river.

Water quality is affected by the use of fertilisers, herbicides and pesticides to a greater degree on the Karatara river system than on the Hoëkraal river system. This is because of the relatively large cultivated area east and west of the Huis river, as well as pasture farming on the bottomland areas of the Karatara river before it enters Karatara vlei. Since 1981 there has been a rapid increase in the area covered by the water weed, Salvinia molesta. The water hyacinth, Eichornia crassipes occurs to a lesser extent. These weeds frequently indicate the presence of high nutrient levels. Salvinia molesta is causing surface river flow rates to decrease, and it brings about problems for property-owners attempting to use Karatara river water. It will take a repeated series of high rainfalls, such as occurred in 1981, to move this weed downstream into the lake. The rougher surface waters (wind exposed) and fluctuating salinity levels have limited the growth of Salvinia in the lake.

Although the Karatara river has higher sediment loads than the Hoëkraal river, a possible alleviating factor is Karatara vlei, a relatively shallow pan of water into which the Karatara river runs before entering the channel which leads into Swartvlei. It is possible that sediment settles in this vlei before river water enters Swartvlei.

6.3 LEGISLATION APPLICABLE TO AGRICULTURE

The most important act is the Conservation of Agricultural Resources Act no. 43 1983, which came into operation on 1 June 1984. The Soil

Conservation Act of 1969 has been repealed. Other acts such as the Water Act 54 of 1956, and the Subdivision of Agricultural Land Act 70 of 1970, are relevant to the study.

Those aspects of these acts, which are of relevance to the amelioration of water quality and erosion problems associated with agricultural activities, will be mentioned specifically.

1. The Conservation of Agricultural Resources Act of 1983, has the following objectives:

'to provide for the conservation of the natural agricultural resources of the Republic by the maintenance of the production potential of land, by the combating and prevention of erosion and weakening or destruction of the water sources, and by the protection of the vegetation and the combating of weeds and invader plants' (Government Gazette, No. 8673 1983).

'An officer of the department designated as executive officer by the Minister shall exercise the powers and perform the duties conferred or imposed upon the executive officer by or under this Act or a Scheme. The executive officer shall exercise his powers and perform his duties with due regard to any instructions issued by the Minister' (Government Gazette, No. 8673 1983). The executive is designated certain powers of investigation. In order to achieve the objects of the Act, the Minister may prescribe control measures which shall be complied with by land users to whom they may apply.

Such control measures may relate to:

- a) The cultivation of virgin soil;
- b) the utilisation and protection of land which is cultivated;
- c) the irrigation of land;
- d) the prevention or control of waterlogging or salination of land;
- e) the utilization and protection of vleis, marshes, water sponges, water courses and water sources;
- f) the regulating of the flow pattern of run-off water;
- g) the utilization and protection of the vegetation;
- h) the grazing capacity of veld, expressed as an area of veld per large stock unit;
- i) the maximum number and the kind of animals which may be kept on veld;
- j) the prevention and control of veld fires;
- k) the utilization and protection of veld which has burned;
- l) the control of weeds and invader plants;
- m) the restoration or reclamation of eroded land or land which is otherwise disturbed or denuded;
- n) the protection of water sources against pollution on account of farming practices;
- o) the construction, maintenance, alteration or removal of soil conservation works or other structures on land; and
- p) any other matter which the Minister may deem necessary or expedient in order that the objects of this Act may be achieved, and the generality of this provision shall not be limited by the preceding of this subsection.

Different control measures may be prescribed in respect of different classes of land-users or different areas or in such other respects as the Minister may determine.

Any land user who refuses or fails to comply with any control measure which is binding on him, shall be guilty of an offence.'

Two other important aspects of this Act are that

- i) the Minister may, with the concurrence of the Minister of Finance, grant payment of subsidies in respect of construction of soil conservation works, reparation of damage to agricultural resources or conservation works by natural forces, reduction of livestock numbers to restrict detrimental effects of drought, reclamation of damaged land, planting of crops which improve soil fertility or reduce erosion hazard, and combating of weed or invader plants;
- ii) the Minister may establish a conservation committee in any area determined by the Minister: the committee promotes the conservation of the natural agricultural resources in the area concerned in order to achieve the objects of this act. Members of the committee are appointed by the Minister.

A Conservation Advisory Board has also been established. This Board advises the Minister on various matters arising from the application of this Act.

More details on the control measures mentioned above (a-p) are given in Government Gazette No. 9238. Details on those measures applicable to problems in the study area are given below.

a) Cultivation of virgin soil.

Except on authority of or written permission by the executive officer, no land user shall cultivate any virgin soil: provided that such authority shall not be required in respect of virgin land for which an approval has been granted in terms of section 4A of the Forest Act 72 of 1968 (now repealed).

b) The Cultivation of land with a slope:

Except on authority of a written permission by the executive officer, no land user shall cultivate any land if it

- i) has a slope of more than 20 percent or
- ii) has a slope of more than 12 percent and is situated in specified areas and has certain soil types and physical properties.

The magisterial districts of George/Knysna are not included in the specified areas. Some of the specified soil forms and physical properties mentioned do correlate with conditions found in the study area, i.e. soil forms such as Estcourt, Fernwood, Glenrosa, Kroonstad, Mispah, Sterkspruit, Hutton and Swartland; and physical properties such as effective soil depth less than 500 mm and clay content of A horizon less than 15 percent.

It is not known why the area has not been included, but this might be because it is largely a pasture farming area and slopes of this type are not expected to be cultivated. An extension officer for the area suggested that often the greatest problems arose with the twelve percent slope as a farmer might risk cultivating a 12% slope, whereas a twenty percent slope could not be easily cultivated. The establishment of annual pastures and maize production do both require considerable cultivation. Once the pasture crop is established, good cover is provided, but the relatively shallow root systems of the pastures cannot anchor the topsoils on long steep slopes under conditions of sustained rainfall. Cultivation was seen to occur on very steep slopes in a few parts of the study area, particularly west of the southern half of Main Road number 26 in the Karatara river system. The limit to cultivation appeared to be a slope so steep that a tractor pulling a plough uphill would risk being halted by the discs of the plough digging into the soil too deeply. This sort of cultivation is rare, but cultivation of twelve percent slopes is more common.

None of the control measures applying to slopes will have any effect in this area as

1. This is not a specified area;
2. Prohibition i) (no cultivation of slopes of over 20 percent) is not applicable to slopes which were already under cultivation on the date of regulation commencement - providing that those slopes were already protected against excessive soil loss due to erosion through the action of water. At present, there is little sign of 'excessive'

soil loss in the area except where landslips have occurred. These landslips have been due to a combination of natural (topography and soil types) and man-induced factors (livestock movement, removal of deeper rooted dense protective vegetation and, in some cases, cultivation of steep slopes). In this study sediment-laden runoff is a greater problem than erosion. However, it is the natural conditions including so-called 'abnormal rainfall', rather than man's activities which are held to be responsible for sediment-laden runoff. However, it takes only one 'abnormal rainfall' to destabilise an area, making it more vulnerable to a 'normal' rainfall. As occurs in many parts of South Africa nature's protective mechanisms have been disturbed or removed. Marginal land is being farmed, land which may be farmed safely for several generations but which is vulnerable to 'abnormal' storm events.

The legislation for protection of cultivated land against erosion through the action of water (Regulation 4) states that certain measures should be adopted by the land user concerned to prevent such erosion. Such measures include:-

- soil conservation works to divert runoff or restrict runoff speed of runoff water;
- cultivation of land in such a manner as to reduce runoff speed of runoff water;
- use of crop rotation systems or alternate strips of undisturbed cover crop;
- maintenance of crop residue and
- establishment of a suitable grazing crop and withdrawal from cultivation.

In the study area there is almost no attention paid to the quality of runoff or its destination, as these factors are not significant to property owners. The use of soil conservation works is limited in this area. The above legislation, if applied, would, therefore, perhaps be more relevant to the area than the legislation referring to cultivation of steep slopes.

The Act refers to control measures formulated for protection of cultivated land against erosion through the action of wind, and prevention of waterlogging and salination of irrigated land. Wind erosion and waterlogging both occur in the region, the latter being of greater significance in relation to water quality. If larger areas were irrigated the problem would be more serious.

Of greater importance is the legislation applying to utilisation and protection of vleis, marshes, water sponges and water sources, which is reproduced below.

1. Subject to the provisions of the Water Act, 1956 (Act 54 of 1956), and subregulation (2) of this regulation, no land user shall utilise the vegetation in a vlei, marsh or water sponge or within the flood area of a water course or within 10 metres horizontally outside such flood area in a manner that causes or may cause the deterioration of or damage to the natural agricultural resources.

2. Every land user shall remove the vegetation in a water course on his farm unit to such an extent that it will not constitute an obstruction during a flood that could cause excessive soil loss as a

result of erosion through the action of water.

3. Except on authority of a written permission by the executive officer, no land user shall -

- a) drain or cultivate any vlei, marsh or water sponge or a portion thereof on his farm unit; or
- b) cultivate any land on his farm unit within the flood area of a water course or within 10 metres horizontally outside the flood area of a water course.

4. The prohibition contained in subregulation (3) shall not apply in respect of -

- a) a vlei, marsh or water sponge or a portion thereof that has already been drained or is under cultivation on the date of commencement of these regulations, provided it is not done at the expense of the conservation of the natural agricultural resources; and
- b) land within the flood area of a water course or within 10 metres horizontally outside the flood area of a water course that is under cultivation on the date of commencement of these regulations, provided it is already protected effectively in terms of regulation 4 against excessive soil loss due to erosion through the action of water.

The most important subregulation is number 3b. In the study area cultivation near

watercourse areas occurs wherever practicably possible, particularly in the Diep-Wolwe river area. The power of the regulation is much reduced by its not being applicable to such areas already under cultivation (4b). Much would depend on the definitions and implications of the words 'excessive' and 'protected'. What is certain, is that post-rainfall runoff from these areas has a high sediment load and that few attempts have been made to divert, slow or trap sediment-laden water. Water may be diverted off fields in some cases by means of furrows, but is directed into the nearest available watercourse without the necessary attention to the path it takes to the watercourse. It is the writer's opinion that the provisions of regulation 4 are not met in these vulnerable watercourse areas.

There is a possibility that regulation 2 could be misused. Land-users could remove vegetation which has a beneficial role to play as regards bank protection and runoff dispersal. The 'greenway' function of vegetation is important. However, alien vegetation does not give greenway protection and should be removed.

Regulation 8 refers to regulating the flow pattern of runoff water, the emphasis being on prevention of soil loss by water erosion. Creation of an obstruction which will disturb the natural flow pattern of runoff water or removing or altering an existing obstruction or diverting runoff water from one watercourse to another in such a way as to cause soil loss is prohibited. As far as could be determined, runoff water is rarely controlled or diverted in any manner, except through dam building in watercourse areas. Problems are created by uncontrolled

unfiltered runoff and non-maintenance of natural runoff channels.

Correctly designed channels or naturally vegetated channels could ameliorate this problem.

Regulation 9 refers to utilisation of veld ('veld' refers to uncultivated land under indigenous vegetation or vegetation that can be used as grazing. (Note: in this report the word grassland replaces veld. Grassland refers to land on which the indigenous vegetation has been cut or removed and which is used for grazing. A variety of grasses grow in the area once the bush is removed, including Eragrostis plana ('Taaipol').) Grassland makes up a large proportion of the study area. There are numerous prescribed measures in the regulation designed for veld protection (the word 'veld' will be used when in reference to the legislation), such as alternating grazing and rest periods and control of number and type of livestock. Subregulation (1)(d) is perhaps the most relevant to the study area. It states that

'A suitable soil conservation work shall be constructed and maintained in order to

- i) utilise the veld concerned in alternating grazing and rest periods;
- ii) protect the veld concerned against excessive soil loss as a result of erosion through the action of water or wind; or
- iii) collect sediment from run-off water.

It is possible that number d(iii) could be used effectively here.

Problems in grassland areas more commonly relate to uncontrolled movement of livestock in areas adjoining watercourses, grazing of grassland in wet periods and overgrazing. The extent of damage depends on number of animals, grazing period, slope and type of grassland. Grassland is often reserved as wet period grazing so as to avoid trampling of more delicate and expensively established pastures. These problems are only partially covered by the regulation.

Regulations 10 and 11 refer to grazing capacity of veld and number of animals that can be kept on veld. Specific recommendations are made and are applicable to the study area. However, the carrying capacity of the study area's grassland zones fluctuates with climatic and topographical conditions and this would be one of the most difficult factors to determine and regulate. The situation is further complicated by the small size of many of the farms in the area.

Regulation 12 refers to prevention and control of veld fires, i.e. no land user may burn any veld on his farm unit or utilise as grazing any veld on his farm that has burned, without the written permission of the executive officer. Grassland in the study area is usually bushcut and rarely burned. As far as could be determined, fire is not a significant factor in the agricultural area as regards possible side effects on water quality.

Regulation 13 refers to the obligation of the farmer to restore and reclaim eroded land. This would be applicable in the case of the landslip areas. The topography makes effective restoration difficult.

Few landowners had attempted to restore landslip areas.

Regulation 14 refers to restoration and reclamation of land when such land has been disturbed or denuded during activities other than mining or prospecting. An example might be removal of soil for dam construction. This regulation would possibly be used in such instances. The earth walls of dams are rarely restabilised. This sometimes occurs naturally as grass and vegetation (usually alien) grow on disturbed embankments. In most cases the embankment erodes before this occurs, with the result that the kloof dams in the area have high sediment loads. There is little chance that existing disturbed areas will be stabilised.

Part II of Government Gazette (number 9238, 1984) deals with regulations relating to the control of weeds and invader plants.

Invader plants occur along almost all the watercourses in the area, particularly where natural vegetation has been removed. Regulation 16 (3) states that 'if invader plants of a kind specified in column 1 of Table 4 occur on a farm unit in the area specified in column 2 of the said Table opposite the kind of invader plant concerned to such extent that they are or could be to the detriment of the production potential of the natural agricultural resources, the land user of the farm unit concerned shall, by means of as many of the measures set out in subregulation (1) (uprooting, felling, cutting, burning etc.) as are necessary in his situation, control those invader plants effectively.'

Included in column 1 of the above mentioned Table 4 are the most commonly

occurring invader plants in the area such as Acacia cyclops, A. mearnsii and A. melanoxylon. The area specified in column 2 is, in all cases, the Republic, the last two mentioned plants being excepted where they are commercially cultivated. Small stands of these plants were planted in the past but have now been removed although seedlings are still coming up in the areas which are now pine plantations and along most watercourses.

It is questionable whether these plants are affecting the 'production potential of the natural agricultural resources' as watercourse areas are not supposed to be cultivated. It appears that their removal is not obligatory in such cases. While it seems that the removal of such alien vegetation in watercourses is desirable, Regulation 16(3) does not seem to provide the control needed.

This ends discussion of the control measures of Act 43, 1983. The controls cover most of the stated problem areas as regards soil loss in the area. One exception might be the control of livestock movement in watercourse areas. In addition, the presence of permanent grazing crops adjacent to watercourse areas is, in some parts of the study area (areas with long steep slopes and erodable soil types), no guarantee that considerable soil loss will not occur after sustained rainfall, particularly when riparian vegetation has been removed.

It has been stated that one of the factors preventing effective conservation farming is the small size of some of the farms in the area, leading to cultivation of marginal land and, in some cases, overgrazing or

grazing of vulnerable lands in unfavourable weather conditions. The Subdivision of Agricultural Land Act 70 of 1970 stipulates that agricultural land may not be subdivided unless the Minister of Agriculture (or delegated authority) has consented to such subdivision. There is no provision for consolidation of existing uneconomic farm units (Fuggle, Rabie et al. 1983, p.158). This act may prevent further subdivision of farms in the area, but will not prevent continued farming of marginal lands on existing farms.

The Water Act, number 54 of 1956 aims 'to consolidate and amend the laws relating to the control, conservation and use of water for domestic, agricultural, urban and industrial purposes; for the control of certain activities on or in water in certain areas; for the control of activities which may alter the natural occurrence of certain types of atmospheric precipitation; for the control, in certain respects, of the establishment or extension of townships in certain areas and for industrial matters'.

An important aspect of the act is that the Director General may instruct any person to construct water works for the control, conservation and use of water. Water works include structures such as canals, channels, reservoirs, protecting walls, embankments, weirs, dams, filters and sedimentation tanks 'constructed for impounding, storage, passage, drainage, control or abstraction of water... or the filtration or purification of water or effluent, or protection of water sources against pollution, erosion or siltation or flood control, or protection of any water work

or irrigated land'. The act could possibly be used to obtain greater control of runoff in the Swartvlei catchment area.

Section 23A of the act concerns prevention of pollution through farming operations. The act states that:

1) If the Minister is of opinion that the concentration of any livestock or any substance or the carrying on of any farming operations on any land is causing or is likely to cause the pollution of public or private water, including underground water, he may require the owner of such land or the person carrying on such operations to take, at his own expense and within a period determined by the Minister, such steps as the Minister may deem necessary for the prevention of such pollution, and may, if such requirement is not complied with, cause the required steps to be taken and the expenses incurred thereby to be defrayed out of moneys appropriated by Parliament for the purpose, and may recover such expenses from the said owner or person.

3) Any person who wilfully fails to comply with a requirement of the Minister in terms of subsection (1) shall be guilty of an offence.

This section of the act may be applicable to control of use of pesticides, herbicides and fertilisers, as well as to control of livestock-carrying capacity.

Section 59 (2) of the Water Act states that 'whenever, in the opinion of the Governor-General -

- a) the flow of a public stream in any particular area should in the national interest be regulated or controlled by damming, cleaning, widening, straightening or altering the course of the channel or by taking such other steps as may be necessary for the prevention or control of silt or for the purpose of lessening the possibility of damage to land which is riparian to such stream in the event of flood; or
- b) any land is required for the protection of any portion of the catchment area of a public stream,

the Governor-General may, by proclamation in the Gazette declare the channel of any stream or portion thereof, together with such portion of the land on either side or both sides of the said channel, or any other area situated within the catchment of the stream, as he may consider necessary for such purpose, and as may be defined in the section, to be a catchment control area, and he may from time to time in like manner... repeal any such proclamation.'

The Water Act also provides control measures for irrigation and dam construction activities.

If some of the discussed legislation could be legally enforced, it would go some way towards reducing the sediment loads of the watercourses in the study area. The most important legislation is that referring to cultivation of watercourse areas.

6.4 PLANTATIONS IN THE AGRICULTURAL AREA: THEIR MANAGEMENT AND SIGNIFICANCE IN RELATION TO THE EROSION POTENTIAL OF THE AREA

Plantation areas in the agricultural zone are comprised of small scattered areas on the more inaccessible parts of farms or larger areas owned by private companies. Many of the small areas on private farms are being clearfelled at present and, in most cases, pastures will replace them. These scattered areas of pine and Eucalyptus trees have rarely been subject to the usual degree of management, such as regular thinning or ground-vegetation clearing.

Remaining pine and Eucalyptus plantations on farms cover about 50 - 55 ha in the Diep-Wolwe river system, 25 - 35 ha in the Klein Wolwe river system, 13 - 44 ha in the Hoëkraal river system and 285 ha in the Karatara river system. The largest proportion (> 200 ha) in the Karatara system occurs on property 58.

6.4.1 Klein Wolwe River Area

There is an estimated 501 ha of pine plantation on property 19. Most of the trees are over 25 years old and will be clearfelled in the near future at ages of 30 to 40 years. Management activities until present have included thinning and road and firebreak maintenance. Problems have been experienced during wet periods due to the clayey nature of the soil. The area may be considered stable as regards erosion hazard at present, but clearfelling may alter the situation, particularly as both pine trees and roads occur in close proximity to watercourses,

particularly on the northern half of the property. Much will depend on the areas clearfelled in a single period and climatic conditions during and after the clearfelling operations. The Klein Wolwe river is relatively small, but is able to transport considerable quantities of sediment into Swartvlei after sustained rainfall. It would be advisable to monitor the situation in future. It would be necessary to distinguish, at their source, between sediment originating from roads as opposed to that from cleared plantation areas.

6.4.2 The Hoëkraal River Area

A large area of 2095,7 ha is under plantations in the Hoëkraal river system. Of this area, 1337,1 ha is comprised of trees of the Pinus and Eucalyptus species, whereas the rest of the area (758 ha) is indigenous or alien bush.

Individual forested areas are as follows:

Property 41

Until 1983/84 there were 220 ha of pines on this property, with the largest proportion of trees being over 22 years old. Twenty five to 30 ha have been clearfelled since then, and each year (1985-88) approximately a further 30 ha will be felled. The felled areas will be put under annual pastures for at least 2 years and then permanent pastures. Some of the area will be used for maize. The area may be considered as having low erosion potential as slopes are gentle and most of the steeper slopes are under indigenous forest.

Property 23

916,3 ha of this property is afforested, consisting of 711,3 ha of Pinus radiata, P. pinaster and P. ellioti trees and 205 ha of Eucalyptus diversicolor. The largest proportion of trees was planted between 1962-1970 and first fellings will occur from 1990 onwards (30 year rotation). The steeper slopes are still covered in indigenous forest (an estimated 440 ha) and, as the soils are sandy and relatively deep and infiltration rates are good, the area may be considered stable as regards erosion potential.

Properties 24, 34, 36, 37, and 44

Property 36, with a total size of 358,1 ha, has 75,4 ha under P. radiata pines which were planted in 1977/78 in an area previously cleared for pastures. The rest of this property is indigenous forest. During establishment, the area was fertilised with superphosphates and magnesium sulphates. The trees will be felled at 30 years of age.

The area may be considered stable as regards erosion potential at present. A vulnerable area during clearfelling operations will be the source area of a tributary of the Geelhoutboom river (which is a tributary of the Hoëkraal river). Trees have been planted through the stream. However, indigenous forest downstream will act as a filter for water originating in this tributary. The presence of duplex soils in the area (sandy loam with an underlying clay layer at a depth of 200 - 400 mm) makes it more vulnerable to erosion than the deeper sandy area of property 23.

Property 44 (42 ha) has been under 41,5 ha of pines until 1985. They are to be felled in 1985. The area will then probably be put under pastures. This area is more vulnerable to erosion than property 36 and clearfelling may affect the water quality of the Geelhoutboom river which is bordered by wattle (Acacia mearnsii) and pine trees rather than indigenous forest.

Property 37 (110,4 ha) was clearfelled in 1983/84. Pines are regenerating naturally on the property. Erosion potential is low due to the presence of indigenous forest on the banks of the Hoëkraal river.

There is a small area of pines on property 34 (12,5 ha), the rest of the area being grassveld (35,5 ha).

Approximately 45% of property 24 is made up of pine and Eucalyptus plantation. The area is used largely for recreation. Any clearfelling or other activities will not affect Swartvlei water quality as there are no watercourses in the area (recent sands).

6.4.3 The Karatara River Area

There are approximately 1156,2 ha of plantation in the Karatara area, the remainder of the area being made up of indigenous forest and grassland (97,8 ha). The properties concerned are numbers 61, 69, and 77.

Property 61

There is an estimated 1023 ha of plantation in the Ruigtevlei area east

of the Karatara river. Ages of the trees vary between 6 - 30 years old. Clearfelling operations are not likely to occur for another 5 - 10 years. This area is not important as the volume of water contributed to the Karatara river from here is minimal. The deep sandy soils of the area reduce erosion potential.

Property 69

Sixty three ha of this property falls within the study area. On the property are 10 ha of pine and Eucalyptus trees. The rest of the area is under Wattle trees (Acacia mearnsii), fynbos and grassland. The trees are to be felled in 1985 and either pastures will be established or natural regeneration of pines may occur. Activities here are unlikely to affect the Karatara river's water quality due to the river being well protected by forested embankments.

Property 77

There are approximately 123,2 ha of plantation on this property of 168 ha. The rest of the area is grassland (an estimated 15 ha) or indigenous forest (an estimated 29,8 ha). Most of the trees are between 16 - 25 years old and will be felled in 5 - 14 years. Several small tributaries of the Karatara originate in the area and future clearfelling operations might affect water quality, as trees grow close to the watercourses. There will be some chance for sediment to settle out in the downstream area of the tributary, before it reaches the Karatara river mainstrem. The soils in this area are extremely vulnerable to erosion, as can be

seen on the road cutting opposite the eastern border of the property.

Mixed pine and Eucalyptus plantations occur on property 58, which has been divided into 28 portions. The area is used for recreation.

Recreational and clearfelling activities will not affect Karatara river water quality unless the existing indigenous vegetation on the steep slopes above the Karatara mainstream and the Karatara tributary on the northern border of the property is removed. Some small-scale experimental farming has been carried out on one of the portions above the Karatara mainstream. Erosion occurred when construction of terraces for crops and buildings was carried out on the slopes, but the water quality of the Karatara will not have been affected as activities took place far enough upslope. The vulnerability of the area to erosion was clearly visible. The presence of clay (which becomes extremely hard when dry, but semifluid when wet) under the sandy topsoil makes any disturbed area unstable. This area would be subject to landslips in the event of sustained high rainfall.

The plantation areas in the agricultural zone are not contributing high sediment loads to any of the river systems at present, but in some cases, as in the Klein Wolwe area (property 19) and Karatara area (property 77), clearfelling activities could change the situation. As stated in Section 5.2, factors such as climatic conditions during and after clearfelling, selection of slip paths and logging areas, use and maintenance of plantation roads, the areas clearfelled and their proximity to watercourses will all determine whether water quality will be detrimentally affected.

6.5 SUMMARY AND CONCLUSIONS

Each of these river systems has the potential to contribute sediment to Swartvlei after sustained rainfall conditions. Both natural and man-induced factors influence the severity of sediment contribution. Man has not recognised the vulnerability of the natural system he is exploiting to sediment loss, either through runoff or soil slippage. It is the removal of nature's natural protection mechanisms which reduces the area's capacity to resist the effects of man's activities. The steep topography on mainstream river banks and presence of indigenous bush have prevented man from placing greater marginal areas under agriculture. The area can be agriculturally productive in the long term if the natural limitations of the area are recognised. If they are not recognised, productivity levels and productive area will decrease and water quality will deteriorate to the detriment of Swartvlei and the Wilderness Lakes system. Some of the most basic steps to be taken to maintain productivity and water quality are revealed in this section. A summary of these factors would be as follows:

- Protection and management of watercourse zones, including re-establishment of natural vegetation and gradual elimination of exotic vegetation.
- Construction of vegetated runoff channels off steeper slopes, particularly where there are no contours and downslope ploughing. Runoff should be diverted through greenways where possible, to allow sediment deposition. Construction of conservation works, such as retaining walls and contours, is also recommended.

- Careful monitoring of the different carrying capacities of different slopes and pastures under varying weather conditions with appropriate adjustment of number of livestock.
- Control of livestock movement in watercourse areas.
- Establishment and maintenance of permanent pastures on vulnerable slopes, together with clusters or strips of larger, deeper-rooted vegetation.
- Closer monitoring of the effects of ploughing, particularly in relation to lifting of clay layers to the surface and reduction of infiltration and increase in compaction potential. This would include the establishment of the depth of the clay layer and appropriate adjustment of plough blades. In shallow soil areas, establishment of semi-permanent or permanent pastures may be advisable, with surface ripping to encourage infiltration of water and root penetration.
- Revegetation of disturbed areas, such as dam walls and perimeters.
- Careful control of irrigation practices, particularly prevention of excess runoff.
- Where possible, prevention of excess sediment runoff during dam construction or enlargement, particularly when heavy machinery is being used.
- Re-establishment of permanent vegetation in areas where pines have been clearfelled.
- Stabilisation of landslip areas.
- Maintenance of farm roads, including placing of drainage

structures in appropriate areas with carefully selected runoff zones. Particular care must be taken where roads cross or run adjacent to watercourses.

- Increased awareness of property owners of the sensitivity of the lakes system to sediment-laden runoff. A more positive role should be played by conservation and extension officers.

The above measures could go some way towards reducing sediment loads originating from the agricultural zone. However, adoption of such measures would entail some effort and sense of responsibility from the landowners in the area. This is unlikely to occur spontaneously. For this reason perhaps the first two measures are the most important. Landowners only have to refrain from cultivating or overgrazing watercourse zones and vulnerable slope areas. In addition, there is legislation which reinforces adoption of such measures. If one considers only water quality (and not long-term productivity), then the natural filtering and soil stabilisation actions of dense vegetation may be adequate as regards reduction of sediment volumes to Swartvlei.

CHAPTER 7

ROADS, ROAD CONSTRUCTION AND RECREATION

One of the main sources of sediment has been the roads and road construction activities in the area. All of the rivers entering Swartvlei are affected in some way. In most instances, tributaries of the rivers are affected rather than the main channels. The frequency, quantity, and duration of rainfall determine whether a significant quantity of sediment is transported into the main channels of the rivers and thereafter into Swartvlei. The velocity of water flow is thus the determining factor.

A description of the roads in the study area is given. Those areas where the sediment loads of rivers or their tributaries are influenced by the nature of the road or reconstruction activities are noted.

(Refer to Fig. 6.2).

7.1 THE NATIONAL ROAD

This passes south of the lake portion of Swartvlei, and traverses the upper reaches of the Swartvlei estuary, together with the railway. This road will not be discussed further as it does not affect the catchment rivers in any way.

7.2 THE OLD MAIN ROAD (NUMBER 14) RUNNING FROM CROSSROADS IN THE WEST TO BARRINGTON IN THE EAST, A TO I.

It is this road which crosses all the catchment rivers of this study. This road is undergoing reconstruction at present. Reconstruction is taking place between Hoekwil in the west and the farm "Lancewood" in the east. Reconstruction activities began in 1978, and will continue until 1985/86, depending on the availability of funds. The reconstruction includes the building of a new bridge over the Diep-Wolwe river. The distance between the Rondevlei turnoff (western border of the study area) and Barrington (eastern border) is 22,7 km. Of this, 7,3 km has been surfaced. There are four quarries on this road, one of which affects the Diep-Wolwe river directly.

There are several points where the road crosses over tributaries of the main rivers, which contribute varying quantities of sediment during rainfall periods. Travelling west to east, one finds the following problem areas (Fig. 6.2).

Site A

At the farm "Skuinskraal" (1,4 km from Rondevlei turnoff) a small tributary of the Diep river has its source. The water is piped under the road. The banks of the road are well vegetated, and the road itself does not contribute additional sediment to the tributary. It is not a problem area at present, although there may have been problems in the past when the road was being surfaced. Sand may have been pushed over the road banks and into the tributary.

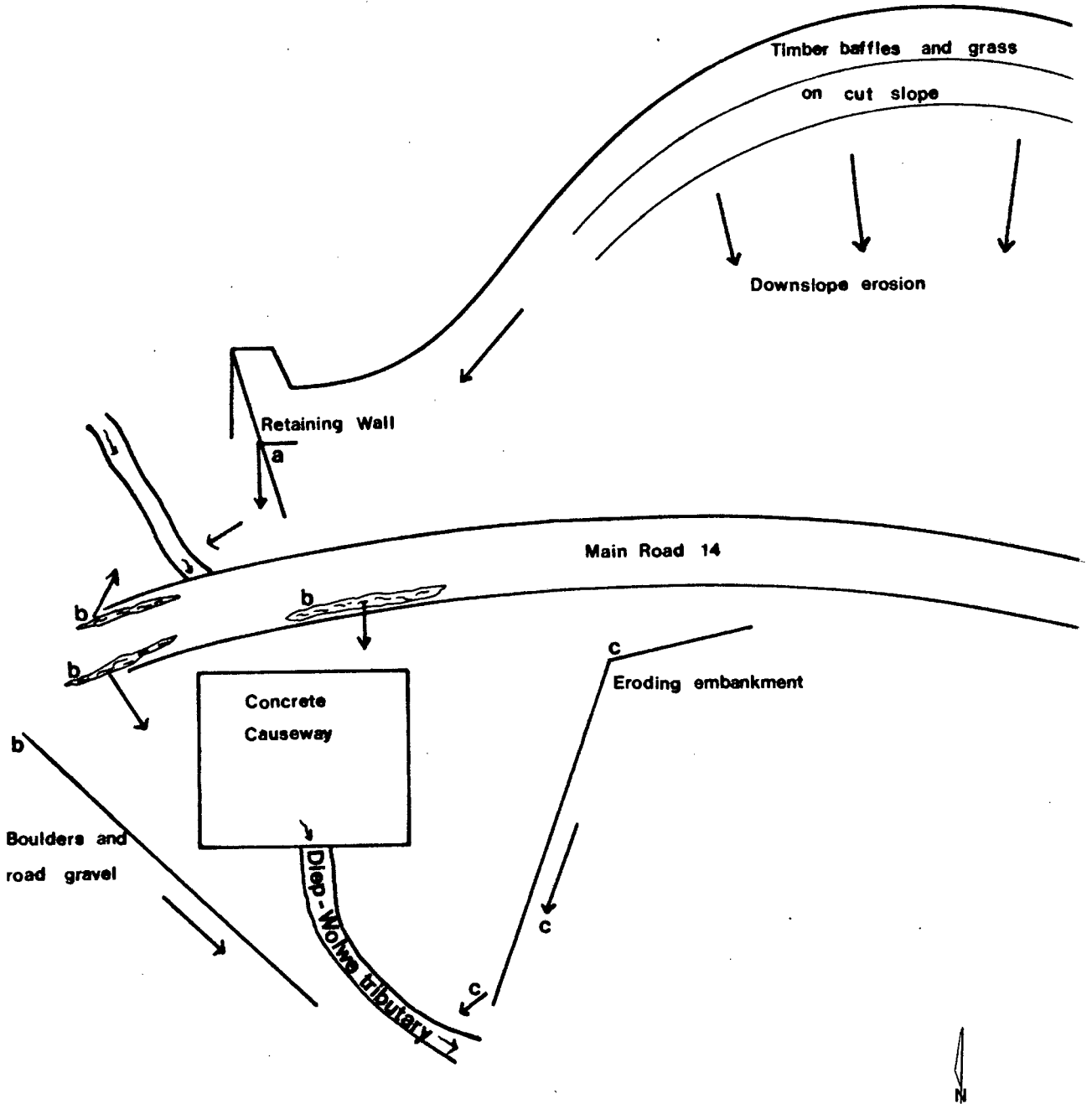


Fig 7-1 SITE B ROAD CUTTING and QUARRY, DIEP-WOLWE RIVER TRIBUTARY

Site B

The first major road-cutting and quarry is situated 2,9 km from the Rondevlei turnoff. The quarries on the main road are composed of weathered granite or quartzitic sandstone. This cutting has been directly responsible for increased sediment loads in the tributary water (see sediment readings p. 226). Sediment is originating at four different sources (refer to Fig. 7.1). This tributary is derived from two tributaries of the Diep-Wolwe river which originate in the Woodville forest, north-west of the cutting. It has been noticed that, after rain, water from these tributaries is sediment-laden before it reaches the road cutting. There is thus a source of sediment independent of the road cutting. However, there is no doubt that the road cutting is contributing additional sediment to the tributary, as the water has higher sediment loads after it has passed under the road. During storm events, sediment can be seen originating from three points of the cut, namely:

- a - At the base of the cut slope sediment washes over a retaining wall and into the stream.
- b - Rainwater collects in pools on the road verges. It erodes through the sandy road banks and runs down-slope into the stream.
- c - Rainwater runs off this steep, bare, unstable slope causing clods of soil to be dislodged at the top of the bank, and erosion gullies to develop on the slope. Dislodged soil collapses into the stream. The sediment-laden water runs adjacent to the road at the base of the road bank. It joins the mainstream of the Diep-Wolwe river downstream of the bridge reconstruction area.

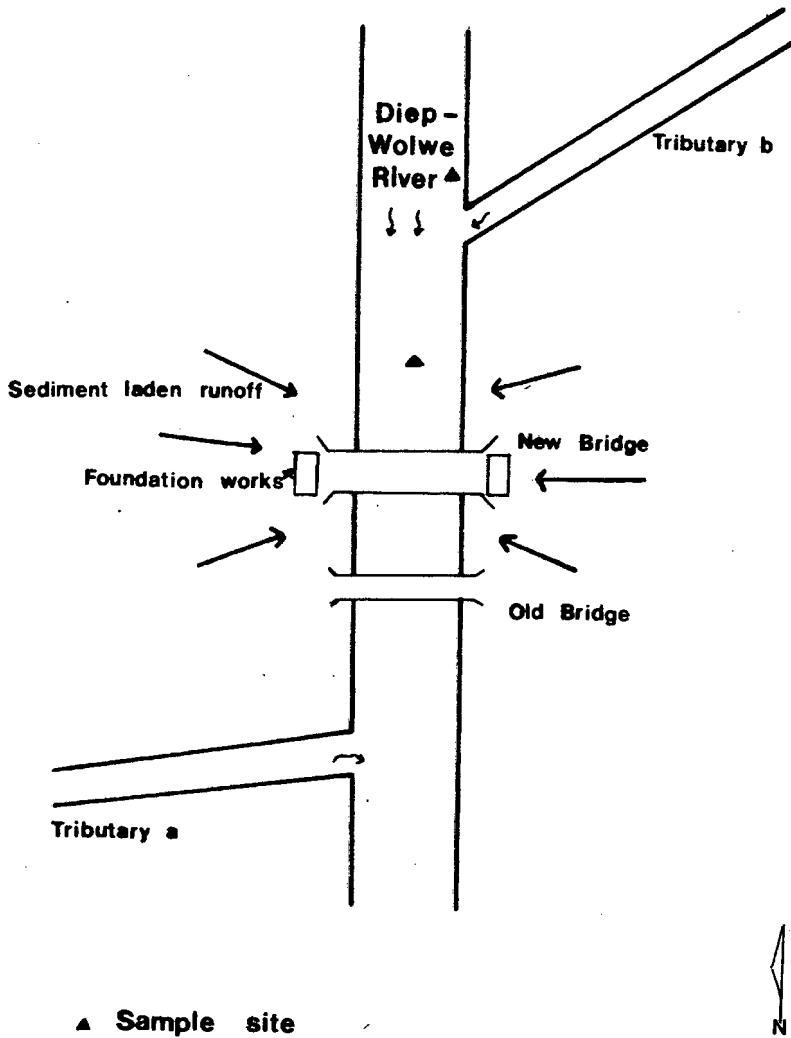


Fig 7.2 THE BRIDGE CONSTRUCTION SITE ON THE DIEP-WOLWE RIVER (Site C)

During dry periods the amount of sediment carried by this tributary is minimal. After rain (> 30 mm) the sediment contribution is significant.

Site C

0,5 km further along the road (3,4 km from the Rondevlei turnoff) one crosses the old bridge over the main stream of the Diep-Wolwe river (see Fig. 7.2). The new bridge is being constructed adjacent to and slightly upstream of the old one. Disturbance of the river banks has occurred, but only in the immediate construction area. Under dry weather conditions the flow of the river is not sufficient to pick up large quantities of sediment from the river banks, and the water remains clear. After rain, however, sediment-laden water runs off the devegetated banks and into the river. The constant movement of construction workers and their equipment across the river also contributes to sediment disturbance. This will continue until construction activities cease (1985/86). However, from what can be seen, the construction activities themselves are not contributing any more sediment to the Diep-Wolwe river than are the tributaries entering the river at the bridge area. The tributaries concerned are:

- a - the tributary south of the bridge, discussed in the previous section (transporting sediment from the road cutting), and
- b - a tributary entering the Diep-Wolwe river north of the bridge. This tributary originates in the forested Beervleibos area, north-east of the river. It passes through pine forest and then

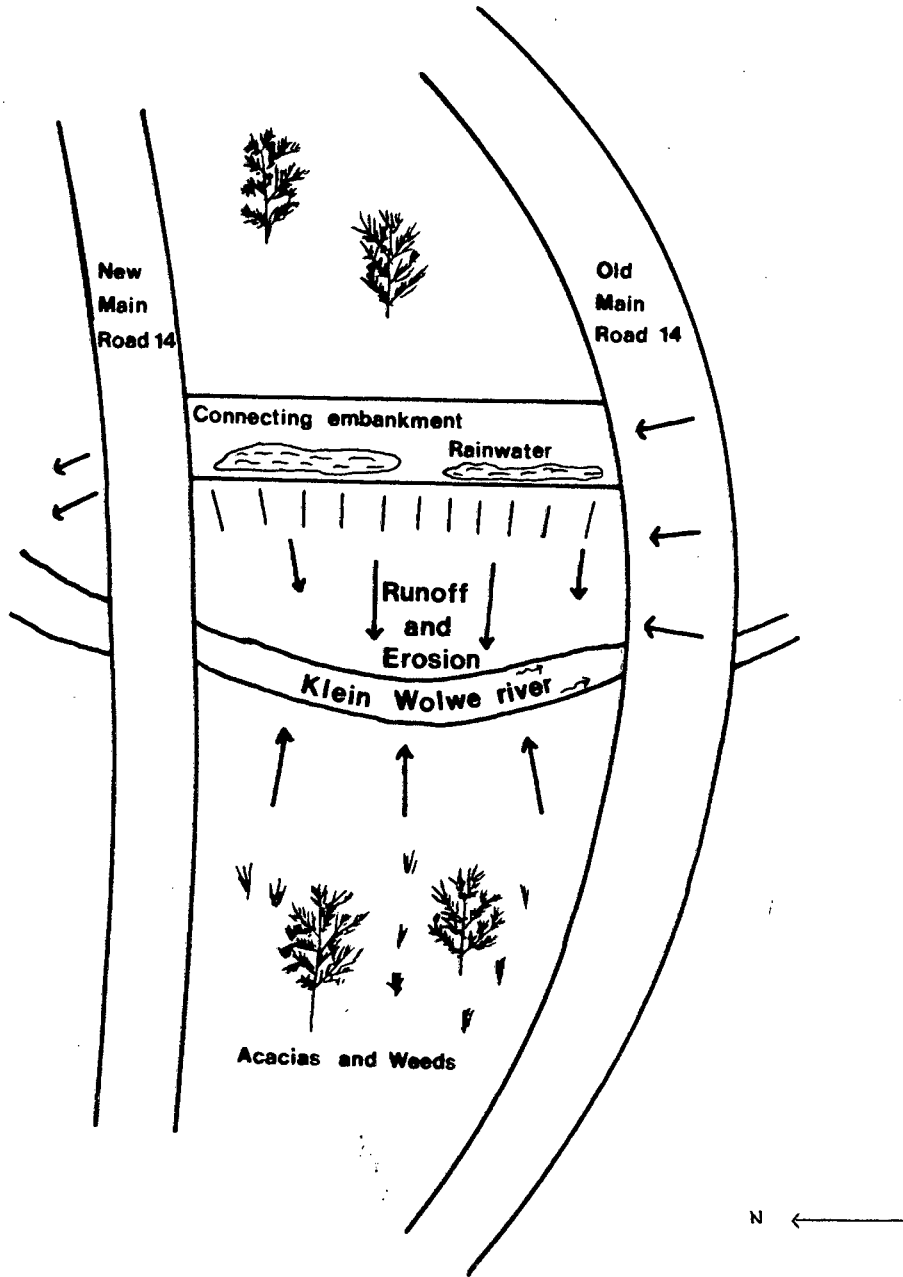


Fig 7.3 SITE D, KLEIN WOLWE RIVER, ROAD RECONSTRUCTION

through several farms, south of Beervlei. The sediment load of this tributary is very high after rain, and the clarity of the water changes visibly downstream of the entrance point of the tributary. Upstream of this point, catchment water remains clear. The sediment load of the Diep-Wolwe river is thus being affected by three different sources, two of which are affected by road construction activities.

Two quarries can be seen on the hill slopes on the southern side of the bridge. The quarries are far enough from the Diep-Wolwe mainstream not to contribute sediment to it.

Site D

6,1 km from the Rondevlei turnoff one crosses the Klein Wolwe river. The road has been straightened at this point (Fig. 7.3). The concrete causeway under the new section of road was completed in 1983. Straightening the road necessitated considerable soil redistribution in the vicinity of the river. The river has had high sediment loads this year, and they were probably higher in the last four to five years when most soil redistribution occurred. Water which collects on the road verges, and runoff from the devegetated, disturbed slopes above the river still contribute sediment to this river. The old section of road is beginning to erode. Sediment from the road is transported to areas where it can enter the Klein Wolwe river. At present the roadworks are not the only sediment source, as the water is sediment-laden before it reaches the roadwork area. The river has its source in pine

forest, and its banks are bordered over most of the area by pine or wattle trees. Pine trees and alien vegetation do not have the same filtering role as indigenous riparian vegetation.

Site E

7,8 km from the turnoff (1,7 km from Klein Wolwe river) one crosses a tributary of the Hoëkraal river. A smaller branch of this tributary has its source just above the road on "Lancewood" farm. Water trickles into a small pool on the northern side of the road, passes under the road and continues through farmland until it joins another tributary of the Hoëkraal river. This tributary is insignificant as flow is very slow. However, after rain, considerable amounts of water, collected on the road verges, wash into this pool and are carried downstream. The sediment collected in this tributary, and others in the same vicinity does not, however, (in a year of average rainfall), affect the main branch of the Hoëkraal river. The reason for this is that these tributaries pass through a large area which is under indigenous forest. The thick vegetation on the river banks, as well as the winding course of the river, encourages deposition of sediment. The Hoëkraal is the only river that does not record abnormally high sediment loads after rain.

Site F

9,7 km from the turnoff (1,9 km beyond "Lancewood" tributary) one crosses another tributary of the Hoëkraal river. As in the above case

("Lancewood"), most of the sediment comes from water which collects on the road, erodes through the sand bank and into the tributary. The contrasting sediment loads above and below the road (see p.226) demonstrate the contribution of road wash to sediment load. Most of this sediment apparently, settles out in the indigenous forest previously mentioned.

11,1 km from the turnoff one passes a quarry, cut into the mountainside of the pass leading down to the Hoëkraal river. The quarry is a visual scar but does not contribute any sediment to the river. One crosses the Hoëkraal river bridge 0,9 km further on. There is no erosion problem at the bridge.

Site G1

This tributary originates on a smallholding. It is bordered by riparian vegetation. The tributary is dammed before passing across the road. The lower reaches of the tributary trickle through pine plantation. The trees are planted to water level. Rain water collected on the road verges runs into the stream.

Site G2

15,6 km from the turnoff (3,6 km beyond the bridge) one crosses the Geelhoutboom river, one of the larger tributaries of the Hoëkraal river. On only one occasion (7.10.84) has water from the catchment of this river had high sediment loads. Under dry conditions the water is clear. After small amounts of rain (up to 40 mm) the water from the catchment remains clear as it passes under the road. The water undergoes a

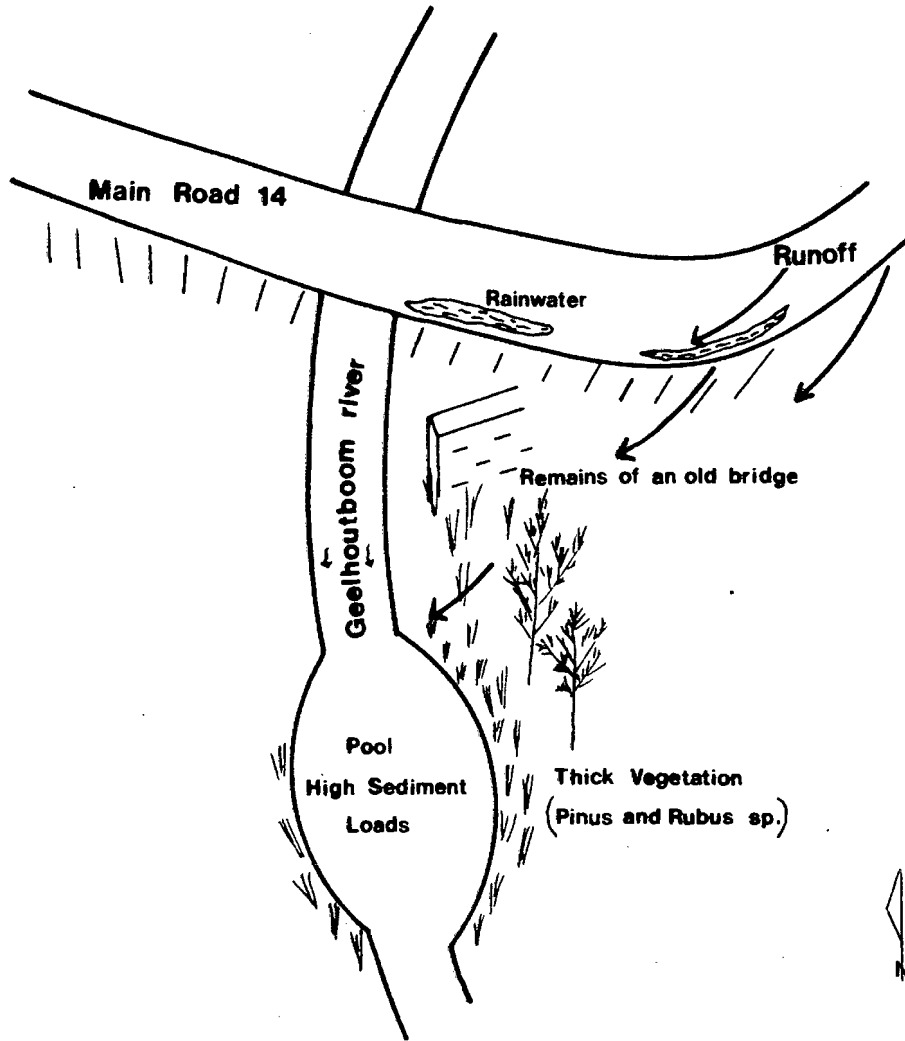


Fig 7.4 SITE G2 GEELHOUTBOOM RIVER (Hoëkraal tributary)

dramatic change in sediment load two to three metres downstream of the road where it appears to enter a pool (see Fig. 7.4). This pool is given its high sediment load by runoff of rainwater from the road. Due to the thick bramble-type vegetation (Rubus sp.) growing over an old broken bridge near the pool, it is not possible to see where the sediment-laden water enters the pool. The source of this sediment-laden water is quite visible on the southern side of the road. It appears that indigenous forest removes most of this sediment before it affects Swartvlei's water clarity. Although the roads are contributing considerable amounts of sediment to the Hoëkraal river tributaries, it does not constitute a problem due to the nature of the country these tributaries pass through before reaching Swartvlei. This is not the case with the Diep-Wolwe and Karatara rivers.

Site H

17,8 km from the turnoff (2,2 km from the Geelhoutboom river) one reaches the turnoff to Sedgefield. Just past this turnoff, the Huis river flows through a concrete causeway, under the road. The Huis river is a tributary of the Karatara river. At present the road banks are fairly well vegetated and there is no erosion into the tributary. However, there is evidence that in the past, when the road was constructed, large quantities of soil were pushed to the side of the road at the area marked H on Fig. 6.2. This soil has eroded, forming deep gullies and caverns. The soil over these eroded caverns is firm, but the entire bank has the potential to collapse with repeated rainfalls. If this occurs, material will erode into a

tributary of the Huis river, which lies adjacent to a small vlei at the base of this slope. Some Acacia mearnsii trees have started growing on the slope, but it would be preferable to stabilise this slope entirely. Most of the sediment entering the Huis river has its source in the Karatara settlement area.

1,1 km beyond the first Huis river tributary the road passes over another tributary, which leads into the Huis river. This one originates in the Karatara area. It has high sediment loads, but these have nothing to do with the road itself (see agriculture p. 169).

Site I

One crosses the Karatara river bridge 1,3 km beyond Karatara village. There are no erosion problems at the bridge itself. A small tributary (labelled iib) running north-east of the bridge, adjacent to the road, brings water into the Karatara just below the bridge. This tributary carries high sediment loads under high rainfall conditions. The tributary originates on two farms in the Barrington area, passing through pine forest and indigenous forest en route to the Karatara river. It has been noticed that rainwater runoff runs down the portion of road adjacent to the tributary. In places it erodes through the road banks, and presumably filters down to the tributary below. The water disappears into the thick bush on the slopes above the tributary.

Road construction, as well as the present condition and characteristics of this road, influence the sediment loads of the rivers concerned.

1,3 km further along the road one reaches Barrington and the Main Road turnoff to Ruigtevlei. There are four roads which branch off main road 14. These roads act as dividing lines between the three main rivers. In all three cases, tributaries of these rivers have their sources in kloofs on either side of the roads.

7.3 THE ROAD RUNNING BETWEEN WOODVILLE AND RONDEVLEI

This road forms the western boundary of the study area. The distance between Rondevlei village and the Rondevlei turnoff is 6,1 km. It is an old dust road (it was in existence in 1937 - records of precise construction date are missing) which serves mostly farmers and foresters. The road is eroding on the steep slope which ascends the plateau but this does not affect any waterway. The road banks are well vegetated.

7.4 THE LANCEWOOD TO EASTBROOK ROAD

Another old dust road (constructed in 1919) runs diagonally between Lancewood and Eastbrook, a distance of 8,9 km. It is bordered largely by pine and eucalyptus plantations. This road is well established, and there are no signs of major erosion on its banks. There is a concrete causeway across the Hoëkraal river just above Eastbrook. The Hoëkraal river frequently flows over this causeway. A small amount of sand and gravel from the road on both sides of the causeway is washed into the river on these occasions, but does not affect its sediment load significantly. A small section of gravel road runs adjacent to

the Hoëkraal river just after crossing the causeway. During the high rainfall period of 1981, the water level of the Hoëkraal river rose up to this road. The road was not washed away but considerable quantities of sediment and sand must have been collected by the fast-flowing water. This could occur again in similar circumstances.

7.5 DIVISIONAL ROAD NO. 54 (8,2 km)

This road runs between Hollywood and Eastbrook. It was reconstructed and surfaced between 1974 and 1977. It forms a boundary between the Hoëkraal and Karatara rivers. Tributaries of both these rivers originate on either side of the road. In places the kloofs are close to the road (as shown on Fig. 6.2). It is possible that during road reconstruction activities (1974-77) some material could have washed into the tributaries (of the Karatara river), particularly at the points marked T, 2 and 4 km from the Sedgfield turnoff. There is no longer a problem as the road banks appear stable, and the areas surrounding the tributaries are well vegetated (pastures or grass and trees).

At point Z, 4,6 km from the turnoff, there is a ditch on the right (Hoëkraal) side of the road. The sides of the ditch are eroding badly. Water from this ditch collects in a small earth dam which is situated at the source of a tributary which eventually runs into the Hoëkraal river. During flood conditions this could be a minor sediment collection point, as sediment-laden water from the dam overflows into the tributary. It must be emphasised that this would occur only in flood conditions. At present there is no problem.

A landslip (marked L on Fig. 6.2) occurred (approximately 7 km from the turnoff) in 1981 and part of the road was washed downslope. A small tributary of the Hoëkraal river runs adjacent to the road at the base of a long steep slope. Material from the road washaway would have affected this tributary in 1981. The tributary banks are well vegetated, and some of the sediment would have settled before reaching the mainstream of the Hoëkraal river. It is possible that this washaway and the subsequent reconstruction activities affected the sediment load of the Hoëkraal river in 1981. There is no longer a problem as the steep slope has revegetated itself, and appears stable under present dry conditions. The banks of the road cutting are still eroding, but this will not affect the tributary.

The road is surfaced between the turnoff at Eastbrook and Ruigtevlei, a distance of 2,6 km. At Ruigtevlei, a concrete causeway crosses the Karatara river. There is no erosion at this causeway. The condition of the causeway was improved in 1978 (resurfaced).

7.6 MAIN ROAD NUMBER 26

The eastern boundary of the study area is demarcated by main road No.26, running between Barrington and Ruigtevlei, a distance of 13,5 km.

This road was reconstructed and surfaced between 1969 and 1973. There are several places along this road where serious erosion is occurring. In most cases this is because the road cuttings are too steep, and vegetation has not been able to reestablish itself. One partially

successful attempt has been made to establish vegetation on an eroding slope 10,3 km from the Karatara/Ruigtevlei turnoff off the main coastal road. This particular slope does not contribute any silt to the Karatara river which runs on the western side of the road. This is not the case, however, with an eroding slope at Melkhoutskraal, 6,6 km from the Karatara/Ruigtevlei turnoff (see Fig. 7.5). A tributary of the Karatara river runs at the base of a steep bank adjacent and approximately parallel to the road. The stream has its origin in pine forest which is being clearfelled at present. It passes under the road where it curves sharply. It then flows through grassed pastures. Storm-water collected from the road is channelled down a concrete and stone channel into the stream. The stream subsequently passes through pastures, eucalyptus plantations and along a ditch at the base of pine plantation. In the pastured areas the stream is not fenced off from cattle. The Eucalyptus trees grow down into the stream and, as the stream is at the base of a hill slope, there is considerable runoff after rain. There are thus several areas where sediment can be picked up by the stream. After rain, the water is sediment-laden before it reaches the area where the road collapsed.

In 1981, due to the presence of groundwater (spring) and the high rainfalls, this portion of road was washed away and had to be reconstructed. A pipeline was installed under the new road to drain water from the upper slopes. This water is directed into a concrete channel which runs down the slope marked A in Fig. 7.5. This water flows into a reservoir tank and into the stream. This water is normally fairly clear. During rainfalls (such as occurred between 5 - 7 October 1984)

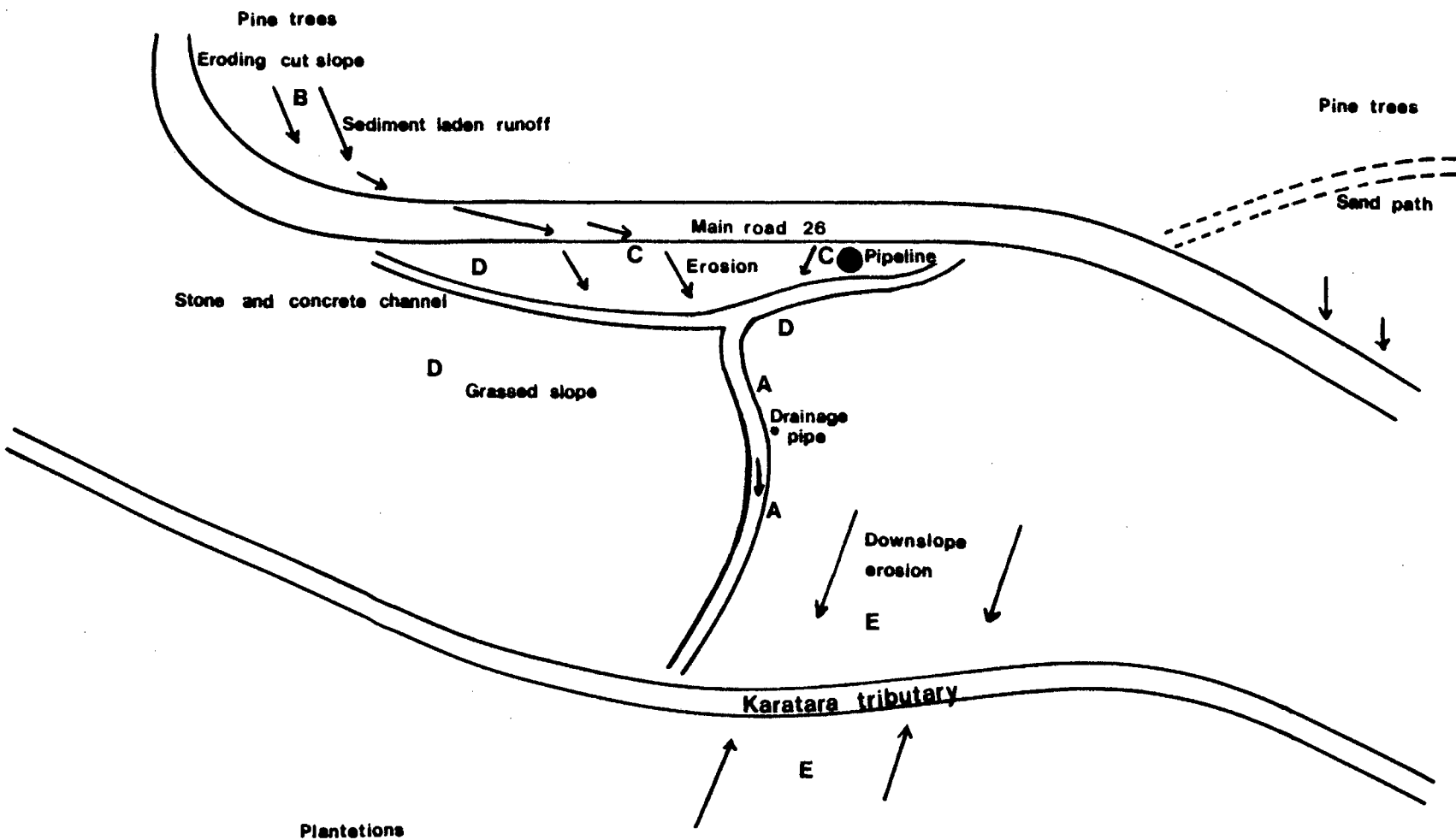


Fig 7.5 MELKHOUTSKRAAL LANDSLIP AREA

water washes off the eroding slope (marked B), and, with its heavy load of sediment, flows across the road. Where it runs over the edge of the road (marked C), erosion gullies are developing which will eventually undermine the road. The water then runs into the channel or down the banks marked D. This water contributes additional sediment to the tributary. Another source of sediment is the embankment marked E. As there is no significant vegetation on the embankment it is eroding away.

There is a continuous trickle of water in this tributary, even during low rainfall periods. Under these circumstances the velocity of water flow is not sufficient to pick up sediment and the water is clear. After rain (> 30 mm) the velocity of the water increases substantially and sediment-laden water flows rapidly into the main branch of the Karatara river. (The owners of the property "Melkhoutskraal" say that the Karatara becomes visibly muddy.) This tributary enters the Karatara river on the riverside farm "Forest Hills". It exits from a kloof vegetated with a mixture of indigenous and exotic trees, meanders across a flat grassy area, and then, as it approaches water level, erodes a donga (about 1 m deep) through which it flows into the river. Where it enters the river a large sandbank (about 2 - 3 m across) has developed. According to a landowner who lived in the vicinity some years ago, the size of this sandbank increased considerably after the 1981 road washaway. The sandbank is firmly established and is not likely to be eroded away until another series of high rainfalls. As the tributary trickles over the sandbank and into the Karatara, a small quantity of sediment is dislodged into the water. Under dry conditions

this is of no significance. Under wet conditions the amount of sediment entering the river increases considerably. The tributary water and the sandbank are significant sediment sources for the Karatara under high rainfall conditions.

It is possible that the sandbank will change the flow pattern of the river in time. Salvinia molesta is increasing at present as there have not been sufficient rainfalls this year to wash it out of the river. The weed slows surface flow. Base flow is relatively rapid, and because the river water is being forced through a narrower area (only 1 - 1,5 m wide), the river bank opposite the sandbank may be gradually undermined. (The above deduction has not been tested in any manner.)

The above observations show that there are several factors which may influence the quantity of sediment entering the catchment rivers and their tributaries. A summary of these factors is as follows:

- The gradient of road cuts, and whether runoff from the cut slopes enters a waterway.
- The erosion potential of sandy road embankments, i.e. the ease with which water collected on road verges can erode through the banks and run downslope into waterways.
- Construction activities at such sites as the Diep-Wolwe river bridge.
- The presence of constructed runoff channels which direct sediment-laden water into waterways (with no natural filter mechanism, such as vegetation, or method of slowing rate of entry into the waterway concerned).

In addition there are several factors which determine whether sediment-laden water entering the waterways will have any effect on the turbidity of Swartvlei. A summary of these factors follows.

- The quantity, frequency, intensity and duration of rainfall, which influences velocity of flow, degree of infiltration, and quantity of sediment disturbed and transported. Under low flow conditions in tributaries, the area (between river banks) over which water runs is decreased and less sediment is collected. Slower flow rates permit sediment to be deposited and trapped before reaching the main branches of the rivers concerned.
- The proximity of the sediment source to the main branch of the river. Tributaries which run through sediment source areas, and which are relatively short, and lead directly into the main branch of the river, have greater potential to cause a significant decrease in water clarity. Those tributaries which cover a greater distance before reaching a river, and which take a relatively winding course, have greater opportunity to deposit sediment.
- The nature of the vegetation the rivers and their tributaries pass through. Where indigenous forest borders the waterways (as on the Hoëkraal river) there is a much greater opportunity for sediment entrapment and deposition. Afforested regions and areas under crops or pastures have less potential for this function.

- To a lesser extent, the number and size of dams situated on the tributaries can influence sediment load. Earth dams can trap sediment-laden water, decreasing the amount reaching the rivers. This has occurred this year. In wetter years overflow from dams can increase the quantity of sediment-laden water reaching rivers.
- The salinity levels of Swartvlei influence flocculation rates. This year salinity levels have been high, and the clarity of the water has been good.

Both natural and man-made features influence silt loads. One questions whether the situation can be improved, and, if so, how? It is clear that vegetation (particularly indigenous forest) plays a particularly important role in decreasing sediment loads along waterways. For this reason, this is where the primary emphasis should be laid when attempting to alleviate the problem of high sediment loads. Slope stabilisation and protection is important. Until now, two methods have been used, with varying degrees of success. These are stone-packing and timber baffles.

Stone-packing has been used on an eroded slope on Divisional road No.54, 8 km from the National Road turnoff to Karatara. Stone, packed together with concrete, forms a wall on the eroding slope. However, because the slope is too steep, a portion of the wall has slipped away, leaving a gap where serious erosion is occurring. This eroding area will ultimately threaten the rest of the wall.

The more frequently used method of securing boxwood planks by means of pegs, and the subsequent scattering of Kikuyu seed, has also had varying degrees of success. It has been used with partial success on the upper slopes of the road cutting and quarry on main road No. 14 (discussed on p.203) and on main road No. 26 (discussed on p.215) However, the success of this method depends on many factors, namely:

- The degree of erosion already present on the slope. The lower slopes of the cut on main road 14 will probably become too eroded for this method to succeed on its own. At the site on main road No. 26 (10,3 km from the Karatara/Ruigtevlei turnoff), this method is not successful where erosion gullies have formed on the slope. It is thus important to implement this method before the slope becomes seriously eroded.
- The gradient of slope, and soil type. According to Jaaback (1981) slopes as steep as 45° or 1:1 have been satisfactorily established to vegetation where rainfall intensities are low, and exposed subsoil horizons are relatively permeable. The rainfall intensities in the study area fluctuate unpredictably and, from what can be seen on the cut slopes, are too intense for the type of soil (sandy to sandy-loam) to accommodate without erosion. The conclusion reached by the Chamber of Mines in South Africa is that the maximum angle for successful vegetation establishment is 1:2 or 27° . The cut slopes on the roads in the area are almost vertical, and, because the roads run almost directly beneath the slopes (particularly on main road No. 26), to decrease the slope would necessitate expropriation of the land above the

cut slope. The land in question usually is the property of forestry plantation companies (private and state), or farmers. The land above cut slopes is rarely intensively used, and would not represent a serious loss to the property-owners concerned. However, costs of expropriation do fluctuate, and are prohibitive. Other costs which fluctuate are the cost of grass, topsoil, and boxwood, and the cost of transporting them varying distances. Machinery and labour costs are more stable. Thus, before selecting a method of stabilisation, one must consider the following:

- The slope of the cutting.
- The nature of the subsoil, i.e. its stability, water infiltration capacity and permeability, nutrient status, and degree of compaction.
- The local climate.
- The availability of necessary materials such as topsoil and baffles (Jaaback 1981).

It is clear that methods other than timber baffles may have to be used on the seriously eroded slopes. Jaaback (1981) reviews current methods, and recommends different types for varying conditions. The various costs have to be taken into account. From the information in his article, it is recommended that other methods of slope stabilisation be employed. In particular, horizontal ridging and seeding may be considered, or diagonal wire meshing, seeding and straw mulching. Due to the degree of erosion already present, topsoiling may be necessary. It

is possible that soil could be obtained from the land expropriated for lessening slope gradient.

Under any set of circumstances there is a method that can be used satisfactorily to stabilise and vegetate steep cut slopes. Although costs are high, the cost of future maintenance will increase as the cut slopes deteriorate. In the study area, there are places (such as main road No. 26) where the road will eventually be threatened by eroding slopes, or falling trees, which perch precariously on the top of cut slopes. These constitute a danger to the roads and the public. The reason that there has not been more damage until now is the below-average rainfall of the last two years. There will be greater problems in wetter years to come.

The reason that little attention has been given to these slopes has been given as the economic recession (pers. comm. Mr Brown, Divisional Council). No funds have been made available for slope reconstruction, stabilisation, or vegetation. Slope stabilisation will occur only when there is a direct threat to the road concerned. In some areas the eroding slopes are on the property of private land-owners (such as at Melkhoutskraal). It becomes the responsibility of the landowner to prevent erosion on the slope. In most cases the erosion is not threatening his own property (although it may affect waterways), and for this reason no steps are taken to alleviate the situation.

The gravel roads are maintained. They are graded as frequently as

is necessary, depending on rainfall. They are usually graded once every six weeks to three months. During the grading process, fresh piles of sand are pushed to the side of the road. These are often swept away by roadwash and into streams.

It is recommended that drainage water from the road verges be channelled away from the roads into areas, which must, preferably, be stepped and grassed. The water should run into a well-vegetated area, rather than directly into a river or its tributary. This would prevent erosion of road embankments, and decrease the sediment load entering streams.

Areas where roadwash enters streams are not given any special attention. The only sites that will be checked regularly (annually) by the Divisional Road authority are those embankments in the immediate vicinity of the Diep-Wolwe river bridge supports.

It is recommended that those areas which contribute sediment to streams (mentioned in preceding pages) be inspected by the roads authorities. In most cases it would not entail great expense to divert the water away from the roads and streams through stepped and vegetated pathways. It may be possible to allow roadwash to filter into the streams, but the flow of water should be slowed to allow maximum infiltration and sediment deposition. The path of water into the stream should not be direct.

The roads are not the only source of sediment, but they do contribute sediment to watercourses after rainfall.

Table 7.1 Sediment loads of Tributaries affected by Road wash or construction activities.

	1 days rain 10-15mm rain samples taken immediately 12 March 1984 Mg/1 GF/F	Dry conditions (no rain) 3 April 1984 Mg/1 GF/F	1 days rain 20-28mm rain samples taken immediately 13 June 1984 Mg/1 GF/F	3 days rain 50-55mm rain samples taken 1 and 2 days after rain 22 July 1984 Mg/1 GF/F	2 days rain 43-50mm rain samples taken immediately 7 Oct. 1984 Mg/1 GF/F	1½ days rain 41-50mm rain samples taken 16 hrs. after rain ceases 8 April 1984 Mg/1 GF/F
<u>Diep-Wolwe Trib.</u> Site B Road Cutting	25.3	10.6	504.6	muddy 780-500	85.0	-
<u>Diep-Wolwe River</u> Site C Bridge	3.1	1.4	27.1	15.8	Catchment 4.2 Trib.b 227.0	-
<u>Klein Wolwe River</u> Site D	70.1	25.5	4590	56.4	-	89.0
<u>Hoekraal Trib.</u> Site E Lancewood	-	30.5	568.0	-	-	-
<u>Hoekraal Trib.</u> Site F	-	-	Above rd. 15.8 Below rd 1082	-	-	-
<u>Hoekraal Trib.-</u> Geelhoutboom R. Site G2	Upper 16.4	Upper 7.1	Upper 11.8 Lower 32.8 pool	Upper 18.2	Upper 128.0	Upper 15.0
<u>Karatara Trib.</u> Melkhoutskraal	-	-	-	71.0	-	209
<u>Main Branches of the Rivers</u>						
<u>Diep-Wolwe River*</u>	-	5.7	5.7	30.9	6.8	-
<u>Hoekraal River*</u>	-	2.7	4.6	17.5	14.8	5.0
<u>Karatara River*</u>	-	3.6	4.2	37.0	11.0**	20.5
	average 4.0	average 4.8	average 28.4	average 28.4	average 10.8	

*Marked on Fig.6.2

** This Sediment load sample for the Karatara river was taken too soon after the rainfall. Insufficient time had elapsed for sediment laden water in the upper sections of the Karatara river to reach the sampling site. The following day the water at this site had a high sediment load.

Note: On 6 - 7 July, 1985, there was between 60 - 70 mm of rain in 2 days, with approximately 40 - 50 mm occurring in 6 - 8 hours on the second day. No samples were taken but all the watercourses showed heavily sediment-laden water. Catchment water was clear with the exception of Karatara catchment water.

7.7 SEDIMENT LOADS: ROAD AREAS

Refer to Table 7.1 and Fig. 6.2 .

Table 7.1 gives sediment load results from samples taken at seven different points which are marked on Fig. 6.2 .

By studying Table 7.1 some general observations may be made as follows:

- All the rivers entering Swartvlei are affected in some way by the condition of the roads in the area, or road reconstruction activities.
- The sediment load of the waterways concerned is directly influenced by amount, intensity and duration of rainfall.
- The results of the samples are influenced by the time of sample collection, i.e. the period that elapses after rainfall ends.
- Under dry conditions there is no problem of high sediment loads.

Observations at individual sample sites show the following:

- Site B

Intensity of rainfall is probably the most influential factor here.

Intense rainfall is most likely to affect the exposed cutting slopes.

This accounts for the high sediment load of 504,6 mg/l on 13 June.

However, due to the relatively low rainfall, the effect would probably

not be significant as high velocity flow would not continue for a long enough period to affect the main Diep-Wolwe river. Although no sample

was taken on 22 July, the water had a high sediment load (at least

100 mg/l). Therefore, when there is 3 days rainfall, the sediment

loads remain high for at least 2 days after rainfall ends. Rainfalls of long duration would have greater effect on river and lake clarity.

- Site C

These results show the relatively low sediment loads found in the main channel of the Diep-Wolwe river. Water from the upper catchment area remains clear even after 43 - 50 mm of rain in 2 days (as shown by the sediment load of 4,2 mg/l on 7 October). The higher sediment loads of 13 June and 22 July are due to runoff of sediment-laden water from the embankments of the bridge construction site and the contribution of sediment from tributary b (see Fig. 7.2). These increased loads will affect the turbidity of the river and lake, particularly if rain continues for a longer period. The most serious contribution of sediment is from tributary b (227,0 mg/l). The sediment load from this tributary is diluted when it enters the mainstream of the Diep-Wolwe river. Main Road number 14 does not affect this tributary, which has its source in forestry and farm lands north-east of site C. The sediment load of 22 July (15,8 mg/l) demonstrates that the time lapse of 2 days before collecting the sample has probably resulted in a decreased sediment load (when compared with the sediment load of 13 June).

- Site D: Klein Wolwe River

This river contributes relatively little water to Swartvlei, but it has the highest sediment loads of all the rivers in the study area, even under dry conditions. It flows strongly after high rainfalls and can have extremely high sediment loads as shown by 13 June load of 4590 mg/l.

As this river has its source in forest and farm lands further south than the other three rivers (Diep-Wolwe, Hoëkraal, Karatara), its waters are not diluted by clear water from the naturally vegetated upper catchment area. Main Road number 14 has been straightened where it crosses the Klein Wolwe river (Fig 6.2). This necessitated considerable redistribution of soil, and sediment loads must have been considerably higher in 1982/83 than at present. Figure 7.3 shows where sediment is originating. Sediment loads remain relatively high after rainfall ceases, as shown by the 22 July reading of 56,4 mg/l.

Site E (Lancewood) and Site F. Hoëkraal tributaries

Sediment loads are high because of runoff of sediment-laden water from the road. This is clearly demonstrated at point F where the sample taken upstream of the road is relatively clear at 15,8 mg/l, whereas the sample downstream of the road, an area receiving road runoff, is muddy at 1082 mg/l. This demonstrates the extent to which road runoff alone can influence water clarity.

Site G2. Geelhoutboom River. Hoëkraal tributary

The sediment loads obtained on 13 June demonstrate the effect of road runoff - the upper catchment water remaining relatively clear at 11,8 mg/l and road runoff increasing the reading to 32,8 mg/l.

Karatara tributary. Melkhoutskraal. Main Road number 26

Because this sample was taken 2 days after rainfall ceased, sediment loads are lower than might be expected. The sediment load is due to

the road runoff (from the 2 concrete channels discussed in Section 7.6), erosion off the landslip and road cutting embankments, and the nature of the farmlands the stream passes through.

The sediment loads of the main branches of the Diep-Wolwe, Hoëkraal and Karatara Rivers just before they enter Swartvlei

These sediment loads demonstrate clearly that longer duration rainfall (at least 3 days) will have the greatest effect on Swartvlei. The sediment loads taken after 3 days of rain (22 July) are the highest. In addition, the taking of samples 2 days after rainfall ceases allows time for sediment-laden water to reach the lower sections of the rivers concerned. The more constant rainfall over 3 days allows a greater amount of roadwash to enter tributaries (runoff would cease sooner after a single day's rain). The infiltration rate will decrease as rainfall continues, allowing greater surface runoff. Saturation of exposed road cuttings and embankments makes them more susceptible to erosion. There is more time for erosion channels to develop and for natural barriers (such as surface litter and vegetation) to be washed away. The increased quantity of rain increases water velocity. Factors such as these make long duration rainfall of greater significance than short rainfalls. If one averages the sediment loads of the 3 rivers one obtains the results shown on Table 7.2 i.e.

Table 7.2

	<u>Sediment loads</u>	<u>Rainfall</u>
1 day's rain	4,8 mg/l	20 - 28 mm
2 days' rain	10,86 mg/l	43 - 50 mm
3 days' rain	28,4 mg/l	50 - 55 mm

The sediment loads recorded at the lower reaches of the rivers are low when compared with individual sediment loads at the various sample sites. Large quantities of sediment are settling out before reaching Swartvlei. The abnormally low rainfalls of 1984 have prevented excessive quantities of sediment entering Swartvlei. High infiltration rates and absorption of rainfall by farm dams have decreased water flow. In a wetter year sediment loads can be expected to increase considerably. The contribution of sediment by roads and eroded embankments will increase and the amount entering Swartvlei will increase sufficiently to affect light penetration.

7.8 RECREATION

Recreation has had no significant effect on Swartvlei sediment loads. Most recreation occurs on the western and eastern shores of the lake and in the estuary itself. Destabilisation of Swartvlei's shores, either through removal of vegetation or uncontrolled construction of poorly designed slipways or jetties, could make some areas vulnerable to sediment loss. Recommendations against such practices have been made in management proposals for the area, by Howard-Williams and Allanson (1979) and Whitfield (1982).

CHAPTER 8

SUMMARY AND CONCLUSION

Land utilisation and management practices of the Swartvlei catchment are influencing the water quality of Swartvlei. This study has found that:

- there is no single major source of sediment, but a combination of sources;
- the onset of certain rainfall conditions acts as the trigger mechanism for accelerated loss of sediment;
- the topographical and soil characteristics of the area make it sensitive to soil loss;
- man's land management activities in the area have increased its sensitivity to soil loss, largely through the removal of natural vegetative cover and lack of structures to direct runoff.

In summary this study has shown that the future ecological health of Swartvlei depends on the weather. It has been established that rainfall duration, intensity, quantity and distribution determine whether sediment disturbed and transported during storm events will reach Swartvlei and thus influence its light regime. Small storm events (< 50 mm) influence the water quality of the tributaries of the catchment rivers. Storm events of 50 mm and over influence the mainstreams of the catchment rivers and light penetration in Swartvlei at the river inflow points. Long duration flood rainfalls, such as occurred in

1981, bring about massive soil loss in the catchment and cause reduced light penetration over the entire surface area of Swartvlei. The effects of such events can continue for several years.

Both past and present climatic events influenced the clarity of Swartvlei's water in 1984. Firstly, the floods of 1981 caused the Swartvlei estuary mouth to remain open until November 1984, bringing about high salinities in the lake. This resulted in:

- facilitation of sediment flocculation, thereby aiding light penetration;
- the limited regeneration of the macrophytic community.

Secondly, the below-average rainfalls of 1984 resulted in:

- limited transportation of sediment into Swartvlei;
- reduced humic input to Swartvlei.

Thus light penetration in Swartvlei has been good throughout 1984, and high salinities have inhibited macrophytic recovery rates.

The closure of the estuary mouth in December 1984 could have resulted in reduction of lake salinities and macrophytic recovery in spring 1985, but the estuary mouth was artificially opened on 20 July 1985. It was opened due to suspected infiltration of sewage into the estuary from surrounding septic tanks. The continued low rainfalls and the open mouth are maintaining high lake salinities of between 14 - 17‰. The non-seasonal rainfall pattern of the southern Cape makes it difficult

to predict a possible cycle of deterioration and recovery in Swartvlei which will depend on climatic conditions.

Observations in the study area have led the writer to believe that much of the lake's deterioration due to sediment input could be prevented by improved catchment management. Man's activities can influence the threshold levels which determine whether the lake's sub-littoral aquatic plant community recovers or deteriorates after storm events.

By comparing the sediment contributions of the different river systems of the study area, it was found that the Hoëkraal river system, the system retaining the greatest area of indigenous vegetation, has the most acceptable water quality. Although land utilisation in this system is similar to that of the three other river systems (Diep-Wolwe, Klein Wolwe and Karatara), with similar problems of accelerated runoff and erosion, the effects on the river's water quality are minimal. This is due to the filtering role of the natural vegetation of the area. The importance of this vegetation in riparian zones, to act as a natural protective mechanism against upslope and upstream activities, has been emphasised throughout the study.

Most of the sediment which affects Swartvlei's light regime appears to be originating in the lower sections of the catchment area, where agriculture and road reconstruction are the dominant activities. The effect of a storm event in this area is immediate due to: its proximity to Swartvlei, the limited opportunity for settling or capture of sediment, and the intensity and nature of human activity. A storm event here

initiates greater sediment offload than that which occurs in the upper catchment area.

It would appear that runoff from agricultural lands near watercourses could also affect water quality due to heavy fertiliser application and in some areas herbicide and pesticide application. Detection of the components of herbicides and pesticides is difficult. Specific research into levels of these components in Swartvlei water may become necessary.

Relatively large storm events (> 80 mm) are needed to seriously affect water quality in the upper catchment area for any significant period of time. Large storm events in the upper catchment area can intensify downstream water quality problems. Under low rainfall conditions, such as those of 1984, clear water originating in the upper catchment area acts as a diluent for sediment-laden water originating in areas more vulnerable to sediment loss in the lower catchment area.

Several factors, activities and areas which influence erosion potential have been identified. The most important ones are as follows:

1. The Upper Catchment area: Block burning, if it affects the vegetation in riparian zones.
2. The Plantation area: Clearfelling activities and road construction, utilisation and maintenance, particularly in stream management zones;
3. The Agricultural area: vegetation removal or cultivation in

areas too close to watercourses; downhill ploughing and use of the mouldboard plough; limited use of conservation farming techniques such as contour banks, poor maintenance and inappropriate location of farm roads; absence of and non-maintenance of runoff channels; uncontrolled livestock movement in riparian zones.

4. Roads: absence of effectively constructed, appropriate runoff channels; grading and road reconstruction activities; steep eroding road cuts.

The potential for beneficial changes in land use and management activities, so as to decrease problems associated with sediment-laden runoff, varies in each of the above areas. It is felt that a considerable improvement could be achieved in the plantation area and where road reconstruction occurs by means of preplanning and construction of simple runoff structures which can effectively redirect runoff into greenway areas where sediment capture and settling can occur. Some initial expenditure is called for, but the economic and environmental benefits would be unquestionable in both the short and long term. The economic recession has been given (by the area's land managers) as the cause for the absence of such ameliorative practices. However, as damage to the environment and its resources continues, costs of repair increase rapidly. Resource deterioration can go so far as to make repair impossible. The costs to be borne by present and future generations were often unforeseen.

Beneficial changes in land use and management practices in the agricultural area are going to be more difficult to achieve. The large areas of steep topography, the duplex soils, the small size of the properties, the varied socio-economic status and expertise of the property-owners, and the adherence to traditional farming methods and equipment are some of the factors which tend to preclude change. The enforcement of available legislation is also difficult due to lack of manpower, in some cases the nature of the legislation, and differing perceptions of the seriousness of the problem of accelerated runoff and associated reduced water quality. Few of the land managers in the area fully perceive the possible wide ranging nature of the effects of poor catchment management. The deterioration of Swartvlei will also affect the character of the Wilderness Lakes area and the Garden Route. Repercussions may indeed affect the economic viability of the area.

This study came about partially as a result of the dramatic effects of the 1981 floods. The exceptionally high rainfalls of 1981 have been established as the direct cause of damage sustained by the lake and its environs. It is nevertheless felt by the writer that the results of these high rainfalls merely reflect the inherent sensitivity of the Swartvlei catchment area to human impact, a sensitivity only recently perceived. This beautiful part of the southern Cape has, over the years, developed a vegetation which has effectively protected its natural features and resources. Improved management of the quality of runoff seems to be necessary for conservation of the area. Restoration of this vegetation in the most vulnerable parts of the catchment area, the riparian zones, will go some way towards prevention of soil loss and increase of sediment capture.

Although this study was undertaken in an exceptionally dry year, the measurement of ^{suspended} sediment ^{concentrations} in the catchment's watercourses did reveal

- a) Some of the main areas of sediment origin,
- b) The excessively high sediment levels that occur after relatively small storm events,
- c) Possible future sediment loads in a high rainfall year.

Exceptionally high rainfalls will undoubtedly occur again. There are indications that a second series of flood rainfalls will do more damage than occurred in 1981 because of the areas destabilised by the 1981 floods. It is suggested that the economic recession and high capital costs of farming in this area are resulting in greater utilisation of marginal land areas, a greater emphasis on short-term returns than on long-term productivity, and a relatively rapid change in land-owners because of changes in land ownership and hiring of properties.

All the above factors, both natural and socio-economic, contribute towards the deterioration and increasing vulnerability of the catchment area to the forces of nature. It is the responsibility of land managers to ensure that their activities do not threaten Swartvlei's continued productive existence. A greater perception of the natural vulnerability of the area is needed, as is appropriate adjustment of land use practices to the limitations imposed by the natural features of the area.

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APPENDICES

APPENDIX 1A

Rainfall on sediment sample dates

DATE	RAINFALL		
12 March 1984	10-15mm	1 days rain	Samples taken immediately after rain ceases.
20 March 1984	0.8)	
21 March 1984	11.4)	
22 March 1984	1.2)	← 1 days rain
26 March 1984	13.4)	Samples taken immediately after rain ceases.
3 April 1984	Nil		
13 June 1984	20-28mm	1 days rain	Samples taken immediately after rain ceases.
21/22/23 July 1984	50-55mm	3 days rain	Samples taken 1 and 2 days after rain ceases.
7 October 1984	43-50mm	2 days rain	Samples taken immediately after rain ceases.
8/9 April 1985	41-50mm	1½ days rain	Samples taken 16 hours after rain ceases.

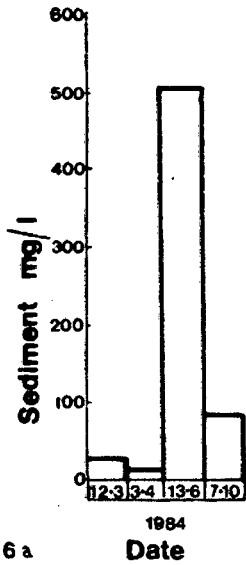
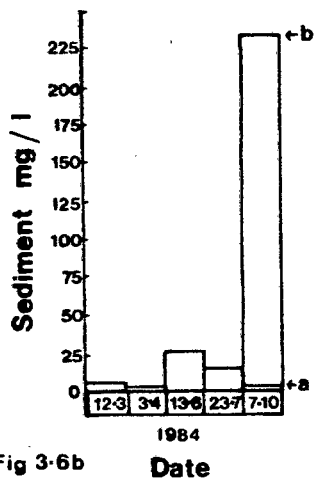


Fig 3-6 a

SITE B



Note: On 7-10-84 a = Catchment water
b = Tributary b

Fig 3-6b

SITE C

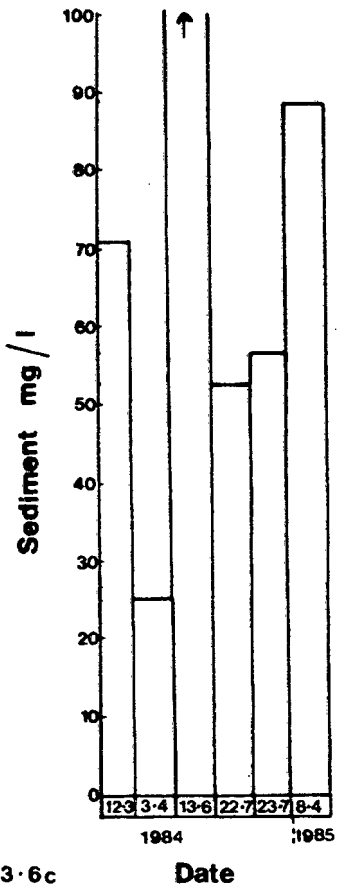


Fig 3-6c

Date
SITE D

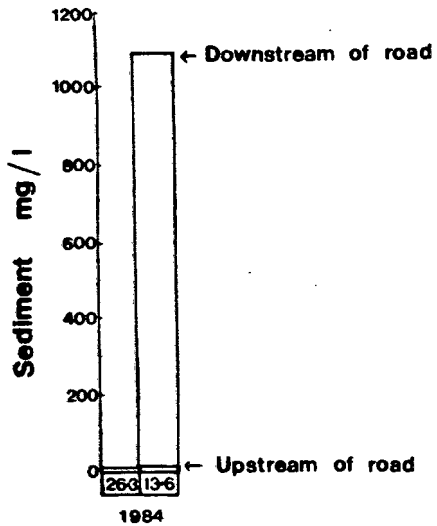


Fig 3-6d

Date
SITE F

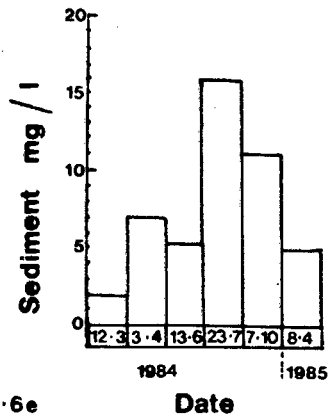


Fig 3-6e

HOËKRAAL RIVER

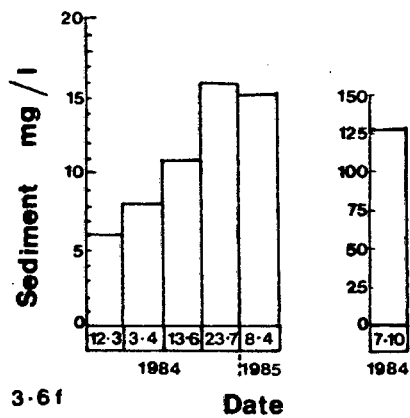


Fig 3-6f

SITE G2

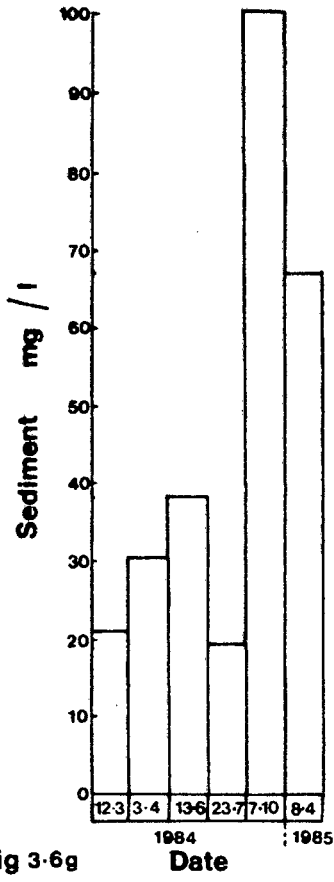


Fig 3-6g

SITE H

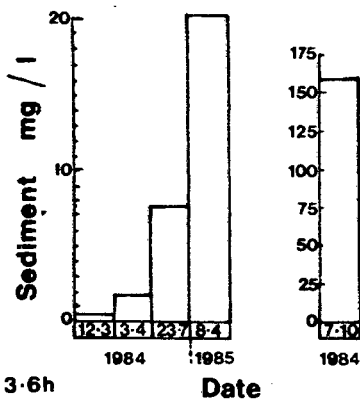


Fig 3-6h

SITE I

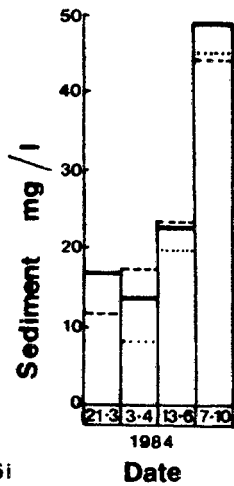


Fig 3-6i

SWARTVLEI

Diep-Wolwe Basin —
 Deep Station - - -
 Hoëkraal Basin

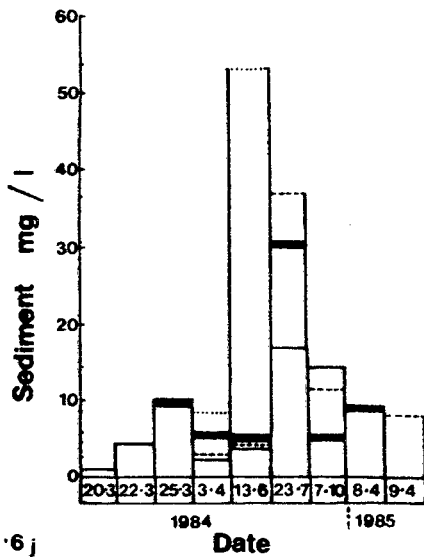


Fig 3-6j

MAINSTREAMS PRIOR TO ENTERING
 SWARTVLEI (* on fig 6-2)

Diep-Wolwe river —
 Klein Wolwe river
 Hoëkraal river —
 Karatara river - - -

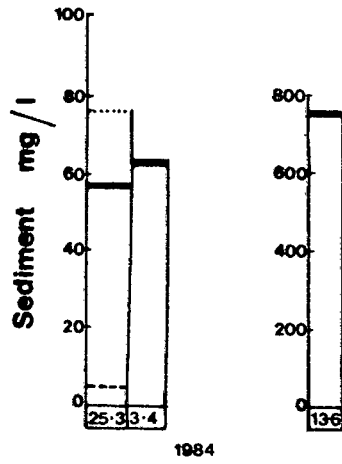


Fig 3-6k

SITES 1 —
2
3 - - -

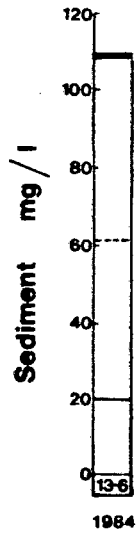


Fig 3-6l

SITES 4 —
5 —
(iv) - - -

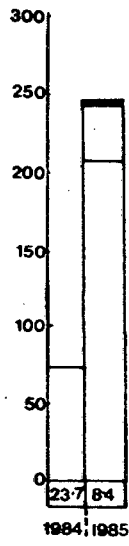


Fig 3-6m Date

SITES: MELKHOUTSKRAAL —
(iib) —

APPENDIX 1B

Monthly Flow Volumes 1977 - 1984

Stations : K4MO3 Diep-Wolwe River
 K4MO1 Hoëkraal River
 K4MO2 Karatara River

Hydrological Year	Station	Monthly runoff in millions of cubic metres.												
		Oct.	Nov.	Dec.	1977			Apr.	May	June	July	Aug.	Sept.	
1976/77	K4MO3	-	-	-	-	-	-	-	-	-	-	-	-	
	K4MO1	3.93	4.15	0.26	1.05	3.58	1.56	0.28	3.46+	0.71	0.47	1.05	1.80	
	K4MO2	*0.53	2.14	0.36	0.34	2.45	1.08	0.25	2.8	0.19	0.13	0.47	1.03	
1977/78					1978									
	K4MO3	-	-	-	-	-	-	*0.00	*-	*-	*-	*-	*0.031	
	K4MO1	2.04	4.42	2.47	1.18	0.21	*0.125	0.46	0.22	0.40	0.27	0.73	0.61	
	K4MO2	1.10	1.05	0.81	0.51	0.15	0.10	0.36	0.20	0.28	0.22	0.74	0.47	
1978/79				1979										
	K4MO3	0.17	0.86	0.11	0.38	0.06	0.08	0.07	0.17	0.18	0.90	*0.74	2.09	
	K4MO1	1.79	1.62	0.65	1.03	0.00	0.30	0.09	0.66	0.60	<u>2.69</u>	1.91	*2.05	
	K4MO2	1.04	2.62	1.27	1.45	0.07	0.19	0.13	0.58	*0.062	-	-	-	
1979/80				1980										
	K4MO3	0.28	*0.09	*0.05	0.11	0.07	0.06	0.06	0.05	0.10	0.09	0.12	0.29	
	K4MO1	0.23	*0.07	*0.02	0.26	0.001	0.00	0.11	0.00	0.21	0.07	0.12	0.90	
	K4MO2	0.10	0.15	0.13	0.44	0.29	0.17	0.25	0.08	0.44	0.18	0.49	1.16	
1980/81				1981										
	K4MO3	0.88	0.32	0.91	3.06	1.76	7.69+	6.34	12.9+	3.64	1.36	3.68	3.36	
	K4MO1	4.07	0.95	1.79	3.18+	4.33	2.90+	2.84	5.68+	5.07	1.11	3.91	3.55	
	K4MO2	1.82	1.31	1.41	<u>4.42+</u>	1.82	<u>3.02+</u>	<u>2.12+</u>	<u>4.99+</u>	1.01	0.26	2.73	0.79	

250

Continued/.....

Hydrological Year	Station	Monthly runoff in Millions of cubic metres.											
		Oct.	Nov.	Dec.	1982 Jan.	Feb.	Mar.	Apri.	May	June	July	Aug.	Sept.
1981/82	K4MO3	1.83	0.86	0.85	0.35	0.44	0.80	2.34	1.27	0.51	1.46	0.35	1.14
	K4MO1	2.71	1.37	1.80	0.52	0.74	1.21	4.02	1.64	0.43	1.72	0.11	1.67
	K4MO2	1.56	0.69	*1.28	0.40	0.88	1.49	3.73	0.58	0.17	0.91	0.09	*0.84
1982/83					1983								
	K4MO3	0.88	0.49	0.24	0.14	0.10	0.13	0.13	0.17	0.70	5.27	0.82	0.62
	K4MO1	0.74	0.64	0.18	0.06	0.09	0.17	0.12	0.26	1.74	3.05	0.73	1.22
	K4MO2	0.26	0.54	0.09	0.08	*0.06	0.43	0.23	0.21	1.54	*0.08	0.17	0.898
1983/84					1984								
	K4MO3	2.74	0.86	0.41	0.30	0.28	0.46	0.24	0.20	0.18	0.29	0.20	0.22
	K4MO1	2.75	1.54	1.35	0.95	0.86	1.74	0.25	0.16	0.14	0.57	0.16	0.18
	K4MO2	1.52	0.93	0.70	0.63	0.50	1.18	0.10	0.09	0.09	0.28	0.08	0.09
1984/85					1985								
	K4MO3	0.31	0.23	0.19	*0.16	*0.12							
	K4MO1	0.40	0.29	0.39	1.22	1.70	1.30	*1.35	*0.38				
	K4MO2	0.36	0.25	0.31	*0.05	1.50	*0.40						

+ Measuring capacity of gauging station exceeded.

* Includes periods of no record.

Source : Directorate of Water Affairs, Pretoria.

Appendix 1C

Tables showing sediment loads and Secchi disc transparencies for three sampling stations at Swartvlei, July 1982 - September 1983, and March and June 1984

The sampling stations are: Deep Station (Mid Lake)
 the Hoëkraal/Karatara basin (East)
 the Diep-Wolwe/Klein Wolwe basin (West)

For location refer to Fig. 3.8 .

Sampling date: 16 July 1982

Rainfall: Monthly total, 71 - 86 mm

Rainfall in week prior to sample date, 5 - 18 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	8,8	2,1
Hoëkraal/Karatara	9,2	1,8
Diep-Wolwe	10,2	1,9

Sampling date: 25 August 1982

Rainfall: Monthly total, 6 - 19 mm

Rainfall in week prior to sample date, 1,5 - 6,0 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	4,8	3,2
Hoëkraal/Karatara	10,9	2,6
Diep-Wolwe	12,3	1,1

Sampling date: 1 September 1982

Rainfall: Monthly total, 86 - 146 mm

Rainfall in week prior to sample date, 10 - 28 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	11,7	2,6
Hoëkraal/Karatara	10,1	-
Diep-Wolwe	10,3	-

Sampling date: 13 October 1982

Rainfall: Monthly total, 70 - 107 mm

Rainfall in week prior to sample date, 40 - 70 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	9,9	2,4
Hoëkraal/Karatara	11,8	1,2
Diep-Wolwe	45,0	0,15

Sampling date: 23 November 1982

Rainfall: Monthly total, 24 - 42 mm

Rainfall in week prior to sample date, 5 - 8 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	6,1	2,4
Hoëkraal/Karatara	5,3	2,9
Diep-Wolwe	6,8	2,2

Sampling date: 8 December 1982

Rainfall: Monthly total, 38 - 57 mm

Rainfall in week prior to sample date, 9 - 19 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	7,1	2,1
Hoëkraal/Karatara	8,7	1,8
Diep-Wolwe	6,3	1,3

Sampling date: 7 January 1983

Rainfall: Monthly total, 18 - 49 mm

Rainfall in week prior to sample date, 5 - 15 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	7,9	3,5
Hoëkraal/Karatara	8,3	2,6
Diep-Wolwe	9,6	1,7

Sampling date: 4 February 1983

Rainfall: Monthly total, 27 - 76 mm

Rainfall in week prior to sample date, 11 - 24 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	7,6	2,7
Hoëkraal/Karatara	7,5	1,8
Diep-Wolwe	9,3	1,3

Sampling date: 3 March 1983

Rainfall: Monthly total, 42 - 67 mm

Rainfall in week prior to sample date, 20 - 35 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	9,5	2,4
Hoëkraal/Karatara	7,5	2,1
Diep-Wolwe	9,7	1,8

Sampling date: 20 April 1983

Rainfall: Monthly total, 31 - 48 mm

Rainfall in week prior to sample date, 18 - 20 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	2,3	5,6
Hoëkraal/Karatara	10,0	2,9
Diep-Wolwe	14,1	2,1

Sampling date: 17 May 1983

Rainfall: Monthly total, 38 - 62 mm

Rainfall in week prior to sample date, 18 - 22 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	9,2	2,5
Hoëkraal/Karatara	4,9	3,1
Diep-Wolwe	7,9	1,6

Sampling date: 26 June 1983

Rainfall: Monthly total, 92 - 133 mm

Rainfall in week prior to sample date, 5 - 14 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	6,8	1,7
Hoëkraal/Karatara	7,1	1,6
Diep-Wolwe	7,2	1,6

Sampling date: 18 July 1983

Rainfall: Monthly total, 104 - 176 mm

Rainfall in week prior to sample date, 0,1 - 0,4 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	9,4	4,0
Hoëkraal/Karatara	9,7	2,4
Diep-Wolwe	9,0	2,4

Sampling date: 28 July 1983

Rainfall: Monthly total, 104 - 176 mm

Rainfall in week prior to sample date, 90 - 171 mm

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Karatara River Causeway	17,8	0,4
Hoëkraal River Causeway	4,9	1,0
Wolwe River Causeway	18,4	0,4
Swartvlei Railway Bridge	17,8	0,4
Swartvlei Mouth	16,0	0,4

Sampling date: 2 August 1983

Rainfall: Monthly total, 15 - 21 mm

Rainfall in week prior to sample date, 38 - 72 mm

	<u>Sediment load mg/ℓ GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	19,2	0,6
Hoëkraal/Karatara	12,0	0,5
Diep-Wolwe	14,2	0,7

Sampling date: 3 September 1983

Rainfall: Monthly total, 53 - 76 mm

Rainfall in week prior to sample date, 4 - 6 mm

	<u>Sediment load mg/ℓ GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	19,9	0,3
Hoëkraal/Karatara	53,0	0,2
Diep-Wolwe	62,0	0,2

Sampling date: 21 March 1984

Rainfall: Monthly total, 72 - 101 mm

Rainfall in week prior to sample date, 15 - 26 mm

	<u>Sediment load mg/ℓ GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	11,9	2,5
Hoëkraal/Karatara	-	-
Diep-Wolwe	17,1	1,5

Sampling date: 13 June 1984

Rainfall: Monthly total, 19 - 46 mm

Rainfall in week prior to sample date, 22 - 42 mm,

	<u>Sediment load mg/l GF/F</u>	<u>Secchi disc (m)</u>
Deep Station	23,3	-
Hoëkraal/Karatara	20,1	-
Diep-Wolwe	23,1	-

Appendix 2A

UPPER CATCHMENT AREA

CATCHMENT CHARACTERISTICS

<u>Total Catchment Area in km²</u>	<u>Diep-Wolwe</u>	<u>Klein Wolwe</u>	<u>Hoëkraal</u>	<u>Karatara</u>
(according to Hughes 1983)	93,3	17,2	111,0	101,6
<u>Estimated Upper Catchment Area in km²</u>	<u>Diep-Wolwe</u>	<u>Hoëkraal</u>	<u>Karatara</u>	
Calculated off 1:50 000 topographical map with dot planimeter	31,7	40,1	23,9	
	<u>Diep-Wolwe</u>	<u>Klein Wolwe</u>	<u>Hoëkraal</u>	<u>Karatara</u>
<u>Catchment slope</u>	0,25	0,12	0,28	0,25
<u>10 - 85% channel slope m/km</u>	19,9	33,8	111,5	22,7
<u>Drainage density (km/km²)</u>	2,27	2,22	1,80	2,51

Source of Catchment slope data, channel slope data and drainage density, Hughes 1983.

Note: Catchment slope: total contour length x contour interval/total catchment area.

$$10 - 85\% \text{ channel slope} = \frac{H_{85} - H_{10}}{0,75 \times \text{channel length}}$$

with H_n = height at point n% of channel length

Drainage density = total stream length/catchment area

(Hughes 1981)

Appendix 2B

UPPER CATCHMENT AREA

SOIL PROFILES

Soil Pit number 3 shows the following profile

Terrain: Ridge

Slope shape: Convex

Slope %: 70

Slope aspect: south

Parent material: T.M.S.

Vegetation: Fynbos

Soil series: Kanonkop

Soil Form: Glenrosa/Cartref

<u>Horizon</u>	<u>Depth (mm)</u>	<u>Morphology</u>
A1	0-200	Black (10 YR 2/1), fine sandy clay loam; apedal, very friable, frequent fine roots, moderate permeability, gradual transition
A2	200-400	Dark grey (10 YR 4/1); fine sandy loam; apedal, very frequent fine roots, rapid permeability, gradual transition

(continued -)

<u>Horizon</u>	<u>Depth (mm)</u>	<u>Morphology</u>
B21	400-700	Very dark grey (10 YR 3/1); fine sandy loam; apedal; very friable; frequent fine roots; rapid permeability: gradual tonguing transition
C/R	700	Weathered sandstone

Percentage particle size distribution Horizon A1

Coarse sand 5; Medium sand 18; Fine sand 77;
Silt 16; clay 27.

Soil Pit 12 shows the following profile

Terrain: Upper midslope Soil Series: Jozini
Slope Shape: Convex Soil Form: Oakleaf
Slope %: 65
Slope aspect: south

Parent Material: T.M.S.

Geology: T.M.S. Tchando

<u>Horizon</u>	<u>Depth (mm)</u>	<u>Morphology</u>
A1	0-250	Black (10 YR 2/1); fine sandy clay loam; apedal; very friable; frequent fine roots; rapid permeability; gradual transition

(continued -)

<u>Horizon</u>	<u>Depth (mm)</u>	<u>Morphology</u>
A3	250-450	Variegated (10 YR 4/3 - 6/6); silty clay loam; apedal; very friable; abundant clear yellow mottles; frequent fine roots; rapid permeability; gradual transition.
B21	450-800	Black (10 YR 3/1); sandy clay loam; weak fine, blocky, friable; frequent fine roots; gradual transition
	800 +	Weathered sandstone

Percentage particle size distribution

	<u>Horizon</u>	
	A1	B2
Coarse sand	2	2
Medium sand	5	5
Fine sand	93	93
Silt	13	
Clay	13	

Appendix 2C

UPPER CATCHMENT

MODIFIED SOIL LOSS EQUATION

Information extracted from Bosch, J.M. and Hewlett, J.D., 1980.

Following sediment experiments in Georgia, Hewlett (1979) suggested modification of the Field Soil Loss Equation (Wischmeier and Smith, 1965, cited as reference) for application in forest land in the south-eastern Piedmont, U.S.A.

$$E = 400 RKS^{\frac{1}{2}}W^{\frac{1}{2}}$$

where E is the total sediment delivery to the stream in lb/ac/yr;

R is Wischmeier's (1959) annual rainfall intensity index;

K is the Soil Conservation Services' soil erodibility index (Wischmeier and Smith, 1965);

S is the mean basin slope (dimensionless fraction) and

W is a sediment delivery hazard index that varies with intensity and pattern of forest activities.

W is defined by

$$W = \frac{\sum a_i^2}{l \cdot A \cdot L}$$

where a is size of an elemental area of exposed soil;

A is total area of the watershed;

l is the distance of the exposed area from the water divide;

L is the length of slope measured from the water divide to the stream.

This index varies from 0 under complete vegetal cover to 1,0 under bare soil.

APPENDIX 3 A

SOIL PROFILES

Profile 1 : Kleinplaat
Soil Form : Lamotte
Soil Series : Alsace
Slope Shape : Convex
Slope Aspect : South West
Vegetation : Mountain Fynbos

<u>Horizon</u>	Ae	B21	B22	B23 (lithocutanic B horizon)
<u>Limits/Moisture</u>	0-30cm	30-60cm	60-90cm	
<u>Munsell colour:</u> moist	10yr 4/2	7.5yr 3/4		
<u>Texture:</u> % clay sandgrade	0-6 fine	0-6 fine	6-14 coarse	
<u>Structure:</u> grade size type	granular fine weak	weak fine crumbly	structureless	
<u>Consistence:</u> dry moist wet	soft plastic sticky	soft plastic sticky	slightly hard slightly plastic sticky	
<u>Permeability</u>	moderate	rapid	rapid	
<u>Void:</u> frequency size type		few very fine single	common fine dendritic	
<u>Cutans:</u> frequency colour type location			many dark brown clay throughout	
<u>Coarse fragments</u> frequency size shape type			common small angular quartz	

Profile 10 : Bergplaas
Locality : Foothills 33°54'
Soil Form : Klapmuts
Drainage : Moderately drained
Slope Shape : Concave
Slope Angle : 17%
Altitude : 451m Low slope terrace. Narrow interfluves.
Ground Cover : 10%
Geology : Cedarberg (TMG)

<u>Horizon</u>	Ae	E	B2	E
<u>Munsell colour:</u> moist	10yr 4/1	10yr 4/1	7.5yr 4/4	5/4
<u>Texture: % clay</u> sandgrade	sandy loam very fine	sandy loam very fine	sandy clay loam (24-35%) very fine	sandy clay loam very fine
<u>Structure:</u> grade size type	apedal	apedal	weak medium blocky	weak medium blocky
<u>Consistence:</u> dry moist	soft very friable	slightly hard friable	hard friable	slightly hard friable
<u>Permeability:</u>	hydrophobic	moderate	slow	moderate
<u>Mottles:</u> frequency size contrast cause		many fine distinct eluvans		
<u>Cutans:</u> frequency	many	many	many	
<u>Coarse fragments:</u> frequency size shape			few medium-coarse subangular	very few coarse

Profile 56 : Bergplaas
Locality : Foothills 33°51'
Soil Form : Cartref/Houwhoek
Drainage : Well drained
Slope Shape : Linear/concave
Slope angle : 26%
Altitude : 594m
Ground Cover : 80%
Geology : Table Mountain Group

<u>Horizon</u>	A1	B5	B2	C
<u>Munsell colour:</u>	10yr 4/2	10yr 5/8	10yr 5/6	
<u>Texture: % clay</u> sandgrade	sandy loam fine	sandy loam fine	sandy loam fine	
<u>Structure:</u> grade size type	weak	moderate fine blocky	weak medium blocky	
<u>Consistence:</u> moist	very friable	very friable	friable	
<u>Permeability:</u>	rapid	rapid	rapid	
<u>Nodules:</u> frequence size hardness type	very few (<5%)	few (5-20%) medium hard-indurated Fe		
<u>Coarse fragments:</u> frequence size	very few medium	common medium		

Profile 23 : Karatara
Locality : Upper foothills (montane) ridge
Soil Form : Houwhoek/Cartref
Drainage: : Well drained
Slope Shape : Convex
Slope Angle : 18%
Altitude : 536m Crest of slope
Ground Cover : 80% (Boulder outcrop)

<u>Horizon</u>	Ae	E	Bns	R
<u>Munsell colour:</u> moist	10yr 3/1	10yr 6/1	10yr 5/3	Hard sandstone
<u>Texture:</u> % clay sandgrade	loamy sand (6-10%) very fine	sand (0-6%) fine-medium	sandy loam (10-15%) fine-medium	
<u>Structure:</u> type	apedal	apedal	apedal	
<u>Consistence:</u> dry moist	soft very friable	loose very friable	slightly hard very friable	
<u>Permeability:</u>	hydrophobic	rapid	hydrophobic	
<u>Mottles:</u> frequence size contrast cause	many medium distinct eluvans		many medium distinct podzol	
<u>Cutans:</u> frequence		common		
<u>Coarse fragments:</u> frequence size shape	very few coarse subangular	common coarse subangular	common fine-coarse subangular	

Profile 30 : Karatara
Locality : Plateau 33°54'
Soil Form : Estcourt
Drainage : Imperfectly drained
Slope Shape : Linear
Slope Angle : 1%
Altitude : 249m Top slope
Ground Cover : 70%
Geology : Victoria Bay Feldspathic Quartzite

Horizon	Ae	E	B21	Bg (g=gleyed)
<u>Munsell colour:</u> moist	10yr 3/1	10yr 4/2	10yr 5/8	10yr 5/6
<u>Texture:</u> % clay	sandy loam (10-15%)	sandy loam	sandy clay (35-50%)	sandy clay
sandgrade	very fine	very fine	very fine	very fine
<u>Structure:</u> grade size type	apedal	apedal	strong medium blocky	weak medium blocky
<u>Consistence:</u> dry		slightly hard	very hard	very hard
moist	very friable	very friable	firm	firm
<u>Permeability:</u>	moderate	moderate	very slow	very slow
<u>Mottles:</u> frequence size contrast cause	common fine distinct eluvans	common fine faint Fe		many medium distinct
<u>Cutans:</u> frequence type			many clay	many slicken sides
<u>Nodules:</u> frequence size hardness type				very few medium indurated Fe

Profile 34 : Karatara
Locality : Foothills 33°53'
Soil Form : Lamotte
Drainage : Well drained
Slope Shape : Linear
Slope Angle : 37%
Altitude : 621m Upper mid slope
Ground Cover : 10%
Geology : Tchando

<u>Horizon</u>	A11	A12	Bhs	B22	Et	B ₂ + (=buried)
<u>Munsell colour:</u>	10yr 3/1	10yr 3/1	10yr 3/3	10yr 4/4		10yr 5/6
<u>Texture:</u> % clay sandgrade	loamy sand very fine	loamy sand very fine	sandy loam very fine	sandy loam very fine	sandy loam very fine	sandy clay loam very fine
<u>Structure:</u> grade size type	apedal	apedal	weak fine blocky	weak fine blocky	weak fine blocky	weak fine blocky
<u>Consistence:</u> dry moist	loose very friable	slightly hard very friable	slightly hard very friable	slightly hard very friable	soft very friable	slightly hard friable
<u>Permeability:</u>	hydrophobic	hydrophobic	moderate	rapid	rapid	rapid
<u>Mottles:</u> frequency size contrast cause form	many fine prominent eluvans elongated	many fine prominent eluvans elongated	many fine prominent eluvans/organic elongated	few	many	
<u>Cutans:</u> frequency				many	common	common

Profile 44 : Karatara
Soil Form : Oakleaf
Drainage : Well drained
Slope Shape : Concave
Slope Angle : 22%
Altitude : 384m Head Slope
Ground Cover : 20%

<u>Horizon</u>	Ae	B5	B22	C
<u>Munsell colour:</u> moist	10yr 3/1	10yr 3/3	7.5yr 4/6	10yr 6/4
<u>Texture: % clay</u> sandgrade	sandy loam medium	sandy clay loam medium	sandy clay loam medium	sand medium
<u>Structure: type</u>	apedal	apedal	apedal	apedal
<u>Consistence:</u> moist	very friable	very friable	very friable	friable
<u>Permeability:</u>	hydrophobic	rapid	rapid	rapid
<u>Voids: frequency</u>	many	common	common	common
<u>Mottles:</u> frequency size contrast cause				many fine distinct Fe
<u>Cutans:</u> frequency		common	common	
<u>Coarse fragments:</u> frequency size shape	very few medium subangular	very few fine	very few fine	few

Profile 35 : Karatara
Locality : Foothills 33°53'
Soil Form : Glenrosa
Drainage : Well drained
Slope Shape : Convex
Slope Angle : 4%
Altitude : 503m Top slope
Ground cover : 40%
Geology : Tchando

<u>Horizon</u>	Ae	B21	C	C2
<u>Munsell colour</u> moist	10yr 4/3	10yr 5/4	7.5yr 6/8	white/yellow
<u>Texture: % clay</u> sandgrade	sandy loam very fine	sandy loam very fine	sandy loam very fine	
<u>Structure: type</u>	apedal	apedal	apedal	
<u>Consistence: dry</u> moist	very friable	slightly hard very friable	slightly hard very friable	
<u>Permeability:</u>	hydrophobic	rapid	rapid	
<u>Cutans:</u> frequency		many		
<u>Coarse fragments:</u> frequency size shape	very few medium subangular			

Appendix 3B

PLANTATION AREA

QUESTIONS - FORESTERS

What is the size of the plantation?

What types of trees are there on the plantation?

What age are the trees?

When will harvesting occur? (months and years)

What are the management techniques for

- a) clearing a previously unafforested area,
- b) planting, weeding and thinning,
- c) clearfelling,
- d) road construction and maintenance,
- e) firebreak clearing and maintenance?

What use is made of

- a) Herbicides
- b) Pesticides
- c) Fertilisers?

Are there any problems with invasive alien vegetation?

If so, what methods are used to remove it?

What soil types occur in the plantation?

Are there any

- a) erosion problems,
- b) compaction?

If so - under what circumstances has erosion/compaction occurred,

- have any attempts been made to solve the problem,
- what methods have been used?

What type of vegetation borders any watercourses which run through the property?

This is a basic framework for the type of questions asked. Greater detail was requested in some areas.

Appendix 3C

PLANTATION AREA

DEFINITION OF STREAM FLOW RATES

- | | |
|--------------|------------------------------------------|
| Ephemeral | - flows only during or after rain storms |
| Intermittent | - flows 50% of time or less |
| Perennial | - flows about 90% of time or more |

(Bosch and Hewlett 1980)

Appendix 3D

PLANTATION AREA

THE CHARACTERISTICS OF THE BROAD-BASED DIP

The function of a broad-based dip is to prevent erosion by removing storm water from the road efficiently, economically, and without causing difficulty for the driver or his vehicle. A dip should not be used for a seep spring or other continually running water: either the bottom of the dip will erode, or it will remain constantly wet and soft, subject to rutting. Permanent water must be channelled beneath the road in a culvert or rock drain.

The complete dip (Fig. 5.4) includes a short stretch of reverse grade whose junctions with the prevailing grade are at a 15 to 25 degree angle with the centre line, and a longer stretch uphill that will be about 1,2 times the basic grade. Theoretically, the grade from one dip to the next hump should be uniform; in any event, the dip should not merely be scooped out of the lower part of the dip-to-hump reach. Slightly outsloped roads are generally preferred. Outsloping is particularly important in the bottom of the dip, where it should be approximately 3% (250 mm in a 5 m road).

The reverse slope should not be less than 3%; if it is less than that, a 75 mm deep rut will allow water to breach the barrier and continue down the road. The reverse slope should be about 7 m long to allow trucks to roll over it at a reasonable speed. A further requirement

is to align the crest and base of the dip downslope at an angle of 15 to 25 degrees to prevent the sudden break in water velocity that often causes the dip to fill in with road-surface sediments. The skewed bottom will encourage sediments to move off the road. Little racking of the load will result if the skew is kept to a 25 degree or less (2 m in a 5 m road).

The proper spacing of broad-based dips is a function of slope.

Figure 5.5 derived from practical experience in the U.S.A., may be used to determine recommended spacing of dips from the basic grade of the planned road. While the erosion potential of soils as well as local breaks in the terrain should play a role in the frequency of dips, we must leave this adjustment to local judgment and common sense.

If encouraged in a reasonable manner, tractor drivers will quickly learn how to make these dips; with a little experience it becomes easy and natural. A machine with a tilting blade makes the job quicker and easier, but is not necessary. Surfaces can be maintained with road grades, but only if properly operated.

Source: Bosch and Hewlett (1980)

Appendix 3E

PLANTATION AREA

RECOMMENDATIONS FOR AVOIDING DAMAGE DURING
LOGGING OPERATIONSExcessive wheel slip

Reduce tractive force by

- reducing the load
- refraining from skidding up steeper slopes than necessary
- felling trees in the direction they are going to be skidded, as the turning of logs requires greater traction
- not using force to overcome 'hang-ups' behind stumps
- avoiding manoeuvring with the skidder in the field, avoiding sharp turns, and
- avoiding the use of the skidder as a bulldozer.

Soil compaction

- Control traffic
- Preplan the location of skid trails and landings, and choose the method of getting the timber to the skid trail
- No off-road transport other than that specified in the logging plan is to be allowed.

Skid trails

- Should be widely spaced

- Ensure the most appropriate method is used to move wood to skid trails. Use the skidder itself only under favourable soil conditions.

Timber landings

- Should be well placed and small as possible, and developed to create easy working conditions
- Avoid careless manoeuvring of heavy equipment around the landing area.

Wet soils

- Do not drive on badly drained soils during wet periods
- Lay out skid trails on the driest areas available, avoiding hollows, stream banks, etc.
- Do not plan to drive over clearcut areas for more than a few days after cutting
- If skid trails become quagmires, either stop working or go on using the trail. New trails or detours should not be made in these circumstances.

Erosion

- Careful planning of road layout
- Do not lay out skid trails or roads right up or down moderate or steep slopes
- Skid trails should never cross or run close to any watercourse or drainage channel

- Skid trails should avoid wet or badly drained areas
- As soon as logging is completed, take measures to prevent further erosion, for example
 - a) Skid trails which have ruts, compaction or other erosion hazard factors, should be interrupted at intervals by ditches to intercept and divert run-off;
 - b) Scarification and grass seeding may be useful in places;
 - c) Prevent run-off by contouring, channelling, and establishment of a vegetative cover.

(Soil Science lecture notes, Saasveld Forestry College)

Other recommendations given in Grey and Jacobs, 1985, are as follows

- maintain ground cover along watercourses,
- identify high risk areas,
- grades of skid trails should be maintained below 11 degrees.
Grade should be broken to avoid long collection areas,
- areas with risk of landslides will require smaller compartment sizes to avoid soil saturation over large areas, or adoption of a selection silvicultural system. Alternative harvesting systems may be necessary where soils are very sensitive, i.e. highlead, skyline or helicopter assisted logging.
- reduce compaction hazard by reduction of tractive force by increasing tyre size and using lower inflation pressures.

C SLEEPWERKGEM. BOOM OF BLOK VOL = _____ M³

GEM. SLEEPAFSTAND = _____ M

TAAK BEPAAL VANAF TABEL = _____ BOME OF BLOKKE.

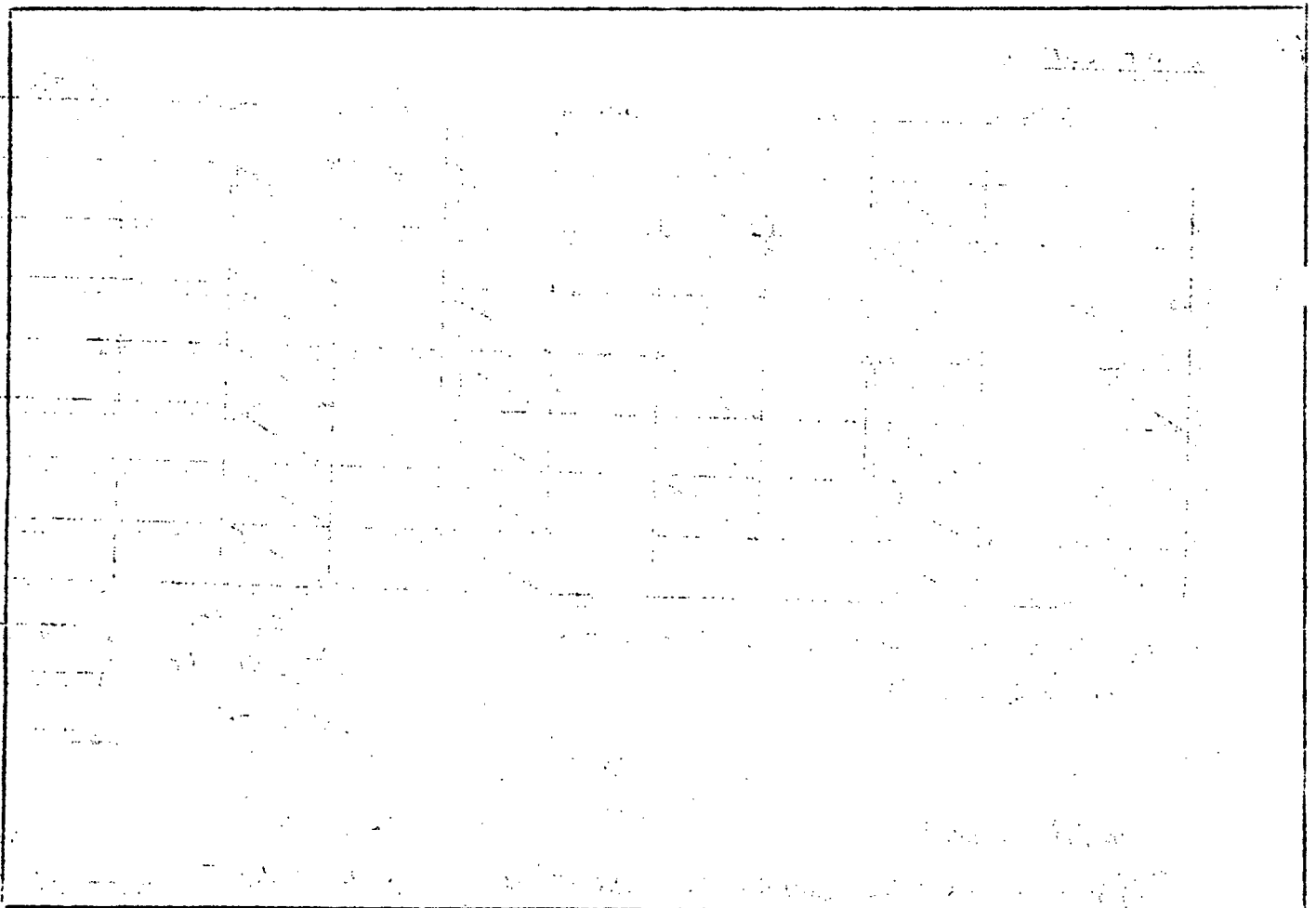
D STAPEL MET HANDTAAK = 18 M³ PER EENHEID

AANTAL BLOKKE X GEM. BLOK VOL ÷ 18 = _____ EENHEDE.

E SKRYWERS

(i) AANTAL BLOKKE ÷ 400 x 2 = _____ EENHEDE (KRAAKWAP)

(ii) AANTAL BLOKKE ÷ 800 x 2 = _____ EENHEDE (DUNNING)

VAK SKETS

Appendix 4A

AGRICULTURAL AREA
BARRINGTON SOIL PROFILE

Soil form: Estcourt

Terrain Morphology: crest of plateau

Slope shape: convex

angle: 7° (16%)

aspect: south-west facing

Geology: Kaaimans/Homtini

Horizon: Ae Depth 0 - 24 cm

Munsell colour: greyish brown (10 YR 5/2, dry, 10 YR 3/2, moist)

Structure: moderate to strong, coarse, prismatic

Consistence: slightly sticky and non-plastic in the wet state; firm
to very firm when moist, hard to very hard when dry

Permeability: slow

Mottles: few, fine to medium, faint, rusty, irregular

Cutans: few, soft, small insect casts

Roots: small, common, random roots

Boundary: clear wavy transition

Horizon: B1 Depth 24 - 35 cm

Munsell colour: very dark grey (10 YR 3/1, moist)

Structure: moderate, medium to coarse, subangular blocky

Consistence: sticky and slightly plastic when wet, firm when moist,
extremely hard when dry

Permeability: slow to very slow

Cutans: common to many, prominent, black organic/clay cutans throughout
horizon

Nodules/Concretions: many indurated, small, Fe/Mn

Coarse fragments: few, quartz, medium, rounded/irregular

Roots: few, very small, random

Boundary: clear tonguing transition

Horizon: B21 Depth 35 - 80 cm

Munsell colour: very dark grey (10 YR 3/1, moist)

Structure: primary structure is strong, medium to coarse prismatic;
secondary structure consists of peds

Consistence: sticky to very sticky and plastic in wet state, extremely
firm in moist state and extremely hard when dry

Permeability: very slow

Cutans: many, prominent black/grey, clay/organic cutans on ped faces

Mottles: common, fine to medium, distinct, red/yellow/green/brown,
irregular mottles

Roots: few, very small roots around peds

Boundary: clear tonguing transition

Horizon: B22 Depth 80 - 100 N cm

Munsell colour: dark, greyish brown (10 YR 4/2, moist)

Structure: strong, coarse to very coarse, prismatic

Consistence: sticky to very sticky and plastic when wet, extremely
firm when moist, extremely hard when dry

Permeability: very slow

Cutans: common, distinct, greyish brown, organic/clay cutans on ped
faces

Mottles: many, medium, distinct, red/yellow/brown/grey irregular mottles

Roots: very small, very few roots between peds

Particle size distribution %

	<u>Horizon</u>	<u>Ae</u>	<u>B1</u>	<u>B21</u>	<u>Saprolite</u>
2-0,5 mm Coarse sand		0,5	14,8	0,5	0,0
0,5-0,2 mm Medium sand		4,4	3,2	0,7	0,9
0,2-0,02 mm Fine sand		69,1	39,5	21,6	44,2
0,02-0,002 Silt		16,2	10,0	6,2	5,0
< 0,002 Clay		9,5	29,2	69,3	49,3

Exchangeable/extractable Cations me/100 g oven dry (100°C) soil

	<u>Horizon</u>	<u>Ae</u>	<u>B1</u>	<u>B21</u>	<u>Saprolite</u>
Na		0,5	1,7	2,9	2,2
K		0,0	0,0	0,0	0,0
Ca		0,7	1,8	3,0	1,8
Mg		0,9	3,2	6,1	

Appendix 4B

AGRICULTURAL AREA

QUESTIONS - PROPERTY OWNERS

What is the size and position of this property?

How many hectares are there of each type of pasture on the property?

At what time of year does field preparation, planting and harvesting occur?

What types of implements do you use on the property?

How many head of livestock are there on the property (dairy, beef and sheep)?

Have any new areas come into production in the last 20 years?

Have you removed any indigenous vegetation on your property?

What is your water source?

What is the predominant soil type on the property?

Are there signs of erosion on the property?

Under what circumstances and in which areas has erosion occurred?

What methods have you used to (a) prevent erosion

(b) repair damage caused by erosion?

Have you changed your (a) methods of farming

(b) type of farming in the last 10 - 15 years?

What do you feel is the most appropriate type of farming for this area?

What crops, pastures or vegetaiton types occur adjacent to the watercourses on the property?

What quantity of (a) fertiliser

(b) herbicides

(c) pesticide

do you use on your various crops and pastures?

Appendix 4C

AGRICULTURAL AREA
HERBICIDES AND PESTICIDES

<u>Name</u>		<u>Application</u>
Afalon/Linuron	475 g/kg wettable powder	1½-2½ kg/ha
Buctril/Bromoxynil	225 g/l emulsifiable concentrate	1½-2 l/ha
Basegran/Bendioxide		125 ml in 5 l to 100 m ²
Bladex/Atrazine-cyanazine	167 g Atrazine 333 g cyanazine/l	2-4,8 l/ha
Brominal		1,5-2 l/ha
Eptum super		3 - 4 l/ha
Gleen/Chlorsulfuron	750 g/kg wettable granules	15-17½ kg/ha
Goal/Oxyfluorfen	240 g/l emulsifiable concentrate	3-4 l/ha
Gramoxone/Paraquat		2,5-5 l/ha
Hoelon/Diclofop-methyl	284 g/l emulsifiable concentrate	0,8-1,25 l/ha
Lasso/Alachlor		5 l/ha
MCPA/(Phenoxy acetic acid) (Potassium salt)		50 ml in 5 l to 100 m ²
Fenatrol/Chlorfenac	180 g/l solution	2l in 10l water
Agrisulphan	endosulphan	1 kg/ha
Bexadust	gamma-BHC	15-20 kg/ha
Dithane	mancozeb	2-4 kg/ha
Lannate	methomyl	200 g/ha
Malathion	mercaptotion	10-15 kg/ha

<u>Name</u>		<u>Application</u>
Metasystox	demeton-S-methyl	500 ml/ha
Ortho Monitor	methamidophos	500 ml/ha
Tamaron	methamidophos	500 ml/ha
Parathion	parathion	10-15 kg/ha
Roxion	dimethoate	500-750 ml/ha
Crotofos	monocrotofos	0,75 l/ha
Sumicidin	fenvaterate	250-375 ml/ha
Sumisclex	procymidone	0,75 kg/ha

Source: Department of Agriculture, Plant Protection Institute
and Agricura (a division of Sentrachem).

Appendix 4D

AGRICULTURAL AREA

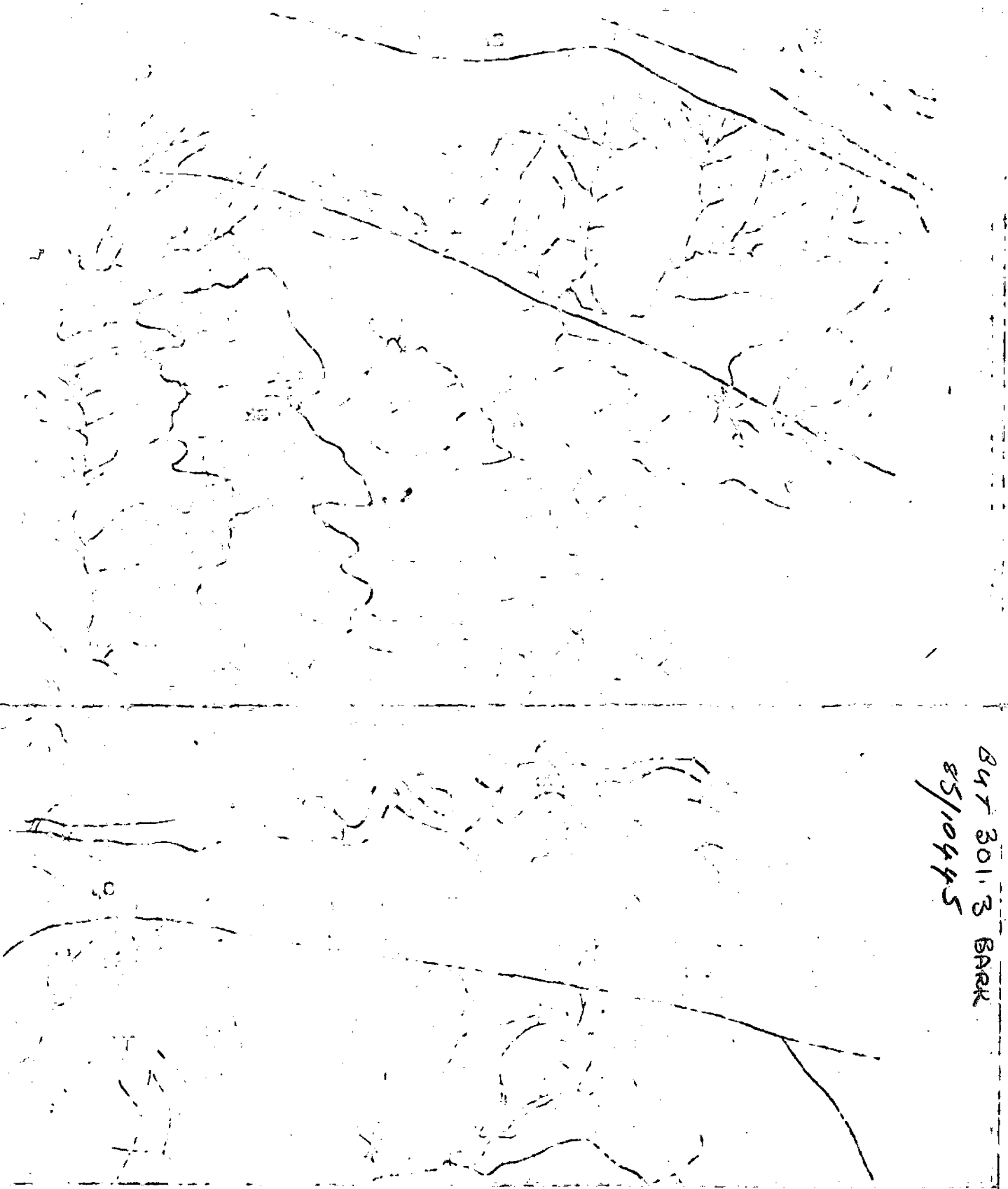
KARATARA SETTLEMENT

At present, Karatara is under the jurisdiction of the Department of Health and Welfare. The total area of the settlement (including farmlands) is 316,72 ha. The built-up business and residential area covers 55,2 ha. This will increase to approximately 86 ha in the future as the settlement expands. Approximately 100 new stands will be developed around the northern and western boundaries of the settlement, as well as on the triangle of ground in the vicinity of the reservoirs. New sewage, water reticulation and electricity works are being introduced. Karatara, eventually, will be proclaimed a township and placed under the jurisdiction of the Outeniqua Divisional Council.

(Mr Kruger, Karatara, Department of Health and Welfare, pers. comm.)

FIGURE 4.1

847 301.3 BARK
85/10445



FORMATION
 COBALT
 TORONTO
 KOPPEL

SIBON SECTION OF BRITISH COLUMBIA

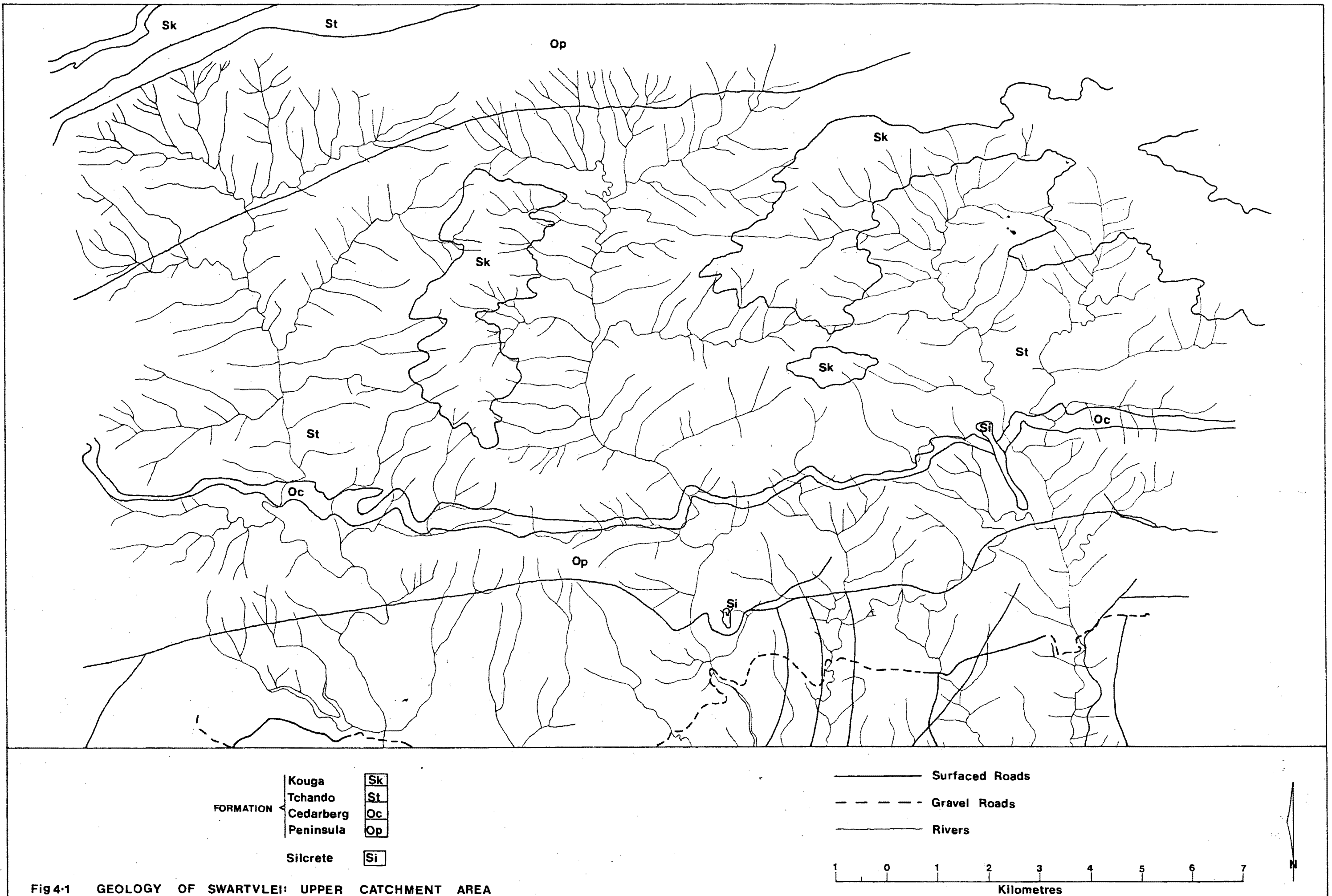
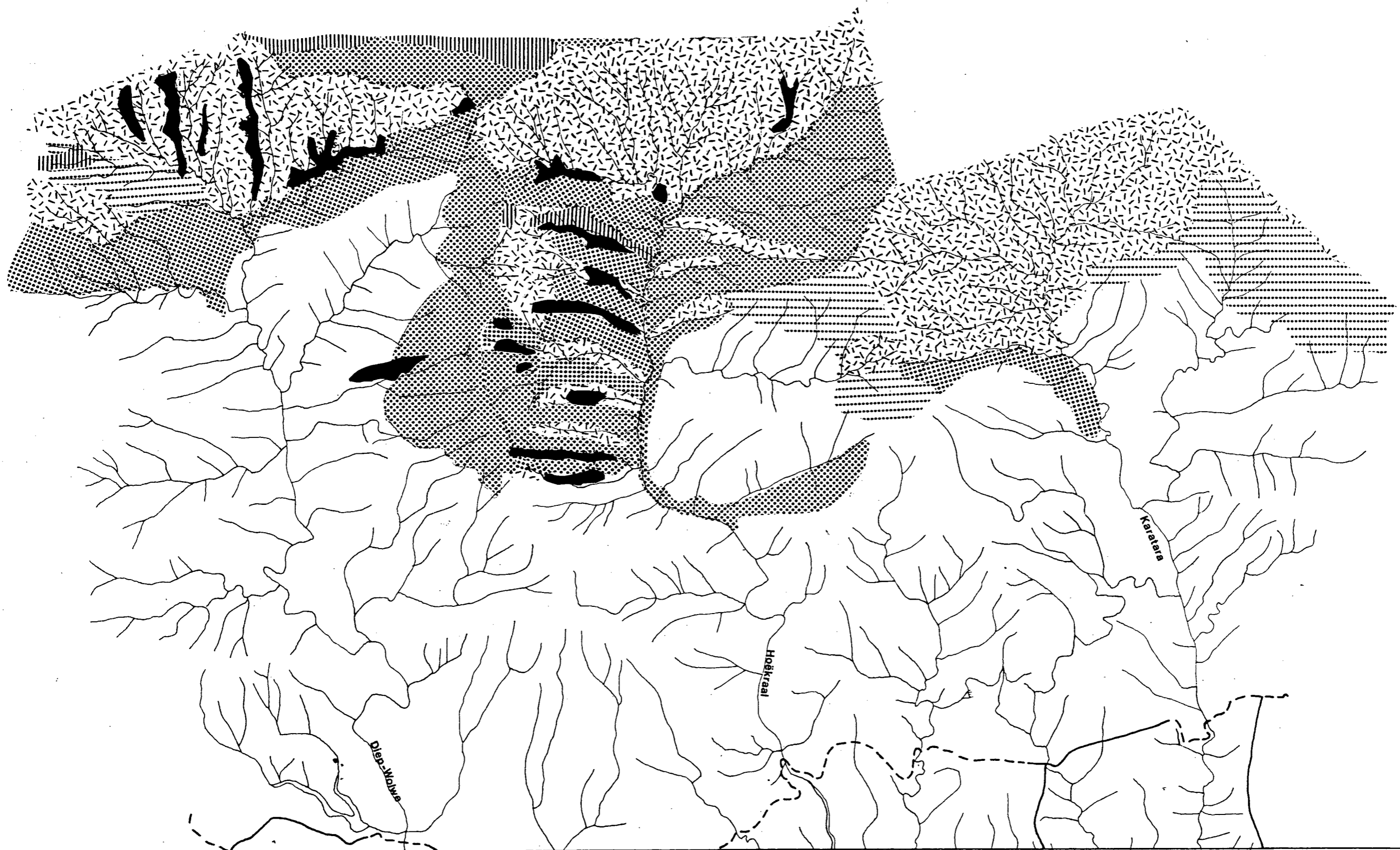


Fig 4-1 GEOLOGY OF SWARTVLEI: UPPER CATCHMENT AREA

BUT 301.3 BARK
85/10445



Legend:-

||||| P1a *Leucadendron eucalyptifolium*, Proteoid shrubland

▒ P1b *Leucadendron uliginosum* shrubland

⋄ P1c *L.eucalyptifolium*, *Berzelia intermedia* shrubland

H1s South slopes: Wet Heathland

H2 North aspects: Graminoid Heathland

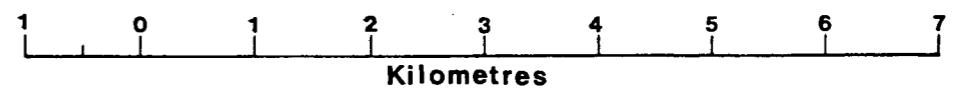
■ Indigenous Forest

———— Surfaced Roads

- - - - Gravel Roads

———— Rivers

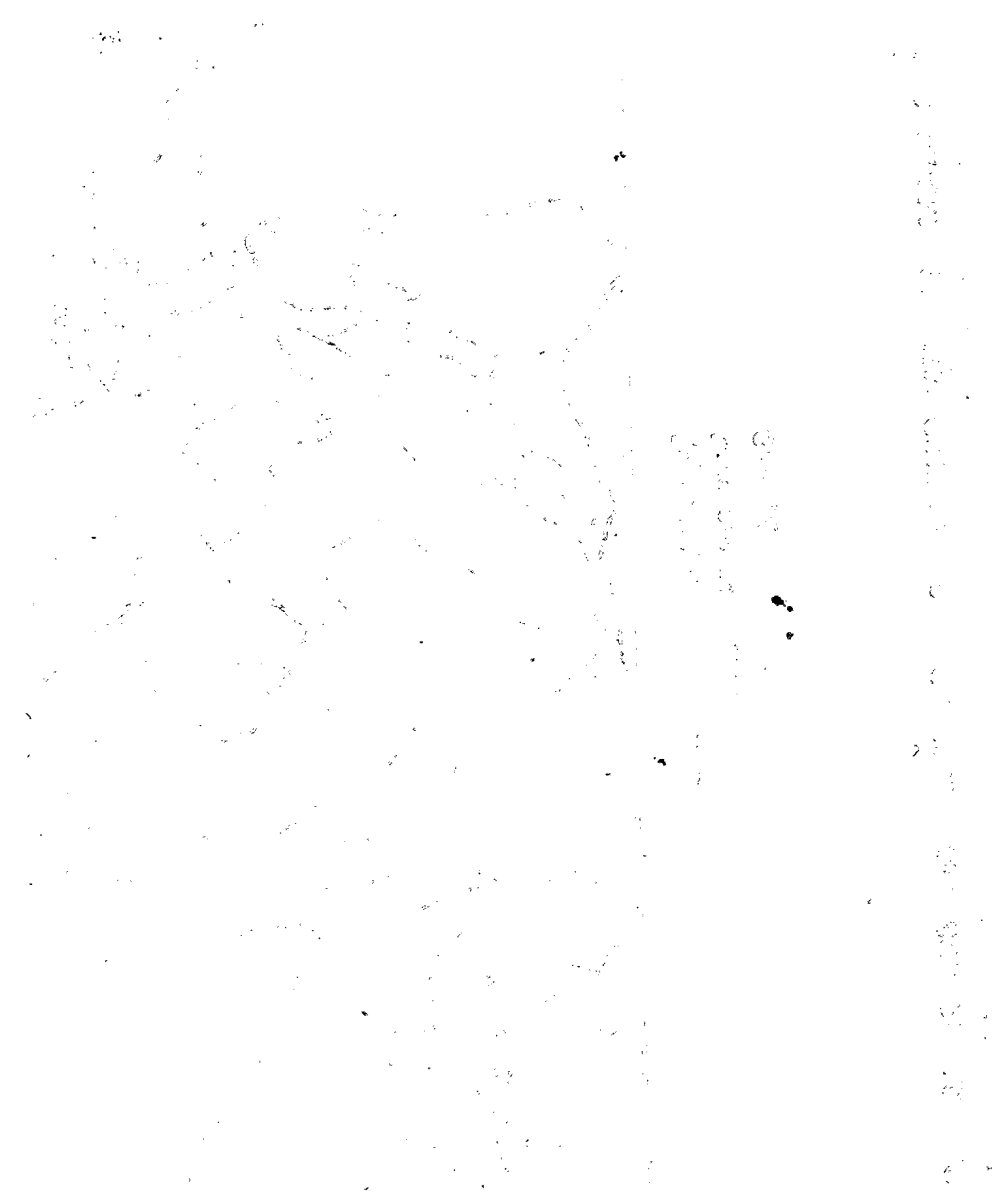
Fig 4-2 PLANT COMMUNITIES IN THE OUTENIQUA UPPER CATCHMENT AREA



SOURCE: Policy Memorandum: Southern Cape and Tsitsikamma forest region

BUT 301.3 BARK.

85/10445



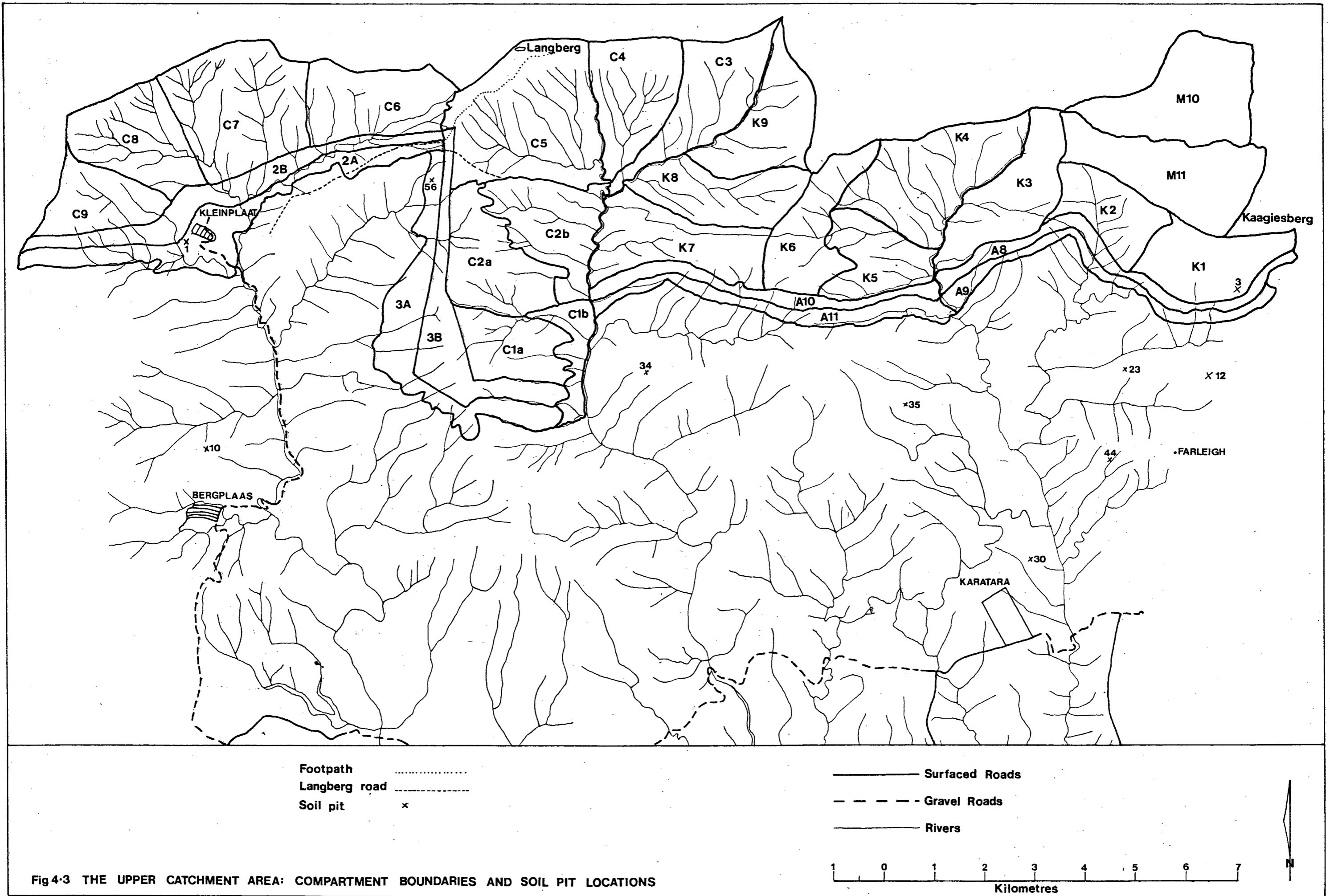
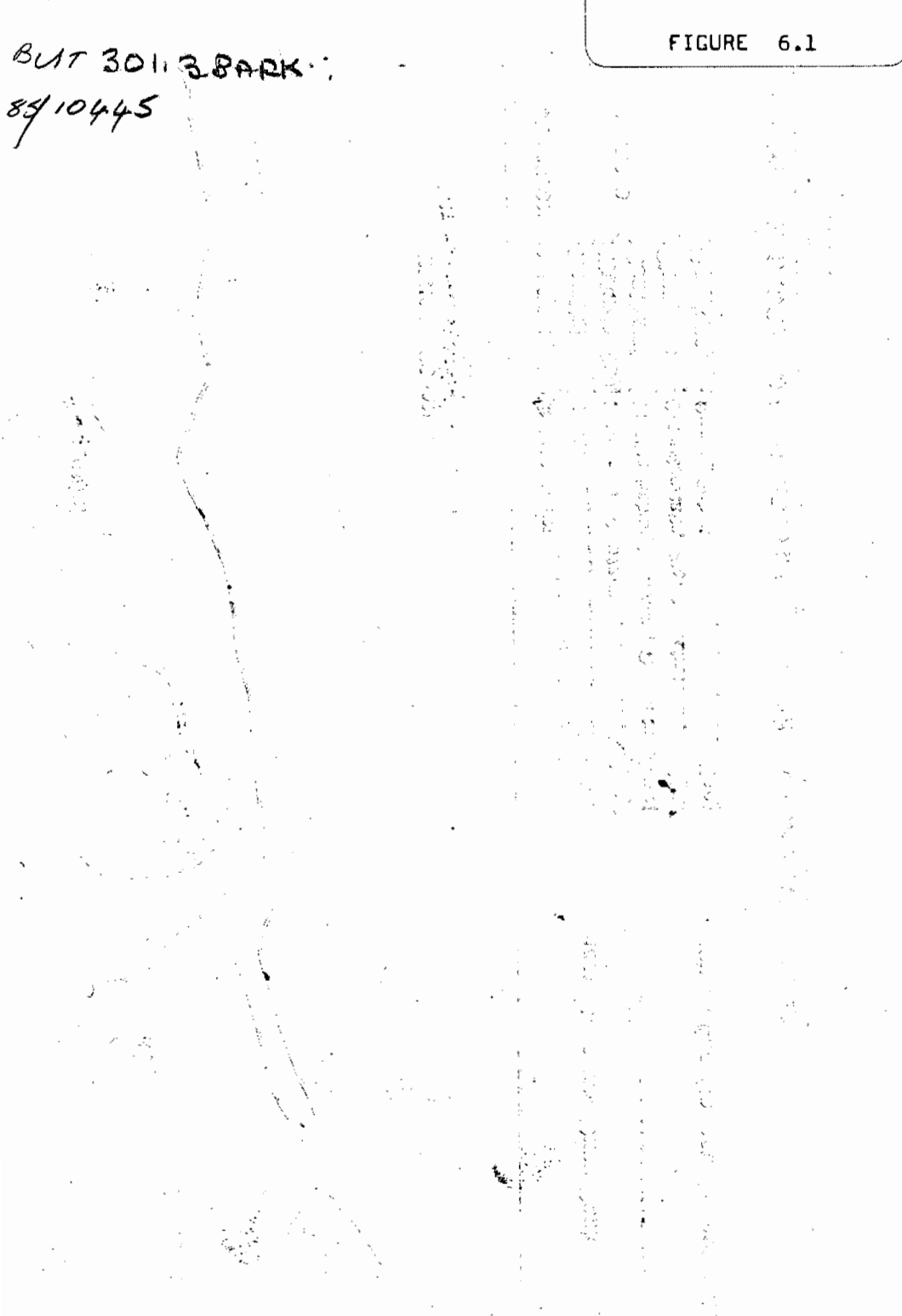
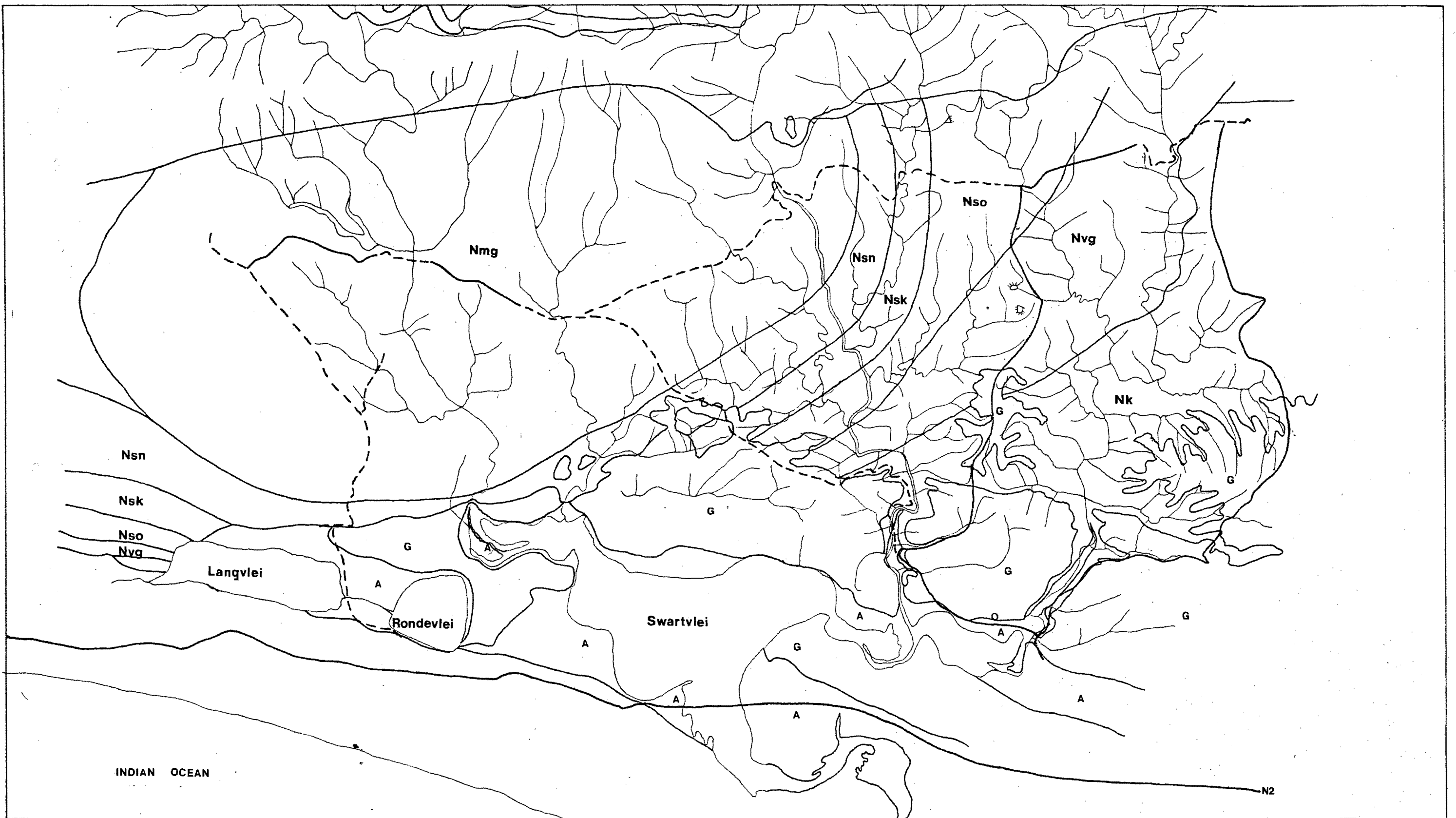


Fig 4-3 THE UPPER CATCHMENT AREA: COMPARTMENT BOUNDARIES AND SOIL PIT LOCATIONS

BUT 30113 BARK:

8910445





FORMATION	MEMBER	DESCRIPTION	
Kaaimans	Homtini	Phyllite	Nk
	Victoria Bay	Feldspathic Quartzite	Nvg
	Soetkraal	Phyllite, Schist, Hornstone, Quartzite	Nso
	Skaapkop	Gritty Quartzite, Phyllite, Schist	Nsk
	Sandkraal	Quartz, Schist	Nsn

- Fixed Dune and Dune Rock G
- Alluvium A
- Gneissic Granite and Granodiorite Nmg

- Surfaced Roads
- Gravel Roads
- Rivers

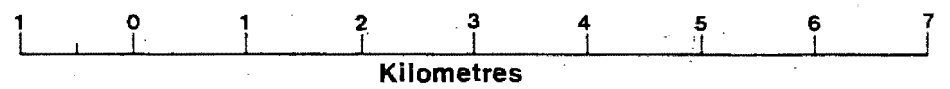


Fig 6-1 GEOLOGY OF SWARTVLEI: LOWER CATCHMENT AREA

Information source: 1:250 000 Outdshoorn 3322 and Geological Survey

BUT 301.3 BARK

85/10445

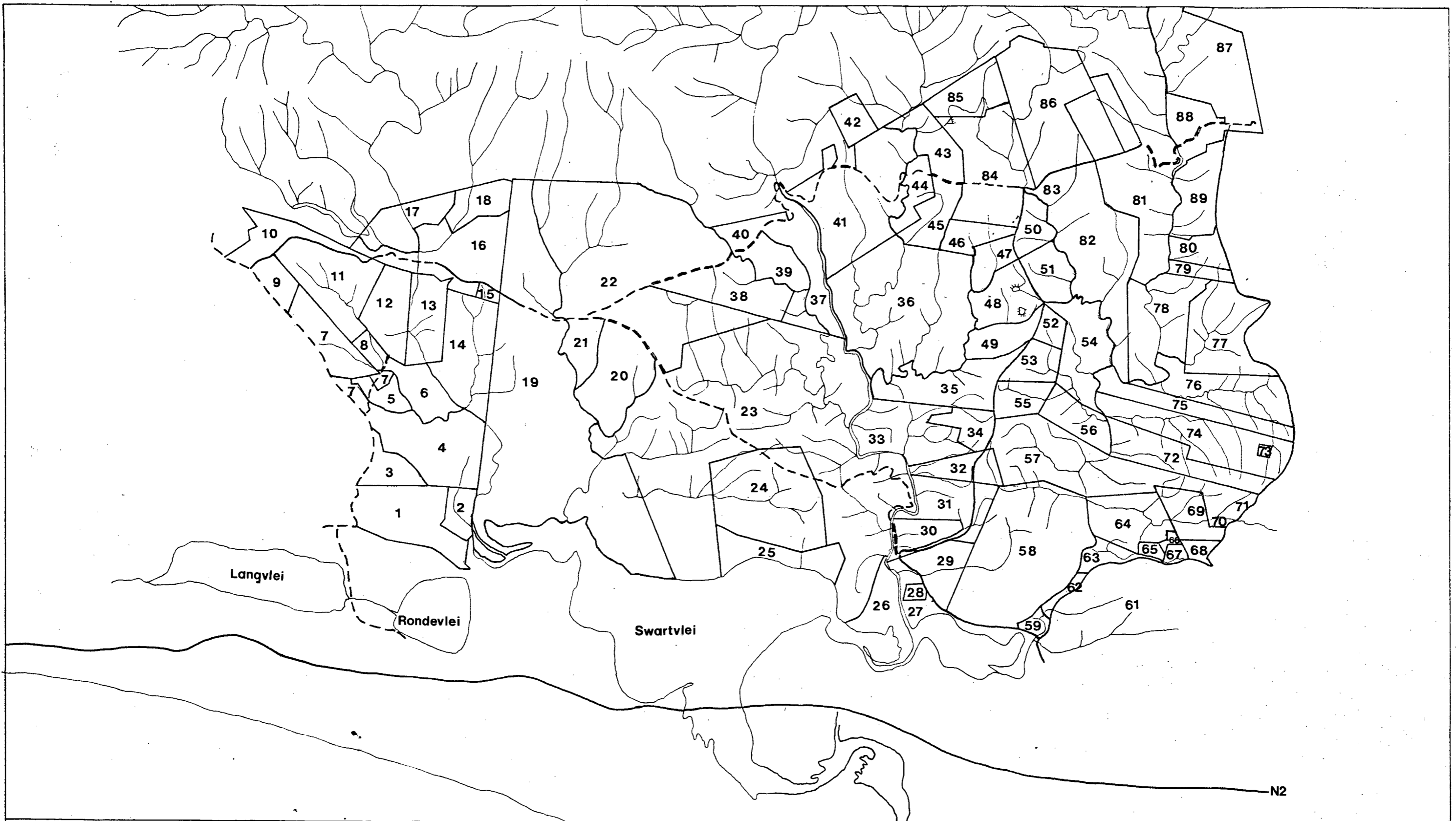


Fig 6-5 SWARTVLEI LOWER CATCHMENT AREA:
FARM BOUNDARIES AND ALLOTTED NUMBERS

————— Surfaced Roads

- - - - - Gravel Roads

————— Rivers

