Spatial and Temporal Aspects of Soil Erosion in Mt Ayliff and Mt Frere, Eastern Cape Province, South Africa.

by

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Declaration

I declare that this dissertation is based on my own original work except where stated, and it has not been previously submitted for a degree by any other person at the University of Natal and/or at any other university.

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Abstract

This study is concerned with the physical and human causes of soil erosion. Some quantitative information on the magnitude of soil erosion for different ecoregions in South Africa is available. However, such quantitative data is available only from a few sites. One objective of this thesis is to add to the existing data. Site specific data is provided for the two study areas in the Eastern Cape Province, namely, Chani area in Mt Frere and Brooks Nek area in Mt Ayliff. A comparison is made between the physical and chemical characteristics of the soils found in both study areas. The spatial and temporal extent of the erosion problem is also given. Another major objective is to evaluate the soil rehabilitation measures used at these two areas. An evaluation of the relevance and efficiency of the erosion control measures is made. (For gully erosion especially, the present study provides an evaluation of the suitability and effectiveness of the gully control mechanisms adopted.) Most importantly, a third objective of this study is to investigate the awareness and attitudes of the members of the communities affected by the erosion problem.

Among the many different factors found to be important in the causal nexus that results in soil erosion, it has been found that many of the problems originate from social causes, like that of too large a population for the limited available resources. Added to this, factors like poor development programmes, bad agricultural practices, bad road management, have exacerbated the erosion problem. In other words, from research and interviews conducted in the study areas, erosion problems linked to recent political policies; to farming and to other practices were found to be associated, *inter alia*, with the shortage of land, unemployment, the lack of the necessary farming equipment, overgrazing and so on. To stress the point, the five important factors contributing to erosion were identified as an over exploitation of the land resource for basic needs, bad road management, floods, drought, and concentrated flow on furrows made by both on- and off-road vehicles.

We noted that another important feature of this thesis is to give an account of the psychological attitudes of individuals living near the areas affected by erosion.

Respondents to interviews and to questionnaires generally agree that there has been a lot of change in their natural and man-made environments, especially in terms of gully development and vegetation reduction. However, there is a disturbing level of ignorance concerning the causes and consequences of erosion. When asked to estimate the date of gully initiation in Brooks Nek, for instance, none of the respondents could give even rough estimates or a specific incident leading to the current dominant erosion problem. The general attitude towards the problem in their midst was one of indifference. The general belief is that erosion is caused not by themselves but by natural phenomena. Further, most respondents thought it is someone else's (e.g. government's) responsibility to ameliorate the harmful consequences associated with land deterioration and soil loss.

The data for this thesis have been obtained through surveying the landscape directly over a three-year period (1994-6), and by using aerial photographs for 1982 (Mt Frere site) and 1993 (Mt Ayliff site). Detailed analysis was undertaken of chemical and physical characteristics of soil at both sites. In addition, quantitative and qualitative surveys of people in the area were attempted; to ascertain their understanding and contribution to the problem. The implications, as shown from the results of this investigation, are that the soil erosion problem at both study areas are largely independent of soil characteristics. On the contrary, this study will show that human practices are the major initial causes for soil erosion in all the cases investigated. It was found that over the years, the land use practices in both sites have changed significantly. Factors accelerating the development of erosion forms at Brooks Nek, for instance, include the footpaths and stock trails. In contrast, artificial contouring and poor gabion layout are the major causes in Chani. However, it must be mentioned that it is not always easy to separate the effects of human from natural causes. Once the effects of human activities exceed the optimum limits of soil resistance and resilience, erosion starts. Then erosion acceleration will not necessarily be confined to the original cause(s). Natural storms and floods, or even drought will contribute in accelerating the erosion rates.

CHAPTER 1: INTRODUCTION

This chapter will begin by defining and explaining a few of the key technical terms to be frequently used in this study. An overview of the soil erosion problem and a brief account of its recent history in South Africa will be given. Also, by way of setting the scene, the aims and the structure of this thesis will be outlined. 'Geological soil erosion' is assumed to operate at normal rates within natural ecosystems that are in a state of dynamic equilibrium (Beckedahl *et al.,* 1988). At times, however, a state of accelerated erosion - which is essentially natural with respect to process - greatly exceeds the normal rates. 'Exceeded normal rates', in this context, are related to the conditions of ecological disequilibrium. In other words, the processes fluctuate in response to natural conditions of stress, such as floods, drought, etc. (Beckedahl *et al.*, 1988, 1998).

As the above paragraph indicates, accelerated soil erosion is a process of erosion which is much more rapid than normal or geological erosion (Boast *et al.*, 1978). It is a hypothesis that this study will investigate that accelerated erosion occurs primarily as a result of human activities. According to Bergsma *et al.* (1996) accelerated erosion is probably the most serious and least reversible form of land degradation, particularly in the tropics. In the present study, 'accelerated erosion' is the concept used to distinguish between natural soil loss and the rapid loss of soil that, in turn, is thought to be detrimental to human lives (Beckedahl, 1993 after Boardman, 1990). Such detrimental erosion encompasses the increased erosion process rates that are associated with the impact of human activities. It also includes a range of related issues such as land degradation and destruction, desertification and deterioration, drought and famine. According to Stocking (1995a) these issues are crisis indicators in the perception of people in developed countries about environments in less developed ones.

'Land degradation' refers to the decline in the land's suitability for use. This occurs under certain types of land use, or where natural vegetation cover deteriorates due to soil erosion, salinisation, pollution, or overuse of the land resource (Bergsma *et al.*, 1996). The related concept reversibility or irreversibility expresses a natural tendency to deterioration of the land when modified by human factors. Soil erosion as a land degradation process usually manifests itself as long-term when it is nonreversible, or short-term when it is reversible (Johnson and Lewis, 1995). 'Reversibility' is used as a measure of the extent to which a particular system, such as the soil, shows resilience and stability over time. The concept 'resilience' is used to refer to the capability of the soil system to accommodate the impact of interactions occurring on it, without the soil showing the extent of the impact of such interactions at a particular time. 'Stability' is used in the context of the ability of a soil system to return to the original state after it has been disturbed.

The conditions contributing to erosion may be worsened by the land use practices. 'Land use' refers to the type of activity for which the land is utilised either by human beings or by the prevailing natural ecology. The term refers to certain technological uses of land such as the cropping systems employed. It also refers to social and institutional aspects of land, notably, land tenure; for example, collective land ownership as a form of collective responsibility is one form of land use common among southern African countries (Phillips-Howard and Oche, 1995a; Mushala, 1997).

Even though human influence is acknowledged, it is important to note that at times, severe erosion may occur as a consequence of natural landscape evolution, to such an extent that no attempt at rehabilitation would be feasible. 'Rehabilitation' refers to the process of restoring degraded land until it regains some agro-economic value. This can be a difficult task, particularly if an attempt is made to inhibit the natural geomorphic processes (Beckedahl, 1993; Bergsma *et al.*, 1996). It must be mentioned that as much as different methods of rehabilitation counteract different types of accelerated erosion, only the impact of human activities on those eroded areas is generally counteracted by these means. Before precautionary rehabilitation measures are proposed, we need to take the natural susceptibility of the soil to erosion into account. This means that the soil characteristics (physical and chemical) should first be examined. They are also determining factors to the success of the attempt to rehabilitate the soil. The point here can be put in another way, that is, natural extremes such as floods or drought are capable of initiating soil erosion. In such circumstances, the land can be rehabilitated. But this is rare. For example, a single intense thunderstorm can, after a prolonged dry spell, create a scar many kilometres long and several metres wide, by scouring away the soil through natural geomorphological processes (van Schalkwyk, 1984; Bocco, 1991).

Human-induced or 'anthropogenic erosion' occurs as a result of an imbalance that upsets the equilibrium between soil, vegetation cover, and other environmental attributes (Moore *et al.,* 1993; Bergsma *et al.*, 1996). For instance, poor or non-existent plant cover facilitates the erosion of soil, which would otherwise not take place. This applies, especially, if climatic extremes such as drought also prevail (Hudson, 1981; Beckedahl, 1993; Bergsma *et al.*, 1996). At this stage, it is worth noting the general assumption that views vegetation cover as capable of decelerating erosion. This is confirmed in most research papers. However, Stocking (1995 after de Ploey, 1981) offers evidence of erosion that is caused by raindrops associated with the presence of vegetation. This raises a crucial question on the role played by this variable, *viz.,* raindrops from vegetation in soil erosion.

The term 'sustainability' is used in this research in the same way as Phillips-Howard (1993), namely, the maintenance or enhancement of resource productivity on a long-term basis. The concept thus refers to the successful management of a resource such that it satisfies both human needs while maintaining or enhancing the quality of the environment and conserving the natural resource (Phillips-Howard and Oche, 1995b).

The existence of erosion diminishes the sustainability of the soil resource, thereby constraining the agricultural production capacity of the affected lands. Consequently, eroded agricultural lands lead to lower income for the farming community derived from crop production. Where this phenomenon prevails, many nations are faced with serious poverty and famine (Blaikie, 1985; Boardman, 1988b; Beckedahl, 1993, 1998; Simon, 1997). The rate of soil loss in developing countries such as South Africa is regarded as a major problem, especially given that agriculture is one of the primary economic activities in this country (World Bank, 1994). Soil erosion has caused soil users to seek soil conservation measures that will ensure sustainable utilisation. According to Hudson (1979), there are many conservation strategies that are designed to ensure that soil use can be sustained indefinitely.

Now that some of the key concepts have been explained, let us turn to the next section which deals generally with problems of erosion.

1.1. An Overview of the Soil Erosion Problem

According to Cooper (1991), soil erosion is a serious and escalating worldwide problem. It is associated with poverty in the developing countries. Rural people are pushed to marginal lands for commercial or political reasons. They are forced to strip the land of fuelwood and to resort to overgrazing and/or overcultivation to earn a living. As their poverty and plight increase it is little wonder that they seem unperturbed by the problem of soil degradation that accompanies their predicament.

Soil degradation does not merely affect poor rural areas, of course. It is a consequence also of modern agriculture and its related monocropping and overuse of agrochemicals. This is common in developed countries and it is a hotly debated environmental issue (Meadows, 1985). The perceptions outlined above support the observation of Klugman (1991a) that it is an oversimplification to see the wealth of the developed countries and the poverty of the developing countries as completely unrelated. They have many problems in common, albeit, due to different causes.

South Africa is a 'world in one country'. This country has a mixture of a developed country's environmental problems - such as adverse water and air pollution, acid rain, *etc.*,- as well as a developing country's problems, such as soil degradation through overutilisation (Clarke, 1991; Felix, 1991). Much of the rural areas in South Africa - which are characteristically that of a developing country - are occupied by the poorest sector of the population, namely, black peasants (Cooper, 1991). The Eastern Cape is one such area. It is faced by many intractable environmental problems, especially land use related problems. In fact, the Eastern Cape is a clear example of the land use found in developing regions internationally.

The Eastern Cape Province constitutes 169 580 km^2; 14% of the total land area of South Africa. This province has a population of 5, 865 million which can be broken down into 2, 703 million males (46%) and 3, 162 million females (54%). It is a home to some 16% of South Africa's total population (Madikizela, 1999). The population density is 38.2 people per square kilometre. 63% of the population is unevenly distributed between the rural areas of the province (Stats SA, 1997; Orkin, 1998). Most family-households are - largely as a consequence of the patriarchal nature of rural society - female-headed. These households are designated to be the poorest (Lipmann and Henwood, 1998; Orkin, 1998). For instance, of the total rural communities, 48.7% of the members invariably travel on foot (Lipmann and Henwood, 1998).

Unfortunately, only 11% of the total rural area in South Africa is arable and only 3% is rated as highly productive (Cooper, 1991). Even then, according to the Development

Bank of Southern Africa, a third of all white farmers in this country (20% of the total farming population) are responsible for 80% of commercially viable agricultural produce (Cooper, 1991). Roughly the same statistics applies *pro rata* in the Eastern Cape. The implication of such a scenario is that the black peasantry is the poor. Poverty in the Eastern Cape is severe (71%) and although not confined to one race, it is concentrated among blacks (May, 1998). All such factors are important to an adequate analysis of the human dimension of soil erosion.

The Human Development Index (HDI) - the level of development of population calculated on the basis of life expectancy, education and income - for the province is 0.506 (Population Policy Report, 1998). The index is used to place human progress and human deprivation into perspective (Lipmann, 1998). The 0.506 level of the HDI for the Eastern Cape province is lower than the 0.7 for the whole country and it places the province at a medium scale (Lipmann and Henwood, 1998). There are, however, marked regional inequalities within the province itself. For example, the Wild Coast District Council, part of which are Mt Frere and Mt Ayliff (where the study sites are located), has the HDI of only 0.20. This is not surprising because, nationally, levels of human development and quality of life differ with variation in geographical regions (as well as in race and sex). At national level for instance, the HDI for Africans is 0.50 as compared to 0.66 for Coloureds, 0.84 for Asians and 0.90 for whites (Population Policy Report, 1998). For the Eastern Cape, the HDI for Africans ranges between 0.08 and 0.36 (Lipmann and Henwood, 1998).

The Community Development Index (CDI), a measure of the level of human development used to assess the needs for such development, is 5.2 in the Eastern Cape. This suggests that the need is greater than the average on a scale of 0 to 10. However, zero alone is indicative of a high level of needs, therefore, the province is given a low priority in terms of funding needs to promote human development. Closely linked to CDI is the Development Potential Index (DPI) which is 3.5 for the province (Madikizela, 1999). Zero development potential is also indicative of low priority in terms of funding requirements for promoting human development (Lipmann and Henwood, 1998).

Another factor which (it will be argued for later) affects the attitudes and perceptions of people to erosion - other than the wealth status - is that of the level of education of the local community members. The province has the lowest literacy rate in the country, that is 72.3% illiteracy (Madikizela, 1999 after Census, 1996). Stocking (1995) used the paternalistic/classical ideological model to refer to similar education levels elsewhere. (The details on the effects and role of education on people's perception of erosion are dealt with in Chapter 6.)

Alongside the human aspect of soil erosion, is the physical perspective of the phenomenon. The study of soil erosion and the related problems has shown that it is not realistic to isolate the cause and effect relationship between the physical and human factors because of the thin line separating the two (see for example, Blaikie, 1985 and Stocking, 1995b). People's behaviour is likely to be influenced by the physical characteristics of their resources as well as the magnitude of the threat should they overutilise the physical environment which they depend on. In most poor countries, increasingly impoverished rural people become vulnerable to natural disasters which are induced by human activities. As indicated by Cooper (1991), it can be argued that if data on the two factors were available, predictions would be possible on whether improved or worse conditions should be expected in future in a particular area. Predictions could be achieved if the specific use of soil is matched to the soil characteristics.

If spatial variability is properly handled, an understanding of soil properties and soil behaviour in conjunction with human behaviour, could enable land users to work within the limits of their soil potential (Blaikie, 1985; Uehara *et al.*, 1985; Cooper, 1991). This is the guiding principle to the approach adopted for this study. An ability to deal with spatial variation of soil leads to greater accuracy in assessing soil capability. Knowledge of land use requirements can assist in gauging with precision, the potential performance of the soil. Also, it can help in identifying the consequent behaviour of a soil and the particular soil's ability to respond to rehabilitation measures (and the stabilisation mechanisms to be used).

A wide range of contemporary research indicates that there has been a general failure of rehabilitation programmes that were effected by the government prior to 1994 in the greater part of the Transkei-Ciskei regions and other homelands. This is reflected, for instance, in the research findings of Daniel (1981); Steele (1988); Weaver (1988); Cooper (1991), and Hanvey (1991). As a result, a number of researchers recommend a revival of the indigenous conservation methods as an alternative to the government initiated strategies or the recommendation that indigenous methods be used concurrently with modern government methods (McAllister, 1992; Phillips-Howard and Oche, 1995a). According to Stocking (1995), less developed countries experience failure in erosion control programmes due to "the ideology around the new philosophy", that reverses the classical perspective, namely, land husbandry. This reversal approach demands that the target should be the production process, which in the case of rural areas in Transkei-Ciskei regions, is land use. This practice is pertinent because erosion is frequently the result of poor land use management strategies and it is exacerbated by the sensitivity of soils. According to Smithen (1981), Transkei region lies in the heart of the area most severely affected by soil erosion. ('Transkei and Ciskei' in this study are used to refer to areas of the Eastern Cape that formed part of the former 'Republics' of Transkei and Ciskei.)

Before reporting on the details of this research, however, it is necessary to review the historical background to soil erosion in South Africa. The next section outlines the research work carried out to investigate the extent of soil erosion in South Africa.

1.2. The Historical Background of Soil Erosion in South Africa

Soil erosion was recognised as a problem in South Africa as far back as 1909 (van Schalkwyk, 1984). Sir Walter Hely-Hutchinson noted in the early 1900s that thousands of tons of rich soil were being carried away to the sea. He is quoted as expressing his opinion '.... that here indeed was a question which demanded the gravest attention'; ... 'it is one which should have been taken up not only by individual farmers, but that the government should lend its influence and, if possible, its assistance in dealing with the matter' (van Schalkwyk, 1984, p1). This initial call, however, was ignored until 1923 when the Drought Investigation Commission identified soil erosion as the main consequence of the greater incidence and severity of drought in this country. The warning issued by the Commission was that if the erosion processes were left unattended, the result could be 'The Great South African Desert, uninhabited by man' (van Schalkwyk, 1984 after Drought Investigation Commission, 1923). Although attempts may have been made to curb the erosion process in South Africa, the soil deterioration process has nonetheless continued, as shown in the works of Oche and Madikizela (1996), and Oche (1997).

In 1933, the first soil conservation schemes were introduced in South Africa (Bennett, 1939). These schemes involved the design, construction and subsidisation of anti-erosion works, dams and water reservoirs. During the same year, a soil erosion research project, titled - *"Effects of soil cover on runoff and erosion"*, began (van Schalkwyk, 1984 after Haylett, 1961). This ultimately led to the Soil Conservation Act 45 of 1946.

Although general erosion concern in South Africa was recorded during the 1900s, it appears that research on soil erosion forms, especially, gully erosion, dates as far back as 1860s (Brady, 1993). Until the middle of the 1950s, the focus on this form of erosion was on control measures and management techniques; after which the scope broadened to cover factors governing gully initiation and development; general gully morphologies, flow conditions, rates and mechanisms of gully erosion including sediment characteristics (Brady, 1993). Most of these studies were focussed mainly on the physical side of the gully environment. The human side was not neglected but it was not the focus, as it generally is today. Other researchers, however, express different opinions on the matter. According to Cooper (1993, p47), the "human dimensions in the discussion of characteristics and causes of soil erosion have been rarely considered by both scientists and agriculturists". Although Fuggle and Rabbie (1994) contend that poor cultivation methods, veld fires and overgrazing have always been regarded as anthropogenic causes of accelerated erosion, little cognisance was given to the human consequence thereof.

In addition, however, contemporary research suggests that there has been a lack of emphasis on the human effect of landscape which has been modified by open mining, railway and highway cuttings, the drainage of fens and other environmental deteriorating processes that are associated with the urbanised society of the mid-19th

to early 20th centuries (Fuggle and Rabie, 1994; Rogerson, 1995; Vogel and Drummond, 1995). Due to the realisation of the extent of land degradation resulting from mining in South Africa, mining companies are only permitted to mine if they can show that they will put in place rehabilitation programmes to restore natural environments to their original conditions (Fakir, 1997). The effect of human activities in the form of agriculture, mining and logging had, earlier, been raised by Lemly (1982) as causing sedimentation of aquatic systems and to the general soil erosion in South Africa, which dominated the period prior 1960. The past four decades brought about a shift in the spatial distribution of impoverished land (and water quality) to the construction of transportation facilities and urban development. This was as a result of the fact that construction sites had potentially high and harmful levels of fertilizers, pesticides, soil stabilizers, oil and gas from machinery, washings from concrete and bituminous mixing and finishing operations, all of which negatively affected soil resilience and led to accelerated erosion.

During the 1990s, most geomorphologists further broadened their research of gully erosion to include the investigation of the extent to which the gullies are a threat to human survival in their vicinity, as well as the extent to which human beings contribute to gully development (Cooper, 1993; Brady, 1993; Beckedahl, 1998). This period, however, emphasised a shift to the human factor, that is to the changes associated with human activities on the physical environment, and problems arising from human attempts to redress the resultant problems, on the environment (Cooper, 1991). The present study has been structured to encompass physical attributes of gully initiation and development, in addition to the role of human activities. An often neglected additional feature of this study is an assessment of the local people's beliefs and attitudes on their role in increasing the problem.

Although the above approach is referred to as contemporary, it appears that the perception of the anthropogenic influence in geomorphology has, according to Nir (1983), been crucial to the discipline even in the early 1960s. Unfortunately, due to negligence, the ideas of some of the noteworthy predecessors were left out of the picture. It could be argued that the neglect continued until the revival of this topic in the 1990s. It is, however, important to note that the study of gully erosion significantly predates the work of Nir (1983). In 1901, Woeif talked about forest felling and the destruction of natural vegetation, rapid urbanisation, the growing need for food and raw materials and the hasty extension of fields at the expense of forests, as the main issues that induce gullying. The 'dissociation between man and the soil' and the agglomeration of population into towns was further alluded to as evidence of an unhealthy state of soil conditions in the rural environments (Nir, 1983).

Research shows that a number of people in South Africa still perceive towns as better than rural areas when the need to be economically successful is the main focus. This perception exists irrespective of the fact that for many years, many families had lived 'successfully' in rural areas (Beinart, 1982; Bundy, 1988). A typical example of the wish to be close to town is the case of the *eTipini* communities in Umtata, where residents of the landfill area would rather settle on a floodplain and feed on the city waste than go back to rural areas, after they had been retrenched from factories and mines (Frost and Mijere, 1997). Although a variety of reasons are cited by such people, apparently the implementation of apartheid laws - which dissociated people from the land - created some imaginary view that there was better life in the cities. Evidence shows that - from a socio-economical perspective - this has threatened the rural people, for it left many under the greatest impact of high poverty levels (Oche and Phillips-Howard, 1995b). Shortage of suitable land for farming and settlement equally had adverse effects on communities. At the same time, the apartheid laws left behind them, labour impoverished families in the rural hinterland (Downing, 1990; Madikizela, 1990; Cooper, 1991; Oche and Phillips-Howard, 1995b; Stocking, 1995a; Simon, 1997). In this study, the history of the impact of both human and physical factors has been used to establish the nature of the erosion processes. While acknowledging the view

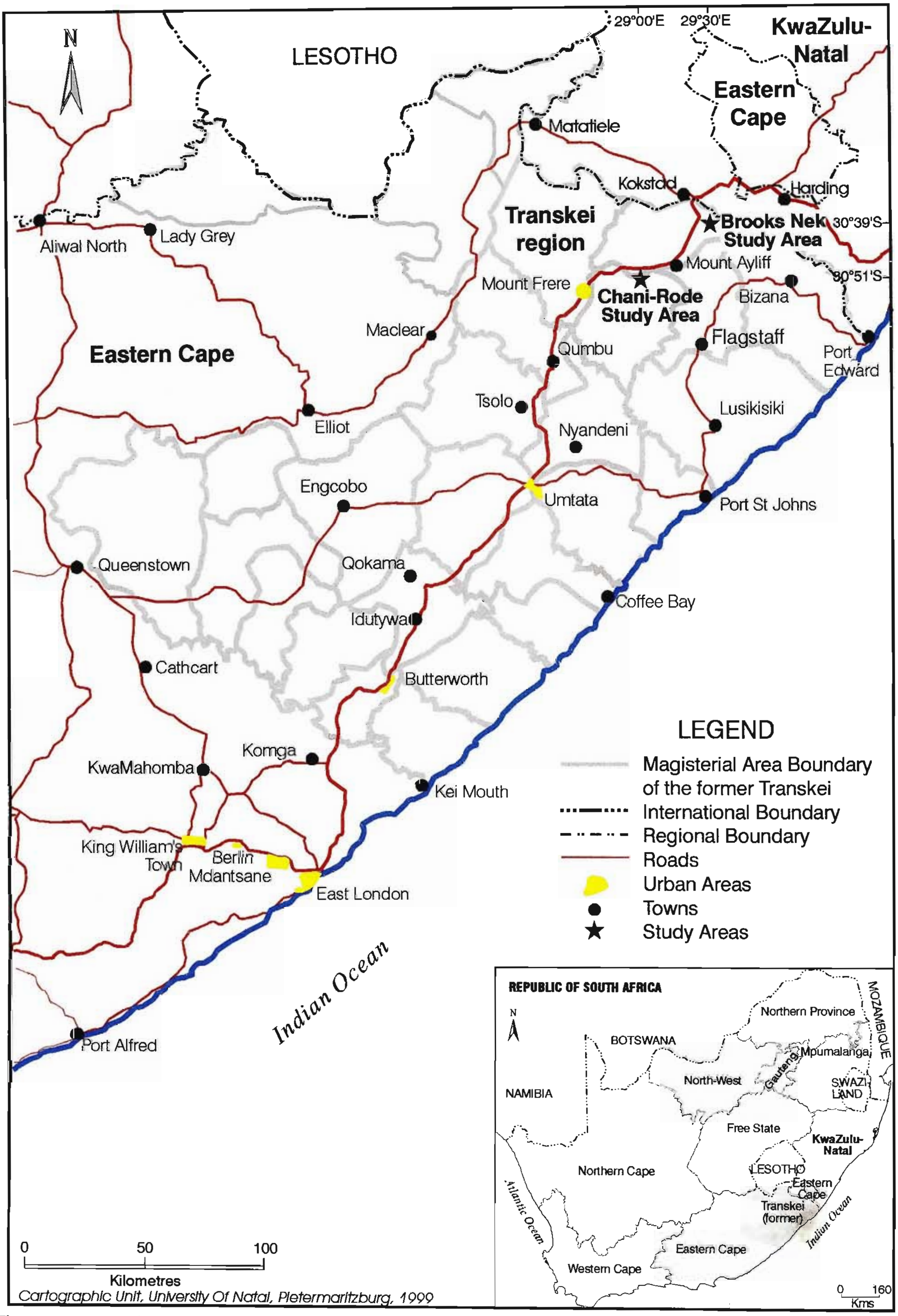

Figure 1.1 : The location of Study Areas

of Dodson *et al.* (1994) that climatic change, as well as human activity can alter biological and physical processes in the environment, climatic variability could not be verified for the study areas due to insufficiency of data.

1.3. Aims of the Present Study

The present study aims to add to the existing data of soil erosion in one part of South Africa. Its aim is to contribute human and physical data concerning the soil erosion situation within two districts, Chani in Mt Frere and Brooks Nek in Mt Ayliff (Fig. 1.1). A second intention in this study is to analyse the physical and chemical characteristics of the soil in the Brooks Nek area and to make comparisons with samples taken from the Chani study area. Another general aim is to evaluate the rehabilitation structures that are in place at the two study areas. Brooks Nek area has been subjected to gabion construction since 1993 whilst the Chani's attempted rehabilitation was completed during the early 1980s. Specifically, the present study aims to:

a) provide site specific data pertaining to the study areas, that can be used to guide future development-potential-plans for the sites and other similar areas in the region;

b) analyse the soils characteristics and make a comparison between the two sites;

c) evaluate the relevance, efficiency and/or effectiveness of the soil conservation mechanisms within the catchment areas and gullies. The intention is to assess the erosion problem before and during rehabilitation attempts in order to prevent foreseeable future problems;

d) to present the spatial and temporal extent of the erosion problem at both sites; and

e) assess the residents' awareness, beliefs and perceptions of their role in accelerating soil erosion

In an attempt to realize the above aims, it became obvious that the following pertinent questions needed to be answered: What erosion control measures are now in place? What mistakes, if any, have resulted in a developing problem of soil erosion? What precautions have been taken to avoid repeating the mistakes (which have been identified to be associated with erosion control measures in the Transkei region since the mid-1970s)? How suitable are the soils on which gabions are constructed for this erosion control mechanism, in relation to their structure and their soil chemistry? The latter question is important because even though gabions are considered to be independent of soil character, evidence has shown that gabions have not been effective on, for instance, dispersive soils (Beckedahl, 1998). What land use management strategy is in place to monitor the gully conditions before and after the implementation of the conservation mechanism?

In line with the view of Cooper (1991, 1993), answers obtained from the above set of questions can ensure that any implemented rehabilitation programmes in the future incorporate lessons learnt from the past experiences. They may guard against incorrect land use practice.

It will be argued that at the Brooks Nek and Chani sites, both physical and human factors play a crucial role in accelerated erosion. A combination of factors including poor land management and planning has influenced soil erosion characteristics in these areas. Both areas show evidence of land use change. Much of the cultivable land is now laying fallow. This can be associated with a deterioration in the surrounding environment and the soil erosion problem could be linked to this. It will be argued also that connected to the change in land use is the political and historical background of South Africa. The 'betterment schemes' (which may have improved conditions elsewhere in the country), had an adverse impact in many rural areas, where their implementation was incomplete. Those latter areas include Brook's Nek and Chani. Since the land use and the political aspects are not mutually exclusive, it is not easy to draw a line between the role played by the historical and everyday impacts and the natural events. What is certain, however, is that both impact severely on the socio-economic conditions and on the attitudes of the people affected.

1.4. The Brief Outline of the Structure of the Present Research

The following is a brief account of how this study is structured. In order to contextualise this study, a review of the existing body of knowledge pertaining to soil erosion is presented in Chapter 2. The last part of that Chapter details the human causes of soil erosion and the characteristics of the different erosion forms. The environmental setting of the study areas covering both the physical environment and human dimensions of land use activities, and the land tenure systems in the Transkei region, are then reviewed in Chapter 3. Chapter 4 focuses on the methods, tools and techniques used to obtain the results. The results are presented and discussed in Chapters 5 and 6. The final chapter concludes with a brief review of the implications of the research. It provides recommendations for reaching meaningful solutions to the soil erosion issues presented.

CHAPTER 2: THE CONTEXT OF SOIL EROSION

In the literature on the subject, an extensive review of the trends and causes of the present state of soil erosion at a worldwide scale is found. This includes a large number of well-documented research reports, for example, Boardman (1988a); Hanvey (1991); Dardis (1991); Dollar and Rowntree (1995), and Stocking (1995a and b). Methods to reduce soil erosion rates and to monitor the response of soil conservation methods - and to ensure sustainable land use and development - have been reported by many research scientists from different parts of the world (Hudson, 1981; Beinart, 1984; Griffiths, 1984; Morgan, 1995). Occasionally, the views of these scholars conflict with each other and sometimes they conflict with those of the actual land users (Bocco, 1991 after Foster, 1988; Dent, 1997). Let us now look briefly at the literature.

2.1. General Background to the Soil Erosion Problem

Research shows that soil erosion is a worldwide phenomenon. As it will be shown in the coming paragraphs, soil erosion manifests itself more severely in some countries than others depending, *interalia*, on the level of the country's technological advancement. At the international scale, by 1991, the IUCN/UNEP/WWF reported that 70% (5.5 million hectares) of all the world's drylands - which are occupied by one-sixth of the world's population - is degraded by the soil erosion process (Scoones *et al.*, 1996). Another report in Scoones *et al.* (1996 after the UN, 1992, p2) projected that about 5 to 10 million hectares of land will become unusable, due to severe annual degradation.

Further projections indicate that by 2020, 1.4% to 2.8% of the world's existing agricultural, pastoral and forestry land will be lost, if the present trends continue. Of the degraded land, 15% of the loss is a direct result of human induced soil degradation, with up to about 7 million hectares of agricultural land made unproductive annually by erosion (Napier *et al.*, 1991).

Evidence of differences in the impact of soil erosion as observed at a worldwide level shows that the United States prioritized research on soil erosion as far back as the early 1980s. This followed the recognition of the long-standing impact of erosion on agriculture (Stocking, 1988a). Of the 75 x 10^9 tonnes of soil eroded worldwide each year, about two-thirds comes from agriculture and this loss costs the world some US$400 billion per year, or more than US$70 per person per annum (Scoones *et al.*, 1996 after Pimentel *et al.*, 1995). The United States incurs a total cost of erosion from agriculture of about US$44 billion dollars $annum^{-1}$, if both on-site and off-site costs are combined (Scoones *et al.*, 1996 after Pimentel *et al.*, 1995).

If we look at soil loss from other studies, in Britain, where there is a mean annual rainfall of 700 - 1 000 mm, a loss of more than 50 m^3 ha^{-1}, with rates reaching more than 200 m^3 ha^{-1} on one field (Boardman, 1988a), is experienced. A large increase in erosion related events occurred in the United Kingdom in the last 25 years; as a consequence agriculture and erosion are depicted as key concerns when formulating public policy (Boardman, 1988b). In the Far East, Northwest China had a record of mean erosion rate exceeding 135 tonnes $year^{-1}$

by 1991. The Yellow River, which drains a significant portion of Northwest China, had a sediment load estimated at 12 tonnes $acre^{-1}$ (0.41 ha^{-1}) $year^{-1}$ (Napier *et al.*, 1991; see also Zhu Xian-Mo, 1995). When considering these figures, however, it is necessary to heed the warning of Stocking (1995 after Lal, 1988) who cautioned on the use of sediment yield as a significant factor, as it is not easy to relate the downstream sediment to its exact source. Nonetheless the concern arises that if these high estimates are made in developed countries, what will the loss be in less developed countries, where monitoring is less meticulous? Part of the response to this key question, lies in statistics presented below on Africa.

For Africa, reports on soil erosion studies can be categorised according to northern, central, western, eastern and southern countries. For instance, 'a staggering total of 87% of the Near East and Africa north of the equator are in the grip of accelerated erosion' according to Phillips-Howard and Lyon (1994) and highlighted by Scoones *et al.* (1996 after FAO, 1983). For instance, Mali and Burkina Faso had estimates or similar assumed soil loss, that was between 7 and 26 US dollars $hectare^{-1}$ $year^{-1}$ respectively (Scoones *et al.*, 1996). In a similar vein, Ethiopian estimated soil loss is between 1.5 and 3.0 billion tonnes, with 50% of this occurring on croplands (Scoones *et al.*,1996 after FAO, 1986). In Kenya, Rowntree (1991) studied just one aspect of soil erosion, namely, gully morphology and identified the same kind of depressing figures. (A similar observation had earlier been made by Dunne (1977) when looking at the soil erosion patterns in that country). So the greater part of Africa is faced with a serious problem with respect to soil erosion. The estimated losses in crop yield due to erosion given by Lal (1995) is even more depressing. He argues that if accelerated erosion continues unabated, yield reduction by the year 2020 for Sub-Saharan Africa may be 14.5%. To support this prediction he points out that annual reduction in total production in 1989 due to accelerated erosion in the continent was estimated at 8.2 million Mg for cereals, 9.2 million Mg for roots and tubers, and 0.6 million Mg for pulses. The reduction in total production in 1989 for Sub-Saharan Africa alone was estimated as 3.6 million Mg for cereals, 6.5 million Mg for roots and tubers, and 0.36 million Mg for pulses. One common problem experienced in all such developing countries is that the available technologies for soil conservation are not easily adopted and implemented, even by concerned farmers (Hudson, 1981; Napier *et al.*, 1991; Hurni, 1993; Ryszkowski, 1993; Mushala and Peter, 1997). Difficulties in implementing them often result in a resistance to conservation strategies. Such a resistance results also from the effects of a "top-down" approach, where the government ministers or their officers "know best". This approach makes a community feel detached from the problem; people do not perceive the problem as being within their own sphere of influence. Let us now turn to southern Africa.

2.1.1. The historical background of soil loss in southern Africa

In southern Africa, a substantial amount of work on the soil erosion problem has been done. Results show that a large amount of soil has been lost, with values attached to the erosion rates varying from 0.5 tonnes ha^{-1} $annum^{-1}$, up to and in excess of 110 tonnes ha^{-1} $annum^{-1}$ (Beckedahl, 1993 after Boucher and Weaver, 1991). The annual value of soil loss in South Africa alone is estimated at 360 million tonnes (Beckedahl, 1998 after Adler, 1981) which is comparable with the 300-400 million tonnes of soil loss range cited by Scoones *et al.* (1996 after Huntley *et al.*, 1989).

Subsequent research on soil erosion and gully form has been carried out in countries like Zimbabwe (Watson *et al.,* 1984; du Toit, 1985; Stocking, 1987a; Whitlow, 1994). Elwell (1985) like Hudson (1957) estimated soil loss at 50-75 tonnes hectare^{-1} annum^{-1} in this country. To put this point differently; Zimbabwe experiences an extensive soil loss affecting about 20% of the country (Firth and Whitlow, 1991). As a result, in 1985 it was reckoned to have incurred the financial cost of Z$2.5 billion on nutrient loss (Stocking, 1986). Much of the land degradation in Zimbabwe has been clearly identified to be caused by anthropogenic factors (Shakesby and Whitlow, 1991). These factors include the end to destocking in 1962, that consequently led to dambo or gully erosion due to the high livestock population (Whitlow, 1994).

In Lesotho, peoples' attitudes to erosion was studied by Gay (1984) while work on gully hydrological systems and gully soil properties has been done by West (1971); Faber and Imeson (1982); Nordström (1988). The effects of sedimentation on water reservoirs were studied by Chakela (1981) whereas the effects of soil erosion on activities such as agriculture, are described by Kishido (1994). In their different works, it is confirmed that nearly all agricultural operations tend to accelerate erosion, a point already recorded by Hudson

(1979). The general trend in discussions around soil erosion reflects a causal relationship between human behaviour and the erosion of soil.

If we look at neighbouring Swaziland, soil erosion has been attributed to the country's high cattle stocking density and to the unlimited grazing on communal areas. Swaziland is reported to have the highest stock density in the whole of Africa (Phillips-Howard and Oche, 1995b; Mushala and Peter, 1997). According to Morgan *et al.* (1997), livestock intensity in the Middleveld of Swaziland alone is 1 livestock unit in every 1.3 ha and there are places where the ratio is 1 livestock unit to 1.0 ha. As a result, erosion is commonly observed along paths connecting kraals and water points from grazing lands, with gully development at focal points around cattle trails. Incidentally, this is a condition similar to the observations made in the Transkei region where the present study took place. An obvious solution would be a reduction in stock numbers. This is recommended by many researchers. But stock numbers directly satisfy the wealth, status and income motives of the cattle owners, as well as the respect shown to the owner by the society (Mushala and Peter, 1997). This value attached to high stock number ownership may be key to the failure of the schemes to deal with soil erosion, and to the failure to control overexploitation of the resource, not only in Swaziland, but in Africa at large. Clearly, a resolution to this issue is crucial to the success of the implementation of stock curtailment schemes, in many African countries faced with the soil erosion problem.

2.1.2. The background of soil erosion research in South Africa

Within South Africa, there is a wide range of soil erosion studies. A substantial number of scientific contributions to the topic have been undertaken, especially in KwaZulu-Natal. These contributions include, for instance, the role of geology on land capabilities to withstand soil erosion (Watson, 1997), the effects of land reform on gullying (Ramokgopa, 1996; Watson and Ramokgopa, 1997), and people's perception of soil erosion and soil conservation strategies (Watson, 1993; Garland *et al.*, 1994; Pile, 1996). The effects of change on, for example, erosion extent (Garland and Broderick, 1992), and the evaluation of soil erosion problems between 'reserves' and 'open areas' (Watson, 1990) also form part of the range of research undertaken. Another significant contribution is on the historical effects of land degradation on the everyday existence of ordinary people in rural areas (Broderick, 1985), and the rates of erosion on non-agricultural rural land (Garland, 1979).

From the Eastern Cape, Weaver (1988) has researched soil erosion on the Yellowwoods Drainage Basin and other parts of the Ciskei. This work is insightful in its mapping and classifying of erosion, to highlight the extent of land degradation and the efficiency of conservation strategies in those areas. The latter research was a reaction to an alarming report by the Ciskei Commission of 1980, which reported that 46% of that region's land was moderately or seriously eroded and 39% was overgrazed (Cooper, 1991). A number of researchers, including Weaver (1991), Hanvey (1991), Cobban and Weaver (1993), and Dollar and Rowntree (1995) have also made contributions, in their studies of soil erosion in the Eastern Cape Drakensberg (the former Transkei and the former Ciskei).

Evidence shows that in the southern African countries, the causes of erosion also extend to include social, tenurial and economic factors (de Wet, 1991; Wilson and Ramphele, 1989; Madikizela and Nontso, 1997). Alongside this, Cooper (1991) maintains that government has directly influenced the extent of soil erosion in very many situations. The basis of this argument is that the state can either assist the population to adapt its land use system to ameliorate the erosion problem, or it can exacerbate the problem by its policies or omissions, leading to overcrowding, and thereby intensifying soil degradation. This statement can be put in a stronger way: a major responsibility for the deterioration of natural soil resource is ineffective or insensitive government policies. According to Weaver (1988), however, the real cause of erosion in this context is the lack of appreciation of conservation principles on the part most of white farmers, who control more than 70% of the nation's arable land. Maybe the general indifference to such principles is due to the fact that, on one hand, until recently conservation policies have not been subject to public debate. On the contrary, most conservation resulted from government-imposed schemes, where local communities were minimally consulted (Phillips-Howard, 1995a; Simon, 1997). The matter is even worse in the former black homelands. They are affected by severe grazing, which has led to a major reduction in the agricultural land conservation value of these areas (Weaver, 1988).

In 1983, Garland called for the mapping and classification of eroded areas in order to assess the efficiency of land conservation measures and to indicate the rate of land degradation. Weaver undertook his work in some Ciskei areas in 1988. In addition to Weaver (1988), later Cobban and Weaver (1993), and other researchers like Whitlow (1994), and later Ridgway (1997), also studied spatial aspects of soil erosion in the regions of Ciskei and Transkei, with special emphasis on gullies and soil erosion patterns. In the Transkei, Dardis *et al.* (1988a and b) and Beckedahl (1996) had already made a considerable contribution to the knowledge of erosion in this region.

There is another side to this matter that we should note. One reason for the decline in agricultural production in the former Transkei region of the Eastern Cape has been demonstrated by Phillips-Howard and Oche (1995) to be a function of the lack of a balanced relationship between indigenous and scientific knowledge. The term 'indigenous knowledge' is used by these authors to refer to a body of knowledge externally acquired but reinterpreted and transformed and incorporated into a particular cultural behaviour, in such a way that people feel as if it is their own. One reason for adopting indigenous knowledge and techniques is that it is hoped that the traditional methods would bring back the general quality of the soils and restore productivity (Zhu Xian-Mo, 1995). Further it is maintained that one result of the decline in the use of indigenous strategies is overstocking. This is now three times the recommended rate in this part of the country. Oche (1996), however, cites also the political and economic setting of the people, particularly rural blacks, as another main contributing factor to the rapid environmental degradation. This degradation problem closely links up with the intense drought impacts that have been experienced in recent times in the Transkei region. Given the size of the regions and the physical inaccessibility of many of its areas – together with the fact that there is discontinuous aerial photography coverage - it is not easy to have access to either primary or secondary data about some significant areas of these regions. The research work mentioned above suggests that the effects due to erosion on the socioeconomic conditions of people living in this area is alarming. This is also highlighted for other countries in the works of Broderick (1985); Stocking (1988a) and Batey (1988). They all agree that developing regions are characterised by not only environmentally sensitive areas but also by soil erosion prone environments.

The high poverty levels associated with developing countries have generally, although not always, been considered as one important causal effect of high erosion rates (Weaver, 1988; Stocking, 1995a). Simon (1997), however, further connects cultural diversity and loss of indigenous lifestyles to high poverty in this context. And of course, there must be very many other causal factors, some of which will be referred to later, associated with such poverty. So this makes it important to have extensive research conducted in the least developed parts of southern Africa.

2.2. Causes of Soil Erosion in General

The causes of soil erosion can be broadly grouped into two trends, human and natural (Johnson and Lewis, 1995). As noted earlier, we are assuming for the moment that human activities can be viewed as the most important factor in changing natural environments. Together with this, natural disasters either worsen the initial conditions or themselves initiate land degradation problems, so that even if human beings try to intervene, often the chance to reverse the conditions approaches a zero possibility. The natural disasters referred to include climatological factors (precipitation, temperature and evapo-transpiration), chemical factors (salinisation and alkalinisation), and geomorphological factors. The natural disasters most commonly experienced in South Africa (though not limited to it) are desertification, floods and drought, which are usually complicated by global warming and the general global climatic system's circulation (Tyson, 1986; Diab *et al.*, 1992; Meadows *et al.*, 1993; Madikizela and Simamane, 1996; Oche and Madikizela, 1996). The extent of the impact caused by such phenomena is global and, therefore, overly complex (so it is impracticable to try to scientifically assess this impact on one specific area).

In addressing the range of factors referred to in the previous paragraphs, pertinent questions have been posed in this study. As we shall see, the response to these questions has made possible an assessment of the extent of the effects of these different factors, *viz.*, the contribution of anthropogenic and natural variables to accelerated erosion. Such an assessment, however, demands the evaluation of the erosion control measures in place; for instance, the effectiveness of control measures is significantly related to their effect on the hydrology (water quality and water relationships) of an area. According to Beckedahl (1993), hydrology is by far the most serious variable affecting soil erosion. He contends that a negative supply of water reduces the chances of vegetation survival. It also lowers the infiltration and storage capacity of soils, and thus, increasing runoff. A sequence of negative effects on the water table subsequently affects vegetation, then it affects animals and inevitably the quality of human life. Let us now consider some of these causes of soil erosion each at a time.

2.2.1. Natural causes of soil erosion

Barnhart and Barnhart (1984) maintain that 3.6 billion hectares of land worldwide is adversely affected by the desertification - a relentless creep of the desert-like conditions into semi-arid regions - phenomenon. This land area is equivalent to one quarter of the total world's land (Scoones *et al.*, 1996). In Africa alone, a 65% expanse of its total land is dryland, and that is 2 billion hectares of the continent. This includes the two-thirds of Africa's land that is composed of arid, semiarid and sub-humid environments. About 400 million African people occupy this land area. A third of the continent is referred to as hyper-arid deserts (SARDC, April 9, 1997). This shows not only that a greater part of Africa is environmentally sensitive but also highlights the notion that sustainable utilisation of resources is crucial.

Over the years, research has indicated that physical (geomorphological) attributes such as soil (erosivity and erodibility) and topography make a significant contribution to soil erosion. For example, in Zimbabwe, local geomorphological factors significantly increased the erosion hazard (Stocking, 1976). (The same observation incidentally applies in Britain (Boardman, 1988b).) Research in this area shows that the relief factor is noted to be closely related to soil differences (Bergsma, 1996 after Lal, 1981) and *vice versa*. Such soil differences include erosivity and erodibility. These variables are both linked to runoff effect. For instance, runoff is influenced by the topography of the area and the intensity and the kinetic energy of rain (Morgan, 1995).

There are other physical soil characteristics at play which increase or decrease soil erodibility; for instance, soil texture, aggregate stability, shear strength, infiltration capacity, organic and chemical components. On the other hand, a certain amount of rain is also required to induce significant erosion. Hudson (1981) has suggested that a value of 25 mm/h is required. (This figure is based on calculations made from his Zimbabwean studies.) A similar value has been suggested in the works of Rapp (1973) in Tanzania, and by Morgan (1974) in Malaysia (Morgan, 1995). In addition to this, it is necessary to note that physical domains operate in a chain that extends across the soil - biological - climatic - geologic (tectonic) components, and that these chains can operate in a cyclic fashion. The physical variables also act as 'catalyst(s) of change' that encompass soil systems, as well as the response of some soil systems to other high and low intensity events. For instance, severe floods were reported during the years 1987, 1995, 1996, 1997 and 2000 in many parts of the eastern half of South Africa (Tyson, 1986; Madikizela and Simamane, 1996; Oche and

Madikizela, 1996). Similarly, droughts were reported all over the country, in the form of agricultural and hydrological drought, during part of 1992, 1993, 1994 and 1995 (Jury and Levey, 1993; Meadows *et al.*, 1993; Oche and Madikizela, 1996; Stephenson, 1996).

Just as important as natural causes mentioned in the previous paragraphs, human interventions are also major influences on the formation and development of relief forms (Trofimov, 1987). Human influence is sufficiently important to change the space and time frameworks within which spatial-temporal structures and related processes take place.

2.2.2. Human induced erosion: a historical perspective

During the early 1900s, Woeif (1901) pioneered the social and iconographical values in geomorphology when he initiated the study of anthropogenic geomorphology (Nir, 1983). In his work, Woeif regarded soil erosion as a result of the inevitable human destruction of natural vegetation. His observation is reiterated by Nir (1983) who maintained that for as long as there is no alternative to ensure that the basic needs for living organisms, such as fuel, housing, food are provided for, the process of destruction of vegetation will continue. Even today, resource utilisation for such needs often leads to overexploitation and overutilisation of natural resources. Another aspect to be considered here is that of rapid urbanisation which leads to a high demand upon natural resources. These general considerations are applicable to South Africa. The urbanisation process and its related pressure on land were experienced, especially during the

1950s, and this was the peak period of the industrialisation process in this country.

One factor related to rapid urbanisation is 'population growth'. Conventional wisdom views the increasing rates of soil erosion as an indirect consequence of rapid population growth (Klugman, 1991b; Sundsbø, 1991; Whitlow, 1994; Morgan, 1995). According to the CNN's "population highlights" (12 Nov. 1997); '90% of population growth is taking place in developing countries'. Research indicates that population pressure creates problems for both developing and developed countries. In Zimbabwe, the rocky parts of the Mtoko Tribal Trust Land, experience a population density of 60% more $kilometre^{-1}$ than is officially acknowledged. This is comparable to the 0.7-hectare $person^{-1}$ or 150 persons usable km^{-2} in South Africa. The pressure of high population numbers leads to the acceleration in deforestation and to the expansion of agricultural land into marginal areas (Klugman, 1991b). It is further argued that the cultivation of marginal lands - for example humid tropical mountainous areas and upland watershed areas where runoff volumes have increased - became the general practice with the advancement of industrialisation and technological knowhow (Mitchell and Bubenzer, 1980). For similar reasons, many developing countries suffer the consequent associated land degradation, and its corollaries such as poverty and famine (irrespective of their technological advances).

According to Klugman (1991b), and Gamble (1992), many of the problems inherited by southern African countries originate from too great a population for the limited available resources. In South Africa, it is argued that this problem might have been avoided if it was not for the laws passed before and during apartheid; a form of social engineering, which crammed millions of people to live in environmentally sensitive and fragile conditions (Cooper, 1991). This resulted in the so-called "limited land resource" in South Africa. It could further be argued that poor resource management and lack of sustainable development strategies worsened the problem. Research findings illustrate that the most significant micro-social factors - affecting the adoption of soil conservation practices at the farm level - are the population pressure on land resources, as well as the land tenure system (Napier *et al.*, 1991; see also Ford and Adamson, 1995).

Another human factor associated with erosion is bad agricultural practices and poor development programmes (Abatena and Teddlie, 1994). According to Cooper (1991), homelands in South Africa accommodated a black population whose density has been of the magnitude of about ten times that of the rest of rural South Africa. Since no adequate resources and infrastructure were provided for subsistence survival, this population sector has had to strip the environment (Klugman, 1991a). This scenario is not limited to South Africa as, in general, soil erosion due to this factor is a sign of all developing countries. According to Cooper (1991, p176), soil erosion is 'associated with and caused by poverty'. As we noted earlier poverty often pushes rural people onto marginal lands to accommodate commercial or political motives, thus leading to a cycle of land degradation. In the process, "the sacrifice of the future to survive in the present" becomes inevitable (Durning, 1989). This, in turn, leads to land degradation, which exacerbates the insecurity of the poorest people, especially with respect to food. It results in a reduction in biodiversity, a decline in water quality and a decrease in the health status of the affected people.

2.2.3. Other indirect human causes of soil erosion

The list of other human causes of soil erosion is long. Speaking generally, it could include cultural, social, economic, institutional (e.g., tenurial), technological and educational factors. These, either singly or jointly, have had a crucial impact on rates of erosion, and they have given rise to a limited range of conservation strategies in developing countries (Peter and Mushala, 1997). Research in southern Africa shows that such factors have been poorly investigated, even though research - that brought about a substantial increase in knowledge regarding the mechanics of soil erosion processes and their relationships with the physical environment - began as early as the 1940s. For instance, it is only recently that systematic research was undertaken on the economic, social, institutional and political factors to determine the relevant relationship with soil erosion (Stocking, 1988b; Morgan, 1995; Mushala and Peter, 1997). In contrast, in Asia, these factors have been long identified and long ago the highest rates of soil loss were recorded. An example is that of the People's Republic of China where the impact of the rates of soil loss were recorded in the 1980s. Even at that time, it was found to have reached crisis proportions (Napier *et al.,* 1991).

another indirect human cause of soil erosion noted in this study is the land tenure system and land ownership systems. The causal impact of these factors are more complicated than at first might appear. They are accompanied by additional problems such as the lack of knowledge, lack of information about such variables as the status and land use patterns (for example, farming and building material), and the lack of expert advice. In this study we hope to show that such factors, individually or collectively, limit the chances of ensuring sustainable land resource use in South Africa. Regarding knowledge, for instance, many rural subsistence farmers believe that the burning of their grazing land guarantees, in return, a better grass quality. It is now known, however, that this is not always the case, especially where such a practice is carried out every year. Similarly, research in the former Transkei Republic shows that farmers have not been properly assisted by such services as extension officers. As a result, their agricultural activities have led to serious environmental degradation, including soil erosion (Bembridge, 1997). We shall return to these matters shortly. At this stage, we now need to consider some of the characteristic forms of erosion.

2.3. Characteristics of Soil Erosion Forms

In the literature, the soil erosion process is said to manifests itself at both the macro and micro levels through a series of stages. The distinct nature of the detachment and the transportation processes involved in each erosion form, at any of the two levels, make it necessary to either study or present them separately. The first part of this section focuses on the distinction between different erosion forms.

In southern Africa, nine major contemporary soil erosion forms can be identifiable (Beckedahl *et al.*, 1988; Dardis, 1989) (however, Imeson and Kwaad (1980) categorize them into four types). Table 2.1 presents the nine major forms as compiled by Brinkcate and Hanvey (1996) based on the classification by Beckedahl *et al.* (1988) and Dardis *et al.* (1988b).

Table 2.1: Soil Erosion Types in southern Africa (after Brinkcate & Hanvey, 1996)

Type	Cause or Source
1	Unconfined sheet and rill water-activated erosion
2/3	Unconfined water or wind erosion, with areas of net erosion and deposition
4	Confined tunnel/pipe erosion
5	Confined water-activated erosion dominated by soil piping and cavitation
6	Closed-open conduit networks (that is, continuos gullies)
7	Open conduit networks (i.e., continuous erosion)
8	Degrading gully remnant
9	Highly degraded surface dominated by rill and sheet erosion, often dissecting bedrock

The first form (Type 1) is associated with overland flow or sheet flow. This erosion type develops during heavy rainfall, when sheet flow concentrates in many small definable channels, causing rill erosion. Soil properties, rainfall intensity, and slope are also significant to in-between rills, a product of interrill erosion (Imeson and Kwaad, 1980; Zhang and Miller, 1993). Rills are a miniature version of gully erosion form (see, for example, research reports by Faber and Imeson, 1982; Dardis and Beckedahl, 1988a and b; Liggitt and Fincham, 1989; Swanson, *et al.*, 1989; Shakesby and Whitlow, 1991; Brady, 1993; Watson, 1993; Zhang and Miller, 1993; Boucher and Powell, 1994; Abrahams *et al.*, 1995; Watson , 1997; Watson and Ramokgopa, 1997). Gullies, in turn, can expand and develop into higher order badland landscapes (Yair, 1980; Bryan and Yair, 1982). Beckedahl (1993, 1998), however, contends that the natural processes which cause these landforms do not always uphold the sequence outlined above. For example, there are cases where the expected erosion form exists without the prior existence of the expected initial forms. For instance, topographic control over surface flow is equally capable of developing rills or gullies without following either defined channels, subsurface continuum, or a pipe system (Dardis and Beckedahl, 1988a; Beckedahl, 1993, 1996, 1998).

By definition, 'rills' are surface-scoured micro-channels of less than 30 cm in depth. These often occur on agricultural land, and can be obliterated by cultivation (Boucher and Powell, 1994; Beckedahl, 1993, 1996). According to Imeson and Kwaad (1980) and Boucher and Powell (1994), an increase in concentrated flow deepens and broadens rills to an arbitrary depth of 50 cm - the minimum depth used to differentiate gullies from rills - (Bocco, 1991). A commonly accepted categorisation technique of rill erosion is, however, through the analysis of channel flow characteristics, rather than rill depth or size. If this method is used, a rill constitutes a large number of flow concentrations that are uniformly distributed over an area (Imeson and Kwaad, 1980). The fundamental basis for differentiation is on the behaviour of the gully and rill phenomena. One of the important behavioural characteristics is that rills depend on water supplied from an interrill and they behave more like river channels. Another not so common but significant feature is the role of slope stability on sidewalls (Piest *et al.*, 1975). If a slope is unstable and the sidewalls frequently collapse, the depths of rills increase and this gives rise to the formation of a gully. Even though the differences in depth may be small at an early stage, the effects of great depths constrain human interaction with the environment, such that farmlands become inaccessible, making it difficult to productively use the land resource in question.

Let us turn now to gullies. As with rills, in the literature on this subject, different views surface when gullies are differentiated from other forms of erosion. Gullies are open channels, usually steep sided, generally U- or V-shaped in cross-section. They are usually bare of vegetation, but this depends on whether they are continuous or discontinuous types (Imeson and Kwaad, 1980; Boucher and Powell, 1994). As the previous paragraph suggests, gully erosion is like rill erosion except for the differences in magnitude or scale. Gully refers to a very narrow; or a long, narrow and hollow valley (and/or channel) worn in the earth or unconsolidated material; or it refers to any erosion channel so deep that it cannot be crossed by a wheeled vehicle, or eliminated by a farm implement (Brady, 1993 after American Geological Institute, 1972). Although such a definition is very general, it gives us a broad picture with which to identify a gully. Gully features, however, are unique to each area; therefore, no single definition is sufficient to define every gullied area (Brady, 1993). (Details on gully erosion are discussed in subsection 2.3.1.)

The final stage of land degradation occurs when gully erosion leads to a badly eroded state of the land (badlands), such that rehabilitation can only be left to natural processes (Yair, 1980; Bryan and Yair, 1982). Badlands occur as intensely dissected landscapes, where vegetation is largely absent and agriculture is impracticable (Bryan and Yair, 1982; Dardis and Beckedahl, 1988a; Dardis, 1989; Beckedahl, 1996). This last state of erosion (badland topography), is not as pronounced and continuous in South Africa as it is in some other parts of the world. Comparably speaking, South Africa does not have extensive badlands but it has small-localised occurrences of this form. In eastern southern Africa where such badland erosion features are more common, they are a function of subsurface erosion, which has finally become exposed by roof collapse (Beckedahl, 1977; Beckedahl *et al.*, 1988; Dardis *et al.*, 1988b; Dardis and Beckedahl, 1988b; Dardis, 1989; Beckedahl, 1996, 1998). A more detailed consideration of gully erosion is pertinent at this stage, since this form is a key concept to this study.

2.3.1. Gully Erosion

In his study of gully erosion, Bocco (1991) in line with Rubey (1928) estimated that gully erosion studies have been pursued for nearly a century. Bocco, however, felt that this phenomenon still remains poorly understood. Results have been confusing and contradictory (Bocco, 1991). This observation is reiterated in the view of Imeson and Kwaad (1980), who also thought that the processes of gully erosion are not well understood. They suggest that a proper approach to this type of erosion should be made through studying the erosion phenomena responsible for gully formation. They maintain that the evaluation of gully processes and their link between past, present and future events, will make it easy to understand gully morphologies. At the same time, it was not forgotten that many different factors trigger the complex sequences of events that results in gully development (Dardis, 1989).

Other work on gully erosion has been carried out in Australia by Crouch and Blong (1989), and Pickup and Chewings (1996). In South Africa, significant contributions on the gully erosion problem have been made by Imeson and Kwaad (1980); Beckedahl and Dardis (1988); Dardis and Beckedahl (1988a and b); Dardis (1989); Liggitt and Fincham (1989); Beckedahl (1996); Watson, 1996, 1997; Watson and Ramokgopa (1997) and others.

2.3.1.1. Causes of Gully Erosion

Gully erosion results from both natural and human factors. The physical causes of gully erosion include surface erosion by overland flow and rill erosion. Both are widely viewed as primary mechanisms in gully initiation and development (Ireland *et al.*, 1939; Swanson *et al.*, 1989 after Brice, 1966). The slope geometry variables (angle, length), aspect and curvature also influence runoff, drainage, soil temperature, and soil erosion. The influence differs with variation in soil properties, even if the landscape position is more systematic (Brubaker *et al.*, 1994). According to Imeson and Kwaad (1980), Boucher and Powell (1994) and Beckedahl (1996, 1998), topographic convergence and seepage sources produce gully types that are the resultant landforms of concentrated runoff and this is closely linked to the effect of curvature. In observing seepage behaviour, Speight (1980), however, found no correlation between contour curvature - associated with topographic divergence or convergence - and soil moisture content. Anderson and Burt (1980) argued that this is due to the fact that Speight (1980) related these parameters to localised contour curvatures. They maintain that the existence of convergence plays an important role in throughflow generation. Beckedahl (1998) also confirms this hypothesis.

According to Speight (1980), soil water patterns can be explained by reference to larger scale topography, rather than just contour curvature. Profile curvature (the rate of slope change) is thought to have an effect on either acceleration or deceleration of flow, and subsequently influences aggradation and/or degradation processes. This is due to the fact that curvature usually traverses to the slope direction, referred to as 'planform curvature' (Zevenbergen and Thorne, 1987). In other words, the planform curvature is the most influential factor in convergence and divergence of flow. In addition, micro-variations in soil properties, like the area of slope, are equally significant in gully formation. The area of a slope is in itself, however, hydrologically meaningless in measuring hillslope catchment (Anderson and Burt, 1980).

Soil type is another equally crucial factor in determining gully development. In southern Africa, gullies are ubiquitous (together with other soil erosion forms) on soils which have stratigraphical evidence of the sequences of periods of evolution that are of comparative stability (Price-Williams *et al.*, 1982; Dardis *et* *al.*, 1988a). These are indicated by the development of humic layers and stone lines, as well as by intervening periods of instability that are represented by colluvial sediments of up to 5 metres thick. Soils of such thickness are related to gully and sheet erosion (de Villiers, 1962; Botha, 1992). The effect of colluvial and alluvial sediments especially, have been found to be linked to gullying throughout Swaziland and Zimbabwe, and to the gully erosion phenomenon dominant on highly erodible sandy or silty colluvial sediments (Crouch and Blong, 1989; Dardis, 1989; Shakesby and Whitlow, 1991). Once the process of gullying starts, it self-sustains and continues to grow on its own, independent of the factors that originally started it.

Gullies, as the most dissecting and degradational symptoms of accelerated erosion, have the most effect on human operations over a landscape (Gardiner and Dackombe, 1983). Even though gullies start as insignificant small rills, they grow to sizes that have proved to have serious implications on a variety of human economic activities (Sharpe, 1938). The seriousness of the threat of gullies to living organisms can be highlighted when the relationship between their on-site and off-site effects as well as on such variables as water supplies, on hydrological changes, (dams, river water supply and flood hazards), and on the whole ecosystem, are taken into account.

It is worth pointing out in passing that a range of other human activities are hindered by gully erosion. These include many practices, for example, farming, walking across gullies, constructing settlement structures, etc. Hence gully erosion is a major concern to people in many countries. Since the 1900s, for instance, South Africa is one of the countries which have made an effort to control, rehabilitate and to conserve soils. Rehabilitation programmes have been researched, suggested and implemented. Policies have been made and laws passed. The erosion problem, however, continues unabated. In other words, reports and recommendations to solve or ameliorate the problem continue but there is no holistic plan or programme that has successfully implemented the recommendations.

2.4. The Anthropogenic Context of Erosion in South Africa

2.4.1. Sociopolitical Factors

Something needs to be said about the sociopolitical background that is an important constituent of the anthropogenic nexus causing land degradation in South Africa. Information on the land tenure system in the Transkei region overlaps with the general South African tenure system. Hence, the discussion in this section may extend to include the general scenario of the South African tenure system. For instance, the land tenure system during the pre-colonial period required that almost every mature married man had, as a customary right, access to a residential site. This site encompassed a garden lot, a cultivable field, and access to communal grazing land. This practice was applicable across the country (Bundy, 1988; McAllister, 1992; Phillips-Howard and Oche, 1995). According to Southey (1981), such land "ownership" was a prerequisite to being a fully-fledged member of the community. The economic lifestyle was mainly characterised by the customary land tenure. Even though land belonged to the community, once allocated, it would be passed from parents to children (Carsterns, 1981).

The communal land tenure system was also "customary". Each tribal territory's Headman, had custody over the resources necessary for subsistence farming. In the Southern Bantu pattern of land tenure (McAllister, 1992), such resources included even perennial water, fuel wood, an area within which to hunt and gather, and access to thatching grass (Madikizela and Nontso, 1997). Every communal surrounding land belonged to the past, present and future members of the tribe, and was administered through the community representative, namely, a chief or headman.

Collective land ownership and the agro-pastoral farming system were dominant among traditional tribal groups in South Africa and in the Transkei. Often, the land held as a family property was leased out if the family lacked the means to keep farming going. The land was rarely sold (Carsterns, 1981; Southey, 1981; McAllister, 1992). Even where land was temporarily leased (never, it seems, with intention to make profit), the ultimate right of repossession (and the control over such things as the trees in the surroundings) remained under the control of the original owner. Leasing usually occurred every other year, for leaving the land to lie fallow was a common practice. This was an indigenous appropriate land management measure that was, and is still, believed will improve the productivity of land. These traditions are still practised in many other African countries like Nigeria, Sudan, Mali, and Morocco (Kolawole *et al.*, 1996; Mohamed, 1996; Wedum *et al.*, 1996; Hamza, 1996; Millar *et al.*, 1996). One reason that this way of managing the land continues, is due to the fact that these countries were not affected by extreme policies that restructured land acquisition and ownership, like that of apartheid in South Africa.

In the Transkei region, at the present time, land ownership is still under the custody of a chief who, together with Headmen, allocates land on request. The traditional tribal boundaries are still used to ensure control over land use and resource allocation. Communal grazing is still the only form of land use practised by stock farmers. Many areas in this region are dominated by small landholders and small scale subsistence farmers.

In the study areas, Brooks Nek (Mt Ayliff) and Chani (Mt Frere), during and after "betterment planning", most of the black South Africans lost their land to the State (their land became State Lands). Furthermore, in Brooks Nek some land which local people used became part of the "Kokstad municipal area". Generally, the "betterment scheme's" policy limited accessibility of blacks (as they were designated homeland "citizens") to areas designated "South African" territory for whites only. People had to focus and concentrate their activities, particularly grazing, to the demarcated homeland boundaries. As a result, over-utilisation led many residents to abandon subsistence farming and give such land over to grazing land for their stock to survive (Southey, 1981, McKenzie, 1984).

2.4.2. Other Historical and Political Factors

Since the beginning of industrialisation, an increasing amount of fossil fuel has been burnt; forests have been cleared and large areas of land used for agriculture. One of these results has been the global alteration of the chemical composition of the earth's soils, hydrological cycle components, and the atmosphere. In other words, the changes due to industrialisation had far-reaching effects on soil and water; and they had effects on the content of greenhouse gases, which led to ozone layer depletion and other climatic related implications in the atmosphere (Menzel, 1991; Diab, 1992; Joubert, 1994). A combination of these factors has led to an increasing effect on the balance between earth's soils and the related vegetation (Fakir, 1997). In other words, such factors have led to a high susceptibility of soil to erosion. Menzel (1991) mentioned the need for continued research in soil characteristics in order to obtain concrete sets of information on these variables. This knowledge is essential for the purposes of maintaining the soil capacity, as well as for protecting soils against deterioration and degradation.

South Africa has experienced its own extensive rural-to-urban population movements, particularly since the late 1960s. The accompanying rural desolation was caused by the hope to escape poverty. The lack of land in rural areas and the declining returns from agricultural practices *vis-a-vis* their increasing family sizes, began to overwhelm many peasants. Mining which had begun to take over from agriculture in importance (since the 1930s), was becoming the major employer in South Africa. One reason of this was overutilisation of the land resource to meet the increasing national population and the related demand for food supply. At the same time, the population increase also led to a shortage of land to allocate for other activities, such as grazing land, arable land, etc. In addition, new policies, such as the "betterment schemes" of the 1950s, resulted in landlessness for many sectors of the population. The reshuffling of land due to apartheid worsened the problem; land confiscation by the government cleared-off African people living in the then so-called "black spots". This problem was not limited to the Transkei region. For example, by 1980, in the former Ciskei, 2% of rural families were not only landless but had no land rights (Daniel, 1981; Ramphele and McDowell, 1993).

The traditional communal and tribal form of land acquisition was also dislodged during the colonial era, as African land was expropriated for white settlement. Individual land tenure was substituted for the communal tenure. Two distinct legal forms of ownership took over the communal system, namely, the Certificate of Ownership and the Quit Rent systems (Southey, 1981). The former was not dissimilar to the traditional tenure rules. But land became the nation's property and the individual would be granted Right of Occupation. The latter, Quit Rent, was the most prominent. It required the purchase of title deeds as a prerequisite for land ownership. As a result, many Africans were evicted from their areas of residence under the legal framework of the Native Land Act (also known as Black Land Act No. 27 of 1913); the Native Trust and Land Act (also known as Development Trust and Land Act No. 18 of 1936); the Natives Act (also known as Urban Areas Act No. 21 of 1923); Group Areas Act No. 41 of

1950; and Black Communities Development Act No. 4 of 1984. The last apartheid law mentioned, ensured that the holding of land by whites in historically black areas would not be practically possible, even if individual whites desired to do so. Notwithstanding this, however, according to Davenport (1990), these laws were designed primarily to protect white landowners against blacks, and not the other way round. The overpopulation of rural land that such social engineering gave rise to, is an important human factor in land degradation.

2.4.3. The Socioeconomic effects of Apartheid

Around 1945, the state interrupted the nature of settlement and subsistence by introducing planning programmes (Phillips-Howard and Oche, 1995a). The intention was to combat the deterioration of natural resources and to improve the agricultural development in black rural areas (Madikizela, 1990; McAllister, 1992; Madikizela and Nontso, 1997. The Tomlinson Commission was set up to investigate the possible solutions and alternatives. Tomlinson's work culminated in the implementation of the 'betterment planning' during the late 1950s, based on his recommendations (Tomlinson Report, 1955). In many cases, the 'betterment' implementation was forced on people, sometimes with the assistance of the police (Madikizela, 1990; McAllister, 1992 after O'Connell, 1981; Madikizela and Nontso, 1997). Brooks Nek residents still recall some violent clashes where relatives died during the implementation of this policy.

Further, as a consequence of the situation discussed in subsection 2.4.1. under the apartheid policies, black Africans were confined to reserves and forced to become tenants on what was once the 'white Settler's land' (Letsoale, 1987). This intensified the frustration of black South Africans, as most of them were not in a position to purchase title deeds. This was associated also with the increased pressure to enter the cash economy and the increasing dependence on migrant labour (since 1935). Due to their eviction from 'black spots' (and some parts of South Africa entirely) to the 'homelands', too many people were concentrated in small areas, resulting in an inevitable resource over utilisation and over exploitation. This caused an alarmingly high rate of soil destruction and land degradation.

One further socioeconomic factor needs to be mentioned. In an attempt to reduce soil erosion, the South African apartheid government 'intervened' in the name of conservation, through its land rehabilitation or betterment programmes. Unfortunately, these programmes failed to fully address the problem they were intended to solve. There is no evidence of a successful land conservation process associated with this time period. The only success that can be mentioned is that these programmes served the economic and political interests of the white minority (and not land rehabilitation) (Madikizela, 1990; Cock and Koch, 1991; Cooper, 1991). In other words, instead of adopting the betterment scheme as a response to environmental degradation, it was used to effect political restructuring and to strengthen controls on mobility (Lodge, 1987). A successful implementation would prevent black farmers from competing with white counterparts due to land dispossession (Louw and Kendall, 1990;

McAllister, 1992). Consequently, arable farmlands were consolidated, stock ownership limited, with kraals grouped into 'convenient small villages'. Grazing, residential and cultivation areas were re-divided and, inevitably these changes led to forced removals and the dislocation of people (Lodge, 1987). For the first time, arable, grazing and settlement areas were separated, and often fields were demarcated far away from their places of residences. To say the least, this was an inconvenience to people who usually had to walk considerable distances in order to till their land. People were introduced to formal village-type of life, in exchange for their traditional isolated homesteads.

In many parts of the present Eastern Cape province (which now extends to include the former Republic of Transkei), "betterment schemes" were left incomplete and people who once had land, were left without property (Madikizela, 1990). According to Harvett (1994), such state intervention caused social distress throughout the country without improving the natural environments. The people affected were never properly consulted, the compensation scheme was underfunded.

According to some commentators, the state programmes that displaced and relocated people during the apartheid era in South Africa are comparable to Nepal's, where as a result of government policy large tracts of land were left under attended, small holdings overburdened and millions of people had no land (Durning, 1989). Durning also mentions that in Costa Rica, large-scale pastoralists invaded arable land. The latter left the majority of the poor, arable farmers without land. In both cases, the repercussions were similar to that experienced in the Transkei region, in that people with insufficient land resource, used the land they did have unsustainably. Sometimes people changed the land use patterns for which the soil has been found suitable, to a totally different one, in an attempt to increase the yield. They seem quite unaware that they trigger erosion by such practices and so lower their own socioeconomic standing. To stress the point here: the people affected showed a manifest ignorance of one root cause of their problem. Even today, a very low percentage of rural people, especially blacks, understand their soil conditions. Yet, soil constitutes a major resource in their economy.

As mentioned earlier, in the Transkei where many people were totally deprived of owning land, they reverted to the traditional method, that is, access land through lease. As a result of this practice, also, overexploitation of land took place. This was partly due to the fact that the lessee lived in fear of eviction (and starvation) believing that the land would be returned to the 'legal' owners. Similar experience to the Eastern Cape is evident in the experiences of the Mgwali and Lesseyton mission communities, in the Border Corridor between the old Ciskei and old South Africa, Eastern Cape (Buckle, 1995).

As the previous sections indicate, the policy of 'betterment' had not only social, political, and economic but also ecological implications. These may be summarised in terms of the effects of residential relocation, the general reorganisation of space, the effects of agriculture, and the effects of other aspects of the local economy on conservation and the environment. Millions of black South Africans, especially those who depended entirely on farming (in the former Republics of Transkei, Boputhatswana, Venda and Ciskei (TBVC) and other homelands) were relocated to less productive and poor areas (Cooper, 1991 after Durning, 1990). This resulted in massive landlessness, tenure insecurities, poverty and overcrowding. It also led to overlapping and competing tenure systems (Balatseng, 1997). It also led to serious problems for the land.

2.5. People's Perceptions and Attitude - the Post-Apartheid Scenario

The situation dealt with in section 2.4 changed and so did the behaviour of people after the 1994 election. For some time after that election, many blacks interpreted democracy as a total reversal of earlier actions and policies, that is they saw democracy as involving the taking of land from whites and transferring it to blacks. This is in line with what Sachs (1971) once referred to as returning "land to the tiller". Letsoale (1987) had later described this view in the following way: "just as land was taken away from blacks because they were black, so must land be taken from whites because they are white". Since democracy in South Africa means, at least, the right to choose where to live and how to live there, this is interpreted by many as meaning that people can go back to their original areas. They believe they can reclaim land that had been confiscated by the old government system, under the pretence of resettlement. This has complicated the problem because the original owners cannot own their land without infringing the rights of the current owners. In fact, it can be argued that both owners have rights of ownership to the same lands! In some areas, this has caused a shift of tension between people and government, to people towards other people. It certainly is a confusing factor and an important issue in designing soil conservation and rehabilitation policies.

We noted earlier that land degradation in South Africa is associated with poor land management, (especially before 'betterment scheme' programmes). At the time of writing, unfortunately, this situation has continued and even worsened in some areas of this country. It has led to today's perception that the 'betterment schemes' were inadequate and failed. The schemes are thought to have encouraged overconcentration of people in the most rugged, sensitive areas of the country. As a result, the government has legislated 'the right to land restitution' or 'land claims Court (Ramphele and McDowell's recommendation, 1993); Court cases are allowed on claims from people who experienced forced removals and land dispossession after 1913 (Green Paper, 1996). One consequence of this is that, many people (all over the country) have already moved to resettle in areas that were once considered unsuitable for the forms of land use they are engaged in. The people concerned felt that "they were free at last". And because there was no control on their movement and thoughts, the major problems that overtly caused the old government to remove them from those areas - e.g. soil quality degradation - was neglected. (In a sense, the original conservation objectives are tampered with when such moves continue to happen without intervention by the relevant law enforcing bodies.)

People who are now occupying areas that are sensitive to erosion may recognise the need to look for better sites. But this is seldom viewed as a top priority. As indicated in a number of research studies (for example, Beinart, 1984; Vogel and Drummond, 1995; Brinkcate and Hanvey, 1996), people tend to consider problems related to lack of jobs, poor infrastructure and provision of basic human needs (e.g. water supply, proper sanitation, electricity, good quality roads), as more being urgent than soil erosion control. We have been arguing that these issues are never isolated from their origins, which are political and related to the socioeconomic policies, particularly those of the old apartheid South Africa. Pressure on land and lack of provision of facilities are always linked to the broader national and political planning. It is not surprising therefore that most environmentalists allude to such human factors in debates on environmental problems (De Wet, 1987, 1991; Beinart, 1989; Wilson and Ramphele, 1989; Drummond and Manson, 1993; Vogel and Drummond, 1995).

In summary, this chapter has introduced the literature on the erosion problem by focussing on research done on the topic at the international, national, provincial, regional and subregional levels. At the subregional level, a more detailed breakdown of erosion forms and their characteristics has been made with respect to natural processes and to anthropogenic factors. The role of sociopolitical history and educational aspects have been stressed, as well as their direct and indirect roles in causing erosion. The next chapter deals with the environmental setting and the contextualisation of factors contributing to the erosion impact at the Brooks Nek and Chani areas, Eastern Cape province.

CHAPTER 3: ENVIRONMENTAL SETTING: BROOKS NEK, Mt AYLIFF AND CHANI, Mt FRERE SITES, TRANSKEI, E. CAPE.

Chapter 3 is divided into three sections. Section 3.1 deals with the geology, geomorphology, terrain, soils, climate and vegetation of the Transkei region and the study areas. Section 3.2 considers the main socioeconomic conditions, stressing especially, population pressure, both from stock and from human beings in the Transkei region and in the districts where study areas are located. Section 3.3 is a general description of the study sites with emphasis on the location, general erosion and land use characteristics.

3.1. Physical Background to the Transkei Region

The Transkei region of the Eastern Cape lies within the southeastern part of South Africa (Fig. 1.1, p15). It falls within the natural boundaries demarcated by the Great Escarpment on the north and northwest, the Kei River on the west, the uMtamvuna River to the northeast, and the Indian Ocean to the southeast. The stepped relief of this region is observable, with mountains reaching a maximum height of 3000 metres above sea level (m.a.s.l.) forming the inland boundary (Transkei Development Report, 1987). An extremely wide altitudinal range in the High Drakensberg is found ranging between 1500 and 2500 m.a.s.l. Coastal parts of the Transkei region lie between 500 and 1 000 m.a.s.l.

3.1.1. Geology

As indicated in the work of Watson (1997), geology can be an indicator of the land capability to withstand soil erosion. It can also help governments to identify viable land in their land delivery process. As there is no quick, cheap and efficient means to identify such lands, the knowledge of such natural characteristics as the region's geology, rainfall potential, soils and vegetation quality are crucial. Even when these variables are known, the most critical aspect is their interdependence, coupled with the anthropogenic influence; this is to say, how has the land been treated by human beings, or how they make use of it without tipping the balance of the natural system.

According to Hawkins (1980) and McKenzie (1984), major geological formations in southern Africa indicate that there are five major identifiable geological eras, namely, Archaean, Pre-Cambrian, Palaeozoic pre-Karroo, Karroo and Post-Karroo. Erosion, earth movements or igneous activities separated each of these eras. For the Transkei region, only the last three, namely the Palaeozoic pre-Karroo, Karroo and the post-Karroo eras are of significance. Pre-Karroo is estimated to have been laid down about 300 million years ago (McKenzie, 1984 after King, 1972). Again, King (1982) placed the Karroo era at about 250 million years ago (a period that is from an overlap of the Permian) and the late Jurassic is date to about 75 million years ago. The post-Karroo is formed from the Quaternary deposits (McKenzie, 1984). The Karroo System/Group is the most extensive (Transkei Development Report, 1987). This system or group can be broken down according to changes in climatic environments. They can be understood in terms of four phases. According to Maud (1996), these phases are Dwyka (polar glacial), Ecca (cold temperate), Beaufort and Lower Stormberg (warm temperate) and Upper Stormberg (hot desert).

Table 3.1: Stratigraphy of the lithologies of the Transkei study areas (after Kent, 1980)

Super-group	Group	Subgroup/ Formation	Mean max. Thickness (m)	Lithology	Age Period (ka)	Location
1	2	3	4	5	6	7
Karoo	Beaufort	Adelaide & Tarkastad Subgroup	100-1000	Shales, mudstones, siltstones, sandstones , basalt tillite, basalt	Permo-Triassic (250)	Greater part of southern Transkei; area between coast & foothills of Drakensberg Escarpment and adjacent Natal & Lesotho territories
	Ecca		300	Shale, coal, mudstone, greywacke, carboniferous & subordinate sandstones.	Permian (280)	N.E. districts of Transkei.
		Dwyka Formation	>1000 (variable)	Tillite, diamictite, shale, mudstone	Permo-Carboniferous (350)	N.E. districts of Transkei.

Table 3.1 indicates that the Karroo sediments of nearly 6000 metres thick are the dominant underlying material of the Transkei region. Beaufort rocks comprise

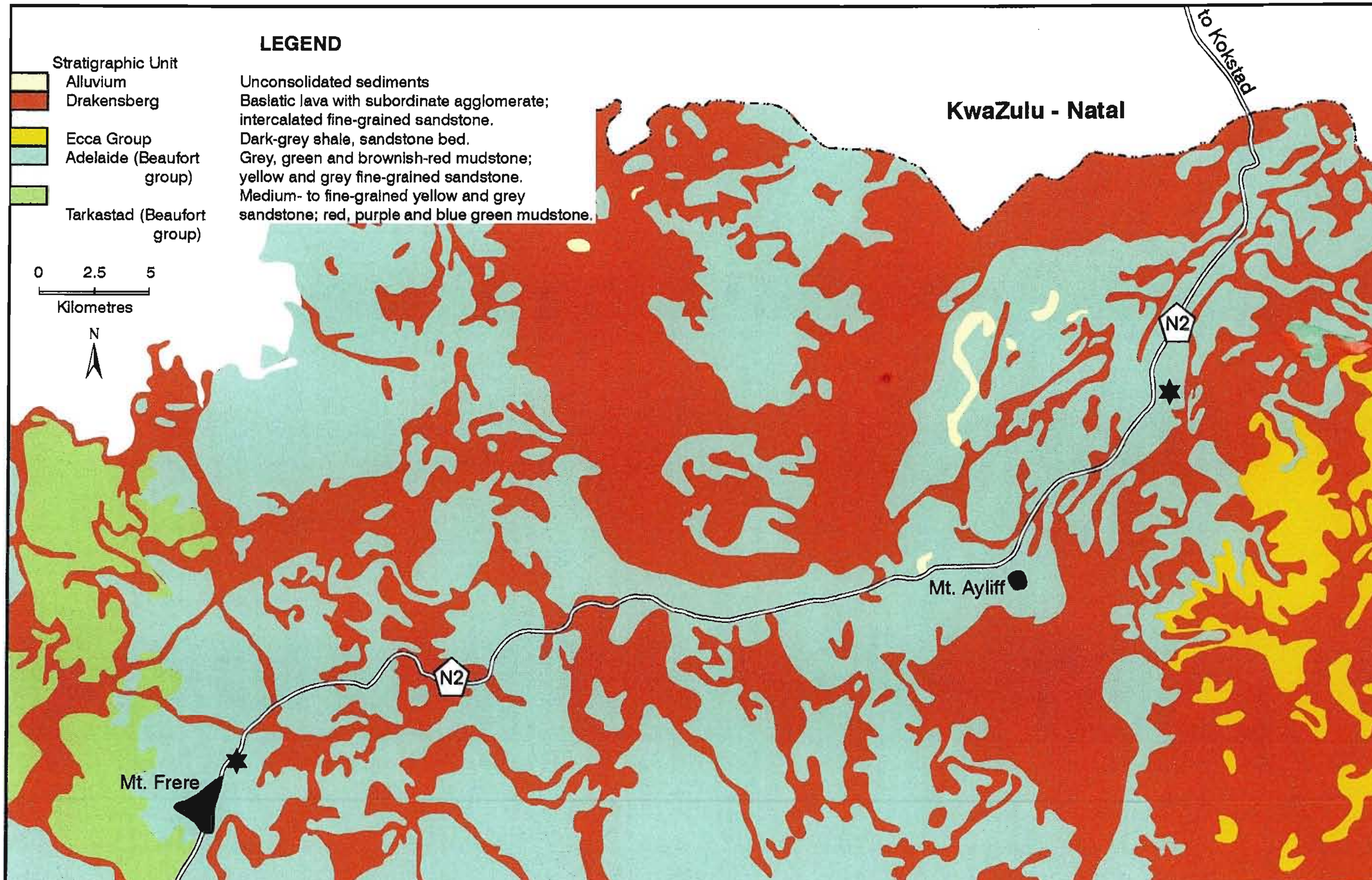

Fig. 3.1. Simplified Geological Map of the Study Areas (*) (information extracted from Surveyor General information, 1:250 000 sheet 3028 Kokstad)

of a variation of grey sandstone and thick bluish grey mudstone, which is reddish if found near the top of the soil solum (A- or O- Horizon area). The red colour is often identifiable in dongas, where the Beaufort sedimentation is exposed (McKenzie, 1984). The red colour is indicative of the warm climatic conditions during mudstone accumulation (King, 1982). As rocks of the Triassic period, they reflect a combination of features that are of the late Mesozoic and early Palaeozoic eras (Geological Series Map 1977/79).

There is an extensive component of dolerite in the region. The dolerite rock is extensively exposed in the Transkei region, with varying proportions of other rocks within the Karoo sequence. It reaches a maximum of 40% in the Ecca and decreases upward to a minimum in the Elliot and higher formations (McKenzie, 1984 after Karpeta and Johnson, 1979; Transkei Development, 1987; Maud, 1996). The pre-Quaternary landscape has been dominantly affected by fluvial and to a lesser extent by marine processes.

Both study areas are underlain by dolerite rocks and dolerite dykes, as well as by the Beaufort Group of the Karroo sequence. The dolerite and dolerite dykes are intermingled with grey, green and brownish-red mudstone. Yellow and grey fine-grained sandstone of the Adelaide formation are present, as well as the medium to fine-grained buff sandstone, red, purple and blue-green mudstone of the Tarkastad formation, as summarised in Table 3.1 above and Fig. 3.1. These rocks are responsible for the red soil layers found in some parts of the channel catchment areas (von Brunn, 1996). Sedimentary rocks of this kind are overlain by red soil layers, one of which is mudstone. The latter are found thinly layered on top and across the channel floors. Intermittently, the mudstone layer is faulted, making it possible thereby to determine the underlying igneous material. At the Chani site, some sandstone layers are exposed where the mudstone is broken.

The above kind of situation has been analysed and explained by von Brunn (1996). He notes that it is as a consequence of weaker mudstone layers that had been deposited onto the igneous bedrock. This is normal of sedimentary rocks to be found underlain by igneous rocks (especially in cases on intrusive dykes like those found in Brooks Nek). Rock weathering and erosion along the mudstone lain sections have taken place without any obvious difficulty. This explains why today the channel course follows the southwest to northeast trending.

Analysing Brooks Nek alone, von Brunn (1996) maintains that the geology is of sedimentary beds that belong to the Beaufort Group. These rocks were deposited about 230 million years ago (Ma). The sedimentary rocks were then intruded by igneous material in about 190 Ma. One result of this is that volcanic sills and dykes are common. Adjacent to the study site lies a dolerite dyke and this accounts for the bedrock that the river flows on. This hypabyssal igneous rock (dolerite), that is found along the streambed, lies within co-ordinates

30°39'14"S and 29°30'09"E, where another tributary joins the main river system. Also at this point, the dolerite bedrock joins the mudstone bedrock that underlines the main tributary to uMvalweni River.

3.1.2. Geomorphology

According to Dardis *et al.* (1988a), east-flowing rivers - that have relatively small drainage basins, mainly due to high relief ratios - drain the eastern Escarpment. A number of remnants of abandoned channelways are found scattered over this region, and a number of superimposed and antecedent drainage lines result in high-gradient, high-sinuosity fluvial systems. Related to the latter is the degradational nature of the drainage networks, with no channel storage. Considerable downcutting and degradational drainage systems, that were independent of topography, are attributed to the post-Mesozoic tectonism by King (1982).

The evolution of the Transkei regional landscape from the period of Gondwana has been through a series of tectonic uplifts, denudation and deposition, all of which have had an impact on the landscape since the Cretaceous period (King, 1982; Maud, 1996). In general, the Gondwana landscapes have been displaced by the cyclic uplift, and denudation has occurred from some of the southern African parts (Partridge and Maud, 1988), both processes giving rise to the present landscape. It is reckoned that between the late Mesozoic and the Pliocene epoch, the Transkei region experienced uplifts four times (McKenzie, 1984).

Table 3.2: Main Characteristics of the Six Intermission and the Geological Time Period of their Initiation (after McKenzie, 1984; Partridge and Maud, 1988))

Intermission	Land surface	Period of Initiation
I	Gondwana Landscape	Jurassic or older
II	Post-Gondwana Landscape	Early and Mid-Cretaceous
III	African Landscape	Late Cretaceous and Mid-Tertiary
IV	"Rolling" Surface	Miocene
V	Valleys and Plains	Pliocene
VI	Deep River Valleys	Quaternary

As illustrated in Table 3.2, cyclical land surfaces resulted from six periods. The first two intermission surfaces are only found in Lesotho and no longer to be found in the Transkei area.

According to Mckenzie (1984), the other four periods are still observable in the Transkei region. The Intermission III - which followed the period of uplifts - raised the interior of the Transkei region in more than 8 million years, by more than 1000 metres. Over this period, all early Mesozoic traces were destroyed, leaving the African surface to undergo an intense soil evolution that led to removal of most soluble constituents from the topsoil. The results were the formation of the characteristic crust of ferricrete or calcrete plains. (This may explain the source of pedocretes at the Mt Frere site.) The Transkei region has since been characterised by lateritic, poor and aged soils, that were covered by poor grassy vegetation.

Twenty million years ago, gentle uplift led to the exposure of the remnants of the

Intermission III, through incision by accelerated flow of streams and rivers. The existence of the Miocene period (Intermission IV) with less differentiated soils and the reduced importance of laterites, can be witnessed from the typical rolling terrain of the central Transkei region (Mckenzie, 1984).

During Pliocene, another uplift episode followed and it led to the renewed denudation of the planed and rolling surfaces, from the Intermissions III and IV in the Transkei region. During the renewed denudation, river basins began to form as a result of the retreat of region's scarp hillslope forms. This resulted in some rivers having highly elevated basins during Intermission V period. Soils of this stage were very young and dongas continued to form (Mckenzie, 1984).

The final intermission stage (Intermission VI) began during the quaternary era at the closing stages of the Pliocene epoch. This stage was characterised by another tectonic uplift of the order of 1000 metres, leading to steepening river courses and deepening valleys, as is the case today (McKenzie, 1984).

The present terrain surfaces are of Intermissions III-VI. Denudational processes of erosion and deposition are continuing with the younger surfaces expanding as older ones retreat and diminish. More than 130 million years ago, these landscape changes took place and are important in understanding the topography, soils, vegetation, climate and human activities. This does not only have significance to the study areas but to the whole of the Transkei region.

As we have noted, the Brooks Nek and Chani study sites are found in Mt Ayliff and Mt Frere areas, respectively. These areas are on the humid eastern and northern parts that are associated with deep residual soils. But these are often covered with shallow transported soils.

3.1.2.1. Morphology

According to McKenzie (1984), the topography or terrain of the Transkei region can be linked directly to the geomorphological processes discussed earlier. The most distinct features are the three structural units, namely, the steep mountainous area of the Drakensberg, gentle undulating inland, and the structurally complicated coastal strip.

Table 3.3: Terrain Morphological Units in the Transkei Region (after McKenzie, 1984).

Unit	Description	Position and Dominance	Relief Range (m)	Dominant Material
1	Tablelands	Northeast Coast	130-900	Sedimentary rock of Natal Group
2	Highly Dissected Hills	Coastline south of uMzimvubu R	130-450	Similar to Tablelands Escarpment
3	Highly Dissected Low Undulating Mountains	Immediately inland of Tableland	150-300; 300-600	Dwyka Tillite of the Karroo era
4	Undulating Hills	Inland of Unit 3	130-450	Ecca Group
5	Irregular Undulating Lowlands with Hills	Central Transkei	30-450	invariably Beaufort Group (Intermission IV)
6	Lowlands and Mountains	S. W. corner of Transkei	>450	Beaufort Group
7	Low Mountains	N. E. of Transkei - Minor Escarpment	450-900	
8	Undulating Hills and Lowlands	N. E. area of Transkei	<200 - 450	
9	High Mountains	North of Transkei-Drakensberg	>900; 1500-3000	

As shown in Table 3.3, these three structural units can be broken down further into nine terrain morphological units. Mckenzie (1984) refers to slopes greater than 5% on relief of less than 450 m as 'hills', while 'mountains' have the same slope per cent but their relief exceeds 450 metres. Lowlands have relief of less than 210 m and slopes of less than 5%. Overall, the terrain morphology of the Transkei region depicts a sharp fall from the inland boundary of Lesotho (Drakensberg) towards the coast. This is a short distance of 160 km at its narrowest parts. As mentioned earlier, the aspect is dominantly southeastern with clear terraces sloping down to the coast. This coastal orientation is due to the monoclinal nature of the new southeastern African margins, which were flexed down to and beneath the sea (King, 1982; McKenzie, 1984; Transkei Development Report, 1987; Partridge and Maud, 1988; Maud, 1996). This is a reflection of a pattern that can be correlated to that of the geomorphology and of geology of this part of South Africa.

In locating Mt Frere and Mt Ayliff study areas within the classification of the Transkei region offered by McKenzie (1984), we are able to say that Mt Frere areas lie in the middle of the irregular undulating lowlands with hills (Unit 4).

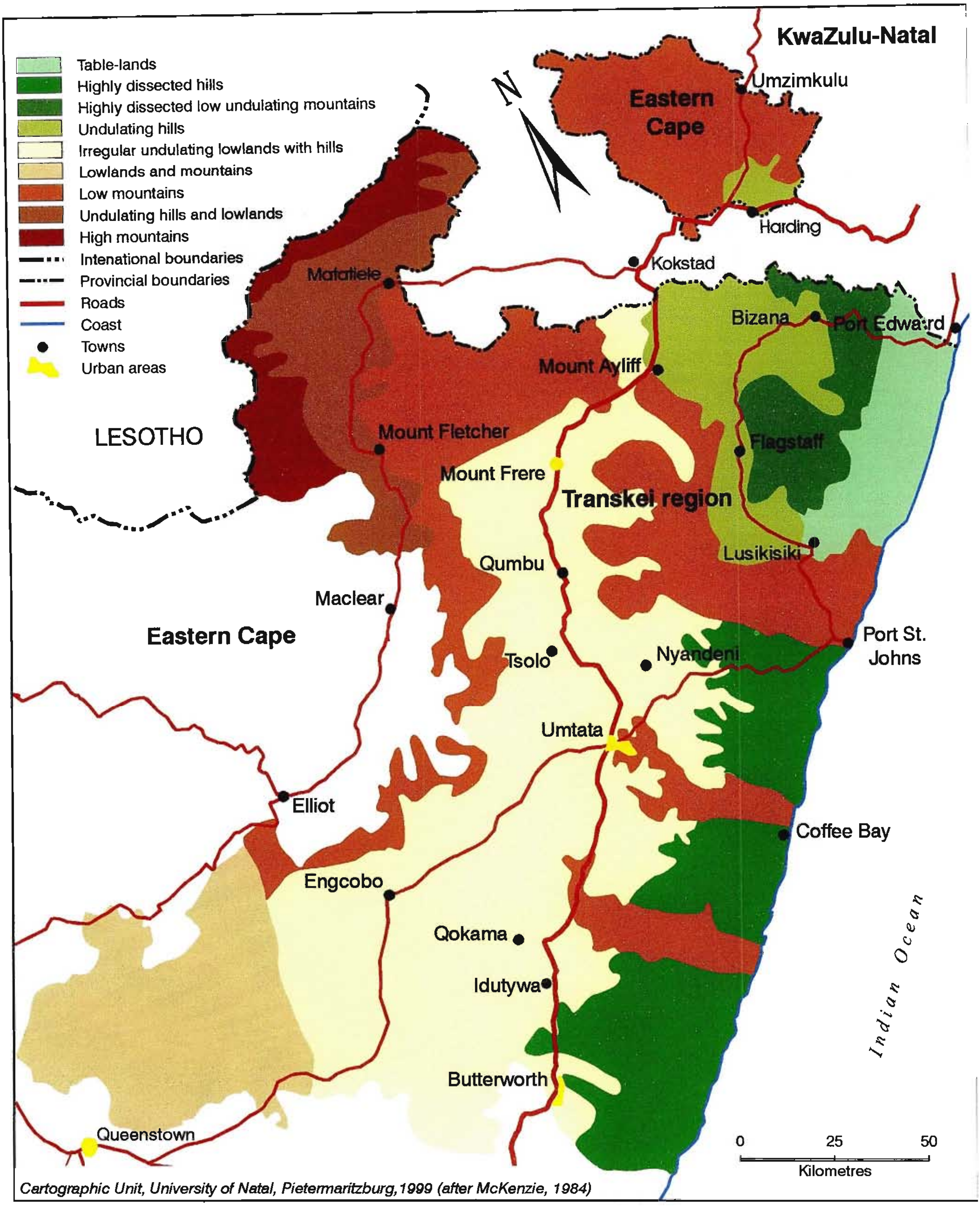

Fig. 3.2: Morphological Terrain Units for the Transkei Region of the Eastern Cape Province (after McKanzie, 1984)

Mt Ayliff site lies within the undulating hills (Units 5) (see also Table 3.3 and Fig. 3.2 for both study areas).

3.1.2.2. Soils

The more humid eastern and northern parts of southern Africa are believed to have a reasonably uniform soil profile, as well as reasonably uniform engineering properties of the materials within any specific horizon of the profile and within any specific land facet (Brink, 1979). The Transkei region is, however, characterised by relatively discontinuous surfacial sediment cover, consisting primarily of colluvial deposits. This is an important difference to note. It highlights the seriousness of making general assumptions about eastern humid areas of southern Africa, (within which the Transkei region is found). The Transkei region is characterised by areas of thick surficial colluvial sequences (de Villiers, 1962; Faber and Imeson, 1982; Dardis *et al.*, 1988a) and the area provides an ideal site to examine the age and the stratigraphy of such sequences (Beckedahl *et al.*, 1988). Similar colluvial sediments are also present over a wide area of the subcontinent, from Zambezi in the north to the upper reaches of the Orange River to the south. They extend to include Swaziland, Lesotho, and parts of present day provinces of KwaZulu-Natal, Northwest and Free State (Watson et al., 1984). These deposits occur as infills at topographically induced sections, on hillslopes and in valley bottoms.

The Transkei region lies in the heart of an area that Smithen (1981) described as the most affected by soil erosion. Beckedahl (1996) indicated that this area was ideal for examining geomorphic features of soil erosion and other likely factors influencing it. Previous research, for example, the works of Loxton, Hunting and Associates (1978a-c); Grey (1978) and Laker (1979), also indicated that although detailed soil surveys for the Transkei region had already been carried out, is was for specific interest only. Van der Merwe (1962), for instance, simply studied soil groups in the region. Aspects of arable soils and areas of similar topography were observed by Wood and van Schoor (1976), whilst McKenzie (1984) found both sets of information suitable to relate to the major geological and terrain morphology of the region. Correlation was based on soil identification that is modelled after the classification of terrain units. This point was noted earlier in subsection 3.1.2.1.

The classifications of soils found in the Transkei region are based on the work of McKenzie (1984). The nine terrain units discussed earlier are used as guidelines. Using Table 3.3, Tablelands (Unit 1) and Highly Dissected Low Undulating Mountains (Unit 3), display a number of common characteristics. For example, they are both comprised of shallow, highly leached and acidic soils (McKenzie, 1984 after van Wyk, 1967). Wood and van Schoor (1976) also found they are both comprised of Fernwood and Mispah soil forms, that are characterised by water free sandy E and water-restrictive Cutanic B-Horizons. Around Lusikisiki itself, Wood and van Schoor (1976) recorded Nomanci, Magwa, Inanda and Kranskop soil forms, all on Dwyka Tillite. These forms have deep (> 1 metre) humic epipedon. Glenrosa, Griffin, Swartland, Hutton, Avalon and Glencoe soil classes are the most commonly found on Ecca beds and Sandstone of Natal Group (from areas north of Port St Johns but south of Lusikisiki).

The Highly Dissected Hills (Unit 2) category factor refers to the coastal part of Transkei area, south of uMzimvubu River, where weakly developed and shallow soils of <50 mm in depth are found. The dominant soil forms are weathered rock (Saprolite) found just below the A-Horizon. On Ecca beds and Beaufort formations (see Fig. 3.2 and Table 3.1 above) are soil forms ranging from Swartland, Mispah, Glenrosa (Wood and van Schoor, 1976).

The Lowlands with Mountains (Unit 6) category is on the southwestern regions of the central plateau. Soils are duplex, solonetzic ('thin, porous underlain by columnar, usually sodic horizon') which are underlain by Karroo sediments (McKenzie, 1984 after MacVicar *et al.*, 1977). Dominant forms are Escourt and Sterkspruit (Wood & van Schoor, 1976).

The Low Mountain (Unit 7) and Undulating Hills and Lowlands (Unit 8) also have duplex and are weakly developed. These soils are composed of highly leached, whitish E-Horizon of the High Plateau Podzol. The Molteno mudstone, sandstone and shale dominate this Unit area. Some parts display a grey, whitish sandy layer with a prismacutanic B-horizon beneath sandy topsoils (McKenzie, 1984 after MacVicar *et al.*, 1977).

The High Mountains (Unit 9) category is on the steep and stony, basalt derived soils that are referred to as "Drakensberg Black clay soils" by van der Merwe (1962). Steep topography, and a wet and a cold climate, result in shallow and weakly developed soils that are of no agricultural significance. The dominant Mayo and Glenrosa have a lithocutanic B-horizon with Milkwood having either hardpan or hardrock.

The Undulating Hills (Unit 4) of the plateau form the greater part of Mt Ayliff. These hills are dominantly underlain by Beaufort formations. This area is characterised by ubiquitous dolerite intrusions (McKenzie, 1984). The dolerite derived soils display a deep, fertile, good drainage capacity and high water holding capacity features (Loxton, Hunting and Associates, 1978a). Areas lying northeast between Mt Ayliff and Bizana, and extending to the uMzimkulu area have lateritic soils. The dominant soil forms include Hutton, Glenrosa, Griffin and Clovelly which all, with the exception of Glenrosa, have either a yellow-brown or red apedal B-horizon (McKenzie, 1984). With the exception of the dominantly steep slopes found over large parts of this Unit area, the rest of the soil is suitable for arable farming.

The areas around Qumbu and Mt Frere form parts of the Central Plateau, that depict more diverse soil forms. In Qumbu alone, Loxton, Hunting and Associates (1978b) recorded 17 soil forms, including soils that are colluvial and alluvial. According to Wood and van Schoor (1976), soil forms such as Mayo, Shortlands and Hutton are common on the dolerite-underlain areas. Blocky structured and dark-coloured topsoils, that overlie deep reddish brown subsoils, are usually associated with such doleritic material. The igneous (dolerite) rocks underlying the Chani study area are responsible for the red soil layers found in some parts of the channel bed (von Brunn, 1996). At some points, where overlying sedimentary rocks have been weathered, these (igneous) rocks have been exposed to erosion. The latter rocks weather to red soil layers that overlay sedimentary rocks. These soils, together with the thinly layered mudstone, are easily identifiable on the channel floor. The latter two (soils and rocks) are intermittently broken (faulted) and they expose igneous material underneath.

The two study areas, Mt Ayliff and Mt Frere are found on the central plateau. Speaking generally, soils of this plateau are considered good quality with 'extremely good' farming potential (McKenzie, 1984). These soils can be categorised into, firstly, lithosols and duplex, partially hydromorphic soils; they both occur on irregular undulating lowland hills. Dominant soil forms in these lowlands are Dundee, Inhoek, Oakleaf. Secondly, red and yellow-brown apedal soils with an orthic epipedon (weakly developed soils) prevailing on the undulating, hilly terrain of the same plateau areas.

3.1.3. Climatic Characteristics

The significance of climatic conditions to soil erosion in South(ern) Africa and, specifically to the Transkei region, cannot be underestimated. In South Africa, most severe soil erosion problems occur where the mean annual rainfall is between 500 and 800 mm (van Schalkwyk, 1984). However, Morgan (1995) and Douglas (1967) reported soil erosion occurring at even lower levels (than van Schalkwyk envisaged). Soil loss reaches the maximum if the effective mean annual precipitation is of 300 mm, otherwise erosion would increase with the increase in precipitation and/or as runoff reaches higher levels.

Climatic data for the Transkei region is limited. For instance, although rainfall has been widely collected, for various reasons, many records are unreliable. One reason here is the neglected instruments (Agricultural Officer, Mt Ayliff). At a general level, however, the Transkei region is categorised under the cfb climatic zone of the Köppen classification. This climatic zone is known to have a warm temperate climate with sufficient precipitation at all months. That means, there is no dry season for this area. Records show that although the warmest month is less than 22°C average, at least four months have a temperature above 10°C (McKenzie, 1984).

The above climatic classification is thought by many writers to be too broad (McKenzie, 1984 after Schulze and McGee, 1978). It is for this reason that Mckenzie (1984) indicated that the Holdrige life zone (bioclimatic) classification

- that allows for variations in terrain patterns and correlation between vegetation and climate - would provide results that could broadly be categorised into the coastal, humid subtropical zone and the inland humid subtropical lower montane.

The central plateau belt, or midland climatic zone, on which the study areas are found, experiences higher daily maximum and minimum temperatures, when compared to the coastal areas. The central plateau belt lies in a wider area that is usually affected by snaps of winter cold and berg winds, that sweep over inland and coastal areas (Lengoasa, 1991).

Of the collected data for rainfall, it has been observed that the rainfall pattern in the Transkei region reflects a variation between 750 mm and 1400 mm in the coastal areas and 500 mm to 1400 mm in the interior, with a decline from east to west (Wood and van Schoor, 1976). Seventy percent (70%) of the rain falls in the summer (McKenzie, 1984). The actual sunshine duration is about 50 - 80% of the possible maximum in summer and it is 70-80% in winter.

The climatic conditions and the pattern observed for the central plateau are explained in line with the distribution of the Unit areas outlined in the previous subsections. This means that the distinct differences are observable in areas of this plateau that lie between the coastal plain, with incised rivers, and the interior plateau. The central plateau is a convergence zone that is characterised by frontal showers falling on the average over nine days of every summer month and five days of each winter month (The Republic of Transkei, 1976). As in most summer rainfall areas, precipitation is in the form of heavy thunderstorms, snowfall (October 1994 and July, 1996), and occasionally, severe hailstorms (the latest was in 1997). In Brooks Nek, a heavy rainfall over two days in July 1995, left many gabion dams - that were constructed during the dry months of May/June - loosely silted-up. After having infiltrated the upper end of the wall, the water trickles out from the bottom end of the gabion walls.

The Transkei region experiences thunderstorms of great intensity. Usually this occurs over 60-90 days per year but the pattern is not definite. If such thunderstorms occur early enough, dryland farming in August, September and even October becomes possible. According to McKenzie (1984), the highest rainfall in the Transkei region is between October and March. Furthermore, research shows that during this time, the coastal areas receive an average of 70% rainfall and the inland gets up to 80% rainfall on average. March is the wettest month (i.e., a month with more rainy days), but the maximum single day rainfall is recorded during October and November months. The driest month (lowest average rainfall record during the summer months) is February (The Republic of Transkei Report, 1976).

Mist and fog occur almost every afternoon in both study areas. During the winter, snow is sometimes found in the mountain areas, at an average rate of 8 days of snowfall per year. The peak fall takes place in July, under normal circumstances. The melting of the snowcap takes place within a day or two; except in October 1993, July 1996, and June 1997, when weeks and even months elapsed before the snow clearing could occur.

In the Kokstad area, an area that lies side-by-side with Brooks Nek, frost is related to the local relief. There is an average frost cover of 116 days, compared to just 61 days of occurrence in Matatiele, which is about 60 km away (The Republic of Transkei Report, 1976).

The study sites are found in the part of southern African that has a climatic N-value of less than 5, which designates areas of annual water surplus (Brink, 1979). This concurs with the fact that the Transkei region, within which Mt Frere and Mt Ayliff sites lie, receives an average annual rainfall of 900 mm (McKenzie, 1984). In fact, these districts receive rainfall ranging between 800 and 1000 mm (The Republic of Transkei Report, 1976). In comparison to, for instance, Zimbabwe, Chani and Brooks Nek areas have values in the range of 500-800 mm. These study areas have their lower limit (500 mm), slightly less than that of the erosion-prone range in Zimbabwe where the critical rainfall zone of 600 - 800 mm recorded (Stocking, 1987b). Stocking contends that 56% of the total surface areas of that country lies in this critical rainfall zone. In fact, he refers to 500-600 mm and 800-900 mm rainfall ranges as subcritical levels to the Zimbabwean climatic conditions.

Van Schalkwyk (1984) paired the potential of rain to cause erosion with the topography over some parts of South Africa over a 25-year frequency period. Brooks Nek is found within 400 - 500 isoerodents in units of E_{I30} from the areas he mapped. As explained later, this is a high erosion index range. Unfortunately, Chani was not covered in van Schalkwyk's study. But later Smithen (1981) produced an isoerodent map of the whole of South Africa. As indicated in Beckedahl *et al.* (1988) in their modified isoerodent map of southern Africa, areas of high erosion indices often correspond to highly concentrated badland topography areas. The Chani and Brooks Nek areas are no exception.

3.1.4. Vegetation

According to Acocks (1975), vegetation in the Transkei region can be classified into thirteen veld types.

Table 3.4: The Veld Types and Sub-Types found within Transkei region (from McKenzie, 1984 after Acocks, 1953, p73)

Vegetation Type	Veld Type (Number)	Sub-Type
Coastal Tropical Forest	Coastal Forest and Thornveld (1) Pondoland Coastal Plateau Sourveld (3) 'Ngongoni veld (5) Eastern Province Thornveld (7)	Typical Coastal-belt Forest - Northern Form
False Bushveld	Invasion of Grassveld by Thorn (22)	-
Karroo and Karroid	Valley Bushveld (23)	Northern Form
Temperate and Transitional Forest and Scrub	Highland/Döhne Sourveld (44)	-
Pure Grassveld	*Cymbopogon- Themeda* Veld (48) Dry *Cymbopogon-Themeda* Veld (50) Highland Sourveld to *Cymbopogon-Themeda* Veld Transition (56) *Themeda-Festura* Alpine Veld (58) Karroid *Merxmuellera* Mountain Veld (60)	Southern Variation South-eastern Variation - -

Table 3.4 outlines the four veld types of the Coastal Tropical Forests category, five types of the Pure Grassvelds and one veld type of each of the other categories, namely, False Bushveld, Karroo and Karroid, False Grassveld, and Temperate and Transitional Forest and Scrub.

Concerning the two study areas, McKenzie (1984) discussed at length many of the veld types following the boundaries of the terrain's morphological units, as captured in Table 3.3, as well as considering each terrain separately. With respect to Units 4 and 5, McKenzie (1984) found that both the Undulating Hills and the Irregular Undulating Lowlands with Hills have outliers of good quality Southern Tall Grassveld (65), Döhne Sourveld (44) and 'Ngongoni (5) on the prevailing doleritic derived soils. 'Ngongoni areas were dominated by *Aristida junciformis* at the time of Acocks's survey in 1953 (McKenzie, 1984).

On Irregular Undulating Lowlands with Hills, the Southern Tall Grassveld is found on the upper reaches of the major river valleys. According to Acocks (1975) and later McKenzie (1984), veld types are transitional between Döhne Sourveld and Valley Bushveld. Soils are highly erodible, as a result Karroo shrub - such as *Felicia Filifolia* which is dominant as far as east of Mt Ayliff - invade severely eroded places. On the valley slopes, savannah veld type dominates with *Acacia Cafra* and *Acacia Karroo* as the most important woody species. Dominant grasses around dolerite outcrops include *Themeda Triandra* and *Hyparrhenia* species. The more stable Döhne Sourveld, found on the flanks of river valleys, is also dominated by *Themeda Triandra* and *Tristachya Leocothrix* but these species get overtaken by *Elionurus Muticus,* specially in areas where selective grazing occurs (McKenzie, 1984).

At study sites, the general vegetation observation made from cross-sectional belts showed an uneven distribution. Details of the extent of unevenness are presented in Chapter 5.

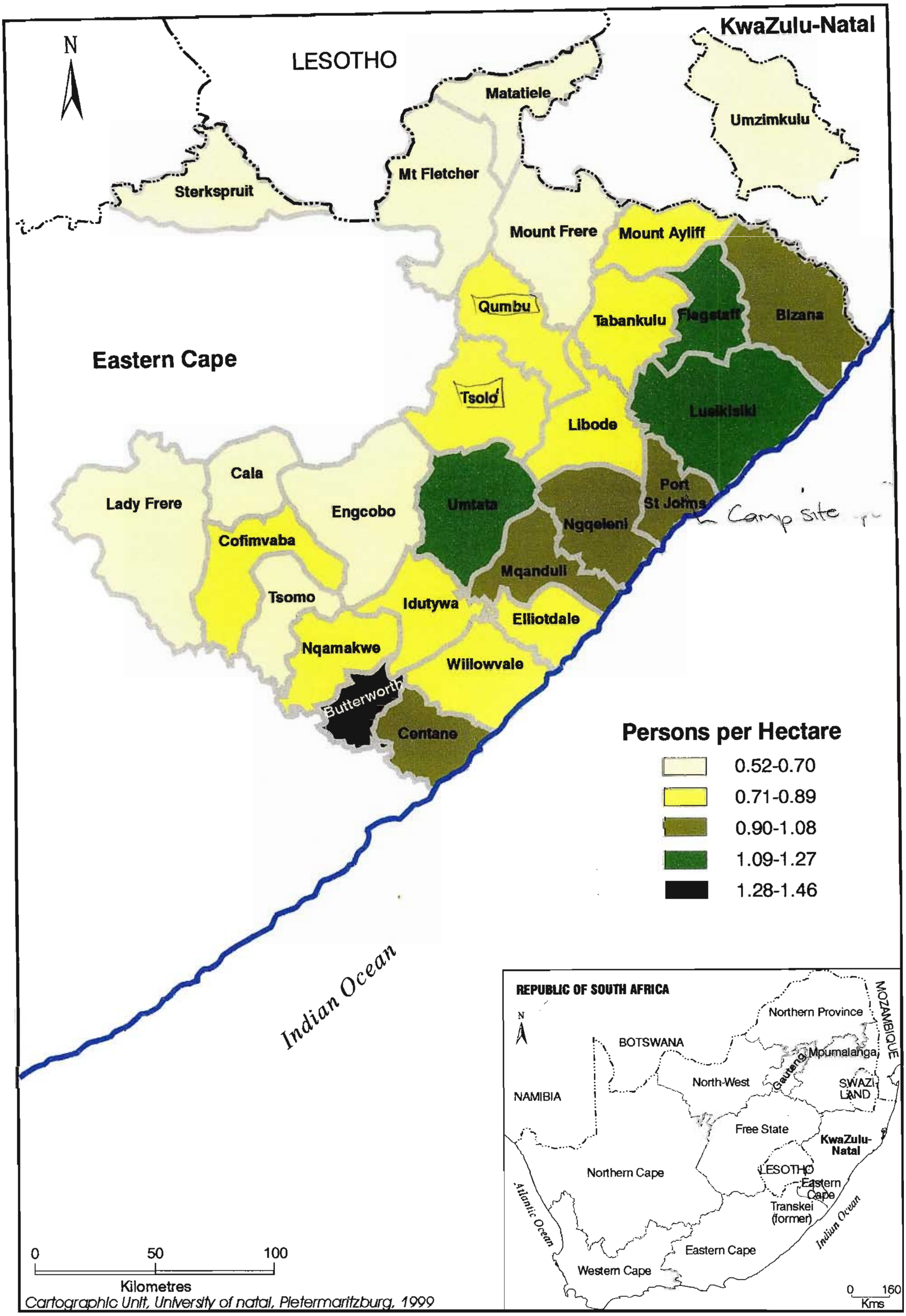

Fig. 3.3 Population density of the Transkei Region for 1991 (After Transkei Land Reform Research Team, 1995)

3.2. Socioeconomic Data

As indicated in Fig. 3.3, population density of Mt Frere is between 0.52 and 0.70 whilst that for Mt Ayliff is between 0.71 and 0.89 people per ha (Transkei Land Reform Research Report, 1991). This scenario neither gives much detail nor the real site specific effects of 'betterment schemes' to the study sites. This gap renders the mean values meaningless regarding population density at the case study site. (Both density cases are based on the total area of these individual districts).

As we have suggested, there is scarcity of land in this region. We noted that the scarcity of land is complicated by changes in land acquisition system, and by the tax system, as well as by the limitations associated with boundaries fixed for the Transkei region during the apartheid political system. As a consequence of the cash-oriented taxation system imposed by the Cape Colonial rule, many Transkei 'citizens' had to work outside their 'country' (McKenzie, 1984). The effect of migrant labour on communities has been noted by Beinart (1982, 1989) and reiterated by Bundy (1988) and McAllister (1992). The problems associated with migrant labour were more obvious in the context of arable agriculture. Disruption in the traditional society's division of labour and to the agricultural economy in general, all led to deterioration in arable farming.

For a while, stock farming thrived as the money that was left after tax payment was invested in this type of agriculture (or 'wealth accumulation'). As a result, however, the whole region of Transkei experienced an increase in soil erosion, due to overgrazing and other kinds of overutilisation of resources. These problems resulted from the increased human and animal population. The Land Act of 1913 led to overcrowding and, subsequently, to deterioration in landscapes. This gave rise to 'betterment schemes', which began to be evident by early 1960s when "the Glen Grey Act of 1894 was extended to the Transkei" region (Wood and van Schoor, 1976; Southey, 1981; McKenzie, 1984).

Further disruption prevailed as it became apparent that small-holder farming - obtained by either certificate of occupation (similar to title deed) or by the one-man-one-lot Glen Grey system - was uneconomical when compared with the migrant labour wages (Southey, 1981; McKenzie, 1984). Migrant labour produced 75% of this region's gross domestic product. This led many farmers to stop farming and migrate to the then urban white South Africa. As a result, Southey (1981) and Bundy (1988) blamed poor agricultural performance and overstocking squarely on the changes in the land tenure system.

According to McKenzie (1984), the Transkei rural land use adversely affected the ecology of areas used both for cultivation and for grazing. Furthermore, he identified 8% of cultivation on unsuitable steeper slopes as having contributed significantly to the erosion problem. The ever increasing demand for land and cultivation of slopes of greater than 15% gradients is considered a further reason for poor agricultural yield. These problems are complicated by the inefficient service of the agricultural extension services and the increasing population in the region.

High population numbers are not limited to human beings in this area. Statistics show a 131% overstocking, when the dot grid method was used to calculate the carrying capacity of stock by district, by veld types, during the late 1970s (McKenzie, 1984 after Acocks 1953). The highest overstocking was recorded in the coastal areas. Mt Frere alone, with a carrying capacity estimated at 49 265 was found to be carrying 80 000 stock (62% overstocking) on average. At the same time, Mt Ayliff with a carrying capacity of 26 005 had approximately 37 000 (42% overstocking) (McKenzie, 1984).

From the above outline, it can be seen that in the study areas, it has been difficult to stop the excess investment on stock, the continued use of poor soils, and the extension of cultivation areas on grazing land, due to pressure of land demand. The 'betterment schemes' made it difficult to accommodate the ever increasing number of landless people. Migrant labour yielded substantial returns that, unfortunately, upset the traditional division of labour and the quality of agricultural production. The engagement and utilisation of marginal land - that is, slopes sensitive to soil erosion - adds to the problem. This use of the marginal lands is a difficult practice to prevent. It is associated with meeting basic human needs by using all available arable and pastoral land, as well as the need for networking in the form of roads, footpaths and stock trails.

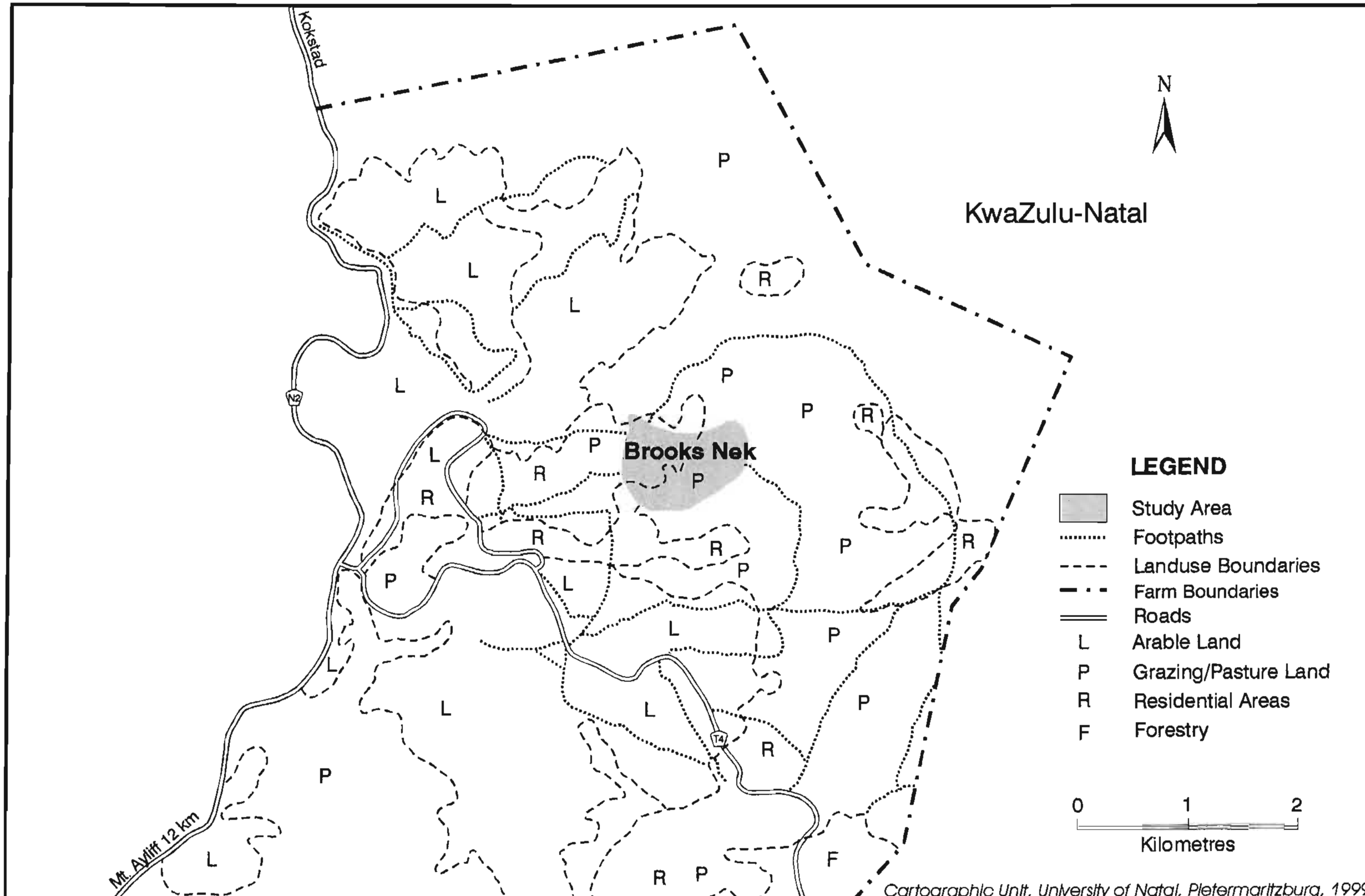

Fig 3.4: Land Use Map for the Brook's Nek site (extracted from Surveyor General, 1:50 000 topographical maps, 3029CB Kokstad / 3029DA Weza, aerial photos 1993)

Added to all of this, building material - which includes corrugated iron with no guttering, roofing metal with no water retention capacity - feeds water in huge volumes to the land, and this is detrimental to the soil. Such practices increase its erosion potential (Beckedahl and Slade, 1992). The construction materials observed in Brooks Nek subcatchment, for instance, include mudbricks and mud plastering. As a result, alongside a number of homesteads, there are scars on the land that present testimony to the physical and rapid removal of soils. The scars are never rehabilitated. And these remnants create easy spots for the erosion process to take place. In other words, the use of soil for building purposes poses an additional demand on soil in rural areas. Moreover, this practice seems unavoidable because local people cannot afford to pay for conventional building material, like expensive bricks. Such practices, however, contribute to accelerated erosion.

3.3. Site specific description of Study Areas

This section first deals with the Brooks Nek site and then focuses on the Chani site. Brooks Nek is one of the rural administrative areas of Mt Ayliff in the Eastern Cape. It constitutes part of the Eastern Griqualand subregion of this province. This is officially designated as administrative area number 9, on the 1:50 000 scale mapsheet. It is found on an overlap of two 1:50 000 scale mapsheets, titled 3029DA Weza and 3029CB Kokstad (Fig. 3.4). On the northeast lying valleyside, the Brooks Nek area extends within co-ordinates 30°39'00" and 30°39'47" South; and 29°30'09" and 29°30'47" East. If a straight line distance is used, the site lies at about 7 km south of Kokstad; otherwise, it is a little more than 12 km by road.

Physically, the north is bordered by a rural landscape, under the jurisdiction of Kokstad, whereas to the east and northeast, lies the rural areas of Harding, extending to include the Weza commercial afforestation. On the western end, the Brooks Nek area is flanked by the N2 road, which runs to Kokstad and Durban one-way and to Mt Ayliff and East London to the other. The main road to Bizana (Fig. 3.4) borders the south and southeastern side.

Brooks Nek is found within the subcatchment of the third order Brooks Nek stream. The Brooks Nek stream, a tributary of the uMvalweni River - which joins uMzintlava River and ultimately uMzimvubu River - had its name extended to the local village, hence the name of the study area. Historically, there is substantial evidence to show that the whole area was once covered by settlements. This was the case until the time of forced removals in the 1970s.

A gully has developed on a zero order valley in this study area. Most of the time it runs dry. It has a deeply dissected channel section of 200 metres in length. Vegetation of the aloe species is plentiful. It is found within the stabilised sections of the main gully dry channel (where water is supposed to be flowing through). The gully is not extended over the whole area but is limited to one corner on the northeast lying section of the subcatchment. Hence, the usual practice of taking catchment area cross-sectional measurements for the entire catchment has not been done for this project. In other words, the gully spread is not affected by the rain water collected from the entire drainage basin area but by water from the surrounding rills. This is because, among other reasons, the surrounding landscape is undulating and irregular. Gully rehabilitation programmes for the greater part of Mt Ayliff began in 1993. Brooks Nek was one of the first areas to receive attention in this district. Presently, evidence shows that a more serious gully erosion problem is underway, particularly where people have been resettled.

During the research period, the research group at this site experienced heavy downpours. For the first time, the statement made by Harvett (1994) that "in every stormy condition, (South African) rivers have an increased sediment yield that decreases the water quality downstream" was evident around the Brooks Nek. The condition was comparable to that dramatised by Wilson and Ramphele (1989, p34 after Alan Paton, 1948):

> ... the great red hills stand desolate, and the earth has torn away like flesh. The lightening flashes over them, and the clouds pour down upon them, the dead streams come to life, ***full of blood of the earth***.

Brooks Nek tributary drains the total subcatchment area of about 800 m^2. This is a small area since Mt Ayliff has an estimated total degraded area of about 900 km^2 (calculated from aerial photographs in Agriculture and Forestry Dept., Mt

Ayliff). However, the small area researched was considered to be sufficient to serve one of the main purposes of this study, namely, to assess the rehabilitation programmes under construction in the area. Let us now turn to the Chani study area.

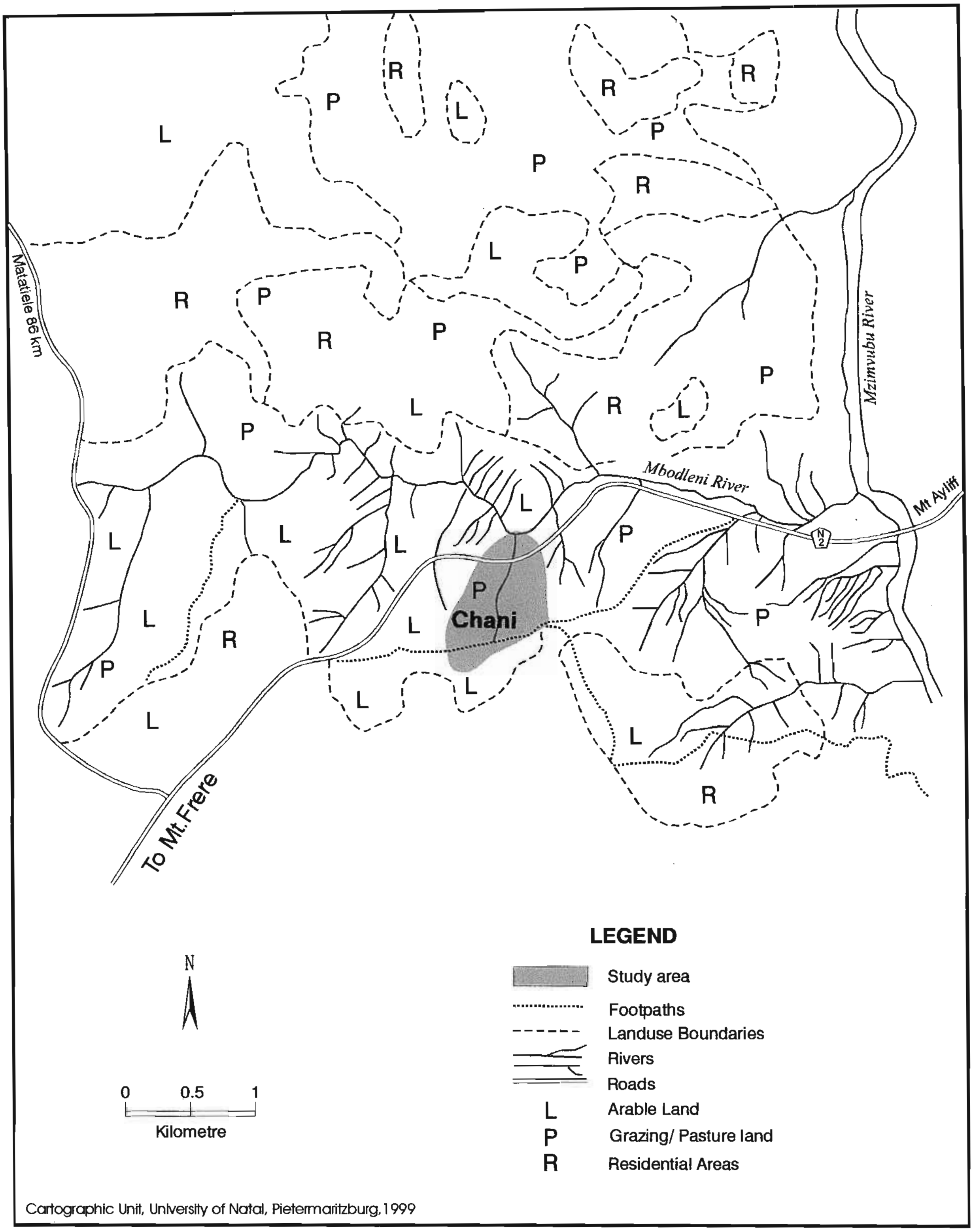

Fig. 3.5: Land Use Map for the Chani-Rode Site (extracted from Surveyor General, 1:50 000 topographical maps, 3029 CC Rode, 1984, aerial photos 1982)

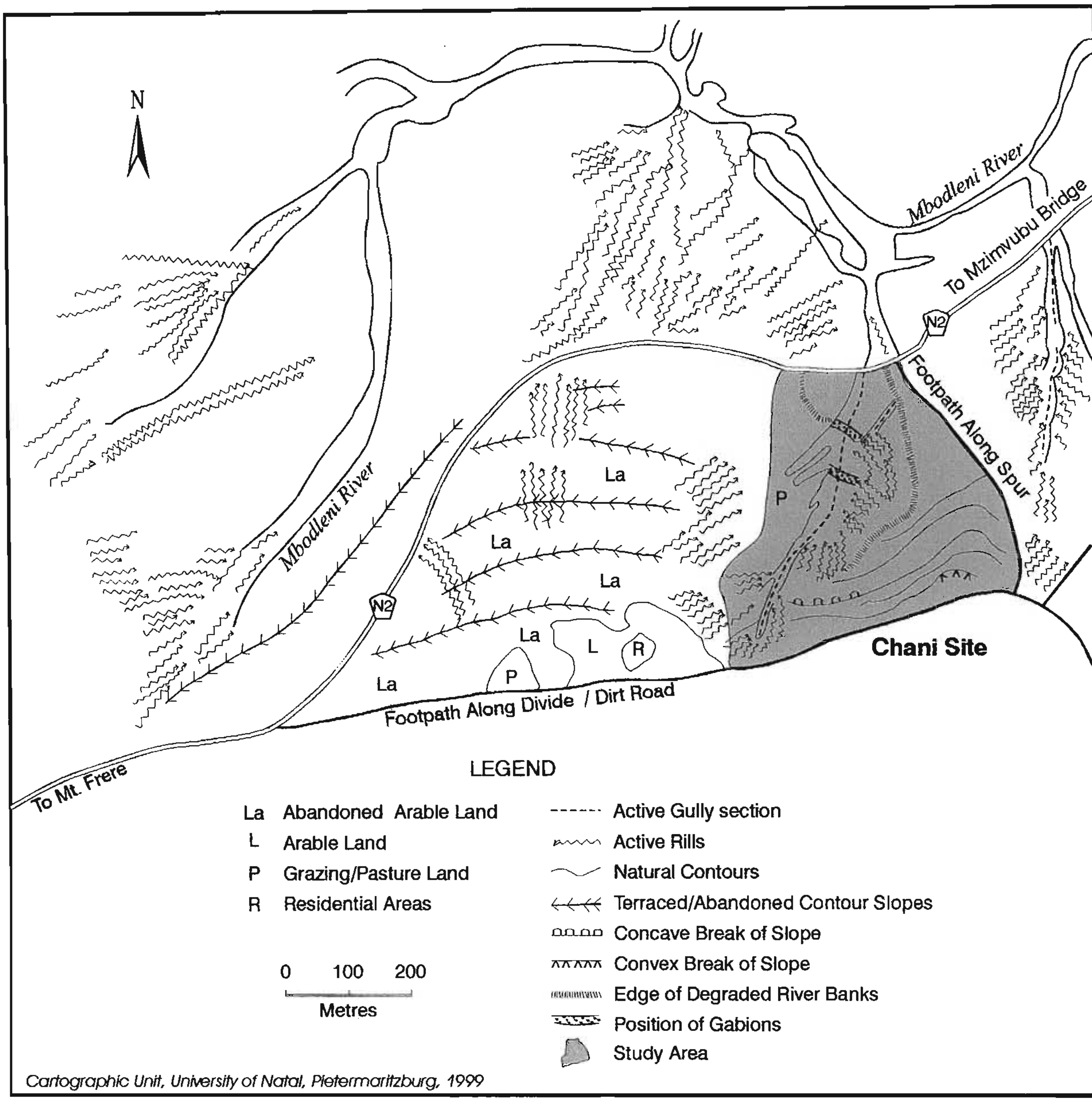

Fig 3.6 Erosion and Morphological Map : Chani-Rode (extracted from aerial photos 1982)

The Chani site is found on a 1:50 000 mapsheet 3029CC Rode. The area extends between co-ordinates 30°51'S and 29°02'E over a total area of about 400 m^2 (Fig. 3.5). Chani, lying about 7 km from Mt Frere to the direction of Kokstad, is also a grazing land for the Chani rural village (Fig. 3.6). It is, like Brooks Nek, dominated by valley side gully erosion.

The gully observed is on the nonperenial tributary of Mbodleni River which, like uMvalweni River, ultimately joins the uMzimvubu River. Unlike at Brooks Nek, however, the badly gullied sections at Chani were once fenced off. At a later time, the structure collapsed due to lack of maintenance of the fence. As a result, stock now graze within the gully floor. On this floor, however, there has been some progress with respect to silting and revegetating. The attempt to rehabilitate the gully was made during the Transkei Five Year Plan of 1978-82, (which might be compared to the 1993 rehabilitation in Brooks Nek). During this time, the nearby National Road (N2) was also reconstructed and tarred. Evidence suggests that the method was not successful. As one drives past the Chani site, along the National road (N2) to East London or Durban, this badly degraded landscape just northeast of Mt Frere is easily noticeable. The most prominent erosion forms are rilling and gullying.

At Chani, there are signs of overland sheet wash, in the parts that are totally bare. Imeson and Kwaad (1980); Trofimov (1987); Swanson et al. (1989); and Brady (1993) have all observed similar sequential occurrences of these forms of erosion in their respective research areas. Compaction - which could possibly be association with raindrop impact - is easily recognisable, especially after or during heavy rains. Since Chani is at a rather high rainfall area (>800 mm), one does not need to visit the area to get the picture. A gully has developed on a concave valleyside slope.

In agreement with Morgan (1995 after Wells and Andriamihaja, 1991), it can be argued that the gully development at this uMzimvubu River sub-tributary has taken place where vegetation has been destroyed and the equilibrium disturbed. This disturbance has happened in three ways. The first way has been through overgrazing and stock trampling. Overstocking has been estimated at 42% (as indicated earlier). The second way is associated with the roads constructed on the upper and lower ends of the study area. It is a significant factor in the causal nexus. The third way has to do with the terracing across the upper and middle end of the gully system. Terracing has been performed in order to extend the natural contours found spreading from the spurs, so that they can extend to join the main gully edges of the degraded river banks (Fig. 3.6).

Some important aspects relating to the background of the physical characteristics of the study areas have been given in this chapter. Also, we have noted briefly socioeconomic, historical and political factors in chapter 2 which are relevant to our understanding of the overpopulation problem in the study areas. It is assumed that all of these are important causal factors of the soil degradation and erosion problems faced in these areas. Before we consider this hypothesis any further, details of the methodology used in carrying out this research will be presented in the next chapter.

CHAPTER 4: METHODOLOGY

This chapter presents a discussion of methods and tools that have been adopted in the study of soil erosion at the Brooks Nek and Chani study areas.

4.1. Data collection

Field observation and data collection of soil erosion forms at the two sites have been carried out over a two-year period. As documented by Crouch (1987), a study of an intermittent natural process like gully erosion over a two-year period cannot provide a complete picture of events. It does, however, provide some basic information for understanding site-specific conditions of each study area. At the same time these observations commenced, it was noted that gullying had progressed to such an extent that rehabilitation programmes (including gabion construction) had been initiated in the late 1970s at Chani and early in the 1990s at Brooks Nek.

Although the Transkei region generally lacks secondary data availability, aerial photographs and topographical maps were obtained and these were used to identify and locate the degraded areas. But the final choice was determined by accessibility and the fact that the two areas have never been studied to provide the specific data collected in this project.

Before detailed field analysis was undertaken, drainage networks were delineated from 1:50 000 scale maps of Kokstad (1980) and Weza (1981) for Brooks Nek. In addition, a 1:10 000 scale aerial photograph (taken in 1982) and a 1: 50 000-scale map of Rode (1982) were examined for Chani. For both study sites, the drainage network and the stream orders were calculated according to the Hortonian method, using both mapsheets of 1:50 000 scale and field surveyed data. Information gathered was complimented by ground-truthing. These tools allowed the determination of the extent of the degraded lands and their exact location.

The first visit to Brooks Nek site was undertaken in October 1994. Regular visits were then undertaken for the next two years. Visits would take a minimum of three days and a maximum of three weeks as determined by the type of data needed. Concerning the Chani site, it has always been possible to make a general survey of this area whenever driving past, due to its proximity to the N2. Detailed fieldwork was undertaken in January-February 1995 with the permission and support of the local communities. Of the erosion forms identified, rill and gully erosion have been observed to be the most prominent and significant forms in both areas.

4.2. Field Work and Laboratory Analysis Preparations

Surveys of the subcatchments were carried out in order to determine the parameters of size, shape and slope factors, as these usually tip the balance of the watercourse with which the gullies are associated. It was found that, although the section where each gully lies was viewed as zero order stream valley in the past, currently they are nonperenial watercourses that obtain water during heavy rains, snowmelt and hailstorm. To determine the similarities and differences between the study areas, an inclusive data collection in the field was undertaken, encompassing both natural variables and human activities.

4.2.1. Field surveys

Grid referencing and ground-truthing were determined by GPS, while a magnetic compass was used for direction. A general survey of the extent of land denudation was made at each subcatchment. The total area of each of the subcatchments was calculated from 1:50 000 maps and aerial photographs. The longitudinal and cross profiles - together with slope angles of the gully sides and rills - were surveyed using a combination of ranging rod, Abney level and measuring tape, as suggested by Gardiner and Dackombe (1983) and King (1985).

Traversing for a slope profile was carried at the surface level along the gully sides, following the gully itself so that information on a gully floor could be collected at the end of each adjacent profile section. At the breakpoint or end of the profile section, gully cross-sections were made to determine the dimensions of the maximum and minimum gully depth, and maximum and minimum gully width. Cross-sections were made at every point of measurement across the gully, to obtain data regarding depth, width at bottom and shoulder width. Gully depths were measured with a range rod. Gully widths and gully lengths were measured with a measuring tape. The shape factor 1 has been determined by dividing bank width by bed width, following Brady (1993). Factors responsible for the formation of the morphologies were determined by observing, in addition to average gully width-depth ratios, rill depths and their spatial distribution. Knowledge of these variables then forms the basis of an overall assessment of the relevance and efficiency of the erosion control measures to be found in the study areas.

In conducting the on-site infiltration tests, the single ring infiltrometer was used following the guidance of Bouma *et al.* (1982) and Wierenga (1985). Although the actual infiltration capacity during the storms may be much less than suggested by field tests (Beckedahl *et al.,* 1988 after Morgan, 1986), it has been used with success to obtain estimates of the infiltration capacity of the soil. Taking into account the crucial surface conditions (surface sealing, crusting and compaction), which influence the soil infiltration capacity and infiltration rates, measurements were made on both vegetated and nonvegetated parts or compacted and noncompacted soils, depending on the site of observation. As it will be seen, other factors influencing infiltration include soil structure, texture, mineral composition, vegetation cover, biological activities, moisture content and surface conditions. Of the latter set of variables, observation of vegetation coverage (%) near the gullies was made to a radius of 200 m away from the gully section itself. Vegetation was identified, based on 1x1 m^2 squares, for a dominant species count in relation to bare surfaces. Soil moisture content was measured (Speedy Moisture Tester) as the rate at which water infiltrates the soil is directly dependent on the amount of water that is already in the soil and/or on the rain water supply in a particular area.

Measurement of the shear strength was carried out with the aid of a Farnel hand shear vane and the results are presented as means of values. All variables were measured from the gully side surfaces. This was mainly due to the fact that gully erosion has removed soils to bedrock inside both of the gullies studied. Measurements for an infiltration rate, soil moisture content and shear strength were made at five points - of 1 metre apart - on noncompacted/vegetated soil. However, for the most difficult compacted/nonvegetated parts, three points of the same spacing were used to measure the same variables, following the method used by Misra and Rose (1995) in their work in Australia.

Soil type and colour changes were recorded, according to the thickness of each layer measured from the gully wall sides. Soil horizon identification, thickness and sampling were carried out using staff, measuring tape and Dutch Augur, as detailed by Bouma (1985) and recommended by Rayment and Higginson (1992) and Baize (1993). In cases where the original A- or O- horizon had been washed away, measurements were made from the topmost soil layers. Field dry soil colours were identified and compared with laboratory wet state results, which were obtained with the aid of the Munsell Colour Chart (1990).

Soil samples were taken at break-of-slopes points (or as close to them as possible) by horizon, following methods used by Bouma (1985), Gutjahr (1985) and Wilding (1985). In cases where gullies showed no definite horizon features, samples were taken from each soil layer using differences in soil colour. Where the break-of-slope fell on stones or bedrock, sampling was done whenever soil was prevalent within the profile section.

Samples were taken from different colour soils and soil horizons, even if such soils were on the same solum. Sampling was made after the gully sidewalls had been cleared of decomposed soil layer and soil was dug off with the aid of a geological hammer. Other than that, auguring was used as an option.

At the same time, it is important to mention that half of the soil samples made for each study site, were sampled from samples taken at points 50 metres and 100 metres from the gullies, on either side. The analysis of the soils shows no significant differences between the soil samples taken at the points mentioned, and those samples taken in the gully sections. Hence in the next chapter it is argued in more detail that the soil properties in either gully erosion locations are not causally responsible for the erosion problem at these sites.

4.2.2. Data management techniques

During profiling, mapping of prominent features onto topographical maps and aerial photographs was carried out following the recommendations of Walker *et al.*, (1968); Gardiner and Dackombe (1983); King (1985); Lenon and Cleves (1986); Thwaites (1986); Clowes and Comfort (1987), and Slaymaker (1991). Slopes are fundamental type of landscape features regarding the determination of the nature's state of equilibrium. Similar effects are caused by size, shape, and plan factors, which disturb the balance of the watercourses. The gullies that have been studied were noted to lie in dry valleys that are sometimes drained by nonperenial watercourses.

In addition to sketched data and information recorded in notepads, photographs have been taken to preserve physical evidence (particularly, for assessing human activities in these areas). The most prominent features, identified at Brooks Nek, are trenches that divert water from the mainstream course, over or across some parts of the subcatchment to individual homesteads and vegetable gardens. At the Chani site, in addition to direct observation, gully erosion, rills and vegetation were also captured by photography.

Samples, which had been labelled using sticky name-tags and kept in sealed plastic sample bags, were transported to the laboratory for further analysis. Soil samples that could not be analysed on the same day were air-dried in the laboratory. Soil properties, including particle size analysis, soil structure and aggregate soil stability, were examined following the methods used by Grieve (1979).

4.2.3. Laboratory Techniques and Data Analysis

For laboratory analysis, soil sample sizes for each site depended on the homogeneity or heterogeneity of the sampling areas. Variations in soil characteristics were found between and within different parts of each subcatchment. For example, Brooks Nek subcatchment had two colour soils as well as discontinuous soil depths. Some areas had rough surfaces. Others were covered by soils of mean depths of just more than 4 m, with parts that had rather well-defined horizons. Some had just one colour layer and horizon. At Chani, average soil depths exceeded 5 metres. Similar to findings elsewhere by Zhang *et al.* (1994), irrespective of their differences in sizes, it was found that each of the sites showed great disparities within itself, in soil structure, texture, colour, depth and horizon development. Between the two sites, however, the differences are not as explicit. Details on this aspect are presented in chapter 5.

Soil characteristics have been analysed also to determine soil suitability for the rehabilitation methods used. An assessment of physical soil characteristics - particle size distribution - was analysed through the dry sieving method (Briggs, 1977a). In the laboratory, each sample was prepared according to Briggs' manual and left to shake for 10 minutes at 70 Hz.

Sieves were arranged according to the Wentworth scale (Briggs, 1977a and b; King, 1985). This scale was chosen because it matched the sieve sets that were available for the tests. Conversion of sieve contents to phi units was done following Smith and Atkinson (1975), King (1985), and Briggs (1977b). Categorisation of sieve contents into gravel, sand and silt, was carried out according to the British Standard Code of Practice (King, 1985).

The Oven dry method was used in the laboratory to test the moisture content of soils, following the approach outlined by Briggs (1977b), Smith (1988) and Dodson *et al.* (1994). The soils were dried at constant weight at 105^{0}C for 24 hours, after pre-weighting and re-weighing had been determined. Then the necessary conversions were made. Notwithstanding the recommended 100 - 150 g of weight for coarser material and 40-60 g for finer sands (Gardner and Dackombe, 1983), exceeding the recommended weight was considered appropriate because, in many cases, the soil samples contained small stones. Sample weights of 200 g were used for all soils tested for both moisture content and aggregate stability.

Soil aggregates, the basic units of soil structure, are formed mainly by physical forces but get stabilised by several other factors, such as organic matter, iron and aluminium oxides, and clays (Lynch and Bragg, 1985). Since the processes of stabilisation and aggregate formation can be concurrent in the soil, concurrent observation of agents becomes imperative. Distilled water, the most significant agent for breaking down aggregates, has been used. Soil aggregate stability (a basic unit of determining soil structure), determines the relationship between water and air in the soil and it provides indices of sheetwash erodibility and structural stability (Smith and Atkinson, 1975).

Testing has been carried out using the laboratory wet sieving method (Lynch and Bragg, 1985; Hazelton and Murphy, 1992). Sieves for aggregate stability ranged from 4000 microns to 63 microns and the top sieve was loaded with a sample of 200 g weight. The 200 grams soil samples were submerged in distilled water. The wet sieve shaker was set at 20 runs per minute and was allowed to run for 30 minutes (Townsend, 1973; Hazelton and Murphy, 1992). Distilled water was used to wash the wet sieves. The size distribution that remained intact, after samples were agitated in a sink full of distilled water, was measured following the method described by Grieve (1979). Soil proportions from each sieve size were dried at 105^{0}C after being transferred to aluminium containers. After relevant deductions of sand, gravel, and clay, these proportions were expressed as a percentage of the original total weight (200 g) of samples, as described by Briggs (1977b) and Ternan *et al.* (1996). The texture was determined using the technique outlined by Fitzpatrick (1986) and results were plotted onto a texture diagram.

The statistical t-test was used to broadly correlate and compare results between the two study areas. It was then possible to make generalisations concerning the soil composition of the sites chosen and to make comparisons with other places in these areas, and with sites that have the same characteristics in other regions of South Africa. This data also provides some scale on which to measure failure or success in areas where similar soil rehabilitation programmes have been adopted.

Finally, something needs to be said about the methods used to observe and evaluate the multiplicity of human factors involved in soil degradation. Clearly, the extent and nature of soil erosion are determined by the nature of the processes operating on the soil. As has been argued above, this can involve the response of the land to edaphic factors such as geology, topography, soil characteristics and vegetation cover. These are normally influenced by natural changes, in terms of climate and geomorphic factors. However, in this thesis we hope to show the extent to which human activities also act as catalyst for accelerated erosion. In other words, in addition to the geomorphic agents of natural erosion - mainly water and wind in this part of the world - human activities, and the perceptions, attitudes of those people affected by soil erosion are critical in this process and need to be investigated. Accordingly, interviews were conducted in the community at Brooks Nek, and questionnaires were given out to those who were directly affected by erosion in both study areas, as well as those who were evidently benefiting from the rehabilitation programmes. In addition to the pertinent questions in chapter 1, p17, more questions which were asked of the interviewees are outlined in Appendix A.

This chapter has addressed methods adopted in data collection, storage and transportation as well as techniques employed in data preparations, processing and analysis both in the laboratory and during the field surveys. Appropriate literature that guided the study methodologies has also been presented. The first part of the next chapter (chapter 5) focusses on the presentation of the results from the field and from the laboratory analyses whereas the second part deals mainly with the discussion as well as the implication that the results pertain.

CHAPTER 5: PRESENTATION AND DISCUSSION OF FIELD AND LABORATORY RESULTS

The first section of this Chapter presents the results from the field measurements and associated observation. The second section focuses on the surveys and laboratory findings. The third section represents a comparative discussion of the results, including statistical testing and analysis.

5.1. Field measurements and profile characteristics of the study sites

For both Chani and Brooks Nek, there is evidence from aerial photography (1982 and 1993 series) that some parts of the catchment had been cleared of vegetation. Following Abrahams *et al.* (1995), an analysis of vegetation cover and topography has been carried out with the intention of establishing their relationships. The results show that the bare upslope areas are most frequently affected by severe erosion and environmental degradation. Along the spurs, footpaths had the greatest impact on vegetation destruction. This is similar to the findings by Pickup and Chewings (1996) in arid Central Australia.

Overall, erosion in the study areas is severe, that is of class 4 (see Brinkcate and Hanvey, 1996), especially around the main gully sections. At the study sites, the additional factors to gullying are ruts in old roads, depressed stock trails, footpaths, and drainage ditches. These have, collectively, led to the kind of gullied environment that is comparable to findings elsewhere by Morgan (1979) and also de Ploey and Gabriels (1980). Both sites are characterised by intermittent bare surfaces that extend over an average of 50 metres away on either side from the actual gully. Easily observable is the sheet erosion that grades to rilled and gullied surroundings. In all gullies, the upper course sections have Type 1 erosion (see Table 2.1, p35). Linear rills (Type 3) also dominate these upper course parts. Around subsystem confluence zones, very severe erosion (Type 5) takes place (Brinkcate and Hanvey, 1996). Type 9 erosion is easily recognisable at Chani. But there is no sign of piping at either site. As these study areas are within grazing lands, the gullies potentially pose a threat to livestock due to their vertical depth.

The infiltration capacity of the soil at either site was tested. Briggs (1977b) and Morgan (1995) indicate that if the infiltration capacity of soil is high, the rainwater absorption rate increases, thereby, lessening the susceptibility of the soil to erosion.

Table 5.1: Infiltration Capacity and Percentage Moisture for the study sites

Study Area	Nonvegetated/ Compacted	Vegetated/ Noncompacted	Summer	Winter
Brooks Nek	120 ml/min (stabilised in 30 min)	200 ml/min	8.8%	4.0%
Chani	33 ml/min (stabilised in 20 min)	50 ml/min	5.0%	3.5%

Results on infiltration capacity and infiltration rates recorded from vegetated and nonvegetated parts of Brooks Nek, as well as compacted and noncompacted areas of Chani, showed an inverse relationship between infiltration capacity and compacted soil and/or high moisture, vegetated soils (Table 5.1). This illustrates that compacted soils have promoted an increase in overland flow which has contributed to the dominant gully erosion in the area. This compaction leads to either waterlogging (e.g., a marsh at Brooks Nek) or to the loss of water transmission pores similar those referred to by Partap and Watson (1994) in their research in sustainable mountain farming. A confirmation of an exponential decrease in infiltration capacity with the increase in crusting area, like that found by Boiffin and Monnier (1985), became possible with the infiltration results. However, the details of the finding - that there is an exponential increase in percentage area affected by crust development in relation to cumulative rainfall (Poesen, 1984) - have not been included in this study, as is considered beyond the scope of the present work.

According to Weltz *et al.* (1989), infiltration rates are reduced significantly after cattle have grazed within an enclosure for only 14 days. Although a detailed investigation of this was not possible, it seems very likely that broadly similar results would obtain in our study sites. The implications here are that overgrazing, trampling and related compaction, reduce infiltration rates, which increases runoff that in turn causes erosion. It seems reasonable to assume that on severely grazed parts of the study areas, that have been subjected to grazing for long periods, similar effects will obtain.

Taking the role of moisture into account, samples were taken during both dry and wet periods - namely, June-July 1995, January-March 1996 and May-June 1996 - so that the bias associated with antecedent soil moisture could, to an extent, be contained. The intention was to check if there was any distinct relationship between the summer and winter moisture readings and infiltration rates from the soils (Table 5.1). When these variables are considered together, it could be argued that compact and bare soils exert major control of the surface runoff generation. The latter two variables do this, by reducing infiltration whereas vegetated and noncompacted soils would either increase or reduce infiltration depending on the amount of moisture that is already in the soils. For soil moisture contained in the soil, Bouma *et al.*(1982), Wierenga (1985) and Morgan (1995) found that high moisture content promotes runoff production in the soil. The next two subsections break the results according to the uniqueness of the characteristics of each site, starting with Brooks Nek.

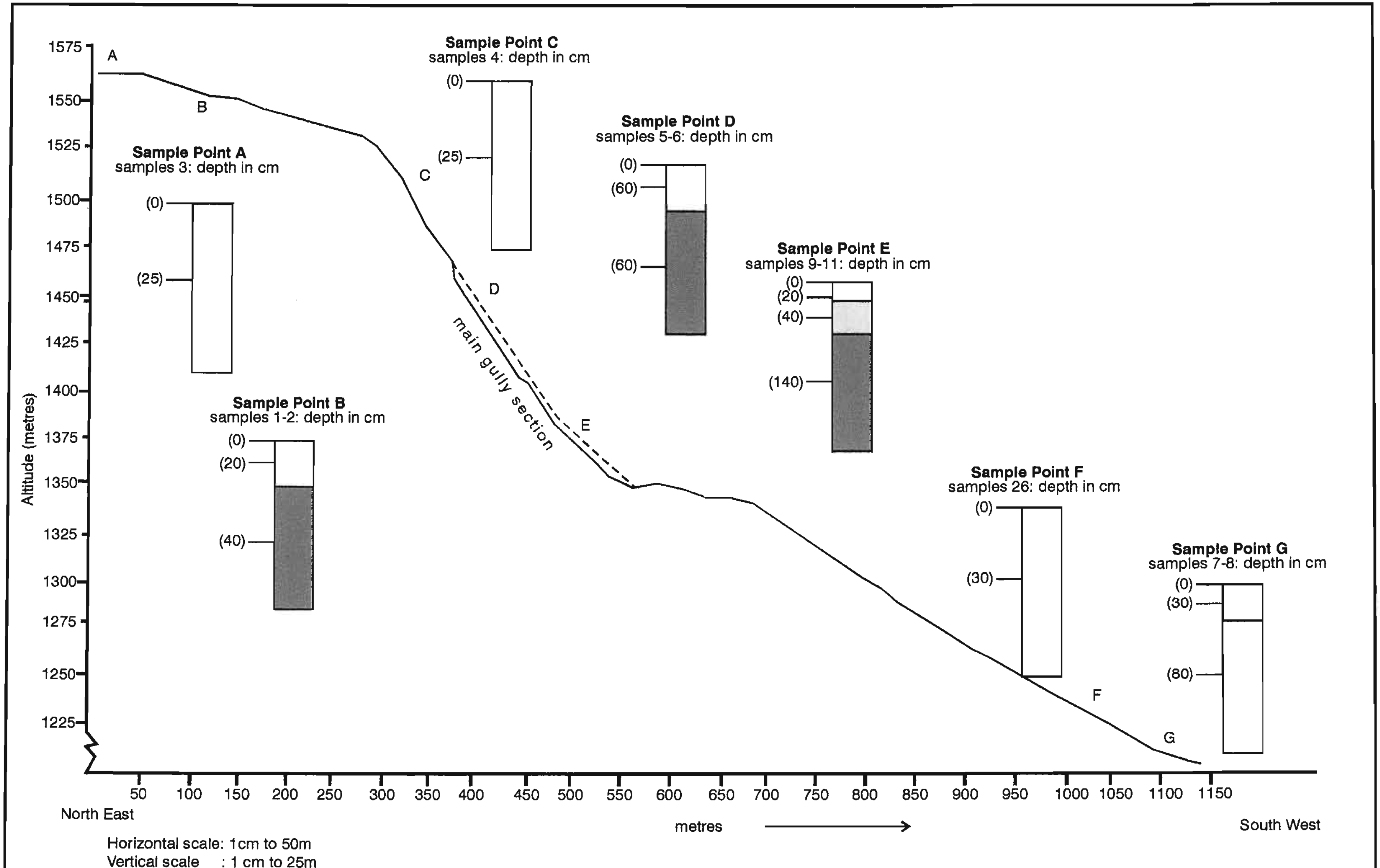

Fig. 5.1: Profile Section of Brooks Nek Study Area

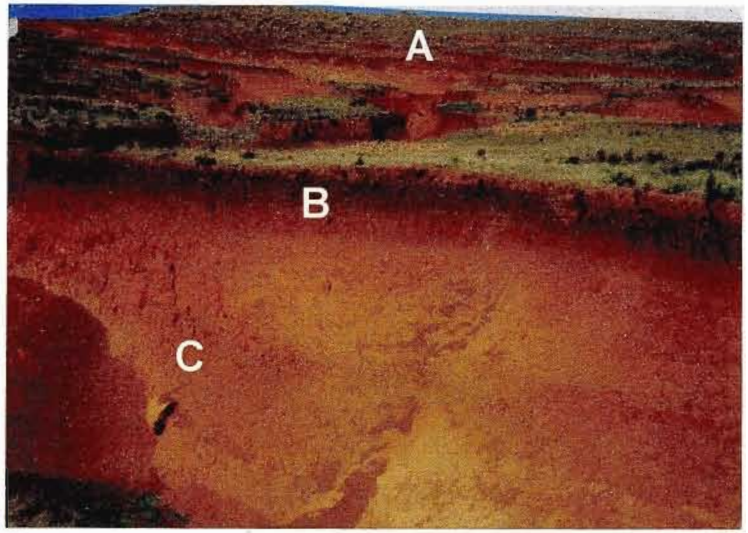

Fig. 5.2.1. A = rills developing from footpaths and stock trails
B = exposed well - defined soil horizons
C = transition of horizons marked by river deposited pebbles

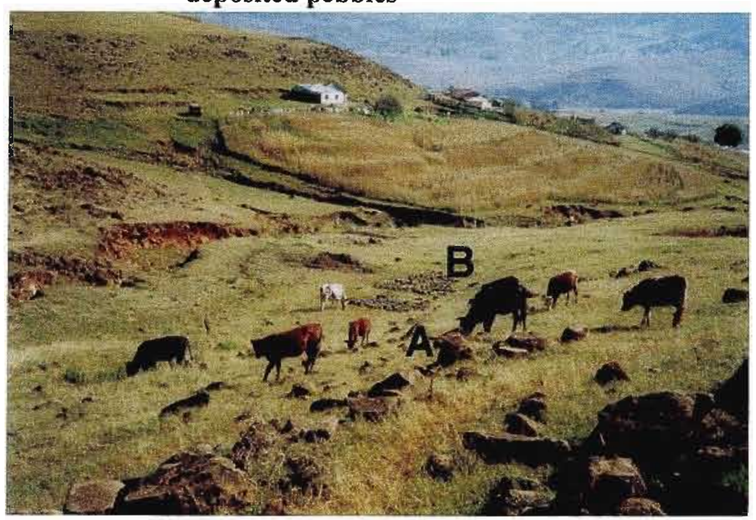

Fig. 5.2.2. A = overgrazing potential
B = mudbrick making site

Fig. 5.2.3. A = overgrazed and fenced off grass species
B = whitish grey soil at the two stream junction

Fig. 5.2.4. A = footpath related degradation on red slopes
B = footpath related degradation on grey-slopes

Figure 5.2. Brooks Nek Site

5.1.1. The Brooks Nek Catchment

The Brooks Nek subcatchment, which forms part of the grazing land for the Brooks Nek community, is found within the altitudinal range of 1220 to 1570 m.a.s.l. (Fig. 5.1 and Fig. 3.4, p84). The greater part of Brooks Nek is characterised by sheet and rill erosion, with gullying limited to the valley bottom. Gullies are prominent in areas that have been denuded of grass and vegetation through overgrazing, trampling and/or soil removal for brick making. Rills have developed on stock trails, tracks, and the footpaths and dirt roads which are found in the subcatchment (Fig. 5.2.1.A). This rill erosion falls within the range of Type 1 and 3 and Type 9 classification of erosion forms (Dardis *et al.,* 1988; Beckedahl *et al.*, 1988; Dardis, 1989). These forms can be linked to the heterogeneous character of the underlying material of eastern, southern Africa (Beckedahl and Dardis, 1988; Dardis *et al.*, 1988a; Watson *et al.*, 1984; Price Williams *et al.*, 1982).

In the study sites, the greatest gully depths are found on the northeast lying slopes as compared to some small scale gully erosion evident on old footpaths of the southwestern slopes. Elsewhere in the greater Brooks Nek subcatchment, a number of gullies have developed due to the culverts which have been placed on the dirt roads traversing the area.

Around homesteads, severe sheetwash erosion can be observed. This is largely attributable to local grazing, brick making, and other home-related activities. There can be no doubt that such activities are environmentally detrimental.

During the field survey, it was observed that stock grazing and browsing were pre-eminent in the subcatchment (Fig. 5.2.2.B; Fig. 5.2.3.B). From aerial photographs, evidence shows that there had been trees around some of the homesteads but these trees are no longer in existence.

For detailed profile information, a general observation was made from the first 20 m distance to the break-of-slope starting from the divide line of the Brooks Nek subcatchment (Fig. 5.1). Figure 5.1 presents a variety of other characteristics observed at the Brooks Nek site. It also summarises the soil samples taken according to soil depth, soil colour, soil structure, aggregate stability and soil moisture content. (For comparison purposes, a similar record for the Chani site is presented in Fig. 5.7 of the next subsection).

From the upslope end (about 1570 m), at about $30^{0}39'18''$S and $29^{0}30'41''$E, partly buried boulders, with a mean size of 15 x 45 x 20 cm^3, were found in an aggregate consisting of a mixture of thin soil layer and rock fragments. Inbetween these boulders the grass-to-rock ground cover is at a ratio of 60%-to-40%.

Table 5.2: Characteristics for the Cross-sections at the Brooks Nek Site

Section	1	2	3	4	5	6	7	8	9
Slope Length (m)	135	139	90	4	100	90	100	150	200
GPS Reference	30°39'24"S;29°30'46"E	30°39'20"S;29°30'42"E	-	-	-	-	30°39'46"S;29°29'44"E	-	30°39'08"S;29°30'09"E
Vegetation Cover (%)	60 Shrubs, grasses	<5 Scrub		<1	<1 Aloe succulents	<5 Aloes	60 Grasses	bare	80 Grasses
Aspect	NNW	NNW	NNW	-	NNW	NNW	SSW	SSW	SW
Mean Altitude (m)	1 550	1 540	1 470	-	-	-	1 440	1 290	1 230
Mean Shear Strength	90 kPa	67 kPa	73 kPa	150⁺ kPa	150⁺ kPa	125 kPa	120⁺ kPa	150⁺ kPa	150⁺ kPa

Table 5.2 above summarizes the relevant results for the profile as well as cross-sectional transections for the Brooks Nek site.

If we consider each transect from the subcatchment divide, as shown in Fig. 5.1, the first two sections were measured to the first gabion over a 300-metres distance. These sections lie between 1550 and 1470 m.a.s.l. (30°39'20" S; 29°30'42"E). Rill and gully surroundings were characterized by grass and shrub cover, which intermingled with stones. The species count along the transect suggests that shrubs comprise 10% of the total quadrate area, while grass cover is about 50%. The rest of the surroundings is mainly stone covered. No bedrock is exposed at this point. In determining soil resistance to shear stress, which is associated with rainsplash and sheetflow, the mean shear strength was measured at 90 kPa (Table 5.2).

Table 5.3: Distance between gabions at Brooks Nek

Gabion	Distance in-between Gabions
½	5 m
2/3	16 m
3/4	15 m
4/4	11 m

When examining the existing gabions, it became clear that these were constructed at inconsistent intervals (Table 5.3). The fourth gabion was laid at a rill with a mean depth of 40 cm, on a stabilised deposit with shrubs already growing inside it.

At the middle of section 2, there are footpaths from which soil has been removed such that both O- and A-Horizons could be identified. This exposure of horizons extended further downhill, as can be seen in Fig. 5.2.1.B. This point is on a bare A-Horizon which reveals the newly deposited red sediments washed from the dolerite soils, which are upslope.

The Brooks Nek soils are divided into two distinct soil forms occurring on opposite slopes and a detailed explanation of each is made in the next few paragraphs.

Table 5.4: General Characteristics of Soils at Brooks Nek Sample Points

Slope Length	Altitude (m)	Sample Number	Depth (cm)	Munsell Colour	Structure	Stability	%Moisture	
							Summer	Winter
20 m	1560	3	0-25	2.5 YR 3/3 Dark Reddish Brown	Crumby	Weak	5.04	3.2
115m	1540	1	0-20	5R 2.5/2 Dark Reddish Brown	Crumby	Strong	5.4	2.6
		2	20-40	2.5YR 4/4 Reddish Brown	Crumby	Moderate	13.5	8.4
65 m	1520	4	0-50	5YR 3/4 Dark Reddish Brown	Crumby	Weak	7.7	6.8
80 m	1470	5	0-30	5YR/4/3 Reddish Brown	Blocky/ Columnar	Weak	10.4	3.5
		6	30-60	5YR/3/3 Dark Reddish Brown	Blocky/ Crumby	Strong	14.0	3.0
30 m	1450	7	0-30	10YR/4.1 Dark Grey	Columnar	Moderate	8.0	4.8
		8	30-80	10R 3/3 Dusty Red	Massive Columnar break-to subangular	Strong	14.0	5.2
150 m	1400	9	0-20	10R/4/6 Red	Crumby	Moderate	5.0	6.4
		10	20-40	10R 4/6 Red	Crumby	Strong	7.0	4.6
		11	40-140	10R 3/4 Dusty Red	Blocky/ Columnar	Moderate	10.0	5.8
500 m	1260	26	0-30	10R 2.5/2 Very Dusty Red (Chroma)	Blocky	Moderate	6.0	5.2

Table 5.4 summarizes the general soil characteristics of each of the 12 samples points. It presents soil depth, soil colour, soil structure, soil aggregate stability, and soil moisture content. These results are based on the observation made in

the field.

The significance of soil aggregate stability needs a special mention at this point. Soil aggregates are the binding units of soil structure. Stability of aggregates, together with size and shape, control the soil pore size distribution which in turn affect the soils physical properties (Lynch and Bragg, 1985). Indirectly, this emphasises the complementary effect that mechanical and chemical mechanisms have on each other. The impact of rain water breaks down the aggregates. This process is followed by compaction and sealing of the surface. The latter two processes adversely affect the rate of chemical dispersion of soil particles (Shainberg, 1985).

The northeastern gully side, which is underlain by dolerite, has red soils in dominance. This is common along the spurs and the divides of this subcatchment. The red colour is explained by the iron content contained by dolerite rocks. These rocks are made up of dark pyroxene (an aluminium silicate) and the white plagioclase. These two components are both rich in calcium and sodium minerals and, when they are oxidised they give the red colour to soils (Von Brunn, 1996).

The southwestern side of the subcatchment is underlain by mudstone material, which forms whitish-grey soils. This is evident on almost half of the area of the Brooks Nek study site. Results for this area are presented from now on, according to the red slopes (southwest facing) and grey slopes (northeast facing) division for the same study site.

5.1.1.1. Southwest facing Red slopes

The third transect starts a few metres from the main footpath and ends at the main gully head, a distance of 90 m. The site is characterised by criss-crossing footpaths and stock trails that connect the hilltop path and the nearby village to Brooks Nek village (Fig. 5.2.1.A). 'Islands' of grass colonies raised above and between severely eroded footpaths (Type 9 of erosion) are observable. The remnants of the original slope surface are still well vegetated in this area. Large boulders, of 30 cm wide x 100 cm long x 40 cm deep, also dominate the transect.

Forty metres across the gully area, 90% of land is bare and characterised by big boulders. Of this 40 m section, the first 15 m has less than 10% shrub cover. This vegetation cover increases farther away from the gully, to about 80%. But it is discontinuous. Rill erosion intermittently occurs at every 10 m average distance within the observed stretch of land. The rest of the immediate surroundings of the gully section has profiles that have been exposed by erosion on the bank-slopes of the deeply eroded footpaths.

Common in all transects, is the inconsistency in the gabion lay out. There is no evidence to suggest that this could have been understood to be a function of variable gully gradient.

Table 5.5. Gabions on rills: Number per distance at Cross-section

Distance	No. of Gabions	Ratio (m)
20 m	7	2.9:1
70 m	5	14:1

At this part of the section (Table 5.5), there are 4 gabions within a space of 20 metres. The first transect has 7 gabions within a 20 m distance whilst over the next 70 m there are 5 gabions. The gabions are unevenly space; some are 3 m apart while others are more than 10 m apart.

The shear strength has a mean value of 73 kPa. This section extends to the last four metres (to the gully head) and depicts special features such as 'island/miniature conical hill' with well-developed horizons. The red top layer, which caps most of the earlier profiles observed, has been washed away from most remnants found immediately above the gully head.

The deepest gully section is adjacent to a marshy seepage point at the rock outcrop on the northeastern side. Of a kilometre long channel, it extends to 200 metres between 1470 and 1300 m.a.s.l. (Fig. 5.1). The Brooks Nek gully system is a continuous type. According to Heede (1970) continuous gullies begin as rills in the headwaters and coalesce to form the main gully.

Table 5.6: Characteristics of the individual sola at Brooks Nek gully

Horizons	Average Thickness	Colour
A	0-15 cm	5 YR 3/4 Brown
B	15-55 cm	5 YR 5/8 Bright Reddish Brown
C and/or R	55-120 cm	7.5 R 4/8 Red or 7.5 R 3/6 Dark Red

Table 5.6 shows details of an individual sola inside the 200 m gully at this site. The C-horizon depicts a number of exposed round boulders on its wall, especially at the B and C transition area (Fig. 5.2.1.C). Generally, the R-horizon shows a well-defined transition, from the highly weathered rock layer at the top through to a massive bedrock exposed at the channel floor of the gully.

The main gully head itself is characterised by a sharp depth transition from rills of less than half a metre to a 5 m gully. Upon measuring and observing the inside of the gully and its immediate surrounding environments, it was found that the main gully floor maintains a continuous depth that is controlled mainly by the exposed bedrock. It was observed that the main gully surroundings and the floor - where soil is prevalent - are stunted by aloe species and other succulents. These vegetation species act as stabilising agents. And stabilisation is evident, especially at the first main gully confluence near the gully head section.

Unlike in the distribution of rills (Table 5.4), gabions in the main gully are spaced between 5 m and 20 m apart, on average 3 gabions are found per sub-gully.

Table 5.7: Width:depth sample data inside the main gully (1470 - 1330 m.a.s.l.)

Sampled Points / Variables	1	2	3	4	5	6	7	8	Means
Mean Maximum Depth (m)	4.50	4.10	1.80	1.00	0.90	3.20	0.40	1.60	2.19
Mean Minimum Depth (m)	4.30	3.90	1.60	1.80	0.90	0.20	0.40	1.60	1.84
Average Depth (m)	4.40	4.0	1.70	1.40	0.90	1.70	0.40	1.60	2.02
Width:depth Ratio	2.1:1	1.9:1	1.9:1	2.0:1	3.7:1	2.6:1	5.8:1	3.1:1	2.3:1
Mean Bed width (m)	4.00	2.40	1.80	2.30	2.50	1.20	1.30	3.50	2.38
Mean Bank width (m)	14.10	13.10	4.60	3.20	4.30	7.50	3.40	6.40	7.08
Average Width (m)	9.05	7.75	3.20	2.75	3.40	4.35	2.35	4.95	4.73
Shape Factor 1	1.60	1.69	1.44	1.16	1.26	1.72	1.45	1.29	1.50

At this point, a number of large size rills joining and/or forming parallel to the main gully section are found, contributing to the increase in depth and width of the main gully section (Fig. 5.1; Table 5.7). The mean bed width ranges between 1.2 and 4.0 metres whereas the mean bank width is between 3.2 and 14.1 metres. The mean minimum depth range is between 0.2 and 4.3 metres whilst the mean maximum depth lies between 0.4 and 4.5 metres. The average depth ranges are between 0.4 and 4.4 metres whereas the average width is between 2.4 and 9.1 metres. The average depth is 2.0 metres and average width is 4.7 metres. The mean width:depth ratio is calculated at 2.3:1 (Table 5.7).

The last 90 m of the main gully extends over and across a small dam. At the time of the field work, a pipe was connected to this small dam, by a 'certain lady' whose name we never got to know, for the intention of supplying water to the communities downhill. Further downslope, a furrow to insert the water supply pipe has been ploughed along the stream. (Unfortunately, by the time the field work period scheduled for this research ended, this water project had not actually taken off.) Aloe type vegetation is identifiable within the gully. At a distance across (about 20 m), more aloe species have been planted in linear form (as hedging for an abandoned garden and kraal). This planting must have occurred in the past before the resettlement process took place. Some remnants of stone-constructed kraal, garden fence, and old household buildings can be identified. Very close to the gully head, there is also a 3 m high heap of locally collected stones intended for use in gabion construction.

In areas surrounding this main gully, several cracks on the bare soils has increased the infiltration rate to 1 litre per minute on average from 20 ml/min on vegetated surfaces and 36 ml/min on nonvegetated (Table 5.1). The exposed layers, with a mixture of brown and dark red (5 YR 3/4) colours, are observable on footpaths found on the surrounding areas (Fig. 5.2.1.A).

Adjacent to the main gully area, two graves have been recently cleaned. They are dated 1973. They are found next to abandoned residential areas. The anthropogenic significance of this will be discussed in the next Chapter. Uphill, footpaths and stock trails are identifiable. These routes dissect slopes of vegetation cover, of 30% vegetation. The vegetation is intermingled with a 20%

stone cover. Shrubs are stunted all over the place at about 10% coverage, with the greater part of the land left bare. The slopes have a series of small scars this is indicative of vegetation loss and the areas where soil has been removed for brick making (Fig. 5.2.2.B). Some old scars are beginning to revegetate but they are under constant grazing and severe browsing.

We turn now to the confluence with the other tributary, which drains the opposite section of Brooks Nek [northeast facing grey slopes]. Stones and resistant grass species cover the rest of the valley sides. This section is covered up to 90% by short grazed grass. The exception is part of fenced off arable land (Fig. 5.2.3.A). Around the area where goats are to be found grazing the shear strength of the soil is 125 kPa on average, lending support to the earlier discussion concerning the compaction of soil associated with extensive grazing. This area marks the transition between the northeast facing grey and southwest facing red slopes of Brooks Nek (Fig. 5.2.3.B). At this area, the exposed greyish white layer is overlain by dark brown soil colour soil (Fig. 5.2.3.B). Details on grey northeast facing slopes are presented in the next subsection.

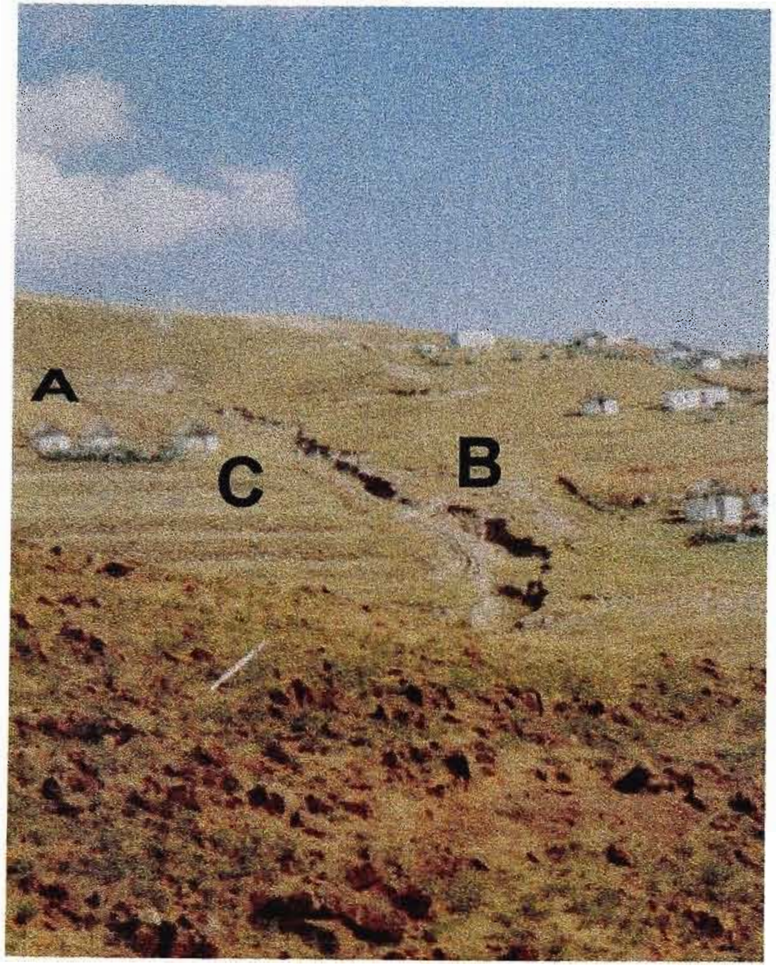

Fig. 5.3.1. A = olive yellow soil sample area
B = saprolitic soil layer
C = abandoned farmland

Fig. 5.3.2. A = furrow redirecting H_2O from river
B = hosepipe

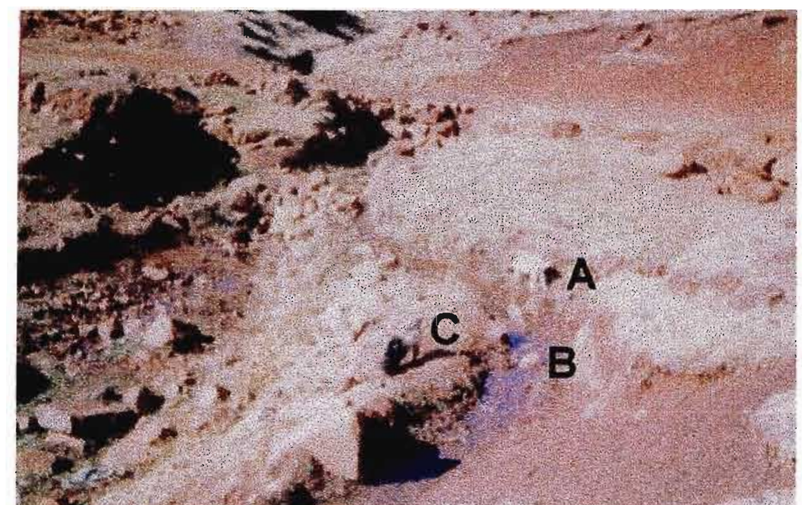

Fig. 5.3.2. A = grazing goat near the furrow
B = shallow water furrowed to construction site
C = grazing in degraded parts

Figure 5.3 Brooks Nek Site

5.1.1.2. The Northeast facing Grey slopes

Figures 5.2.4.A and 5.2.4.B show the northeast trending red dolerite derived and the southwest lying grey mudstone derived soils, respectively. Further upslope (Fig. 5.3.1.A), an augured B-Horizon shows an olive yellow (2.5 Y 6/8) soil, which is sometimes used to paint the inside of the mud huts. Across the valley (1290 m.a.s.l., +_30°39'05"S; 29°30'05"E) is a 2.5 m deep gully incised into saprolite (Fig. 5.3.1.B) with 1.2 m width. Only the top 20 cm soil layer could be augured on this material. From Figure 5.3, it can be noticed that this gully developed in association with footpaths and stock trail traversing between homesteads. Adjacent to the gully, there is evidence of abandoned farmland (Fig. 5.3.1.C). The average infiltration rate here is recorded at 33 ml/min.

At about 1230 m.a.s.l downslope (30°39'08"S; 29° 30'09"E), a network of small artificially made 5 cm deep furrows have been constructed to redirect water away from the main channel towards the brick-making sites and nearby homesteads (Fig. 5.3.2.A). That water is provided for by a hosepipe from upstream during the low water level periods (Fig. 5.3.2.B and 5.3.3.B). This part forms the last section of the study area. It extends to 200 m, from the footpath/dirt road (near where goats regularly graze) to the confluence with the tributary that drains to uMvalweni River (see Fig. 5.3.3.A and 5.3.3.C). About 100 m from this footpath, the stream has eroded the soil to a depth of the order of 7 m. It is striving to reach equilibrium with the main uMvalweni River channel floor. Sidewalls are characterised by well-defined horizons with thick colour differentiated soil horizons.

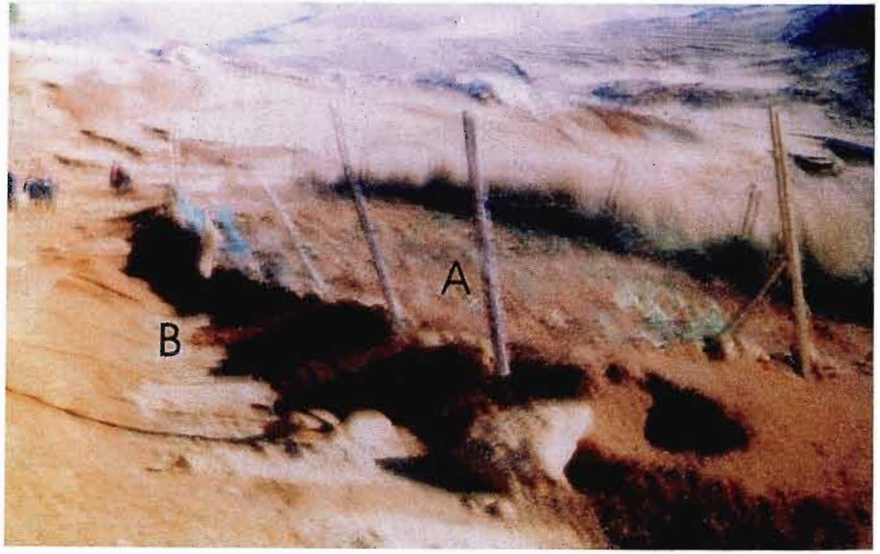

Fig. 5.4.1. A = vegetable garden
B = degenerated furrow

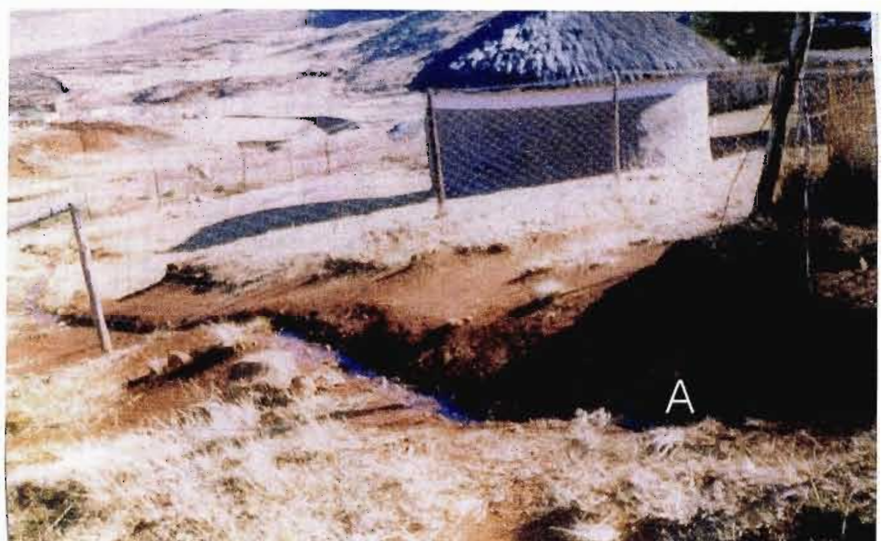

Fig. 5.4.2. A = heavily eroding furrow

Figure. 5.4 Brooks Nek Site

Fig. 5.4.3. A = footpath eroding to rills
B = furrow leading to the point where water is fetched
C = water pipe (collection point)

At Brooks Nek there can be found a couple of homesteads; where water is diverted from the main course for irrigating vegetable gardens (Fig. 5.4.1.A). There are indications that new gullies might develop as more people channel water from the tributaries to their households (Fig. 5.4.1.B; 5.4.2.A and 5.4.3.A-C). At label C, a small pipe is inserted to the minor degraded part - where a footpath cut across - and this facilitates water collection.

If we make a general assessment of the Brooks Nek subcatchment, we may say that the subcatchment is small with a circular shape. This means that all the water collects into the centre. Hence, the valley sides (red or grey slopes) continue to erode. It is, however, important to note that within the subcatchment itself, the area is very irregular. The bifurcation ratio for the catchment is calculated at 0.8, which is less than the normal range of 3 to 5, except for rare cases where lithology is not homogenous (Scheidegger, 1991; Summerfield, 1994). The mean stream length is 1.0 km. The elongation ratio is calculated at 0.7. This ratio supports the statement made earlier concerning the channel irregularity and it illustrates that the channel is sinuous, as the value is far from zero which is standard for elongated streams.

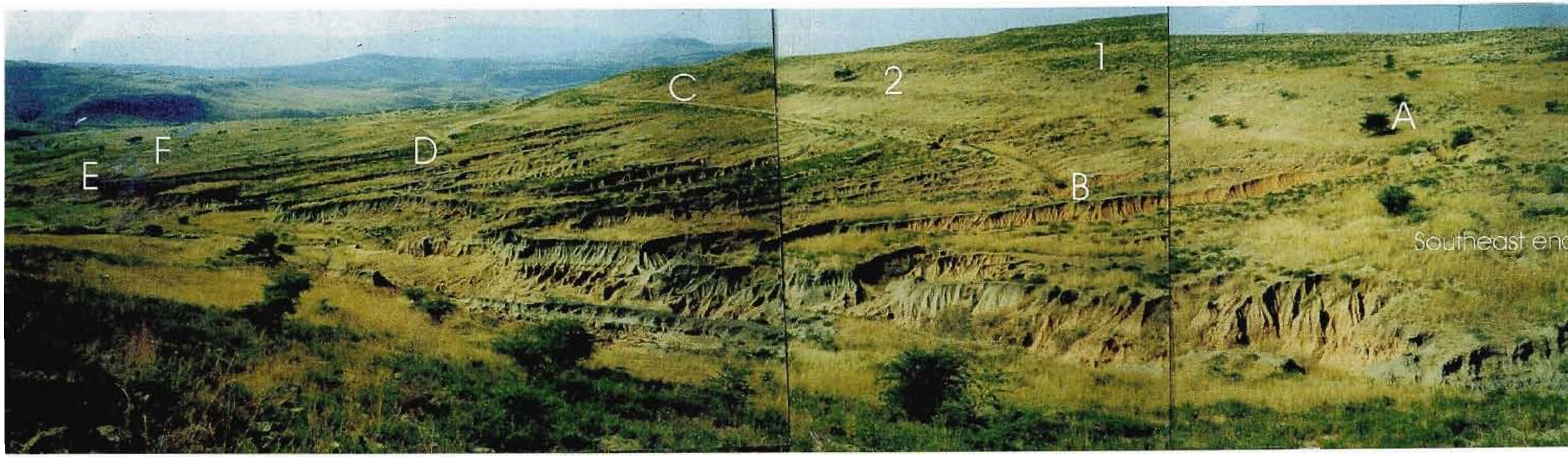

Fig. 5.5.1. A = acacia tree
B = furrow "C's" - water disposing point
C,D & E = furrows
F = footpath/stock trail
1 & 2 = natural terraces

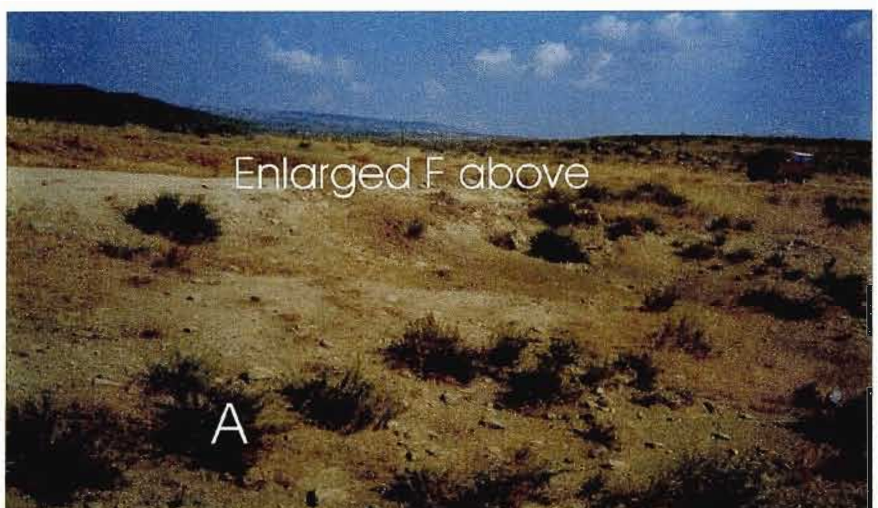

Fig. 5.5.2. A = scrub(vegetation)

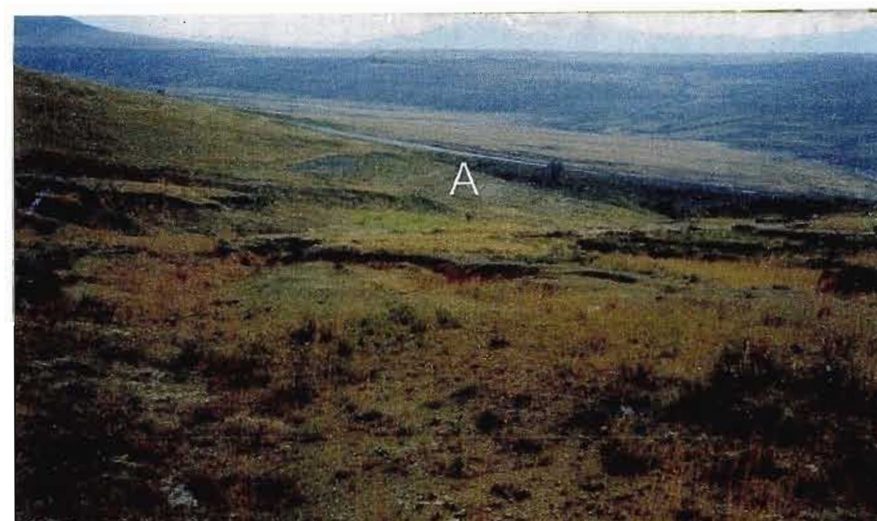

Fig. 5.5.3. A = slopes exposed to erosion during road construction

Figure 5.5 Chani Site

5.1.2. The Chani Catchment

We will now consider the surrounding environmental characteristics of the Chani site. Firstly, the existing vegetation is no longer the result of natural factors only. It is more of a product of veld utilisation patterns by subsistence farmers. The whole of the Chani area is stunted with acacia bush trees and scrub. This is most dominant on the north facing slopes of the catchment, especially near the once cultivated fields which are now laid fallow or abandoned (see Fig. 3.6, p90). Grass species vary in this site from the Tall Sweet Veld to *Cynodon dactylon* (Ahmed and Karar, 1996). Within the catchment, some upslope areas display heavily eroded conditions. From the roadside upslope, there is clearly defined transition of gradual increase in the heavily grazed vegetation cover from 30% (south - hill top) through to 70% towards the valley bottom. The dominant species on this transition is the non- palatable scrub and shrubs (locally known as *isiralarala*).

Secondly, the northwest facing valley side has two natural terraces (see labels 1 and 2 of Fig. 5.5.1). It seems as if during road construction more artificial terraces were furrowed across the slope (Fig. 5.5.1.C, D, E). Unfortunately, these furrows have led to an intense erosion problem at points where the concentrated runoff is disposed of (for example around labels B and E in Fig. 5.5.1). The first furrow (Fig. 5.5.1.C) lies at about 5 m from the upslope fence line. Two more furrows are traceable further down slope towards the National Road (N2). Other furrows are at inconsistent intervals of 105 m, 67 m; 117 m and 39 m, towards the downslope fence line near N2 road (Fig. 5.5.1.D and E). Of these three furrows, the top one has an average maximum width of 16.0 m. The middle one is 5.5 m whereas the lowermost one is 6.3 m wide. The average depth for all three furrows is less than 0.5 m. This extent and magnitude of the furrow depth is comparable to the arbitrary transition depth size between a gully and a rill. This implies that the contribution of these furrows to soil erosion in the area is more or less the same as that of the different erosion forms, mentioned earlier. As a result a lot of damage, associated with these furrows, is observable on the soil, particularly at the confluence of the furrows with the main gully system (Fig. 5.5.1.B and E). This is not surprising since this part is the focal point of the maximum flow collected from and across the valley side. These furrows are actually serving a purpose, namely, they were ploughed to redirect all of the eroded material from up slope, along the contour line, into the main gully. The plan was to trap the eroded material as it passes the gabions set up at the last section of the gully. However, this is one of the causes of accelerated erosion in this gully, as there have been no check dams constructed in the upslope sections of the main gully. The result has been that parts of the catchment surrounding the rehabilitated gully section are continuing to degrade. This happens beyond the gully itself; in other words, new gullies develop in the surroundings (Fig. 5.5.1 around labels B,D,E).

From the above, it is clear that soil loss at Chani has a twofold origin. Firstly, it is due to lack of proper provisions to ensure an effective maintenance of human land use practices. These include poorly designed roads, lack of design and control of footpaths, and stock trails - across and down the area - (Fig. 5.5.1-.2.F), lack of maintenance of gabions, poorly maintained terracing of the upper and middle slopes (Fig. 5.5.1.C-E), overutilisation of vegetation resource, and no consideration given to protect and to allow for recovery time for rehabilitation of the affected areas. It is evident at this site that degradation will progress rapidly. Footpaths along the spur, connecting the nearby villages to the bus stop have created channels for water during storms (Fig. 5.5.2.F). Added to their number of arable lands in the surrounding area have been abandoned (see Fig. 3.6, P90). Another major cause of soil loss is that the area is used for grazing and periodically stock is found grazing at the stabilised gully floor section, as well as on the already badly degraded slopes.

Along the furrowed hillslopes, rill erosion and eventually gully erosion have become worse. These changes are estimated to have started from 1982 to the early 1990s, the period during which the national road (N2) was reconstructed or was improved.

Higher up the hillslope, remnants of a fence is the only evidence that suggests that the gully was once fenced off. The technique failed when the fence began to collapse and it is clear that there was no maintenance facility in the plan.

The situation described above begins to indicate how human activities through land use practices have resulted in the failure of the gabions to curb soil loss. Road construction created slopes, which are steeper than the surrounding gradients. This has led to the removal of the topsoi, and this exposed infertile soils (Fig. 5.5.3.A). The consequences of this practice have been a change in vegetation, and a sequential scenario ranging from tall grass, scrub/shrubs to bush across the catchment. This will be discussed further in the next section.

In a similar manner to Brooks Nek, generally the Chani subcatchment is small with a circular shape that collects the drainage into the centre and erodes the valley sides in the process. The bifurcation ratio was calculated as 2.23. The mean stream length was 0.6 km, with side rills and gully tributaries taken into consideration. The elongation ratio was 0.3, suggesting that the channel is elongated, (that is, approximately linear) as it is closer to the value of zero. The implication is that, based on the consideration of the rate of energy transfer, a sinuous channel is likely to be less erosive than a linear channel. Soil for this area is broadly categorised as sandy loam (The Republic of Transkei Report, 1976). Between Fig. 5.5.1.D and E, the soil is completely removed and some carbonate nodules remain on the surface.

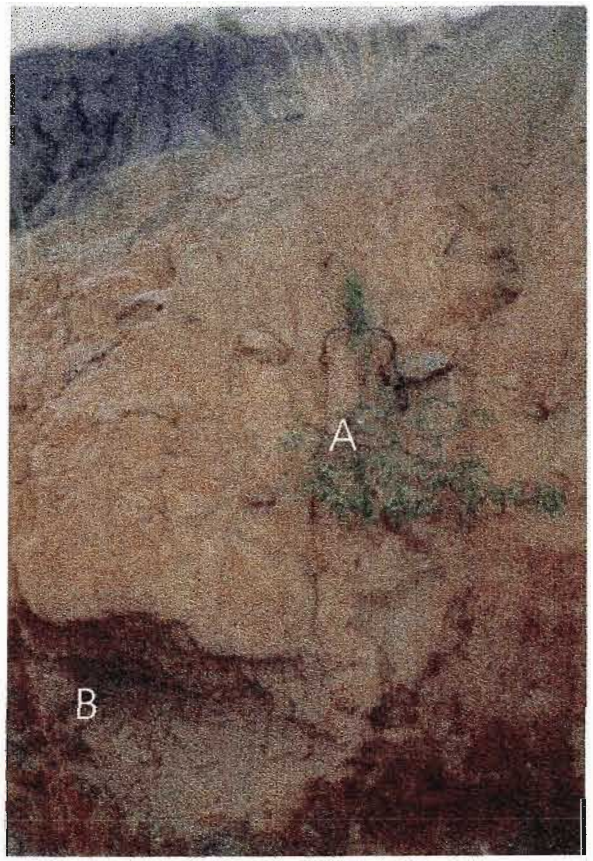

Fig. 5.6.1. A = overhanging vegetation resisting erosion
B = undercutting by fluvial action during high water level

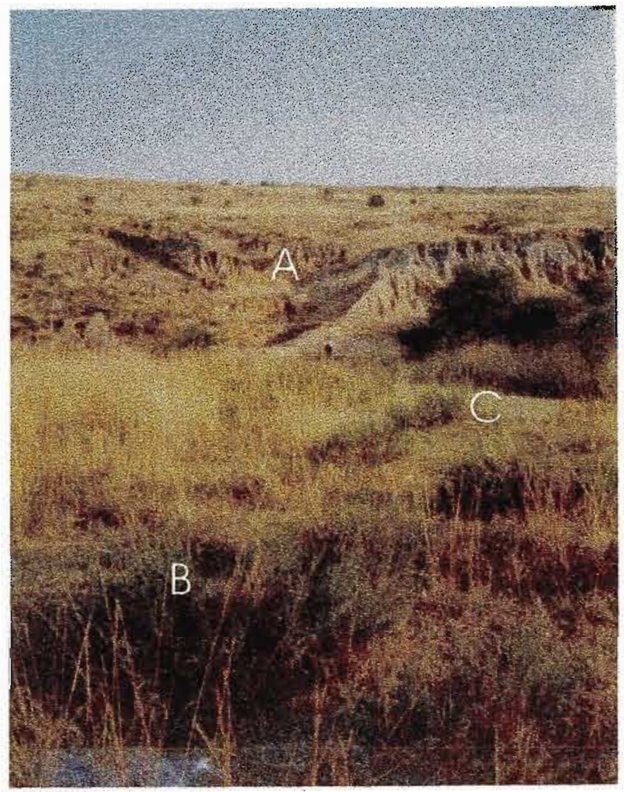

Fig. 5.6.2. A = badly eroded furrow H_2O disposing point
B = vegetation success on silted parts
C = silted up slope end of the gabion

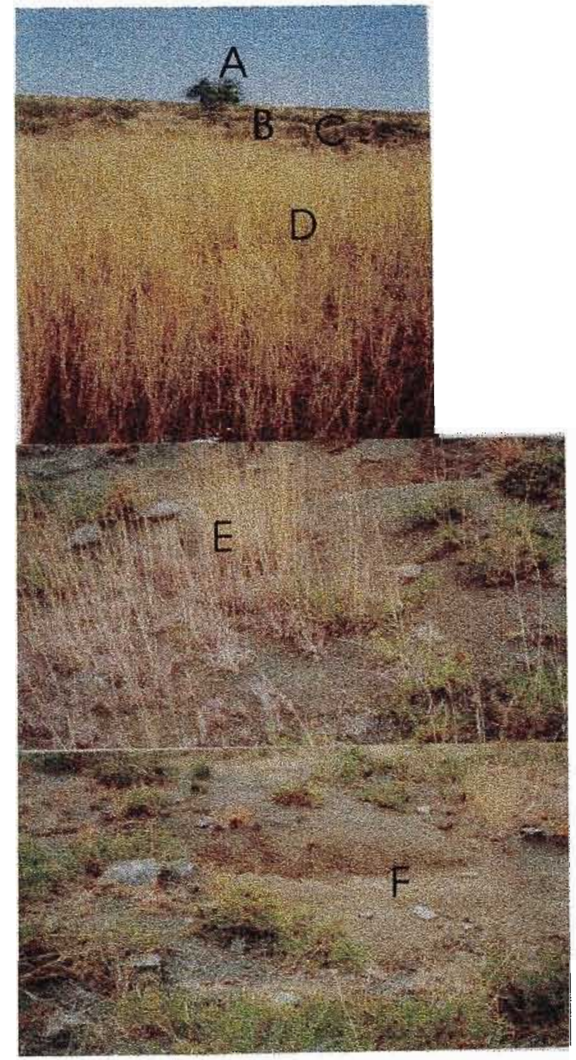

Fig. 5.6.3. A = acacia tree
B = fence line: vegetation type transition and good grass vegetation
C = break of slope and fence
D = tall grass (good condition)
E = heavily grazed grass
F = bare land - vegetation deteriorated

Figure 5.6 Chani Site

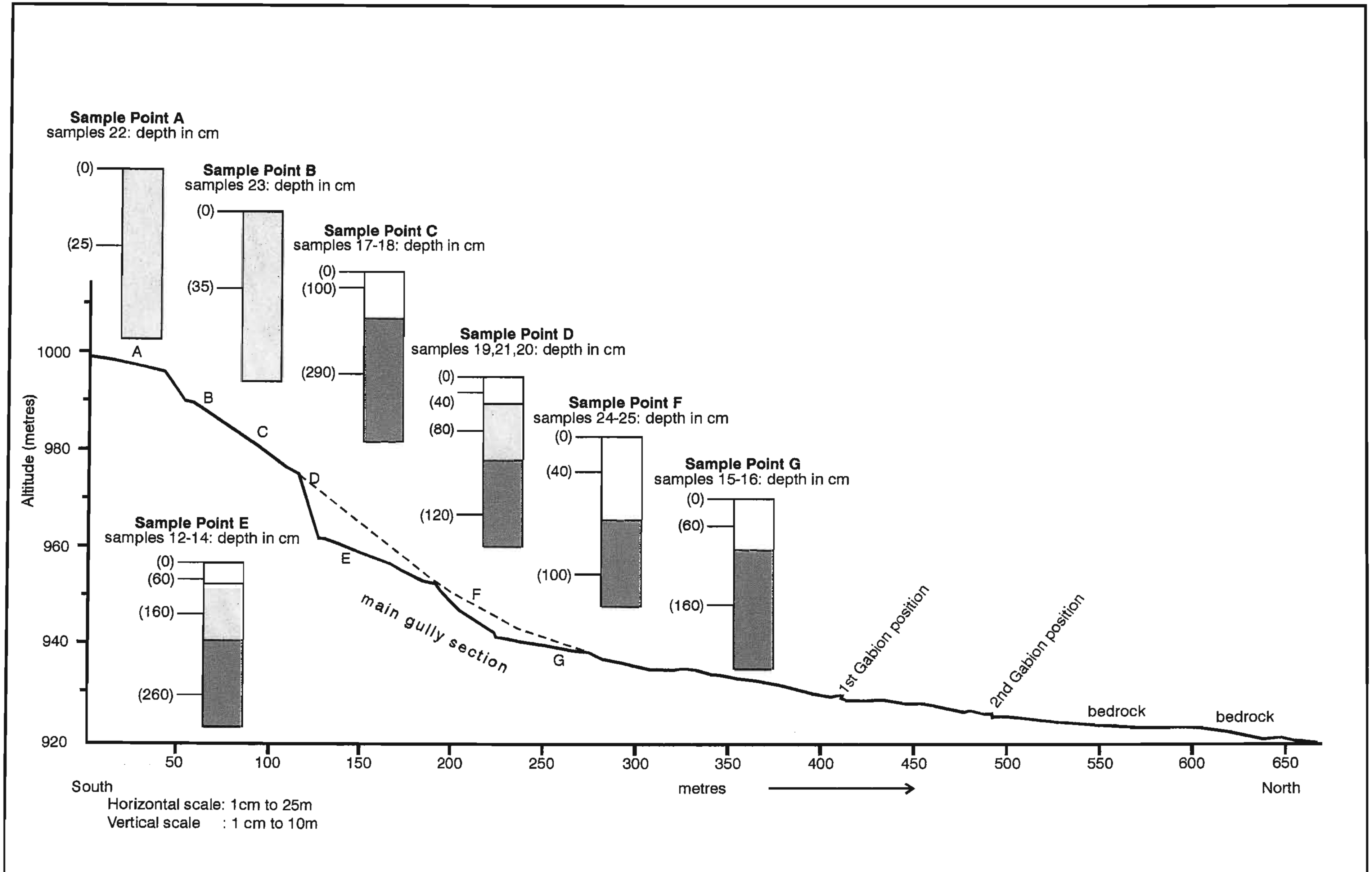

Fig. 5.7: Profile Section of Chani Study Area

ıble 5.8: Characteristics for the Cross-sections at the Chani Site

ction	1	2	3	4	5	6	7	8	9	10	11	12	13	14
pe Length (m)	40	12	38	22	10	37	22	37	56	70	62	84	105	70
'S Reference	30°51'S;29°02'E	-	-	-	-	-	-	-	-	-	-	-	-	-
getation	50 Scrub	50 Scrub, grasses	25 shrub	40 Shrub	80 Tall grasses	-	-	-	-	-	5 grasses	5 *Cynadon*	20 *Cynadon dactylion*	30 Srcub
ver (%)	shrub - *isiralarala*	shrub - *isiralarala*	Acacia bush	grasses	*Cynadon dactylion*							*dactylion*	shrub, scrub	shrub - *isiralarala*
pect	N	N	NNW	NNW	WNW	WNW	NNE	N	N	N	N	N	NE	N
an Altitude (m)	1 000	990	990	980	980	975	970	965	960	955	950	945	935	925
an Shear Strength	-	-	-	-	15 kPa	-	-	-	-	-	25 kPa	10 kPa	-	-

On the northwest facing slope, soil characteristics - from the beginning of the top transect along the straight line gully section - displayed a topsoil of the order of 25 cm deep, which increased to about 60 cm further down towards the fence that fences off the gully system (Fig. 5.6.1-.3 and Fig. 5.7).

The first transect is captured well in figures 5.6. and 5.7, and this top section forms the crest slope form of this valley side. Measurements - started just by the dirt road side (Fig. 3.6, p90) and the slopes - display a heavily eroded upper end. Also there is a clearly defined transition of gradual increase in the heavily grazed vegetation cover (Fig. 5.6.3.B), from 30% on the road side end (south-hill top) through to 70% towards the still intact section of the fence (Fig. 5.6.3.A-D). A further noticeable deterioration of vegetation cover is observed towards the main gully head (Fig. 5.6.3.E-F). This slope is dominantly stone covered and, therefore, has very little soil left to be eroded. The deeper soil section is found nearer the fence and this pattern suggests that by the fence line is a point of colluvial and alluvial accumulation. Pebble characteristics in this area suggest also that the material was plucked from the upper part of the crest by fluvial processes. An improvement in vegetation cover is noticeable towards the road, although there are parts that are deeply eroded (Fig. 5.6.2.A-C). Table 5.8 details the soil characteristics according to cross-sections made and it is followed by an explanation of each of the results (see Fig. 5.8, page 150 as well).

From the previous transect to the break-of-slope, vegetation cover has dropped to 20%, displaying a sharp boundary of mainly bare surface, with colonies of grasses mingled with stones and thin soil. The soil depth (25-40 cm) is shallow. According to Morgan (1995), shallow soils have depth ranges of 20 to 50 cm. The slope has natural terraces with gradients ranging from a minimum of 15^0 and a maximum 19^0 which, according to Morgan (1995), is 'strongly sloping'.

The third transect is mainly bare of vegetation with shrub coverage of 20%. Along the rills is a collection of rock fragments and a number of acacia shrubs growing on the edges of exposed rocks. Rock fragments cover 35-40% of the area. The slope is also furrowed, as in the previous transect, with the soil depth varying but not exceeding 50 cm.

The fourth transect, extending over 22 m towards the fence line, has its first 12 m slope covered by about 75% vegetation. Vegetation cover increases - and acacia bushes of about 2 metres tall have grown in the midst of about 1.5 metres tall grass species - near the fence line (Fig. 5.6.1.A). Thin soils support boulders of 50 x 30 x 40 cm^3 size inbetween the grasses. The last 10 metres to the fence have relatively stabilised shallow, well-aerated soils, of 35-40 cm depth. The soil is well-aerated as compared to soils of the same depth above.

Inside the fence line towards the gully, tall grass covers about 70% of the ground with no signs of overgrazing (Ahmed and Karar, 1996). Further downslope, vegetation coverage decreases and varies between 60 - 65% per square metre quadrate (see Fig. 5.6.1). Stones and rocks begin to sort according to size and most of the rocks are partly buried, with more soil accumulation on the downslope end. Transect 5 extends to the first furrow that was ploughed across the slope. This furrow rechannels runoff and all the eroded material to the main gabioned section of the gully system (Fig. 5.6.1.B-E). This part marks the beginning of the main gully system (Fig. 5.7). It is not possible to access the gully system from this point.

From the gully head (6th transect), both longitudinal profile and cross-section measurements are made by using the channel meanders as guidelines. Boulder measurements had to be carried randomly, that is only in places that were covered by rock outcrops and boulders. This transect begins at about 152 metres from the crest. The gully head has eroded to the underlying rock material. Big boulders of 1 m x 1 m x 0.75 m are hanging on the gully head wall and some have fallen and scattered over the exposed bedrock on the gully floor. White salts can be identified on the rocks parts that form the water course during heavy rain. Gully head erosion is not possible because boulders cover the face of the headwall. Undercutting beneath and around these boulders has left miniature plunge pools. The soil layers framing the channel bankwall range from 5 cm on the start of the transected end (underlaid by boulders) to 50 cm towards the end of 37 metre long meander. The shallower soil layer has been washed from the abandoned farmland and it has a dark blackish colour. The opposite bankwall has three distinct soil horizons that range from grey at the top (40 cm), dark grey in the middle (80 cm) and a red layer adjoining the bedrock (120 cm).

The 7th gully transect has an average gully depth of 4.5 m but with no clearly defined horizons. This is clearer on the east facing slopes (that is, the fallowed field side). Bankwall collapse, which occurred between November 1995 and March 1996, is evident on the gully floor. On the opposite banks, horizons are identifiable but the soil colour is more mixed than in the previous cases. A very dark top layer (part of A-horizon), 100 cm thick overlies a 25 cm thick dark greyish layer. Beneath the latter is the reddish layer of about 3 m thick.

The gully bank at transect 8 is 5 m deep. The floor is of stepped bedrock which has a series of small waterfalls that drop 48 cm to their small plunge pools. Examples of vegetation resisting environmental degradation are found here and there (Fig. 5.6.1.A). Undercutting on the gully sidewalls is also common (Fig. 5.6.1.B). It is a threat to the vegetation species. There are traces of the A-horizon lying on the bedrock floor from the sidewall collapse. The soil layer is mainly thin with no distinct horizon on one side but, on the other, horizons remain the same as that of the previous transect.

Table 5.9: Soil Horizons at the main Chani gully

Horizon	Average Thickness	Colour
O	0-45 cm	Red
A	45-95	Very Dark Grey
B	95- 175 cm	Dark Grey
C	175-295 cm	Grey
R/rock cliff	295-555 cm/805 cm	Red

Gully depth at the transect 9, which extends more than a 56 m slope, has increased to 8 m with distinct horizons on the gully walls (see Table 5.9). Carbonate nodules, reported earlier, were dominant between the convex crest and concave pediment slopes adjacent to this part of the main gully section.

The 10th transect that extends more than a 70 m length, depicts continuous salt deposits on the bedrock. This has the potential to corrode the bare rock gully floor in the interim period (autumn through winter) until the next rainfall comes in spring. The gully depth drops to 5.5 m in this area and the channel bedrock becomes very rugged.

Extending to the first gabion point, a 62 m long stretch has a uniform gradient of 12° and a 3 m deep gully bankwall on one side, whilst very gentle slopes are found on the opposite gully side (Fig. 5.6.2.A). The gabion itself is constructed with a 5 m height, as measured from the gully side wall. The top end of the gabion is silted to the brim, so that no further siltation is necessary or even possible. Vegetation, especially grass, is thriving on the silt and the whole area is showing signs of stabilisation (Fig. 5.6.1.B). At the bottom end of the gabion, siltation is to the level of the first gabion constructed step or level (50 cm thick silt). Although the second step of the gabion has begun to break up, the structure is still effective and rehabilitation appears to be (tending towards) self-sustaining.

The 12th transect extends over an 84 m long stretch to the 2nd gabion. The soil is 1 m deep to the bedrock (augured). From the second gabion's top end, the *Cynodon dactylon* grass has grown naturally to its full soil binding potential. Gabion 2 has a 3 m depth to the channel floor, towards the N2 (Fig.5.7). On the flank of this section, the bank wall side has the sequential series of top dark grey to grey to red, the bottom of which is covered by (at the very top) silt deposits (Fig.5.6.2.A area).

The 3rd gabion, which starts from the second gabion, has a 3^0 slope rise over a 40 m stretch. Pyramid-like remnants of the heavily weathered and eroded grey layers of about 7 m thickness are observable in the surroundings (Fig. 5.6.2.A area and up towards the gully head).

The last transect (14th) lies between the 3rd gabion and National road bridge, more than a 30 m distance. The bedrock is totally exposed on a bank width of more than 40 metres. The gully bank wall is 5 m deep on one side, while the other side has no pronounced boundary between the channel floor and the bank wall; this is to say, the bank is continuous and it has flattened.

Table 5.10: Width:depth sample inside the main gully (about 970-930 m.a.s.l)

Sampled Points / **Variables**	1	2	3	4	5	6	7	8	**Means**
Mean Maximum Depth (m)	15.70	26.60	1.10	10.0	3.10	23.0	3.95	7.90	11.3
Mean Minimum Depth (m)	0.37	0.20	0.60	1.80	1.12	0.20	0.75	0.36	0.65
Average Depth (m)	8.0	12.9	0.85	5.9	2.11	11.5	2.35	4.13	5.97
Width:depth Ratio	1.2:1	1:1.7	6.6:1	1.4:1	1.2:1	1.1:1	2.9:1	6.4:1	2.7:1
Mean Bed width (m)	6.3	4.5	3.3	0.99	1.0	1.5	0.85	12.7	3.89
Mean Bank width (m)	13.6	10.6	8.0	15.8	4.0	24.0	12.8	40.1	16.11
Average Width (m)	9.95	7.55	5.65	8.4	2.5	12.8	6.83	26.4	10.0
Shape Factor 1	2.2	2.4	2.4	15.96	4	16	15.1	3.2	4.1

As indicated in Table 5.10, inside the same main deeply eroded section of the gully, points have been sampled for detailed measurement of depth and width. Secondly, the straight nature of the gully/channel course itself permits this exercise (whereas at Brooks Nek, the conditions are not conducive for (similar) detailed measurement). The mean bed width ranges between 1.0 and 12.7 metres whereas the mean bank width is between 4.0 and 40.1 metres. The mean minimum depth range is between 0.2 and 1.8 metres whilst the mean maximum depth lies between 3.1 and 26.6 metres. The average depth ranges are between 0.9 and 12.9 metres whereas the average width is between 2.5 and 26.4 metres. The average depth is 6.0 metres and average width is 10.0 metres, whereas the mean width:depth ratio is calculated at 2.6:1 (Table 5.10).

Table 5.11: General Characteristics of Soils at Chani Sample Points

Slope Length	Altitude (m)	Sample No.	Depth (cm)	Munsell Colour	Structure	Stability	%Moisture	
							Summer	Winter
52 m	1000	22	0-25	2.5YR 3/3 Dark Olive Brown	Crumby	Weak	1.9	1.0
60 m	990	23	0-35	10YR 4/4 Dark Yellowish Brown	Crumby & Stony Powdery	Weak	4.9	5.3
37 m	980	19	0-40	7.5YR 4/4 Dark Brown	Subangular Blocky	Moderate	2.4	2.1
		21	40-120	2.5Y 4/3 Olive Brown	Subangular Blocky	Weak	3.4	2.8
		20	120-240	5YR 3/1 V. dark grey	Subangular blocky	Strong	2.6	2.0
20 m		17	0-100	10YR 3/2 V. dark greyish brown	Crumby	Weak	1.9	1.5
		18	100-290	10YR 4/4 Dark yellowish brown	Blocky	Strong	2.8	2.6
40 m	950	12	0-60	5YR 3/1 V. dark grey	Crumby	Strong	3.4	2.5
		13	60-220	10YR 3/1 V. dark grey	Crumby-blocky	Moderate	2.8	1.8
		14	220-480	5YR 4/6 yellowish red	Blocky	Strong	4.9	5.2
86 m	960	24	0-40	2.5Y 4/4 Olive brown	Subangular blocky	Weak	6.4	4.8
		25	40-140	10YR 3/2 V. dark greyish brown	Subangular blocky	Strong	2.9	3.2
62 m	945	15	0-60	10YR 3/6 Dark yellowish brown	Blocky	Moderate	3.0	6.4
		16	60-220	10YR 3/1 V. dark grey	Blocky	Moderate	4.5	4.6

Table 5.11 presents other characteristics of all the soil samples taken at Chani, at the 7 sample points. Soil depth, soil colour, soil structure, aggregate stability and soil moisture content observed in the field, are presented. (Figure 5.7, p135 presented earlier shows more details of the information presented in this Table).

A summary analysis of soil conditions reveals that most of the soils at Chani have a subangular blocky and massive structure. The red horizon appears to be coating a dark colour core soil. The red colour (from the ferralitic rocks uphill) has been washed over the dark, well defined core material at the junction between the badly eroded gullies and the original surface level. The reddish muddy water that washes down hill flows over the dark grey layer and deposits the red silt over the dark grey surface.

The mean shear strength of the soil is measured at 115 kPa. This suggests that detachability is limited because usually detachability decreases exponentially with increasing shear strength (Morgan, 1995).

Table 5.12: Characteristics of the individual Sola at Chani gully

Horizon	Average Thickness	(Munsell) Colour
A	20 cm	Brown
B with A eroded	90 cm	Dark Brown
B with A eroded.	100 cm	Red
		Red (chroma 2/2)

Table 5.12 presents the results of the observation of sola differences in soil colour, with increasing depth within the sampled gully section.

If we look at the problems associated with structural erosion control measures employed in the Chani area, a number of shortfalls are clear. As mentioned earlier, the gully stabilisation process could be dated to the five-year-plan of the old Transkei Republic, which extended from 1978 to 1982 (Sotobe, 1989). Evidence from Sotobe's report confirms that the bridge that is found next to the gullied section of this area - as well as the other nearby uMzimvubu River bridge - were built and completed within this period. Some parts of the rehabilitated gully section show a great deal of effectiveness in the rehabilitation measures that were taken. For example, the gully floor has stabilised to such an extent that vegetation is growing on the fully silted top end of the gabions (Fig. 5.6.1. E label area).

On the valleysides, however, evidence of prominent shortfalls include the lack of provisionary measures for the intermediate delivered sediments from the mid-slopes. The joining gully tributaries have no control or no velocity reduction structures, like dams which are necessary to make siltation possible. Instead, ineffective and poorly planned furrows promote erosion through concentrated flow. Gabion construction stands in the way of the constant attempt of the whole catchment to erode all the soil, in order to reach a balanced state. Similar attempts to enhance erosion control by cutting furrows across the depression, to redirect water from upslope into the existing main channel and thus to contribute to headwall retreat, turned out to be detrimental, in a similar manner as occurred at Mqanduli (Beckedahl, 1996). The lack of integrated catchment management and the lack of a multi-disciplinary approach to planning, have resulted in the failure of many initiatives to reduce erosion. The poor land use planning could be blamed for the former government's incomplete rehabilitation programmes in the area. 'Betterment planning' has cost some farmers their valuable arable fields. Across the contours, at almost 90°, a series of rills have developed on land that was once arable (Fig. 3.5, p89 and Fig. 3.6, p90). In many cases, rills have progressed to the early stages of gully development.

The field characteristics of the two study sites have been discussed. The next section focuses on the results of the laboratory analysis of the soil samples taken from the two sites.

5.2. Laboratory Results

The numbering sequence of samples discussed here corresponds with those of the previous section. Similarly, tables are presented as a continuation of tables from the previous sections in this chapter. Laboratory results are divided into, firstly, the physical properties, such as particle size analysis, organic matter percentage contents of soils and other materials, and secondly, the soil chemistry. The analysis is in accordance with Cation Exchange Capacity (CEC), pH, Cation Exchange (CE), dispersion percentage and Exchangeable Sodium Percentage (ESP.

5.2.1. A comparative presentation of the soil physical features

The dispersion test has been done to see if soils, in the sites studied, conform to the findings that the amount of clay dispersion could be used as the most suitable measure of structural stability for vertisols and probably other clay soils (So and Woodhead, 1987; So and Cook, 1993). Baize (1993) concurs with So and Woodhead (1987) who found that the amount of clay dispersion is strongly affected by the amount of Sodium in the soil.

Table 5.13.1: Soil Mechanical Properties at Brooks Nek

Sample No.	%Clay	%Silt	%Fine Sand	%Medium Sand	%Coarse Sand	%Dispersion	%Organic Matter
1	42.82	45.04	11.28	0.63	1.37	10.28	4.16
2	67.38	22.16	8.75	1.00	0.75	4.53	2.06
3	46.32	33.70	11.38	4.81	3.80	2.82	5.65
4	56.20	27.26	11.91	1.80	2.20	6.41	1.33
5	58.94	26.53	7.10	3.05	4.36	4.15	2.86
6	51.82	37.06	8.05	1.45	2.00	10.95	3.33
7	42.33	44.72	10.40	1.15	1.40	14.01	3.19
8	28.29	56.84	10.45	1.80	2.64	23.46	0.80
9	63.94	28.33	5.00	1.49	1.24	10.96	5.28
10	54.32	41.81	3.95	0.10	0.15	12.23	0.26
11	63.15	18.52	10.51	3.91	3.91	6.03	0.54
26	57.40	28.70	9.00	2.83	2.10	2.65	4.96
Mean	52.73	34.20				9.02	2.87

Table 5.13.1 presents individual physical characteristics of soils by sample number for Brooks Nek; Table 5.13.2 details the same data for the Chani study area. Starting with Brooks Nek, the dispersion ratios for all samples range from 2.82 to 23.46%, with the percentage organic matter content of the order of 0.26 to 5.65 (see Table 5.13.1). Dispersion plays a central role in the hydraulic characteristics of the surface seal. As clay measurements need to be done under wet conditions, due to shrinking behaviour when drying, wet sieving has been

carried for both sites. Clay proportion in most samples is greater than those of silt and sand.

Table 5.13.2: Soil Mechanical Properties at Chani

Sample No.	**%Clay**	**%Silt**	**%Fine Sand**	**%Medium Sand**	**%Coarse Sand**	**%Dispersion**	**%Organic Matter**
12	29.16	44.31	21.00	2.79	2.74	14.55	1.60
13	42.95	35.00	14.70	2.85	4.50	11.39	1.60
14	42.14	36.40	19.60	1.01	0.86	15.09	0.14
15	36.17	36.44	23.75	1.77	1.87	13.62	0.68
16	33.64	37.42	19.80	4.15	5.00	16.74	2.20
17	32.28	39.11	21.80	2.93	3.88	18.46	1.33
18	37.57	40.58	19.10	3.75	3.75	20.25	0.07
19	38.22	25.03	31.90	2.25	2.50	15.66	0.40
20	42.45	33.07	17.66	2.96	3.86	30.17	1.53
21	41.05	33.06	20.80	1.80	3.30	14.22	0.80
22	41.91	38.34	12.90	3.32	3.57	9.49	3.33
23	40.48	37.18	14.70	3.35	4.30	9.09	0.66
24	22.16	42.68	21.50	6.00	7.7	27.96	1.46
25	26.48	58.15	10.75	1.49	3.14	24.05	1.99
Mean	36.20	38.34	-	-	-	17.20	1.27

It should be noted that differences in the number of samples whose clay percentage is below or above the mean do not vary much.

Table 5.13.2 for Chani illustrates that the soil samples have a dispersion ratio ranging from 9.09 to 30.17% with the percentage organic content lying between 0.07 and 3.33. The majority of samples have the highest percentage proportion of clay, as compared to the percentage of silt and sand. Most of the clay rich samples have a percentage component greater than the clay component mean value. Also, among the physical characteristics tested, is the particle size analysis. The intention is to provide the textural features of the soils from both sites. Appendices B-1 and C-1 detail the particle size characteristics.

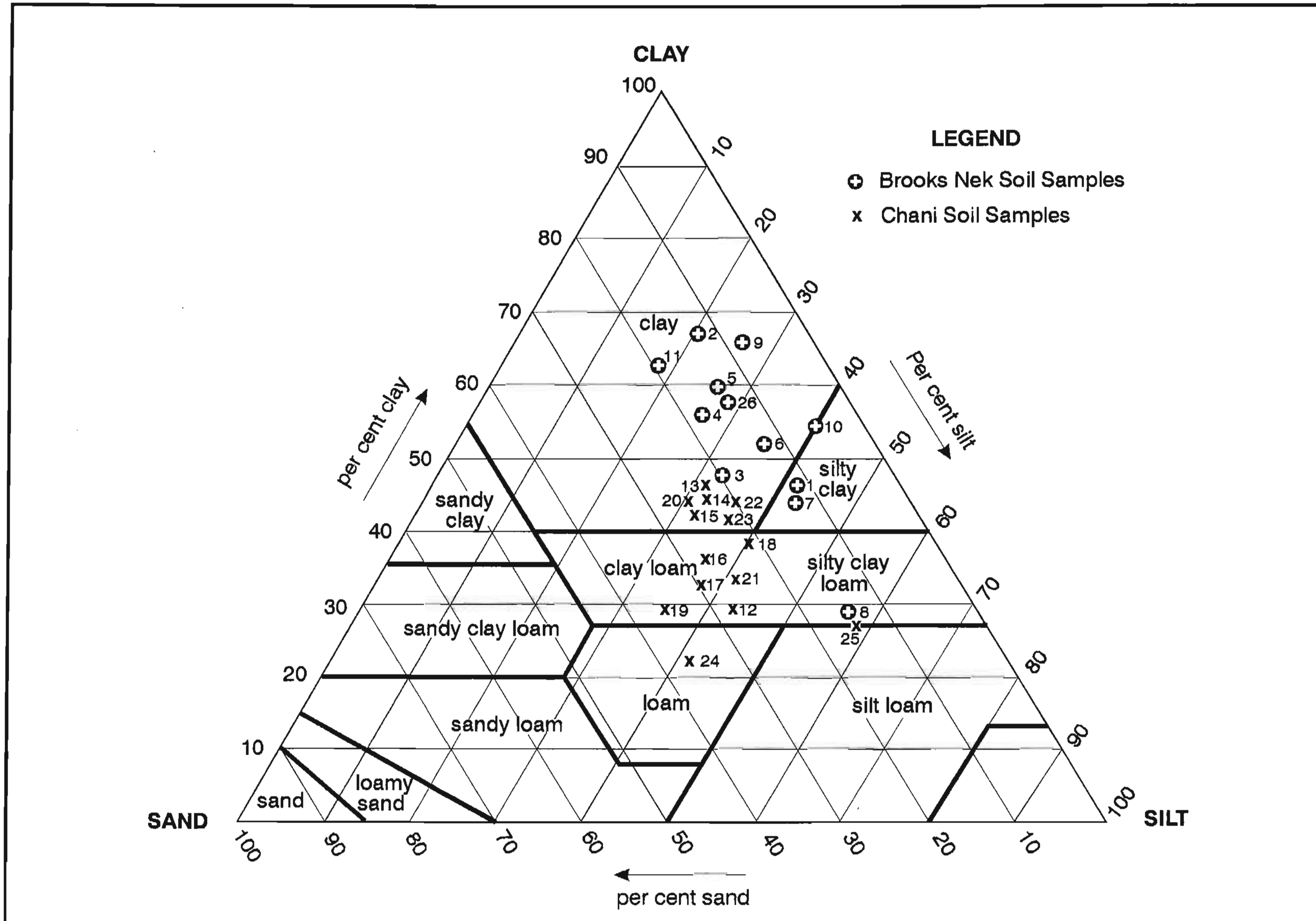

Figure 5.8: Texture Plots for Soils Samples from the Two Study Areas

A diagrammatical comparison of the textural analysis of the soils by study area is made in the form of the percentage of clay (<0.002 mm), silt (0.002 mm to 0.05 mm) and sand (0.05 to 2.0 mm) in Fig. 5.8. At Brooks Nek, the textural range is between clay, silty clay and silty clay loam. The break down shows three samples falling under silty clay, one under silty clay loam (sample 25) and the majority (of eight) falling under clay, on the Triangular textural chart (Fig. 5.8).

At Chani, soil samples range from clay to clay loam with only one sample (sample 24) showing characteristics of a loamy texture. Six samples fall under clay, one is loamy, six are clay loam and one is silty loam.

Although the physical characteristics of the soils at the study site have been presented, it is important that the influence of chemical reaction of soil elements is taken into consideration, especially when such soil physical properties as stability of its structural units, are examined. The same effect, together with that of minerals in soil parent material, is extended to particle size distribution, which ultimately governs the soil's drainage characteristics. Another important factor is that of organic matter which influences the water retention potential of the soils. The next section analyses the chemical aspects of soil characteristics at the study areas.

5.2.2. Soils Chemical Characteristics and Discussion

Field sampling and laboratory preparation for chemical analysis - to determine the CEC, electrical conductivity, pH, organic carbon, ion exchange properties, Sodium Adsorption Ratio (SAR), ESP and other related chemical attributes - have been carried out following the standard methods contained in Uehara *et al.* (1985). In determining which tests to make, options outlined by Baize (1993) in conjunction with the guidelines outlined in the United States Dept. of Agriculture (USDA) have been followed. The actual chemical tests have been carried by the Agronomy Department at the University of Natal in Pietermaritzburg, making use of the methods outlined in the USDA document titled 'United States Dept. of Agriculture Diagnosis and Improvement of Saline and Alkaline Soil' (undated).

The CEC of the soil, that is cations held by electrostatic forces on soil particle surfaces to balance the negative charge, has been tested to determine whether the observed soils have high or low CEC values. In addition, CEC assessment gives an indication of the levels of the exchangeable cations such as Calcium (Ca), Magnesium (Mg), Potassium (K), Ammonium (NH_4) and some exchangeable cation such as Sodium (Na), Hydrogen (H) and Aluminium (Al) being the most critical (Dent and Young, 1981). Sodium is the determining factor of soil salinity whereas Hydrogen and Aluminium are associated with the acidity of soils. The CEC can be summarily referred to as the measure of the soil's ability to retain and supply plant nutrients. In both cases, the relationship is direct. In a sense, the level of CEC of mineral soils indicates a level of the storage capacity of plant nutrient elements. For example, a high CEC is an indication of high plant nutrient storage. An arbitrary breaking point between high and low CEC level is suggested at 10 me/100 grams of soil with more than 30-40% clay (Buol *et al.*, 1980). The general range of soil CEC is between 2 and 60 cmol/kg and this range depends on soil type and humus content of the soil (Rowell, 1994). For example, 3% humus in a soil contributes up to 3 cmol/kg to the CEC. But this depends on the characteristics of pH, soil solution concentration, interaction of humus with clays and (to a lesser extent) sesquioxides, and on bonding (Rowell, 1994; Cresser *et al.* 1995). Humus on neutral soils can, however, be up to about 100 cmol/kg. Therefore, this could contribute significantly to the particular soil's CEC.

With regard to clays, Cresser *et al.* (1995) contend that on uncontaminated soils, a soil with smectite clay (100 cmol/kg) would have a CEC of 40 cmol/kg soil. The contention is based on broad guidelines, and it takes into consideration the many other factors influencing the clay values. When the link of soil nutrient elements and clay amount is made, based on these broad guidelines, the expected amounts of the CEC on soil rich in Mg and Ca, varies within less than 10% of the CEC in very acid soils. On the other hand, Al and H vary between zero in neutral soils and more than 90% of the CEC in very acidic soils. Generally, Na is almost zero on leached soils, but may be up to 50% of the CEC in sodic soils whilst K may be up to only 5% of the CEC. The Ca:Mg ratio vary between 5:1 and 1:2 (Rowell, 1994). For the purposes of further discussion, results for this study are (from this point onwards) presented in tabular as well as in a comparative format.

Table 5.14.1: Soil Chemistry at the Brooks Nek Site

Sample No.	pH H_20	pH KCl	Saturation%	EC mS cm^{-1}	Na meq/1	Ca meq/1	Mg meq/1	K meq/1	ESP	SAR	CEC cmol/kg soil
1	5.95	5.05	50.62	486.0	2.10	1.29	0.91	0.43	3.62	2.00	14.74
2	4.64	4.19	80.03	185.0	0.52	0.44	0.58	0.09	4.96	0.73	4.59
3	4.90	4.17	53.71	189.0	0.60	0.45	0.63	0.10	4.09	0.82	6.58
4	5.31	4.61	67.21	135.0	0.32	0.36	0.48	0.05	3.46	0.46	7.46
5	5.07	4.22	68.27	167.0	0.43	0.43	0.34	0.39	5.33	0.69	4.90
6	5.39	4.93	60.17	752.0	1.04	2.73	3.29	0.19	2.31	0.60	10.58
7	5.51	4.89	58.38	762.0	1.42	2.91	2.95	0.28	2.69	0.83	9.74
8	5.64	4.74	46.33	758.0	2.11	1.85	2.61	0.35	3.42	1.41	7.95
9	5.64	5.01	91.48	497.0	0.68	1.64	1.80	0.63	1.96	0.52	16.76
10	6.03	5.12	112.42	211.0	0.80	0.53	0.61	0.19	2.01	1.06	22.89
11	5.77	5.42	85.14	132.0	0.42	0.37	0.35	0.10	3.04	0.31	10.63
26	5.02	4.10	63.48	178.0	0.42	0.48	0.42	0.28	4.29	0.63	5.67
Mean	5.41	4.70	69.77	371.0	0.91	1.12	1.25	0.26	3.43	0.84	10.21

The summary of soil chemistry presented in Tables 5.14.1 for the Brooks Nek area, like that of the Chani site, give rise to some contrasting results. At the Brooks Nek site, soil is slightly acidic with pH (5.41) and potassium chloride (KC = 4.7). Measurement of the exchangeable cations, indicates levels of, for example, Na 0.91 miliequivalents per unit (meq/1), Ca 1.12 meq/1, Mg 1.25 meq/1 and K 0.26 meq/1. The EC is 371.00 millisiemens per centimetre (mS/cm), CEC recorded at 10.21 cmol/kg of soil and the mean percent of saturation being 69.77.

Table 5.14.2: Soil Chemistry at the Chani Site

Sample No.	pH H_20	pH KCl	%Saturation	EC mS cm^{-1}	Na meq/1	Ca meq/1	Mg meq/1	K meq/1	ESP	SAR	CEC cmol/kg soil
12	6.39	5.31	36.35	387.0	1.30	1.11	0.86	0.19	2.57	1.31	11.78
13	6.78	5.72	49.85	215.0	0.57	0.82	0.66	0.09	2.95	0.66	11.93
14	6.43	5.42	46.13	553.0	1.72	1.85	1.56	0.13	3.67	1.32	9.28
15	6.81	5.71	43.41	399.0	0.87	1.47	1.39	0.05	4.51	0.73	9.57
16	6.63	5.46	40.76	332.0	1.28	1.08	0.85	0.08	2.48	1.30	13.24
17	6.59	5.43	36.73	253.0	0.86	0.86	0.72	0.05	3.80	0.97	10.47
18	7.24	5.96	40.49	463.0	1.76	1.59	1.01	0.06	4.12	1.54	9.00
19	6.55	5.93	48.13	266.0	4.41	8.81	14.6	0.14	5.36	1.29	9.48
20	6.75	5.57	47.79	326.0	1.10	1.02	0.78	0.15	3.19	1.16	12.77
21	7.05	5.96	60.41	367.0	1.63	0.89	0.72	0.08	3.26	1.86	12.93
22	6.27	5.19	53.31	334.0	1.53	1.01	0.63	0.10	2.09	1.69	13.28
23	6.74	5.27	61.21	174.0	0.57	0.62	0.52	0.08	2.23	0.75	14.15
24	6.26	4.72	41.73	194.0	0.46	0.90	0.43	0.18	2.19	0.56	10.08
25	5.42	4.52	39.28	448.0	1.38	1.27	1.23	0.47	4.21	1.23	5.67
Mean	6.57	5.44	46.10	336.5	1.40	1.66	1.85	0.13	3.33	1.17	10.97

At Chani, parameters presented in Table 5.14.2 show slight differences in natural chemical properties. For instance, the pH at Chani averages to 6.57 and the KC is 5.44. These values, however, are not significantly different from those of Brooks Nek. The mean percent of saturation and EC are less at the latter site. They 46.10 and 336.5 mS/cm, respectively. The Na (1.40 meq/1), Ca (1.66 meq/1), and Mg (1.85 meq/1) content in Chani samples are higher than Brooks Nek (as shown earlier). The K (0.13 meq/1) content is lower at Chani as compared to K (0.26 meq/1). But the CEC (10.97) - although within the same range at both sites - is slightly higher than the CEC (10.21) of Brooks Nek. According to Rowell (1994), although using different units, in saline soils the EC is greater than 4 dS/m but less than this value level for non-saline soils.

SAR and ESP are closely related parameters of soil behavioural characteristics. SAR measures the tendency of the water to increase the ESP of the soil. According to Rowell (1994) and later Cresser *et al.* (1995) if, for example, the soil and water come to an equilibrium, ESP is approximately equal to SAR. This is rated by using the classification limit of sodic soils at ESP (=SAR) 15. According to Dent and Young (1981), an ESP greater than 15 causes unstable structure which inhibits leaching and drainage. Buringh (1979), however, suggests a slight difference in this relationship. An SAR of 12 is regarded as almost equal to an ESP of 15 and if an ESP does not exceed 5, it is not harmful. A value increase that exceeds 5 causes soils to develop poor physical conditions (Shainberg, 1985; Rowell, 1994). High ESP is often associated with an excess of soluble salts and pH values greater than 8.5 whereas Ca dominated exchange complex is found in soils with pH values greater than 5.5.

SAR is a useful measure of Na toxicity level. It explains soil behaviour associated with this problem (Shainberg, 1985; Cresser *et al.* 1995). The critical level is dependent on the ratio of Na to Ca plus Mg in the soil. The relationship illustrates that as salts accumulate, the levels of the SAR (and ESP) increase to critical levels that have adverse effects to soil structure.

ESP is the simplest classification of soil sodicity. For sodic soils the measurements are more than 15% whereas non-sodic soils have less than 15%

(Shainberg, 1985; Rowell, 1994). Although ESP is used to classify soil sodicity, critical ESP values depend on solution concentration and both are taken into consideration, even for water if the water in question is to be used for irrigation purposes. In a sense, the salinity of the water determines the extent of structural damage at a given sodicity level. If soils are exposed to high rainfall, even 3-5% exchangeable Na is enough to cause problems in soil structural behaviour (Rowell, 1994). Within this range, Watson *et al.*, 1984, found that soils with ESP of less than 3% are generally tolerant and cohesive and, in line with Buringh (1979), not harmful. At an ESP of between 10 and 15 soil clays are liable to swell and disperse, causing a deterioration of soil structure (Cresser *et al.,* 1995). According to Shainberg (1985), in soils with very low ESP (<1.0), the mechanical dispersion predominates. Shainberg further explains that storms will not produce runoff on soils with ESP below 1.0. This will lead not only to runoff but also soil erosion if the soil ESP is greater than 4.0. The degree of chemical dispersion depends on the ESP of the soil, with increasing ESP resulting in increasing chemical dispersion.

Results (which have been measured) from a composition of saturation extract for both ESP and SAR in Tables 5.14.1 and 5.14.2 for the two study sites are as follows:- Brooks Nek has the mean SAR is of 0.84 which is calculated from a range of between 0.31 and 2.00, and an ESP mean of 3.43 from a range of between 1.96 to 5.33. This latter range falls within the values of 3% and 7% of ESP, that is to say, the lower and upper limits of moderately dispersive soils. Table 5.13.1 shows the mean value of 9% of dispersion at the Brooks Nek site.

If we consider each of the soil samples: sample numbers 1-5, 8 and 26 have ESP exceeding 3% which suggests, on the basis of the percentage alluded to here, that these soils are not resistant to erosion. The rest of soils (Sample No. 6-7, 9-10 and 11) have less or equal to 3% ESP. Therefore, they are less erosive and are in a relatively good structural condition.

At Chani, the mean SAR of 1.17 is worked out from a range of 0.56 to 1.86 and the ESP mean value is 3.33. The ESP value range is between 2.09 to 5.36 which, like in Brooks Nek, falls within the values of 3 and 7% limits of moderately dispersive soils. Analysis of samples number 14-15, 17-21 and 25 show an ESP exceeding 3%. This shows that the majority of samples fall within the erosivity range. This should also explain the mean percent dispersion of 17.2 (Table 5.13.2). It must be mentioned, however, that these values are not dangerous since they are far below 15, the critical transition point. If values are greater than 3% that is an indication of the soil's intolerance to erosion. Soils sample number 12-13,16 and 22-24 have less than 3% ESP. Therefore, these are less erosive. In addition, the Chani site has some carbonate nodules but no similar features are found at Brooks Nek. This could be another explanation for the overall slight differences in soil characteristics in these two study sites. Moreover, they have the potential to strengthen the hypothesis that human activities are mainly responsible for the gullying, especially since gullying takes place on soils that are not necessarily similar except that land use is common on both.

In summary, since the ESP values for both study sites are below 7% from which erosion susceptibility begins, it can be concluded that the soils at both study sites are not naturally prone to erosion. In fact, it must be pointed out that during this study, no records of ESP are as high as 45% which was the level found in Swaziland and Zimbabwe by Stocking (1979) and Mushala and Peter (1997 after Hooker, 1984). It should also be mentioned that not all factors contributing to soil behaviour have been taken into consideration at this stage. In other words, this is a generalised conclusion based on only the few parameters discussed so far.

Overall, it can be maintained that the difference between the ESP and SAR for the Brooks Nek site is relatively wide as compared to the Chani site. The effect of high rainfall conditions on both sites, however, does not appear to have played any significant role in increasing the SAR. The ESP and SAR values are also far less than the limit of 15 and the causal relationship between the two parameters is difficult to establish.

In an attempt to detail the analysis of these results, the CEC value range is related to soil type and textural characteristics. According to Rowell (1994), value ranges (in cmol/kg) are, for sand: 2 - 4, sandy loam: 2 - 12, loam: 7 - 16, silt loam: 9 - 26 and clay loam: 4 - 60. The range width for each textural group is a reflection of the amount and type of clay and organic matter content constituting that part of the soil. If we relate the soil textural analysis ranges to the Brooks Nek's results alone, we find:- first, Fig. 5.8 further breaks down the soil textural characteristics into clay, silty clay and silty clay loam, for this study site. It can be seen that these textural categories do not exactly match the classes outlined by Rowell (1994). (Further textural representation is presented in Table 5.13.1.) The soils at Brooks Nek are characterised by high clay content (52.7) as compared to silt (34.2) and sand (13.1%), all expressed as mean values. The organic matter mean value is 2.9 with a percent dispersion of 9. Fig. 5.8. shows a soil range of clay, clay loam and loam soils which also varies to a degree from Rowell's textural classes.

Comparing Brooks Nek and Chani, both sites can be broadly classified within the 4-60 cmol/kg range referred to by Rowell (1994) but each has a slight variation in mean values from the other. Table 5.13.2 shows that at the Chani study site, the composition of silt (38.3) is slightly more than of clay (36.2) in the soil samples. Sand constitutes 25.1%. If we compare textural characteristics of the samples from the two study sites, unlike at Brooks Nek site, the Chani site has silt constituting a larger proportion of the samples. The reverse is true when we compare clay and sand of this same site. The mean percent dispersion is calculated at 17, a value almost double that of Brooks Nek whilst the mean value for organic matter (1.3) is less than half that of Brooks Nek. The properties discussed so far - especially those based on figure 5.8 and Tables 5.13.1 and 5.13.2 - are crucial when it is noted that for soil to display extreme properties and a pronounced influence on texture, only 40% clay-sized soil particles is needed, as compared to 87% sand and 80% silt (Rowell, 1994). Therefore, the effect of clay on soil textural behaviour is possible at Brooks Nek (which has only one sample with clay content of less than 40%) whilst in the case of Chani, more than half of the samples have clay-sized particles of less than 40%. Clearly, the broad categories are not beneficial to the understanding of the results of the study areas but give an indication of the general pattern displayed by such results. The following paragraphs deal with statistical results as well as a comparison of both mechanical and chemical characteristics of both study areas.

An objective assessment of the validity of the difference between samples from the two study sites has been made by statistically comparing the ESP of soils using t-test at 95% confidence level. This level is recommended by Gardner and Dackombe (1983) as appropriate for geomorphologic applications. However, Ternan *et al.* (1996), found a significant correlation in clay content, organic matter and soil aggregate stability when tested at 99%. The results obtained for the two sites using the t-value is 0.05 which is less than the t-table value of 2.0. This is an indication that no significant difference exists between the two sample sets. There is also no meaningful relationship in the SAR of these soils with the calculated t-value of 1.65. This figure is again less than the t-table value of 2.0. What these results seem to point is that there is no significant difference in the soil composition which would account for severe erosion identified in the study sites. Furthermore, the pattern of the results suggests that the hypothesis that 'soil erosion is a product of human activities' is the most applausable explanation.

In an attempt to classify the soil horizons, the Brooks Nek soil samples 2 to 7 and 9 to 11 consist of a red apedal B-horizon. The 8th sample is an E-horizon whereas samples 1 and 26 are not classifiable within the Soil Classification Working Group range (1991) in terms of their characteristics. In Chani, soil sample numbers 15, 18, 19, 23, 24 could be classifiable as yellow-brown apedal B-horizon, while 14 could be of red apedal B-horizon.

Tests of aggregate stability and particle size distribution were carried out to gain an indication of soil behaviour during laboratory tests (Appendices B-2 for Brooks Nek and C-2 for Chani). In comparing results in Appendices B-1 (dry sieving) and B-2 (wet sieving), some soil samples show considerable differences in soil behaviour between wet and dry states. For example, Appendices B-1 and B-2, sample 1 reflect similarities in the distribution of particles, with just less than 40% being coarse material in both dry and wet states. This pattern seems to dominate most of the ogives drawn except for those mentioned henceforth. Contrary to what has just been noted, the wet state of sample 2 has about 50% of its aggregates constituting coarse material whereas the dry state suggests an almost even particle size distribution. Other differences are observable in samples 5 and 6. Sample 5, although it approaches uniformity in distribution, the distribution is very uneven. Sample 6 has only 20% of coarse material in wet state but 50% in dry, in Brooks Nek. Another contrast is found between samples 7 and 8. Both samples show a fairly even distribution of particle sizes in dry state but very different in the manner they behave in wet state. But they both have between 50 and 55% constituency of coarse material.

Unlike Brooks Nek where a number of the samples show different behavioural patterns, the soil aggregates and particle size distribution of Chani samples reflects uniformity in the shapes of ogives with a very few exceptions. Appendices C-1 (dry sieving) and C-2 (wet sieving) illustrate the similarities and/or differences in soil behaviour depending on the wetness or the dryness of the soils. For example, sample 16 in wet aggregate stability test results (Appendix C-2) shows a clear contrast from the even distribution of particles in dry particles size analysis (Appendix C-1). A similar situation is found between the dry and the wet states of samples 21, 22 and 23. These results are similar to disparities found between wet and dry sieving by McTainsh and Duhaylungsod (1989).

Based on the characteristics of soils from both Brooks Nek and Chani, it has become clear that the soils are derived from the weathering of dolerite rock. These soils contain moderate amounts of organic matter but are rich in Phosphorus (The Republic of Transkei Report, 1976). According to the generalised map of these areas, soils fall in the sandy to sandy loam group (Fig. 3.2, p63). It is important to note that from the site specific results just discussed, neither of the study areas fall into this category. On the contrary, site-specific observation of soil conditions, as shown in Fig. 5.8, shows a range from clay to silty clay to silty clay loam and to clay loam, when both sites are combined. This is a clear indication of the relevance of site specific approach in understanding soils. Normally, the physical properties for all light-textured soils make it easy to cultivate because these soils have good permeability and low water retention capacity. This must be the reason for the volumes of water that are washed downhill, to collect and cut down the valleysides of the valleys under rehabilitation.

These doleritic soils (from both study sites) have been found to be composed of dark coloured topsoils of blocky structure and overlying deep reddish brown subsoil. Van Schoor (1976) reported similar findings from doleritic soils. Apart from the fact that Chani and Brooks Nek experience an almost similar climate, Brooks Nek sometimes experiences extreme cases of snowfall and mist. Other than that, it has been observed that the rest of the characteristics outlined above are found in all areas that are underlain by dolerite rocks, irrespective of the differences in climatic conditions (van Schoor, 1976). Similar to McKenzie's findings (1984), the average depth of topsoil ranges from 45 cm to 60 cm, with subsoil ranging between 60 cm and 90 cm, with profiles of well more than 2 metres deep at the footslopes. This again strengthens the need to reduce the physical and natural factors to a secondary level in the study areas. In the next chapter, it will be argued that factors like the human perceptions and attitudes towards the erosion problem are central to an adequate explanation. We will attempt to show the extent of human activities which exacerbate the soil erosion problem.

CHAPTER 6: THE HUMAN DIMENSION OF SOIL EROSION

It has already been argued that human activities have a profound bearing on the nature and extent of soil degradation. The next section briefly links up the problem of soil erosion in the study sites to the human dimension. Interviews have been conducted and questionnaires completed to ascertain who is living in the area of this study sites, and how they view the erosion problem in their midst. Responses to a questionnaire concerning 'socioeconomic data, human activities and soil erosion', 'soil erosion and rehabilitation programmes', and wider problems related to democracy, have been analysed and are given in this chapter.

6.1. Background to human perceptions and attitudes towards soil erosion

A rationale for this study, among other things, has been to support the general view that geographers need to transcend the dividing lines between the physical study of the soil and natural causes of soil degradation, and the socioeconomic and socio-political context of erosion (Blaikie, 1985). In fact, Blaikie contends that for an adequate analysis of soil erosion and land degradation, we need to overcome the constraining division between the physical and human aspects of erosion and degradation phenomena. This is a call for a more integrated and holistic approach.

In support of the integrated approach we need to emphasise the points made in the earlier discussion. The erosion problem in South Africa has generally been considered a serious threat to land productivity (and thus to economic viability), as well as to natural environments generally (Garland, 1979; Dardis *et al.*, 1988b; Garland and Boderick, 1992; Brinkcate and Hanvey, 1996).

One human aspect (that supports the holistic approach) is to be found in the different perceptions people have concerning erosion. In the Brooks Nek area, soil erosion as a problem proved not to have been a major concern for the local population. This is similar to evidence given in Stocking's (1987) report. Most of the responses in our case study were from people who were actively involved in the rehabilitation programme. Even though the conservation initiatives were put together in a way that allows the community to participate - by letting communities work on the rehabilitation - it transpired, particularly from the interviews conducted, that the majority of respondents were interested only in the immediate financial reward. They were involved in the project only in order to earn a living and not out of conviction in the importance of soil conservation and rehabilitation. Many of them voiced their wish that the present research into soil erosion will 'bring them more job opportunities'.

It is important to note, however, that the eroded areas were identified as "problematic" by some rural dwellers. This was especially true in interviews conducted with those people who lived a distance away from the rehabilitated areas. In such cases, however, the kind of response given by members of the communities directly affected, shows that there are differences in the perception of the soil erosion hazard. The difference is most marked between the responses of the technical staff involved, including the scientific policy-makers and on the other hand the land users. In a nutshell, it is a difference between "the expert" and those who are directly affected by the problem ("the non-expert"). This kind of "them" and "us" situation between these groups is similar to that reported by Mather (1982).

Both study areas have been subjected to incomplete 'betterment' planning, which started during the mid-1950s. The use of questionnaires (a copy of which is given in Appendix A), informal discussions, and interviews also helped to determine the attitudes of the local residents. This approach is advocated as the best way to obtain the kind of information desired (Dixon and Leach, 1973). One set of questions concentrated on the effects of the programme. For instance, why did the respondents think that the rehabilitation work was being done? Have they noticed any improvements as a result of the gabion structures (at Chani especially)? Also the people who participated in the programme's implementation were interviewed with a view to understanding their motives. Would they have participated in the work without remuneration? These were some of the questions asked over and above those on Appendix A. Many of these questions were not included in the open questionnaire because of their sensitive nature (and to prevent possible intimidation from those who may have wanted to influence respondents' answers). To understand these responses perhaps we need first to look at a bit more closely at the socioeconomic and educational levels of these respondents.

Most of the community of Brooks Nek is engaged in micro-scale farming. Many families depend for their survival on the 'gardens' that were allocated to their homesteads (see Fig. 5.4.1.A, p127). Some families, however, have other sources of income, such as wages from one of their member who is working in a commercial farm in the Kokstad area, or is further away working in the mines, or sugarcane farms, etc. Yet others have had supplementary income for the first time, as a result of the remuneration received from the (community-based) gabion construction project.

From a group of 50 people working in the gully rehabilitation programme at Brooks Nek, 26 workers (including the local chief) were interviewed. This 50% sample was limited to community members who were involved in gabion construction. This sample, of course, cannot be taken to represent the demographic structure of the community members at Brooks Nek; it is, however, representative of those who were participating in the rehabilitation programme. The point is that the people sampled may not be representative of the whole economically active sector of the community. In an attempt to partly address this possibility, more interviewees were approached. The second sample was taken from the community members who were not directly involved in the rehabilitation programme. Five respondents were selected for in-depth interviews from the economically active ordinary inhabitants, on the basis of their availability and their willingness to participate.

In analysing the reaction of respondents to the questionnaire from all groups of interviewees, it was soon apparent that only 6.5% could complete the questionnaire without guidance and assistance. Thirteen percent (13%), although literate, were able to complete the task with minimal guidance, whilst 81% had to be guided throughout. (Fifty eight percent (58%) of the interviewees are illiterate.)

In analysing the questionnaire responses concerning the socioeconomic background of respondents, a substantial number (71%) of them were found to have been living at their current homesteads "for as long as they could remember". The other 29% had been relocated under the 'betterment programme' in the early 1970s. Although all the respondents were local residents, some had been shifted from where they used to stay inside the boundaries of Brooks Nek, before 'betterment', to other areas within the Brooks Nek administrative area.

Table 6.1: Education Achievements of Respondents

Level	**zero to Sub-B**	**Std 1-6**	**Std 7-9**	**Std 10**	**other**	**Total**
Number	18	7	4	2	0	31
Percentage	58%	23%	13%	6.5%	0	100

As we noted, the majority of homestead heads are illiterate (58%), with 23% having education falling between grades three and eight (Std 1 and 6) (Table 6.1). Four family heads (13%) had been to school until lower grades nine and eleven (Std 7-9). Only 6.5% of these had been to grade 12 (Std 10) and none beyond.

Table 6.2: Age and Gender of Homestead Heads

Age	21-30	31-40	41-50	51-60
Male	1	5	7	1
Female	1	6	9	1
Percentage	6.5	35	52	6.5

If we look at the demographic profile of the interviewees by both age and gender, Table 6.2 shows that 54.8% were female and 45.2% were male. The proportion was kept close to the gender distribution of participants on gabion construction, where there were more female participants than males. (Incidentally, this is also in line with the gender distribution of the South African population, as indicated in Chapter 1.)

During and after 'betterment', earning a living for most able-bodied males was mainly confined to working in cities. This was necessary in order to boost farm yield and family income. By the 1990s, a substantial number of the notionally economically active people (who as a mater of fact are inactive) were living in the area. Most of them were staying at home due to retrenchment from the mines. This is correlated with (and many would say has led to) socioeconomic ills such as theft, violence and other forms of crime prevalent in this and many other rural communities. (The problem of crime was brought home to the researcher when the dead body of a female member of the community was found near the rehabilitated gullies during the study period.) When considering unemployment and underemployment, results indicated that 87% of those aged between 31 and 50 were officially unemployed (Table 6.4). This figure may be exaggerated due to the unrepresentativity of the sample, as well as sample size. It might well be low as compared to the actual unemployment status in the area.

From the interviews conducted it became clear that farm machinery is identified by the interviewees as a key necessity for those who aspire to work at small scale commercial farming. It was assumed this would to help in long-term employment if subsistence farmers in the area were now to be helped to hire or purchase machinery. In addition, respondents would wish to see subsistence farmers assisted with respect to guarantees for making of bank loans. However, none of the people questioned is willing to apply for such a loan. The reasons given included the bad experiences associated with drought, and the loss of farming activities due floods in the area. These were viewed as making the lending of money to already 'socioeconomically vulnerable' farmers, precarious. So much so that all of the relevant respondents involved were not prepared to risk a loan, unless there are guarantees to disaster relief funds for subsistence farmers, especially those with bank loans.

Let us now turn to some of the answers given by the respondents to questions concerning soil erosion. We will begin with their perception about gully rehabilitation.

Table 6.3: Feeling or Perception about Gully Rehabilitation (%)

Not necessary	essentially a problem	provides jobs	No comments	Total
7	0	21	3	31
23%	0	68%	10%	100

Table 6.3 reflects diverse perceptions and beliefs about gully rehabilitation in the area. Twenty three percent (23%) of the interviewees questioned saw no reason to worry about gullies. Respondents generally viewed gullies as formed and developed as part of the natural process of landscape evolution. This is why most of the interviewees felt there was no point in rehabilitating gullies, since gully erosion is a natural phenomenon and not a major problem (see Table 6.3). In addition, most respondents think that rehabilitation schemes only benefit, in the long-term, members who own livestock. The rest of the community benefit from short-term employment.

Paradoxically, most respondents agreed also that gully rehabilitation programmes have alleviated both soil deterioration and, as a result, some of the unemployment problems. However, they think (quite reasonably) that these programmes are short-term. The need to supplement biological methods of soil conservation by the construction of physical structures, was regarded with indifference. Respondents pointed out that the rehabilitation programme in Brooks Nek was not on arable land but on shallow soil, on steep slopes, and on land where constant grazing could not be avoided. Their explanation of how this constant grazing became necessary was, due to confines and history of state (*viz.* the results of apartheid) and to the local chief's tribal land demarcations.

Table 6.4: Farming problems in Brooks Nek

Economic/Physical problems	Response (%)
Shortage of suitable land	97
Limited land	92
Unemployment/no money for inputs	89
Diseases/stock die	45
No machinery	55
Steep slopes	32
Loss of soil	25

In addition to the view that gully rehabilitation is a short-term solution to erosion, Table 6.4 presents a variety of responses to the farming problems that erosion causes to farming in Brooks Nek.

There is a common view that there is not enough land on which to manoeuvre when carrying out their daily basic farming activities. On the other hand, the general feeling was that in the past, people used to have land for arable farming. Then the government reallocated their land. The consequences of this reallocation included limiting the traditional rotational grazing system, as well as leaving land fallow for a year or two in order to recover and to improve its productivity. These techniques were practised as part of indigenous conservation methods.

Concerning the reasons for leaving arable fields to lay fallow, one of the most frequent responses (from the majority of the people) was this was entailed due to natural causes. Most respondents cited such problems as drought and dry spells. This is understandable. Drought has been a phenomenon common throughout most of South Africa (du Toit, 1985; Lengoasa, 1991; Jury and Levey, 1993; Phillips-Howard and Oche, 1996 and Oche, 1997). Although they alluded to the natural problems, however, they found it difficult to articulate the nature of the causal connection between drought and leaving fields fallow.

Again, in an inconsistent vein, the interviewees' responses to the implications of 'the soil erosion problem' leaned towards identifying erosion as the major cause of the reduction in farming production and in yields. Such a drop in production is regarded as a major reason why many people have stopped cultivating their fields. Respondents insisted, however, that such reduction is not within their control. They saw it as a product of natural phenomena - drought and hailstorms - that, as we noted earlier, often affect their area.

Table 6.5: Perceived factors contributing to Soil Erosion

Causes	Response (%)
Over exploitation of land resource for basic needs	93
Bad dirt road Management	91
Floods	85
Drought	81
Concentrated flow on furrows made by wheel during rain	54
Overgrazing	10
Uprooting of certain type shrubs species for muti	7
Do not know	7
Foot paths/stock trails	3
Disturbance from construction activities	3

Over and above the previously cited views, a variety of other arguments on the causes of soil erosion became apparent, when a number of other possibilities were presented to the respondents in the questionnaires (Table 6.5). They accept that the soil degradation process can be induced by compaction associated with machinery and off-road vehicles, as well as by natural compaction from soil sealing rainfall. But a few respondents connected erosion with overgrazing or uprooting of vegetation (for herbal uses, etc.).

Another important point was the response to the question of whose responsibility it is to prevent soil erosion. Similar to response found by Pile (1996) in the study of Cornfields community in KwaZulu-Natal, the rest of the group thought that it was the responsibility of the government; it is government's responsibility (it seems) to provide all development undertakings. Only 7% of the interviewees felt that the community should take initiatives in reducing the impact of soil erosion. The reasoning supporting the majority view seemed to be that most rural communities - not only in Brooks Nek but also in other parts of the country - do not enjoy any of the advantages from the new opportunities since liberation. It is unfair of the government to leave 'poor, illiterate and unemployed' people to make financially binding, development related decisions, entirely on their own. Included among those who think in this way is the chief of the Brooks Nek area, who at the same time, commended the Agricultural Dept., Mt Ayliff, for initiating the gully rehabilitation programmes for the greater part of Mt Ayliff. He, like the other respondents, however, felt that soil conservation should be given the lowest attention. It should be a low priority, given the extraordinary shortage of basic resources like sanitary services, electricity, and long-term, sustainable development community projects in the area.

The local chief also supported the conservation programme mainly for the financial and educational benefits for his people. He appreciated the role played by the small-scale employment derived from the rehabilitation programme. It has helped to stabilise socioeconomic conditions amongst the participating families. He was asked how often he visited the gully rehabilitation sites between 1993 and 1997. He indicated that he had never been to the site! But he had attended a meeting at the inception of the programme. Further, when passing by on his way to the village on the other side of the hill, he said, he "regularly observes the progress being made".

One other significant finding is worth noting from the interviews conducted. All respondents agreed that there has been a great deal of change in their natural and manmade environments in recent years. Of the respondents, 45% felt that soil erosion was responsible for reduction in vegetation, then this must be the reason why their stock die. Gullies and vegetation reduction were the most noticed natural features of change. Contrary to the findings of Meyerhoff (1991) - who maintained that older people regarded soil erosion as a major problem - none of the elderly respondents (in their late 50s) in our study regarded gully erosion as a major problem. (Our findings are similar to the responses that Brinkcate and Hanvey (1996) found from the Madebe community, Northwest Province.)

As noted earlier, in our attempts to estimate the date of gully development in Brooks Nek (based on the interviewees' responses), none of the respondents could remember when the erosion phenomenon became dominant. Lack of such knowledge made it difficult for us to link advanced gully erosion to any particular major event (floods/drought), for dating purposes. This was important to our study, for prior to the research, it was regarded as the most likely way we would estimate the period of time over which gullying has occurred. Moreover, no aerial photographs or orthophotos are available to us for this area before 1993. (A number of offices and personnel in the Transkei region, who were considered to be in a position to provide much of the needed information, were 'not available' or willing to co-operate, for reasons outside the control of this research.)

From the interviews, the general view seems to be that for as long as people can remember, the Brooks Nek area has been used for mixed activities such as settlement, stock and crop farming - long before the 'betterment' programme. There was never a problem in the old days. Moreover, something or somebody else is to blame for the deteriorating environmental conditions in Brooks Nek. It is certainly not themselves or their activities.

The results clearly suggest that people's level of education, their socioeconomic status, and their needs, influenced their responses to the questionnaire. Their attitudes towards erosion as a problem, opinions on soil deterioration, and perceptions of rehabilitation were very similar to those found by Tuan (1974) and Gay (1984) in Lesotho. The common feature is that the problems of soil loss and general degradation were not their main concern. Such problems should not be on top of the community's priorities in Brooks Nek. Details of the different set of concerns, which dominated the responses to the questions in interviews, have been noted. Let us now say something briefly about the Chani study area and the interviews and questionnaire concerning the attitudes of people to soil erosion.

As noted, Chani - like Brooks Nek - is an area of grazing land. But, unlike Brooks Nek, no part of the erosion at the Chani site is of an immediate threat to household buildings because this site does not lie within the settlement area. It is not enclaved within the residential area. However, some of the few people interviewed, who use the area and are affected by erosion-related problems, used to own arable land within the immediate surroundings of the badly eroded areas. Many of them have stock which currently graze within the gullied area. Interviewees responded in much the same way as the respondents at Brooks Nek. Soil erosion, again, is thought to be due mainly to natural phenomena. There is no notion that the stock owners themselves have anything to do with the problem of erosion. It suffices to warn each other and other stock-herders to be careful not to drive the herd to the edges of the dangerous gullies. And once again, rehabilitation is viewed as the government's responsibility.

In summary, the findings of the investigation of the people in the study areas shows that, respondents questioned at both sites, realise that land use practices have changed. Cultivable lands are laying fallow. We hope to have shown that part of the reasons for this change is that the 'betterment schemes' switched land ownership from individual arable fields to communal grazing land. At the same time, some land has been left fallow due to the lack of means of subsistence farmers to continue arable farming. We hope to have shown that although natural processes accelerate the development of erosion forms in these areas, footpaths and stock trails are the main source of the problem at Brooks Nek, whereas artificial contouring and insufficient gabion layout and design are the major causes of the problem at the Chani area. Alongside this overview, we have seen in this chapter that the communities most affected by soil erosion do not regard this as a major concern in their lives. It is not of their making. And if erosion is a problem, it is the government's duty to do something about it.

The next chapter presents conclusion and recommendations for this study. It must, however, be mentioned that the recommendations presented in the last chapter are not limited to the views of the respondents and the findings of this study. Some ideas are drawn and/or informed by the general developments and initiatives, which are aimed at improving communication and rural livelihood in South Africa.

CHAPTER 7: SOIL CONSERVATION IN THE STUDY AREAS: RECOMMENDATIONS AND CONCLUSION

This research on soil erosion has made it possible to compare features and causes of erosion as well as approaches to the gully rehabilitation process at Chani and Brooks Nek. To make a meaningful assessment of erosion in these study areas, the research was structured to ensure that consideration would be given to the role of both physical (natural) and human factors. A detailed analysis of the soils at Brooks Nek and Chani shows no significant difference in the soil characteristics or structure, or to suggest that the soil was the major cause of erosion. An account of some of the attempts to reverse environmental degradation - rehabilitation schemes, the gabion layout and the reasons for the failure of these efforts - has been given. And an (often overlooked) assessment of local people's awareness - their ignorance of their role in increasing the extent of the problem and of some of its socioeconomic implications - has been presented for the Brooks Nek area, in chapter 6. A brief account on the variables referred to as 'human factors', is also given with respect to the Chani study site.

It must be emphasized that the human factor in soil deterioration has been found to be complex because of its synergic relationship with the physical factors and *vice versa*. We saw earlier in chapter 3 - from an overview of the Brooks Nek site - that people have removed stones naturally stabilising the natural soils, for intended gabion construction and, for making kraal and garden fence walls. Furthermore, people have removed soils from (some sensitive) slopes for construction purposes, and they have opened up trenches to redirect water to construction sites. In addition, the local people have created footpaths, stock trails, dirt roads, etc. The result is an increase (from moderate to severe) in soil compaction over a large percentage of the site (see Table 5.1, p102). We have noted that this compaction restricts vegetation roots penetration into the soil, and causes a loss of transmission pores and the water storage ability of soil. In other words, the degradation has made the soils increasingly susceptible to stress. Around the trails and footpaths especially, the loss of transmission pores has made the soils prone to waterlogging in periods of high rainfall (see Table 5.1, p102). To make matters worse, once erosion is initiated, this study confirms that, if not appropriately checked, it becomes self-sustaining and self-accelerating. This suggests that at Brooks Nek especially, erosion will accelerate because there has not been a subsequent change in land use patterns. The same problem is already evident at the Chani site.

Chapter 6 shows that the people who participated in rehabilitation attempts (such as gabion construction) were community members with either little or no expertise and with little awareness of the environmental importance of their work. Their motive was simply to obtain work and money. In some respects, this would be acceptable as a form of community empowerment. But without the environmental awareness, it is not clear that they will organise themselves to prevent further erosion and mend damaged sections of gabions after the extension officers have been withdrawn. In fact, their reluctance in this regard was obvious at the time of the interviews. They are uninterested in conservation unless there are monetary incentives. The reasons for this are also clear in their responses in chapter 6. These include the fact that no effort was given in training the community members involved to change their attitudes, whilst they were doing the job. Perhaps, we should be a bit more circumspect here. The study did reveal that some members of the community do realise that their activities worsen the erosion problem. However, speaking generally, they think that they cannot avoid such environmental degradation, as they do not have the means to change their farming and other practices. This too leads to the conclusion that the control measures will not achieve their long-term intended goal. Once again, the recommendation of this study is that some form of an environmental education programme is developed in which the Brooks Nek community (and similar communities elsewhere) are sympathetically informed of the erosion problem, how it is caused and how it can be combatted. What this recommendation implies is that it is crucial for community members to be trained while actively involved in rehabilitation schemes. If they do not participate in a full way - and also in a manner that respects their intelligence and experience - then it is not too surprising, if they do not care about such things. Involving the community in such a programme also ensures that communities concerned can feel proud of the programme. It seems a reasonable and logical psychological generalisation to claim that they are more likely to own, value, protect and monitor the (progress of) programme.

As things stand, however, people from both of the study areas have no access to such data. Even for the newly rehabilitated gabions in the Transkei region (for instance, those where work has recently been done in the Eastern Cape's East Griqualand subregion), no clear, proper record keeping is in place or is easily accessible. Hence any possibility to make a follow-up and evaluate rehabilitation work and other programmes in the region is problematic. So another recommendation would be that copies of all records of those environmental development projects, on which time and money has been spent, be kept by environmental offices (e.g. Departments of Water

Affairs and Forestry; Agriculture; Environmental Affairs, Commerce and Tourism; Public Works, and others). Furthermore, since there is a move to establish community resource centres (and libraries), it is recommended that information about projects that are relevant to local communities be kept in such information centres for easy access. This could also help in reducing repetitive research on these areas for there would be a clear record kept for all the work that has already been done for the areas concerned.

Notwithstanding people's perceptions about what has happened to their soil, soil characteristics have been analysed with the intention of determining their importance to rehabilitation programmes. Results for Brooks Nek and Chani sites indicate that there are little substantial differences between the soils of the two sites. More importantly, there are no features that suggest that the nature of the soils (as such) has played a major role in the initiation of the gully development process. Once again, the people affected need to be informed that it is not the soil itself but their practices that are causing their problems.

The foregoing study has shown that the gap is huge between people's needs for their survival and their basic know-how to utilise their land in a sustainable way. One thing they need to know is the basic secondary data pertaining to soils, on which their arable lands are located. Also of significance is information about crops suitable to their specific soils, if they are to achieve a maximum yield. They also need to be able to identify suitable topography and climatic conditions for their specific areas, and to ensure that all the gained knowledge can filter down to generations to come.

One last point needs to be made concerning soil conservation techniques. In chapter

5, it is noted that the gabion construction technique in Chani has not been satisfactory. It may have been better if other erosion rehabilitation procedures had been carried out, such that the mechanical means were preceded by the use of biological control methods, which elsewhere have been found more effective over short-term periods (Lemly, 1982; Jones, 1987). To stress the point: physical structures alone seem to be insufficient as a method of soil conservation. They need to be used as supplement to the biological methods. The use of Vetiver grass, for instance, is evidently successful in other rehabilitated parts of the Mt Ayliff administrative area. However, it is not used at the Brooks Nek or the Chani sites.

Also consideration should be given to developing some of the degraded slopes at the sites using biological rehabilitation techniques. It is well-known from other research (see Partap and Watson, 1994) that degraded slopes can be divided into strips of land, for different forms of farming, depending on the gradient. The slopes need to be separated by double hedgerows of nitrogen fixing bushes (or trees) planted along contour lines. As well as stabilising the slopes, it is found that soil fertility is enhanced in this way.

7.1: Future Prospects

As seen from the results of this study, the 'soil erosion problem' is accelerating as a consequence of human impact. It has been argued that this is responsible for the greater part of the environmental change at the sites investigated. Although erosion due to human impact result from the direct use of the land *viz.* by farming methods, the evidence indicates that this factor is complicated in our study areas by many other related variables. A particular reference is made to political legislation over the past generations, also to economic factors, lack of education, together with the existing social practices of the people concerned. Some of the following recommendations could assist in the development of solutions to some of these problems.

First of all it needs to stressed that

(i) speaking generally, unless land users' practices change, land resources in South Africa will continue to be degraded. Alternatives to improper land use like overgrazing, the digging away of top soil for construction purposes, unplanned footpaths, etc., have to be found.

(ii) Secondly, and again generally, future approaches to land uses need to emphasize an integrated management of resources. In addition to control over the existing resources (water, vegetation and soil) the steps that are taken should be informed by the past social history of the areas concerned (and of the South African context as a whole). This should take the culture and physical settings of the area into account.

(iii) Thirdly, South African legislation concerning rural development has to be shaped in a way that involves those people affected by it. The present top-down way of legislating on soil conservation has clearly not worked (in the past or is not working in the present). An integrated approach, hopefully, will counteract such attitudes as the reluctance to relocate (as during 'betterment' in South Africa), the reluctance to change from existing practice patterns, (for example, the social significance attached to stock numbers by some South African cultures), and so on. In addition, to avoid the level of failure of many past strategies, future management strategies need to integrate local governments as well as local communities into decision-making structures. (This approached has been successfully adopted for the Metropolitan Victoria area in Australia (Mercer *et al.*, 1994).) Understanding the law and having access to relevant document are necessary and possible for communities, if the local resource centres are provided for them, and they are encouraged to use such centres effectively. Related to the above point, Knight and Holmes (1994), in their support of sustainable land use and land management, argue that the extent to which rangelands are then used sustainably depends on the management practices. In actual fact, this means that the practices have to be adopted by the rangers or managers themselves. A similar emphasis on the importance of local authorities and broad public participation is captured in the international agreements like Agenda 21 (Cock and Koch, 1991; Dent, 1997). The problem, that has not yet been fully attended to worldwide, is how to effectively engage people in a participatory research way.

iv) Fourthly, conservation and rehabilitation techniques need to be reconsidered. The physical methods need to supplement biological measures. Physical structures, like gabions, alone seem to be insufficient; biological methods of soil conservation need to be studied and/or experimented. Where the biological methods are preferred, local (indigenous) vegetation of the area concerned should be used.

(v) Fifthly and most importantly, the design of rehabilitation programmes needs to be such that the people affected genuinely participate in it. This study shows how important it is to educate the people affected by erosion and those engaged in rehabilitation programmes. It is no good just employing people. They need to be informed about the danger of erosion and the need for rehabilitation. The recommendation would be that in future, a regular record of instruction be given to anyone given work on a rehabilitation programme. (Consideration could be given to the issuing of certificates of competence to participants as an incentive (not just money).)

In future, programmes (such as that initiated at Brooks Nek) need community participation as early as at the planning level. In this way, people can try to solve their own problems. In that way, indigenous knowledge could be incorporated into the development scheme. Programmes should be channelled to seek an exchange of information and expertise between the government experts and the community members involved. While such strengths are often reinforced by an individual's level of education, the idea that educated people know best needs to be challenged. It has proved to be a very serious hurdle in getting community members to air their own considerable knowledge. This was found to be a serious hurdle in the Brooks Nek study. Some mechanisms that allow communities to identify their problem from the planning stages, and then encourages them to be involved through to the implementation stage, should be the important desiderata for all such programmes. It seems reasonable to argue that such an active synthesis has received inadequate attention throughout rural South Africa. This is not a new concept. Both Boardman (1988b) and Dent (1997), for instance, believe that soil conservation action programmes should provide education, technical expertise, and the necessary incentives so that the use of land is made within the constraints of its physical characteristics, and land users will want to protect the land from unalterable limitations of climate and topography.

(vi) Sixthly, the government needs to ensure that the necessary resource backup is available for such community-based projects, including provisions for their maintenance. The extension officers need to be integrated into those communities so that information dissemination and sharing with the communities is made possible. This is most likely to ensure sustainable development. In other words, the approach recommended needs to design tailor-made programmes to cater for the physical demands of the degraded environments, and also the demand for the involvement of the affected rural communities.

To stress the important point being made above,

- in future, rehabilitation programmes need to encompass an empowerment plan; a plan that allows all groups of people to be trained to a level of competence, so that they can properly assume full responsibility for their land use and land management;
- the people affected need to be organised around effective institutions, where stakeholders operate on an equal footing with experts involved;
- key information about common resources, rights and responsibilities need to provided;
- professional efforts need to concentrate on decision-support system instead of prescriptive plans;
- the use of local knowledge and local adaptation of appropriate technology should be preferred rather than 'technology transfer';
- and, most importantly, education programmes need to be provided in order to

empower and inform people in all 'degraded' areas (of South Africa).

Lastly, I hope to have suggested that part of the long-term solution is to require land-users to adopt and use soil conservation practices at the farm level and/or construction sites. Once again, this recommendation brings in the need to complement the technical knowledge of combatting erosion, with education and extension services, or ordinary people, and/or linking financial incentives in order to encourage implementation. Only if all fails, do we agree with Hudson (1981) that coercion may be necessary.

Sustainable agriculture is essential - if South Africa is to meet the needs of both a developed and a developing country. To put this point specifically; people in the Transkei region have to live within the limitations of a developing world economy (outlined, for instance, by Pretty (1997)). In other words, people in this region need to concentrate on farming and related agricultural activities as a step towards becoming a developed rural society. The works of Daniel (1981), Beinart (1982), Bembridge (1987) and Bundy (1988) all suggest that during the period before 1913 (especially the 1860s), this region was characterised by such activity, *viz.* they refer to the rise of the most successful peasantry class in South Africa living in this region. It should be possible to achieve the above state again, but this will happen only if the people involved are educated to embrace the practices of sustainable land use and so avoid the ongoing soil deterioration and erosion in their midst. Erosion control and land reclamation not only will lead to present economic development, it will protect the environment for the benefit of the present and the future generations.

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Appendix A: Questionnaires & Interview Schedules

Appendix A: Questionnaires and Interview Schedules

Interviews on matters pertaining to human activities, awareness and attitudes (mark with an x where appropriate and use a separate sheet of paper provided where necessary)

A: Socio-Economic Data

Gender of the responded	F	M			
Are you the head of the house?	Y	N			
Have you ever been to school?	Y	N			
If yes, till what level?	0-sub-A	Std 1-6	Std 7-9	Std 10	Ten+
How old are you?	21-30	31-40	41-50	51-60	60+
Do you own a homestead?	Y	N			
If no, why?					
Do you have agricultural land?	Y	N			
If yes, how many fields?					
Do you encounter problems with your farming activities?	Y	N			
If yes, what do you suggest should be done to solve your problems?					
Do you own livestock?	Y	N			
If yes, do you have problems with keeping your stock?	Y	N			
If yes, what are your problems?					
What do you think can be done to solve your problems?					
Have you got a job besides farming?	Y	N			
If yes, where do you work?					
If no, have you ever worked before?					
What stopped you from working?					

B: Information on Soil Erosion and Rehabilitation Programmes

(Write your answers on the spaces provided. NB: You may use both sides of the papers provided if you need more space).

Do you consider soil erosion a problem in this area? Please give reasons for your answer.		
Who should prevent the occurrence of soil erosion? Govt, land users, community and why?		
If farmers or community, how should they do it?		
If the government, how?		
In your opinion, what factors cause erosion in your area?		
What do you think about gully rehabilitation process in this area?		
Why are you participating in gully rehabilitation?		
Why is it not every community member participating in gully rehabilitation?		
Is it important to have every family involved in the programme?		
I yes, how can you get those who are not involved to come into the programme?		
How should gabions be maintained and by whom?		
Do you have extension officers in this area?		
If yes, where are they based?		
If no, do you think you should have some?		
If yes, what have done, as community members towards having such officers?		
Is community working closely with govt in controlling soil erosion in this area?		

C: Land Degrading Human Activities

Looking around the catchment, what activities have left signs of land degradation	
Is it a good idea to remove stones from some parts of the catchment to gabion construction sites?	
What do you think about using soil for mud-bricking?	
What is your view on furrows dug to redirect water to certain homesteads?	
Do you think footpaths and stock trails cause erosion and why?	
If yes, how can the above problem be solved?	
How do you feel about houses that are built on steep slopes?	

D: Political Moves and Democracy Problems

Is it good for people to locate where they want to?	Y	N
If yes, give reasons.		
If no, why?		
What does democracy mean to you?		
What do you think democracy means to other people in your area?		
What can be done to improve your lives in this area?		
If you were charged with planning for development here, how would you go about it?		

E: Field Description and Morphological Data Sheet

Study Area name:------------------------------ Described by:-----------------------------------

A-Horizon: General Information

Profile Number/reference
Grid Reference
Date
Altitude
Soil Surface
Infiltration Rate
Soil Moisture Content
Horizon Depth
Boundary of previous and next horizon
Soil Colour
Texture
Structure
Status of Organic Matter
Vegetation and Land use
Stoniness

B-Horizon: Site Description

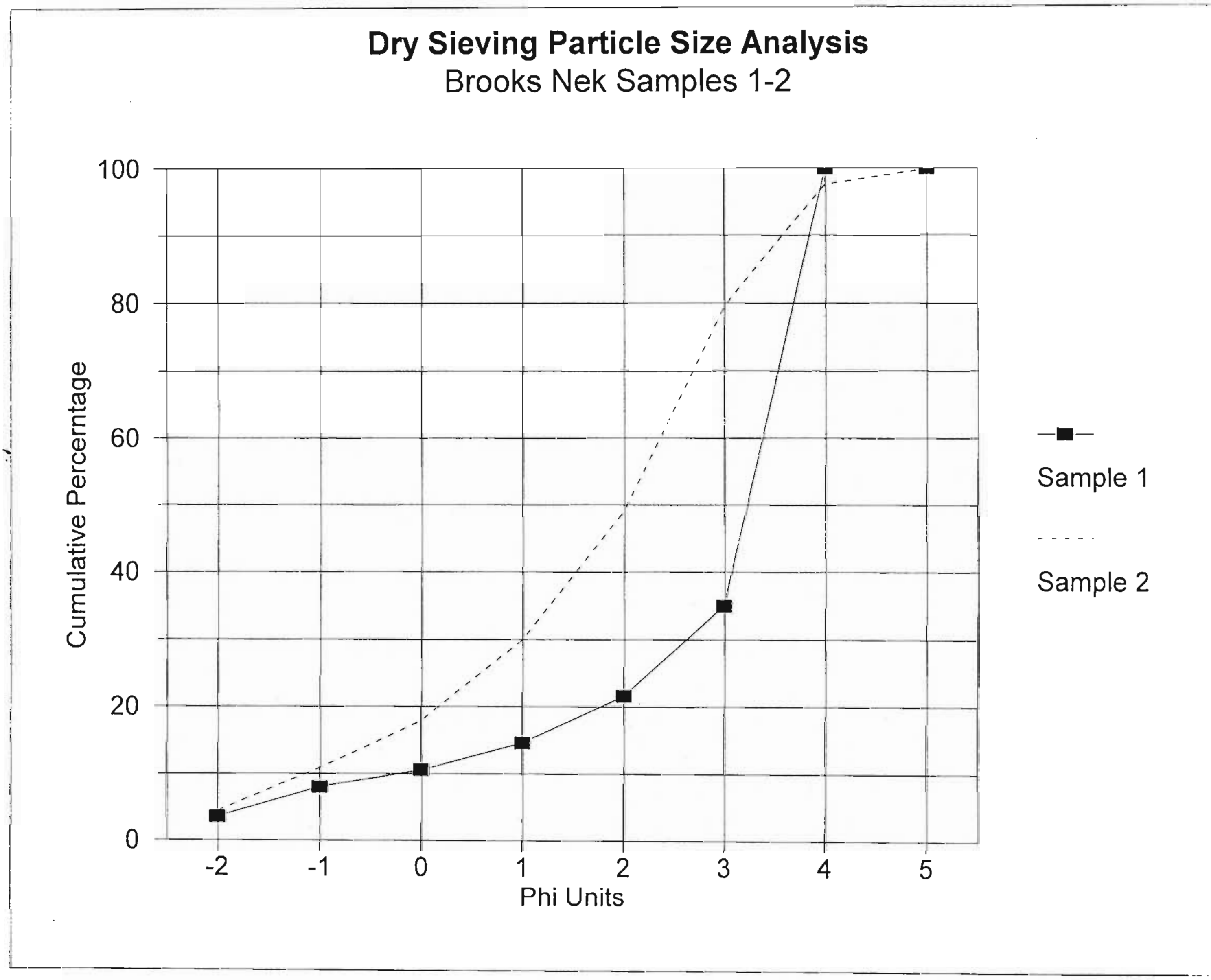
Soil Surface/rock outcrops
Relief
Horizon Depth
Colour
Texture
Structure
Status of Organic Matter
Boundary of previous and next horizon
Soil Moisture Content
Stoniness

C-Horizon: Profile Description

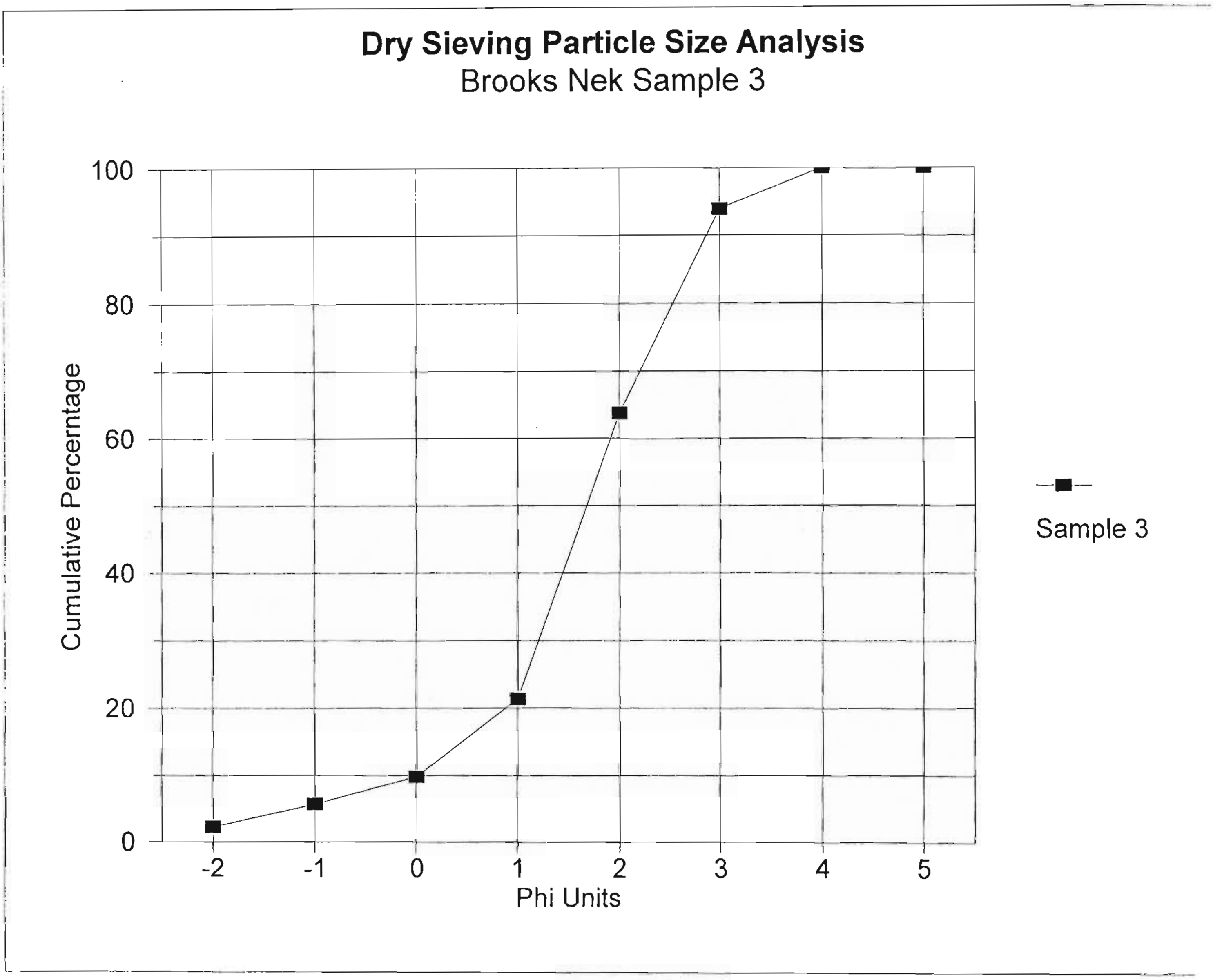
Horizon Recognition/identification
Depth
Colour
Texture
Structure
Status of Organic Matter
Boundary of previous and next horizon
Soil Moisture Content
Stoniness/bedrock

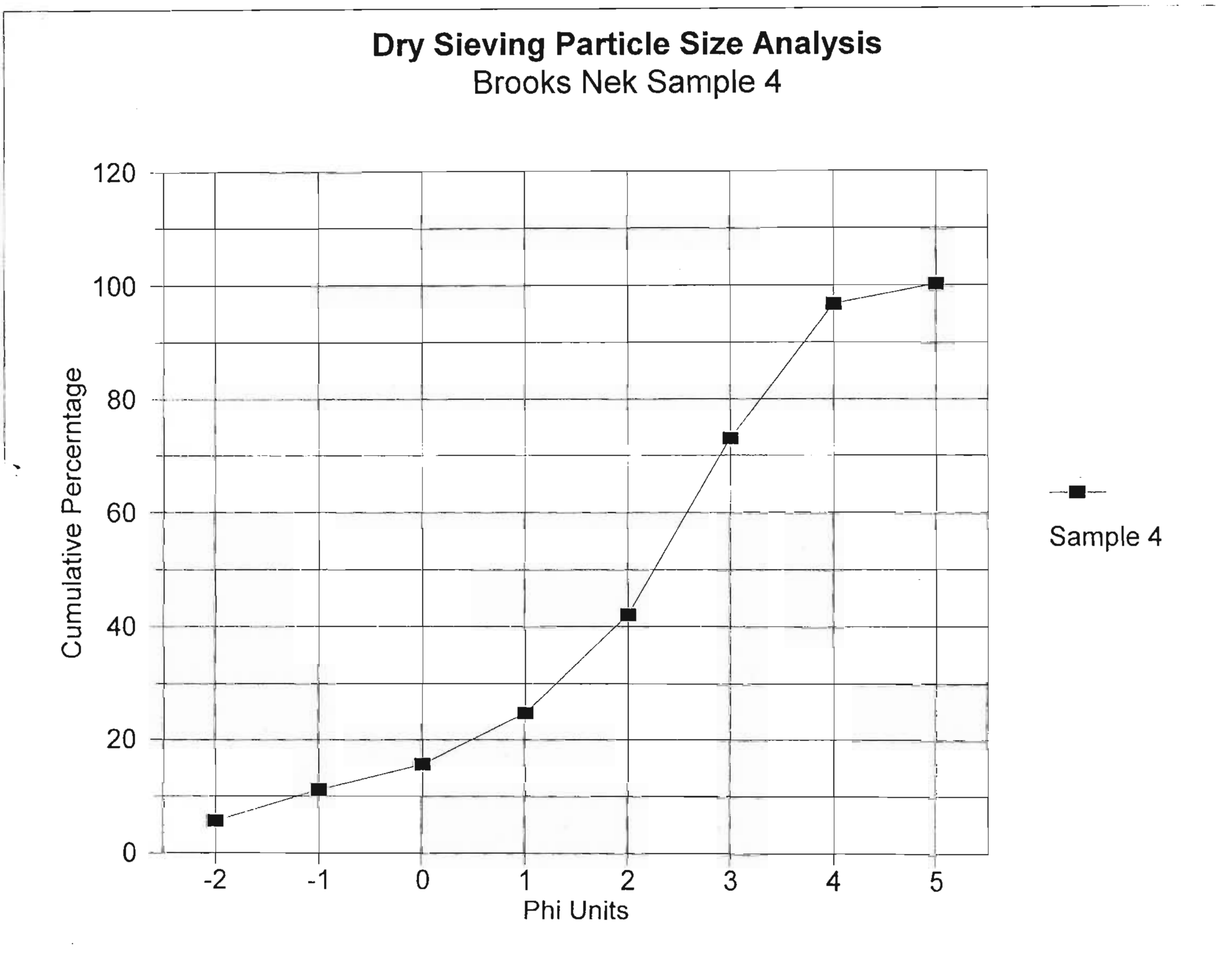
Within gully - bedwidth, bankwidth and depth

Appendix B-1: Dry Sieving Particle Size Analysis

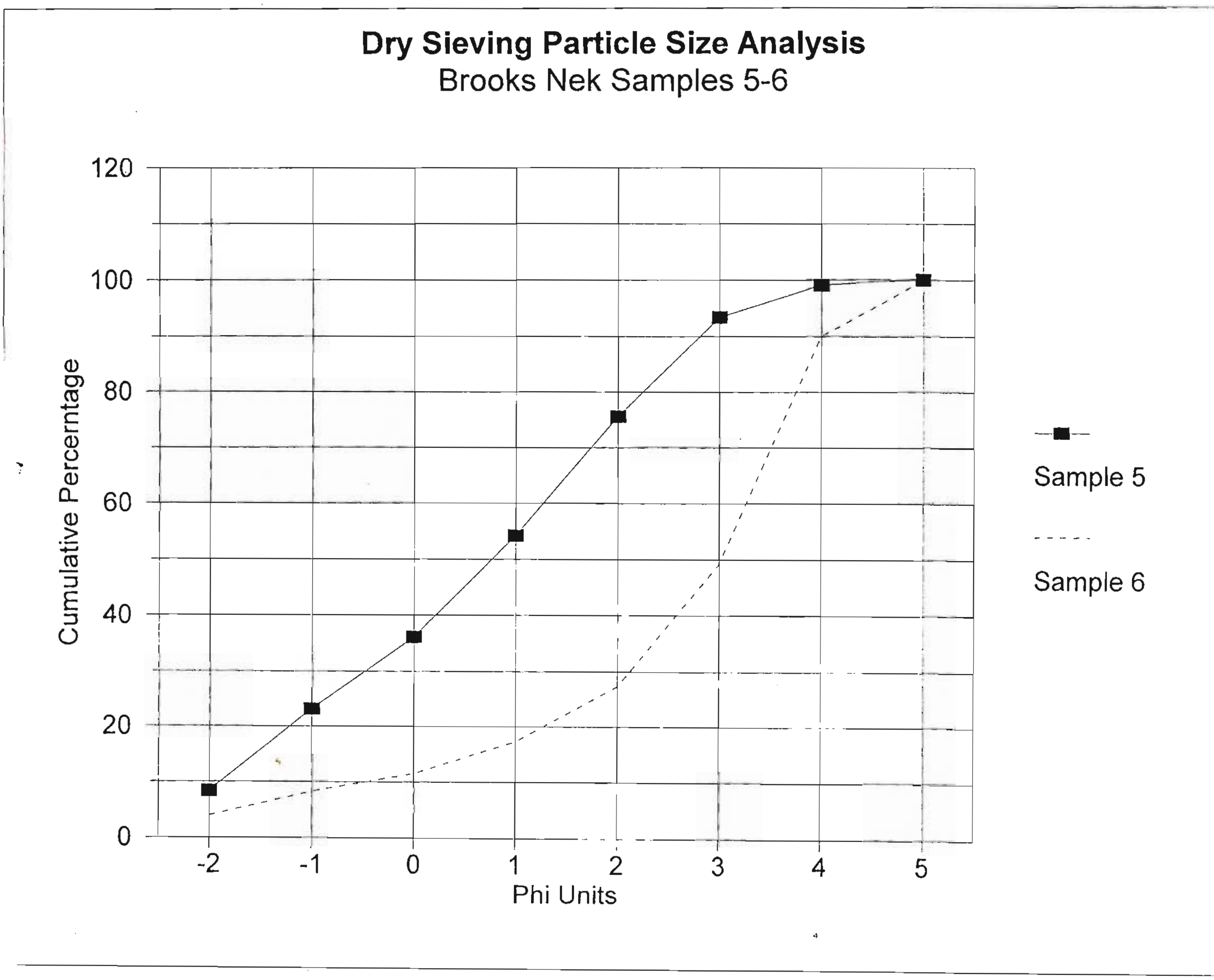


Dry Sieving Particle Size Analysis
Brooks Nek Samples 1-2
Cumulative Percerntage
100
80
60
40
20
0
-2
-1
0
1
2
3
4
5
Phi Units
Sample 1
Sample 2

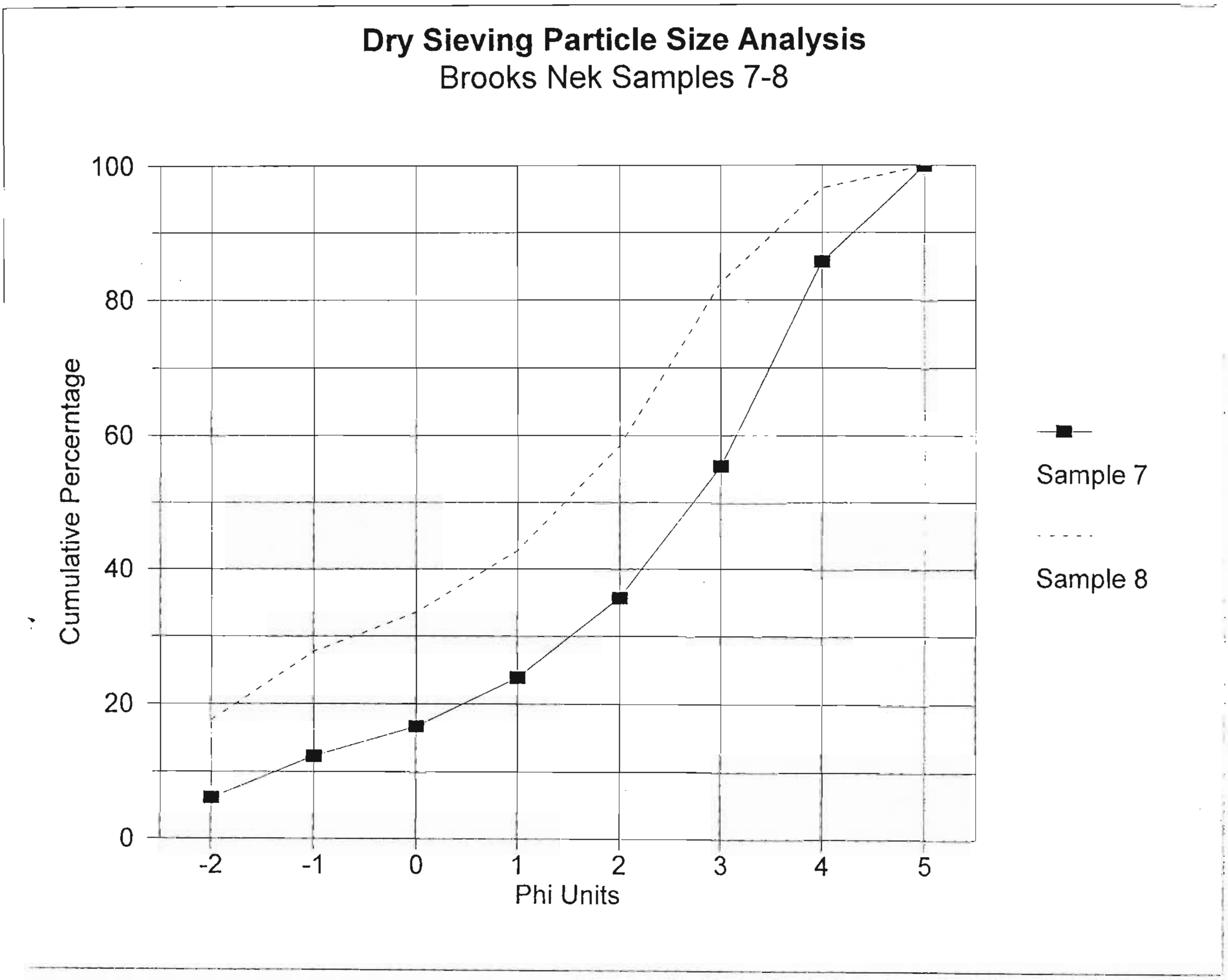

Dry Sieving Particle Size Analysis
Brooks Nek Sample 3
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
5
Phi Units
Sample 3

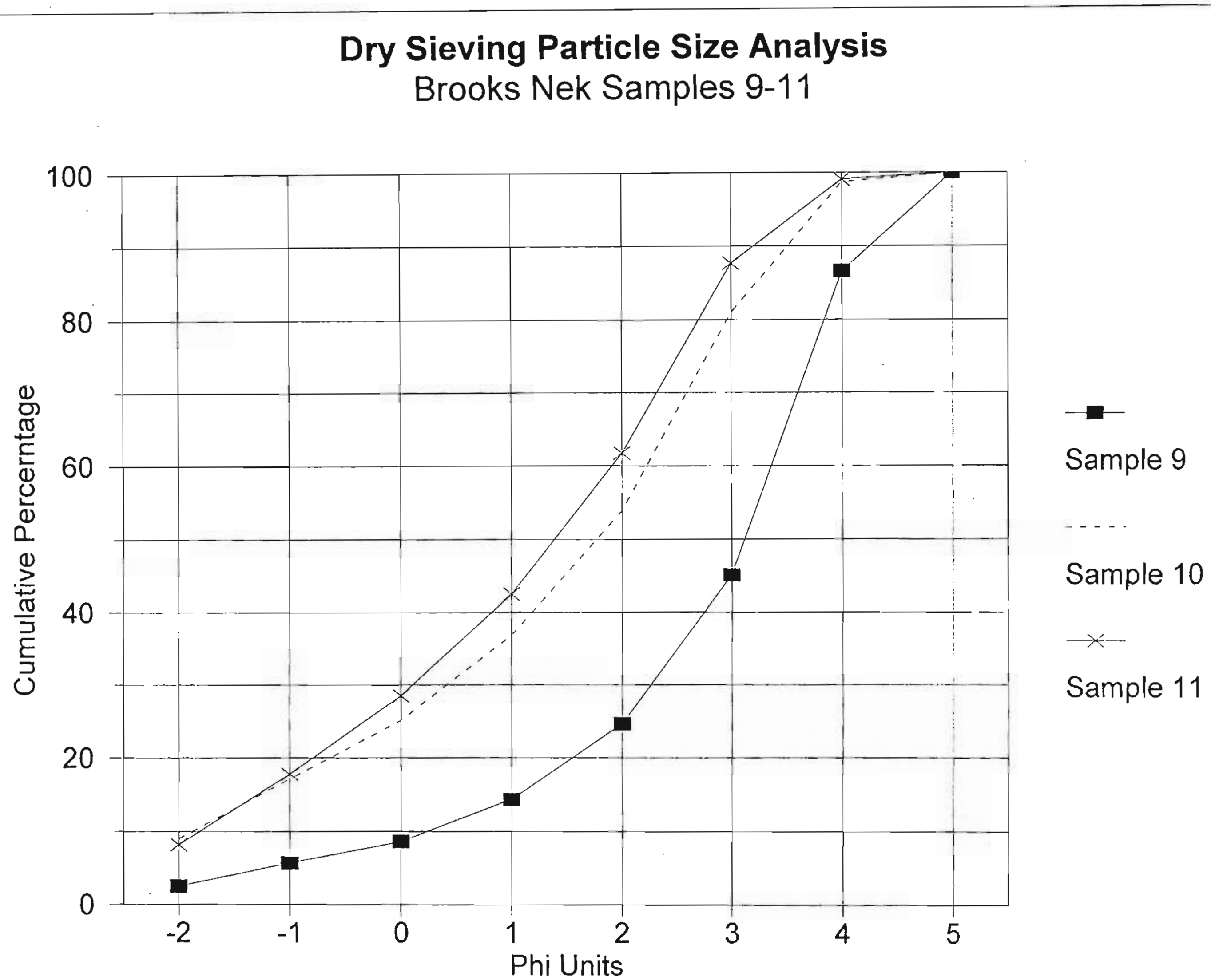


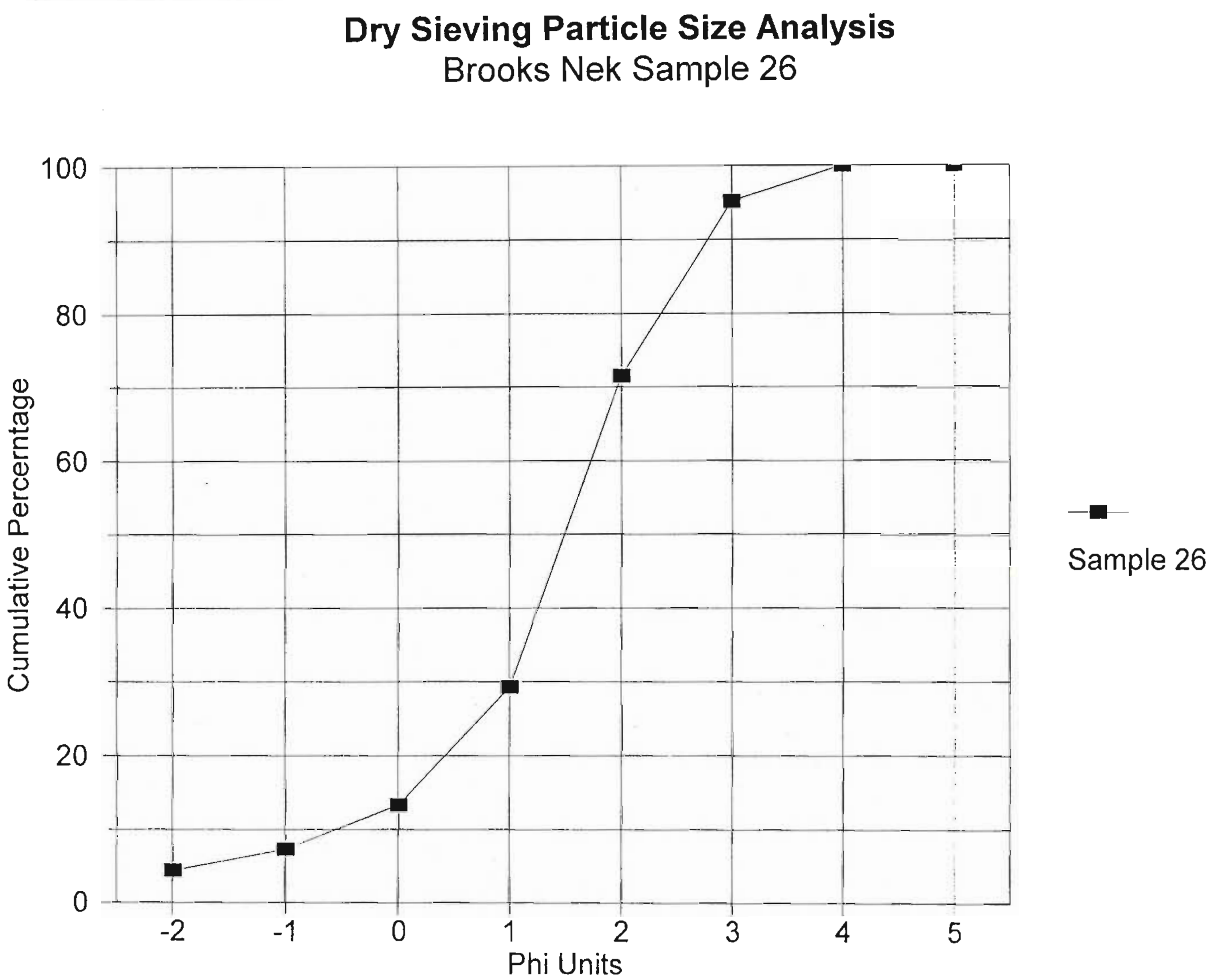
Dry Sieving Particle Size Analysis
Brooks Nek Sample 4
120
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
5
Phi Units
Sample 4



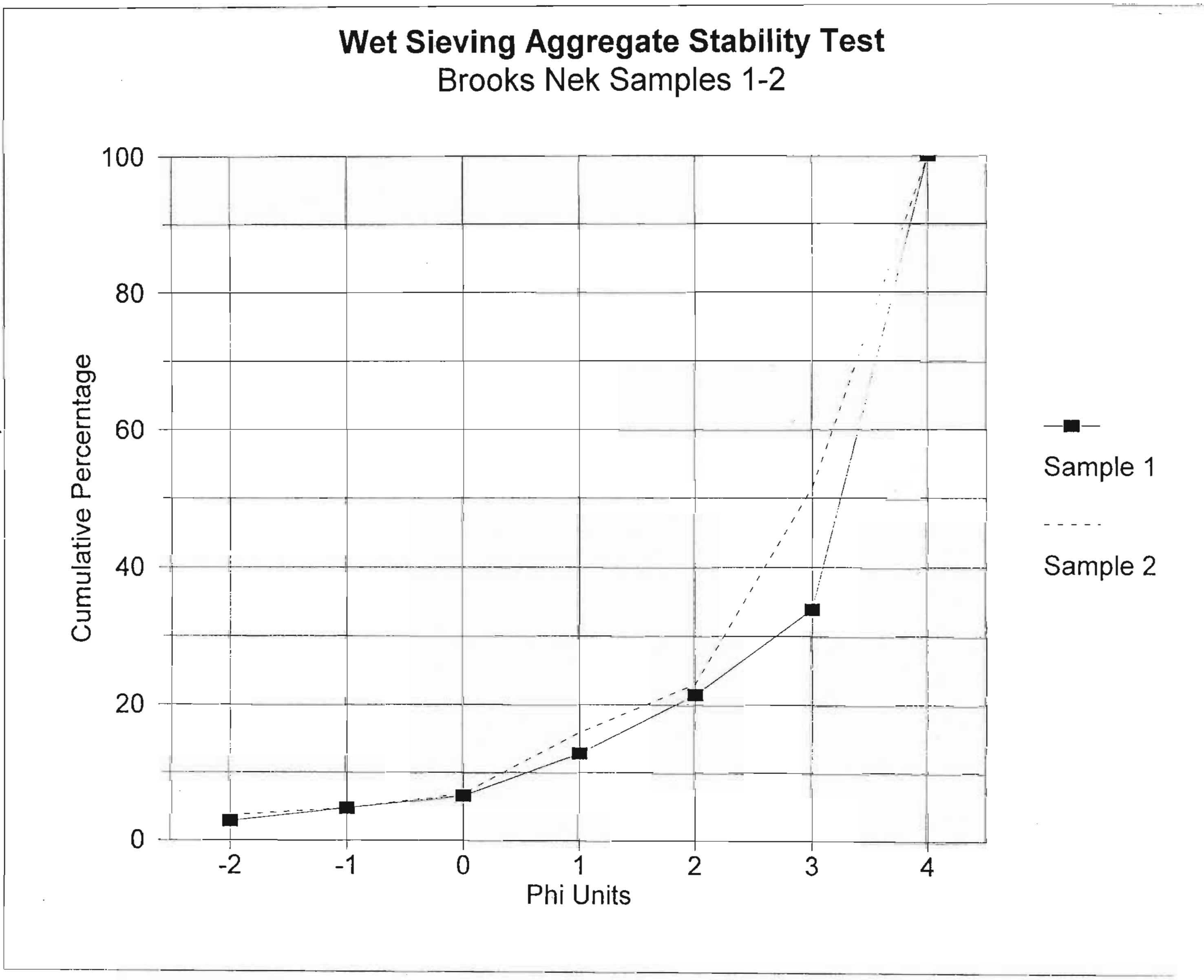
Dry Sieving Particle Size Analysis
Brooks Nek Samples 5-6
120
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
5
Phi Units
Sample 5
Sample 6


Dry Sieving Particle Size Analysis
Brooks Nek Samples 7-8
Cumulative Percerntage
0
20
40
60
80
100
-2
-1
0
1
2
3
4
5
Phi Units
Sample 7
Sample 8

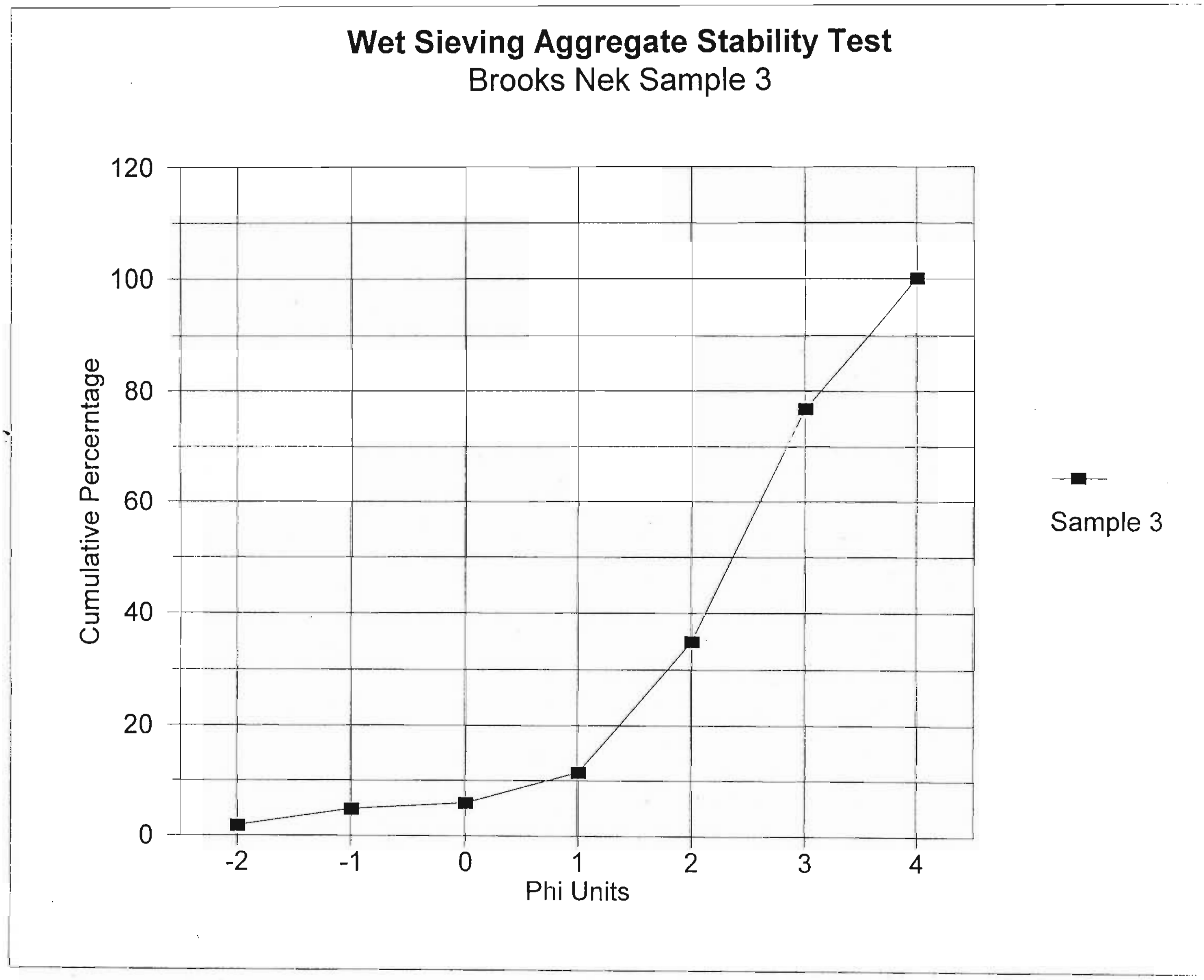

Dry Sieving Particle Size Analysis
Brooks Nek Samples 9-11
Cumulative Percentage
100
80
60
40
20
0
-2
-1
0
1
2
3
4
5
Phi Units
Sample 9
Sample 10
Sample 11

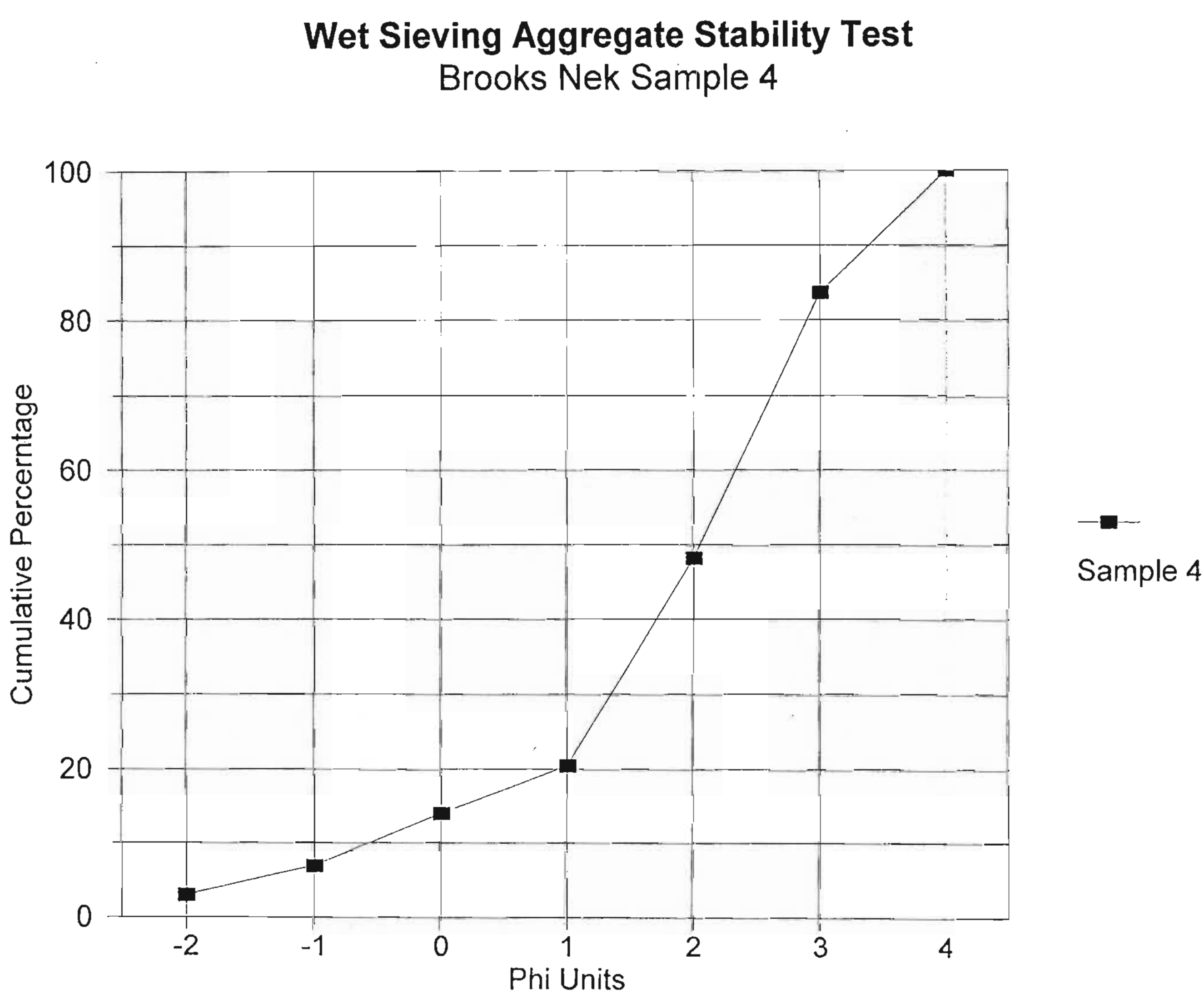

Dry Sieving Particle Size Analysis
Brooks Nek Sample 26
Cumulative Percerntage
100
80
60
40
20
0
-2
-1
0
1
2
3
4
5
Phi Units
Sample 26

Appendix B-2: Wet Sieving Aggregate Stability Test

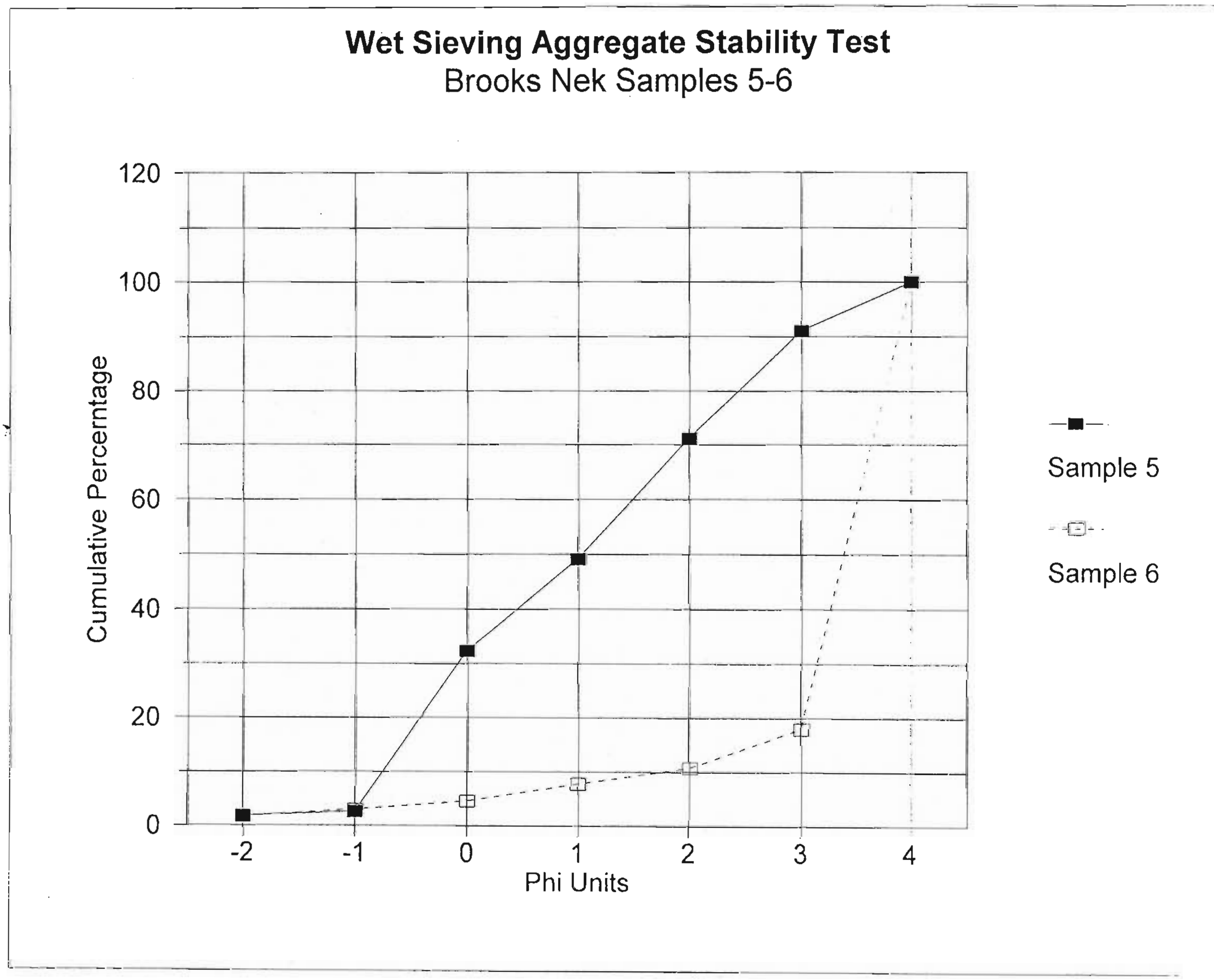


Wet Sieving Aggregate Stability Test
Brooks Nek Samples 1-2
Cumulative Percentage
100
80
60
40
20
0
-2
-1
0
1
2
3
4
Phi Units
Sample 1
Sample 2


Wet Sieving Aggregate Stability Test
Brooks Nek Sample 3
120
100
80
60
40
20
0
Cumulative Percentage
-2
-1
0
1
2
3
4
Phi Units
Sample 3

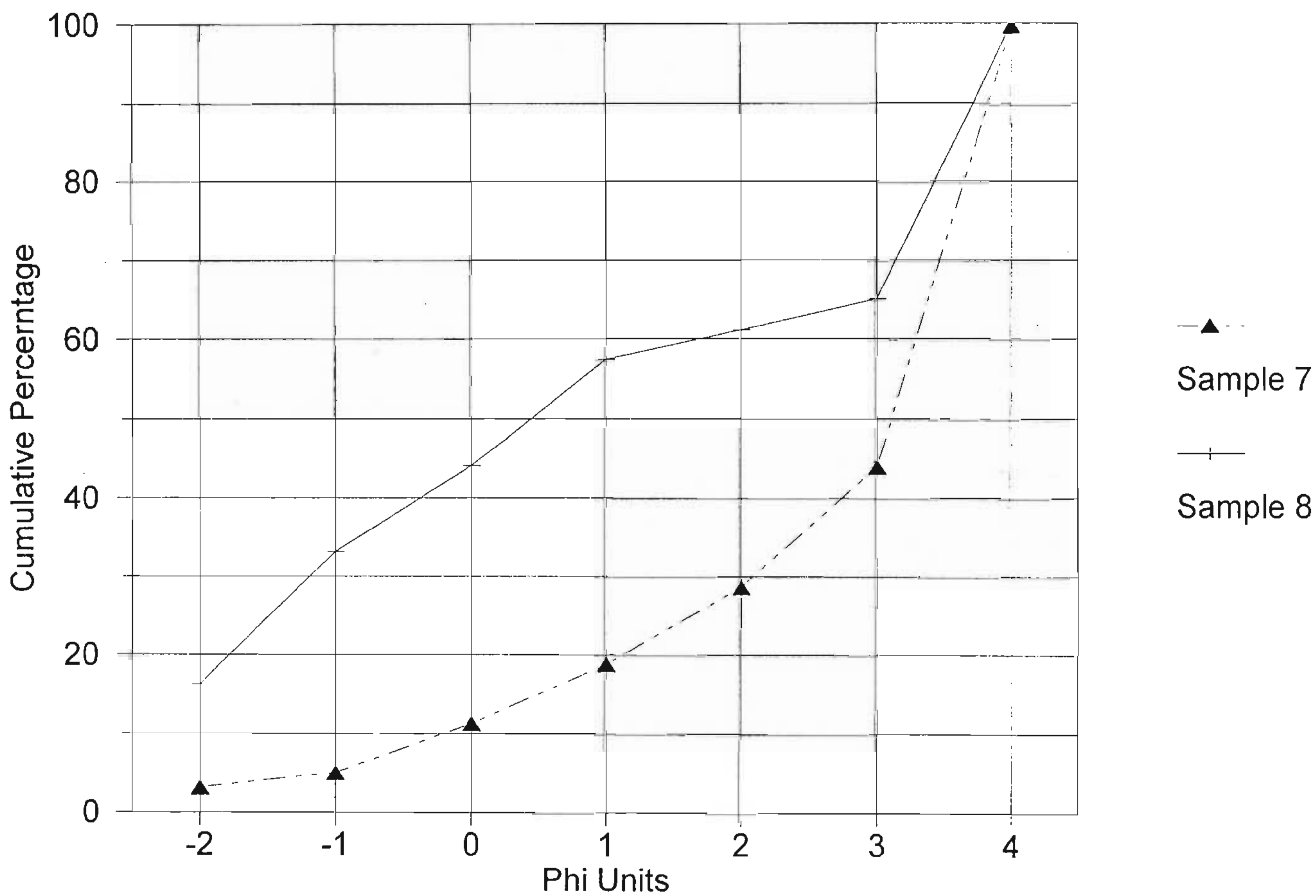


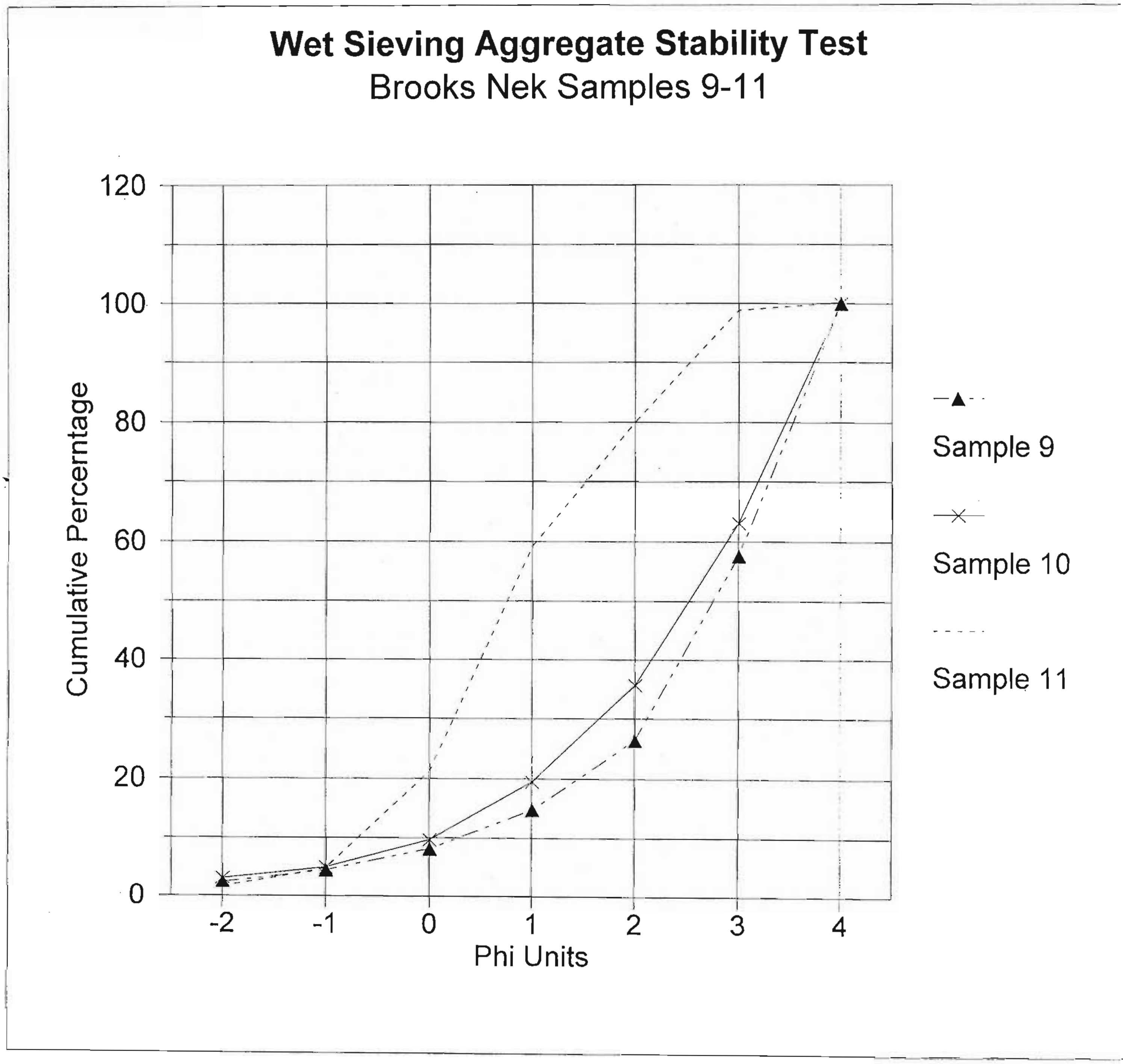
Wet Sieving Aggregate Stability Test
Brooks Nek Sample 4
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
Phi Units
Sample 4



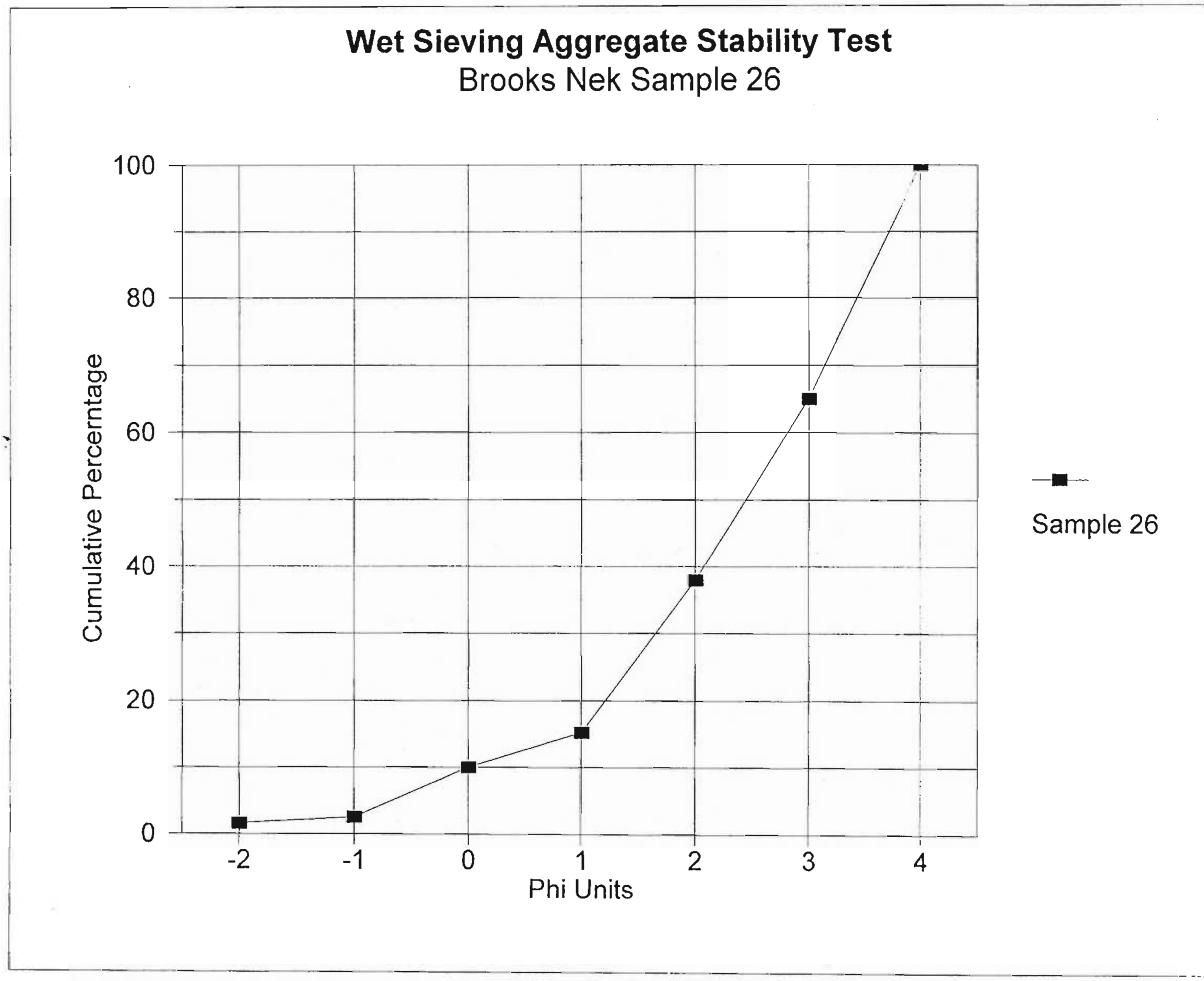
Wet Sieving Aggregate Stability Test
Brooks Nek Samples 5-6
Cumulative Percerntage
120
100
80
60
40
20
0
-2
-1
0
1
2
3
4
Phi Units
Sample 5
Sample 6

Wet Sieving Aggregate Stability Test
Brooks Nek Samples 7-8





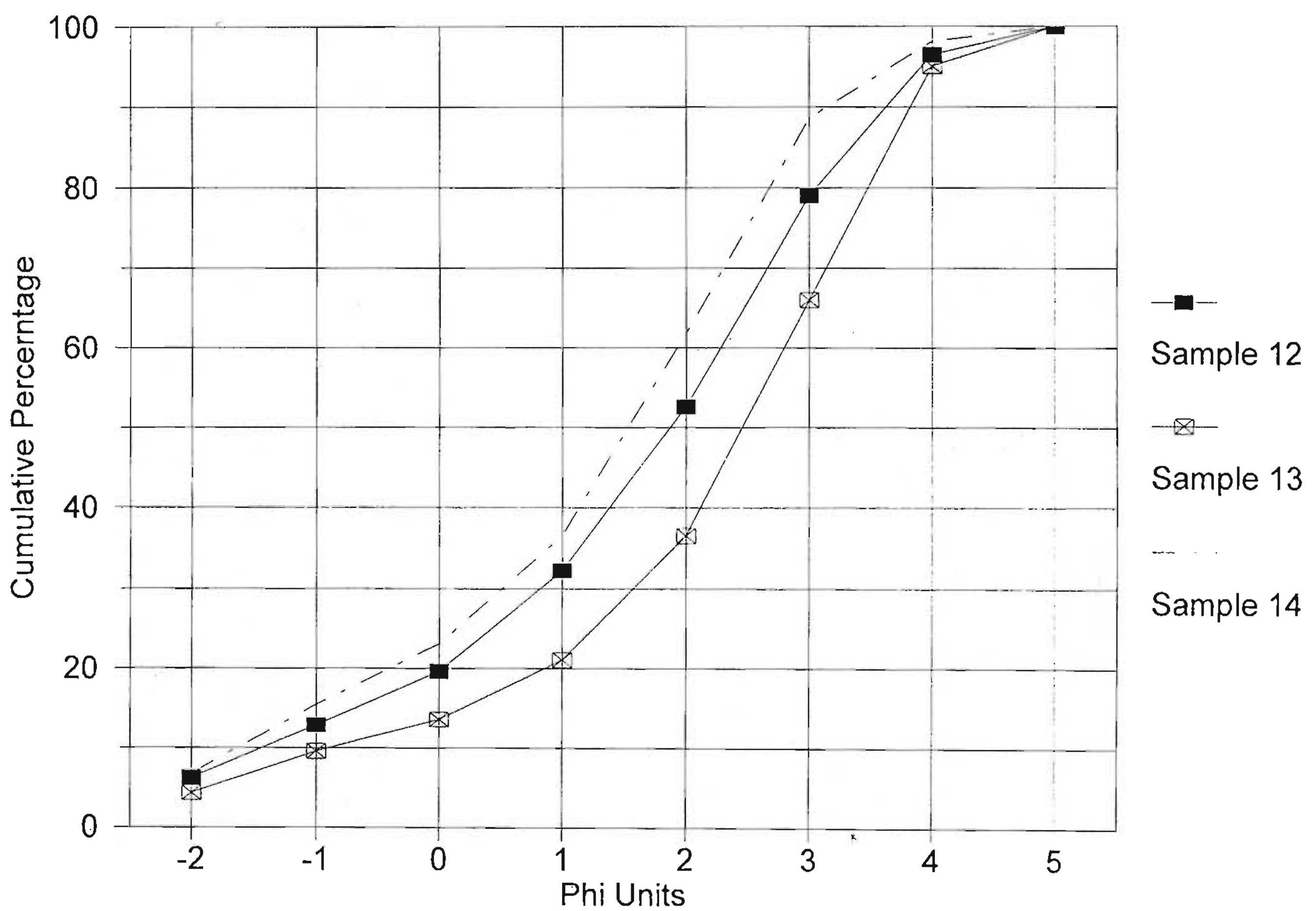
Wet Sieving Aggregate Stability Test
Brooks Nek Samples 9-11
120
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
Phi Units
Sample 9
Sample 10
Sample 11

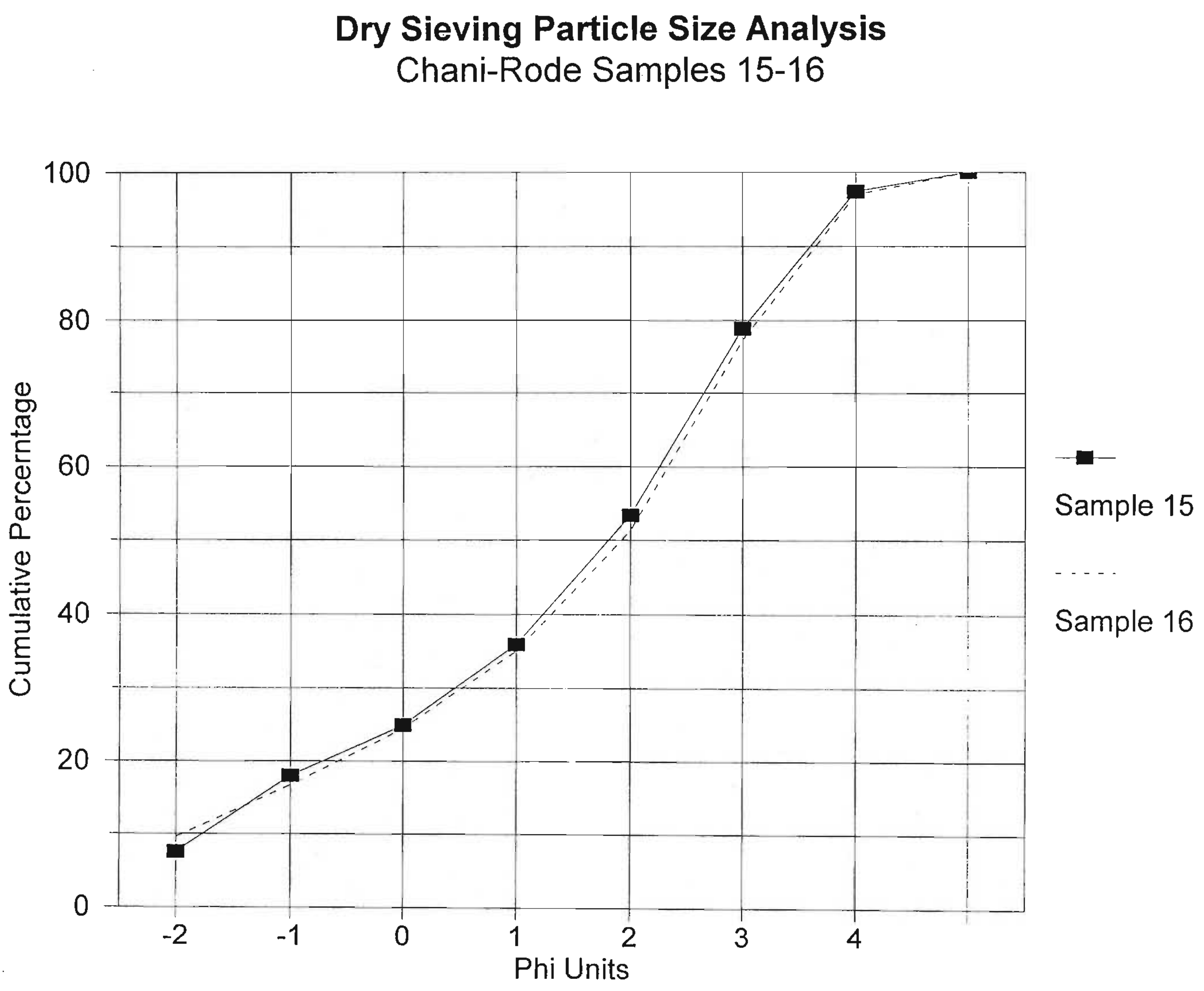


Wet Sieving Aggregate Stability Test
Brooks Nek Sample 26
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
Phi Units
Sample 26

Appendix C-1: Dry Sieving Particle Size Analysis

Dry Sieving Particle Size Analysis
Chani-Rode Samples 12-14




Dry Sieving Particle Size Analysis
Chani-Rode Samples 15-16
Cumulative Percerntage
100
80
60
40
20
0
-2
-1
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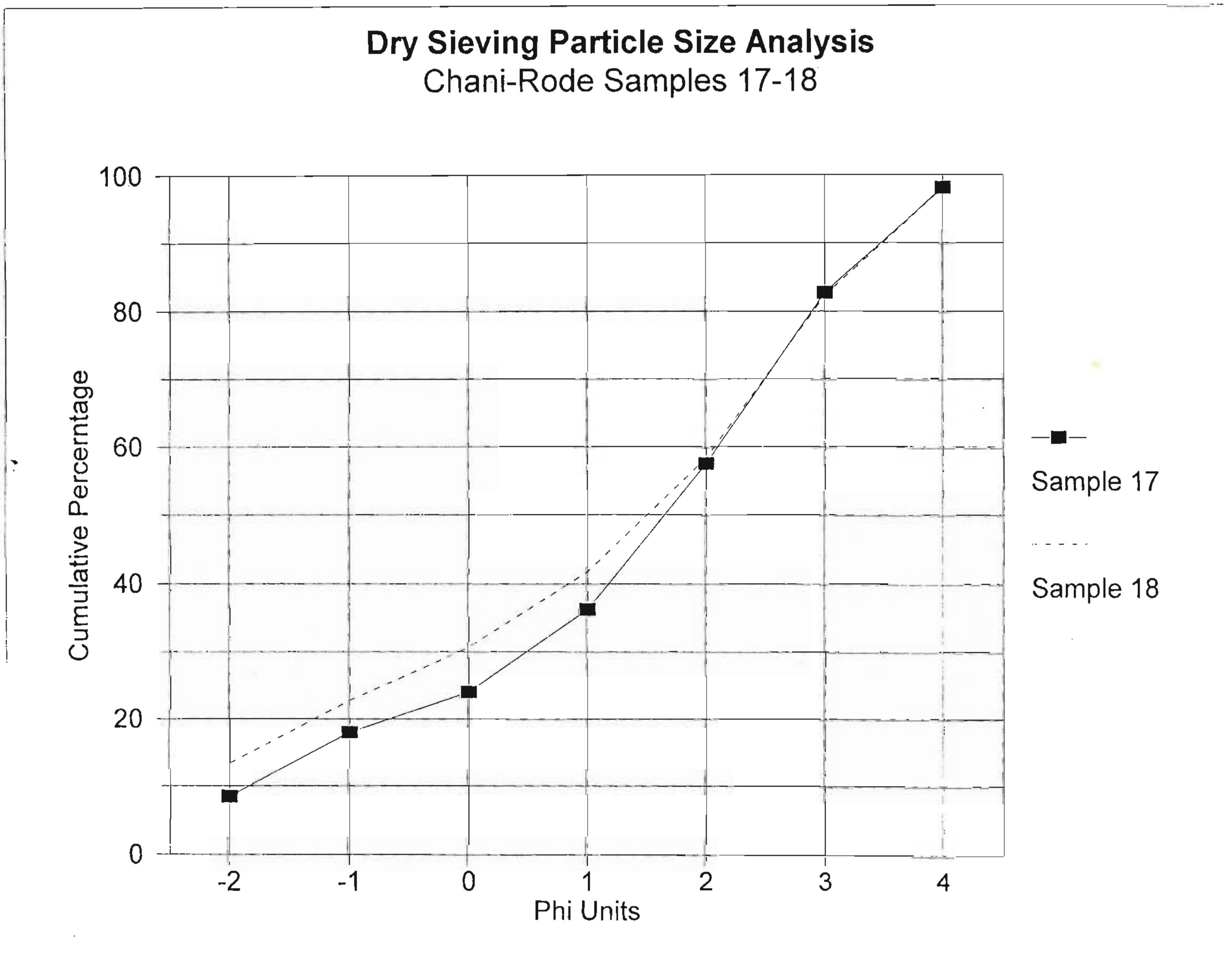
1
2
3
4
Phi Units
Sample 15
Sample 16


Dry Sieving Particle Size Analysis
Chani-Rode Samples 17-18
Cumulative Percerntage
100
80
60
40
20
0
-2
-1
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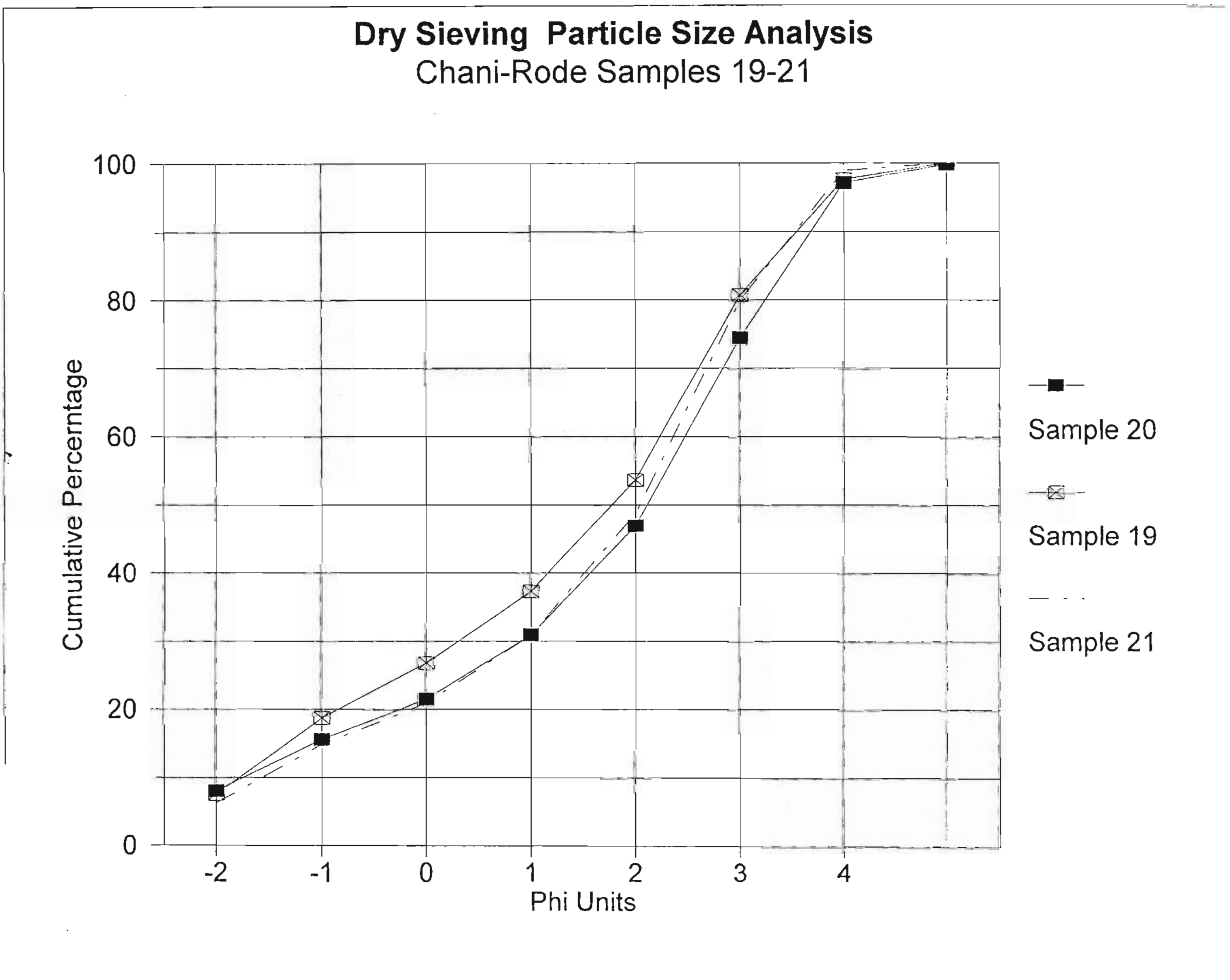
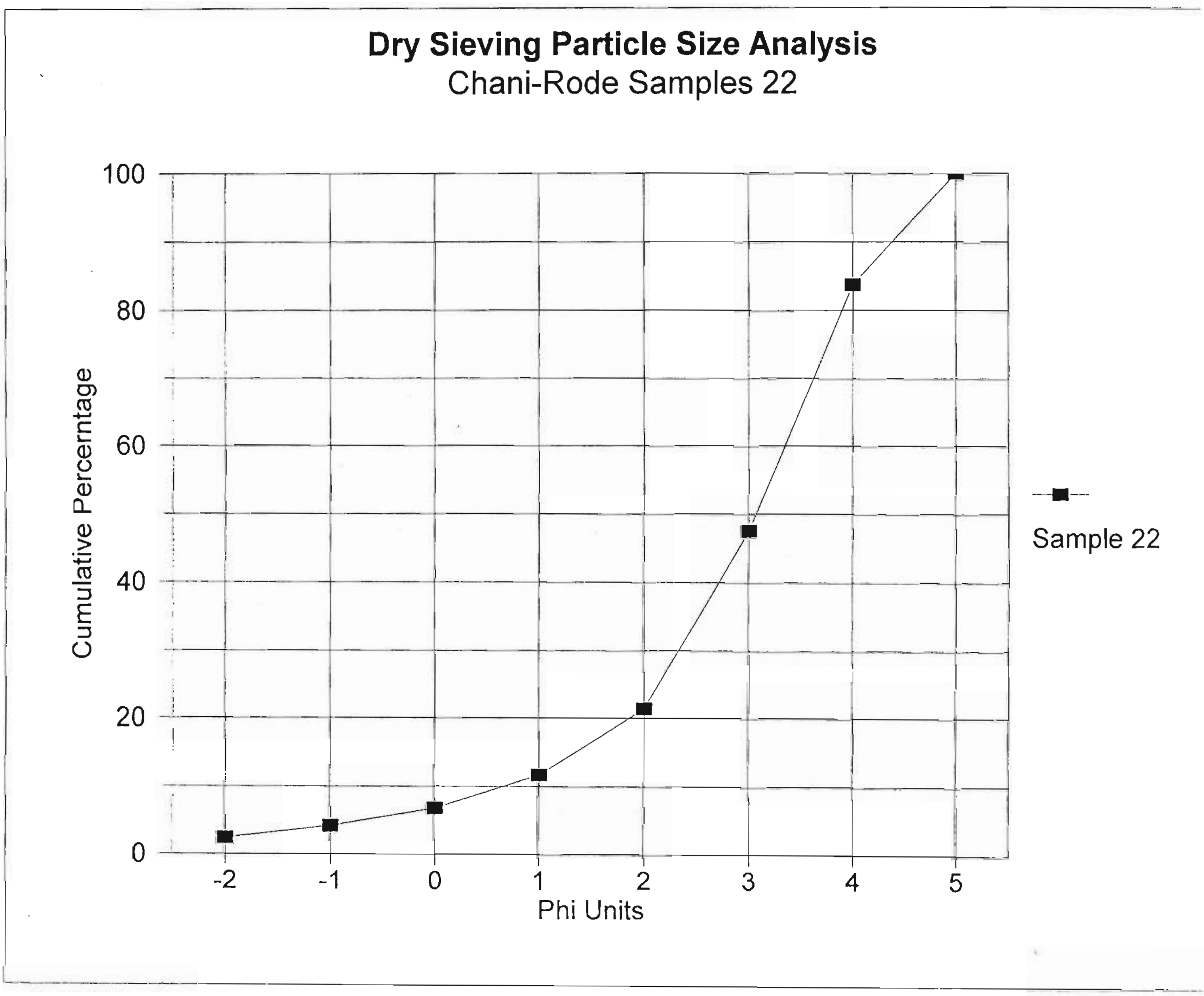
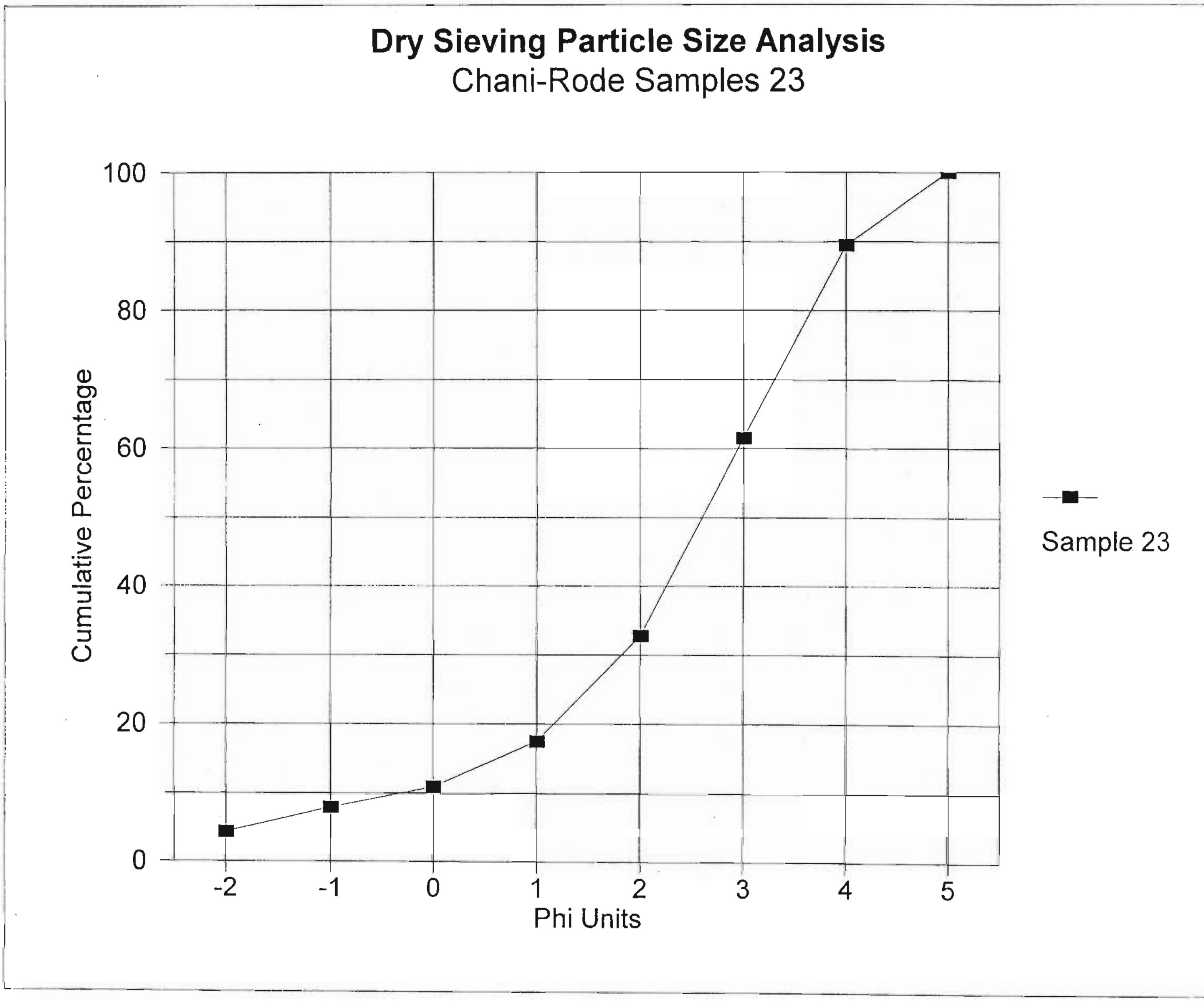
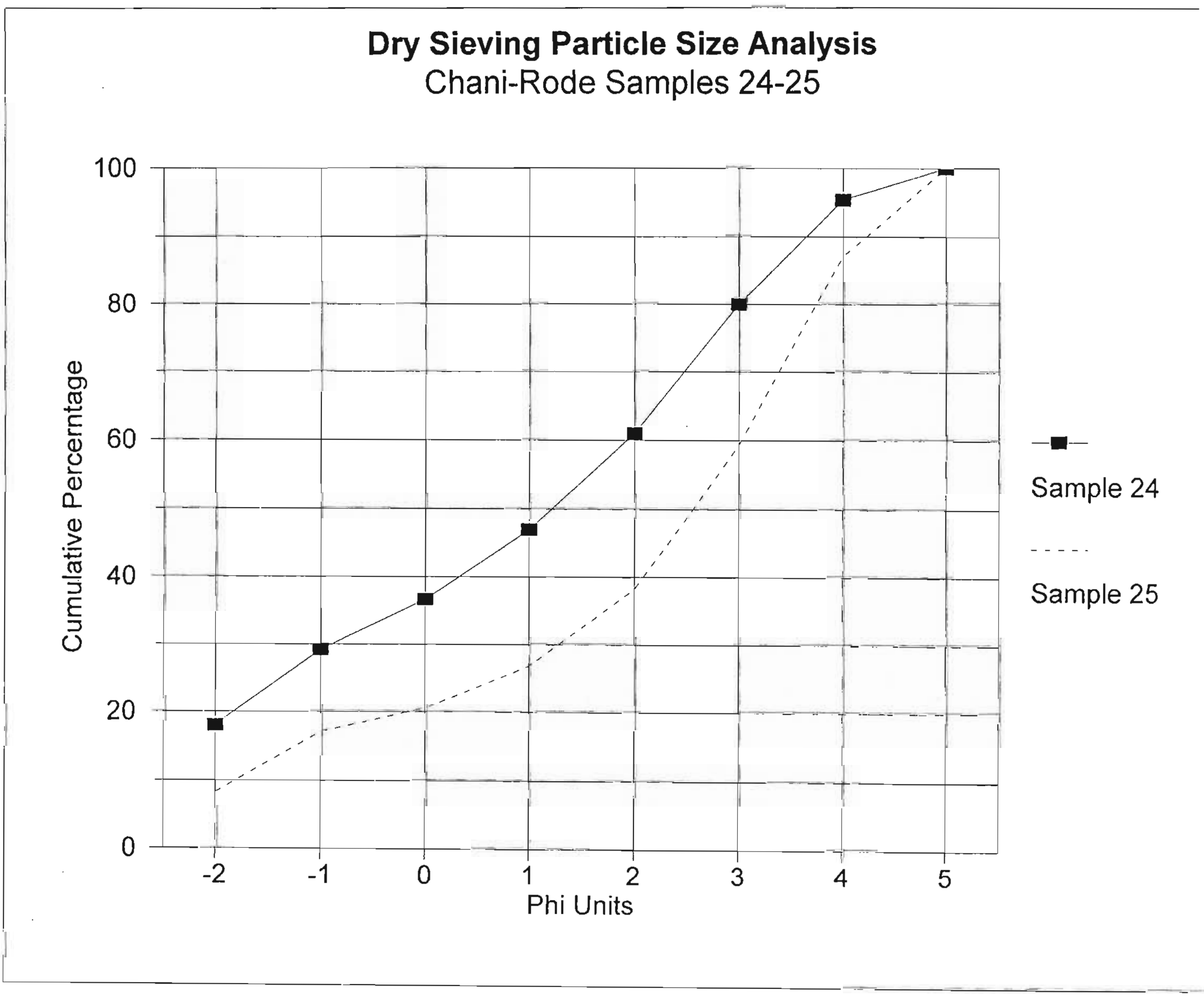
2
3
4
Phi Units
Sample 17
Sample 18



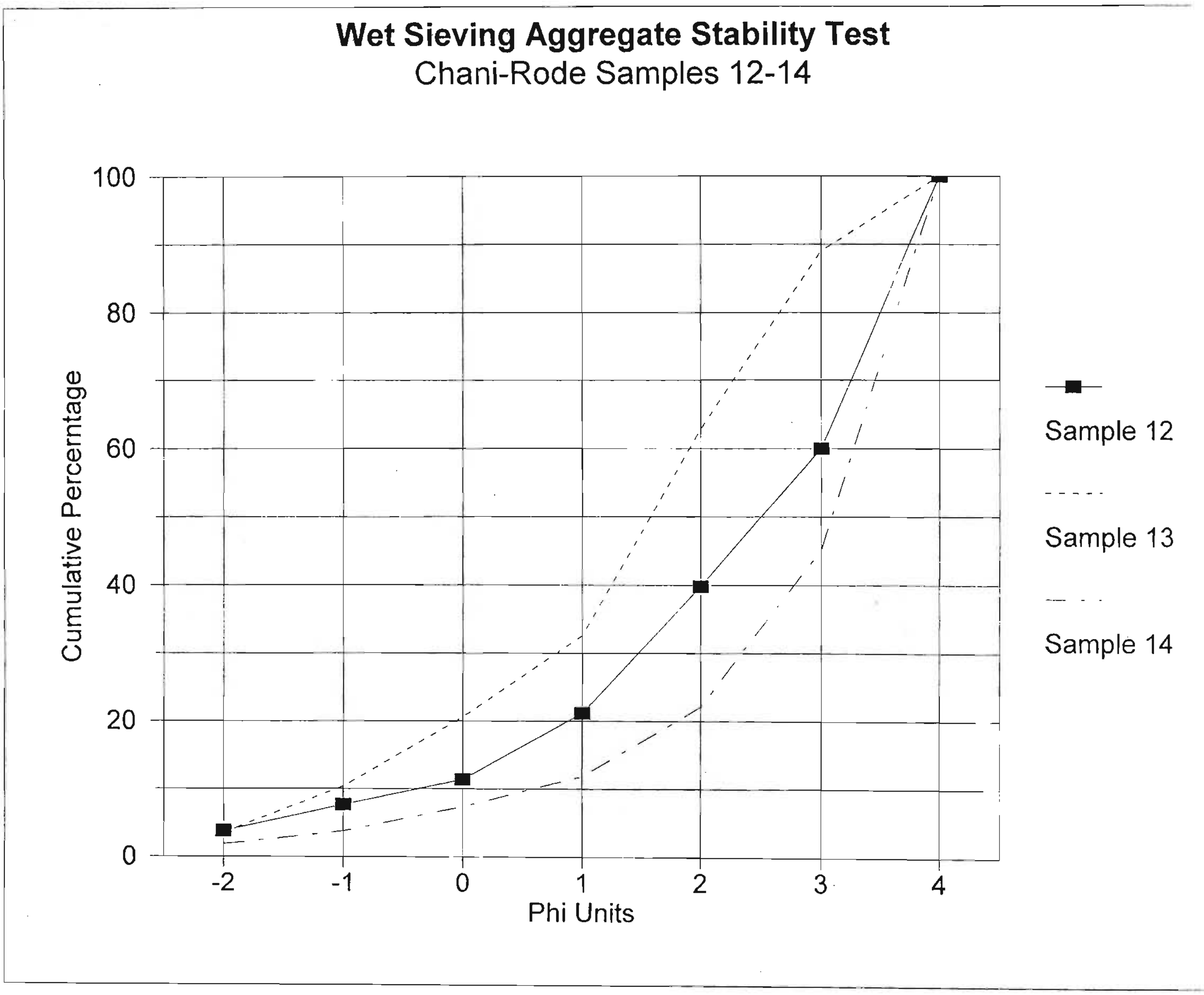
Dry Sieving Particle Size Analysis
Chani-Rode Samples 19-21
100
80
60
40
20
0
Cumulative Percentage
-2
-1
0
1
2
3
4
Phi Units
Sample 20
Sample 19
Sample 21

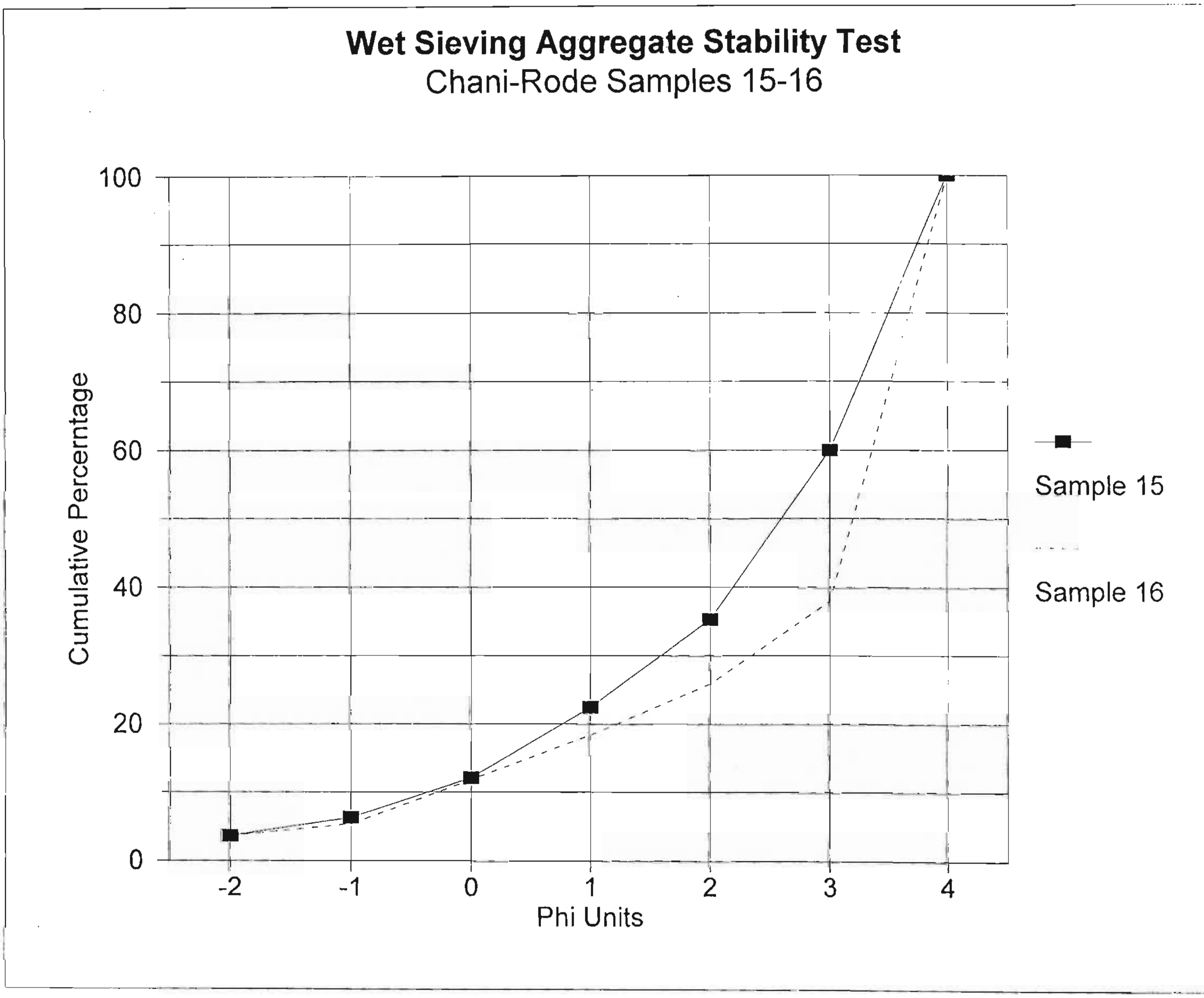

Dry Sieving Particle Size Analysis
Chani-Rode Samples 22
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
5
Phi Units
Sample 22

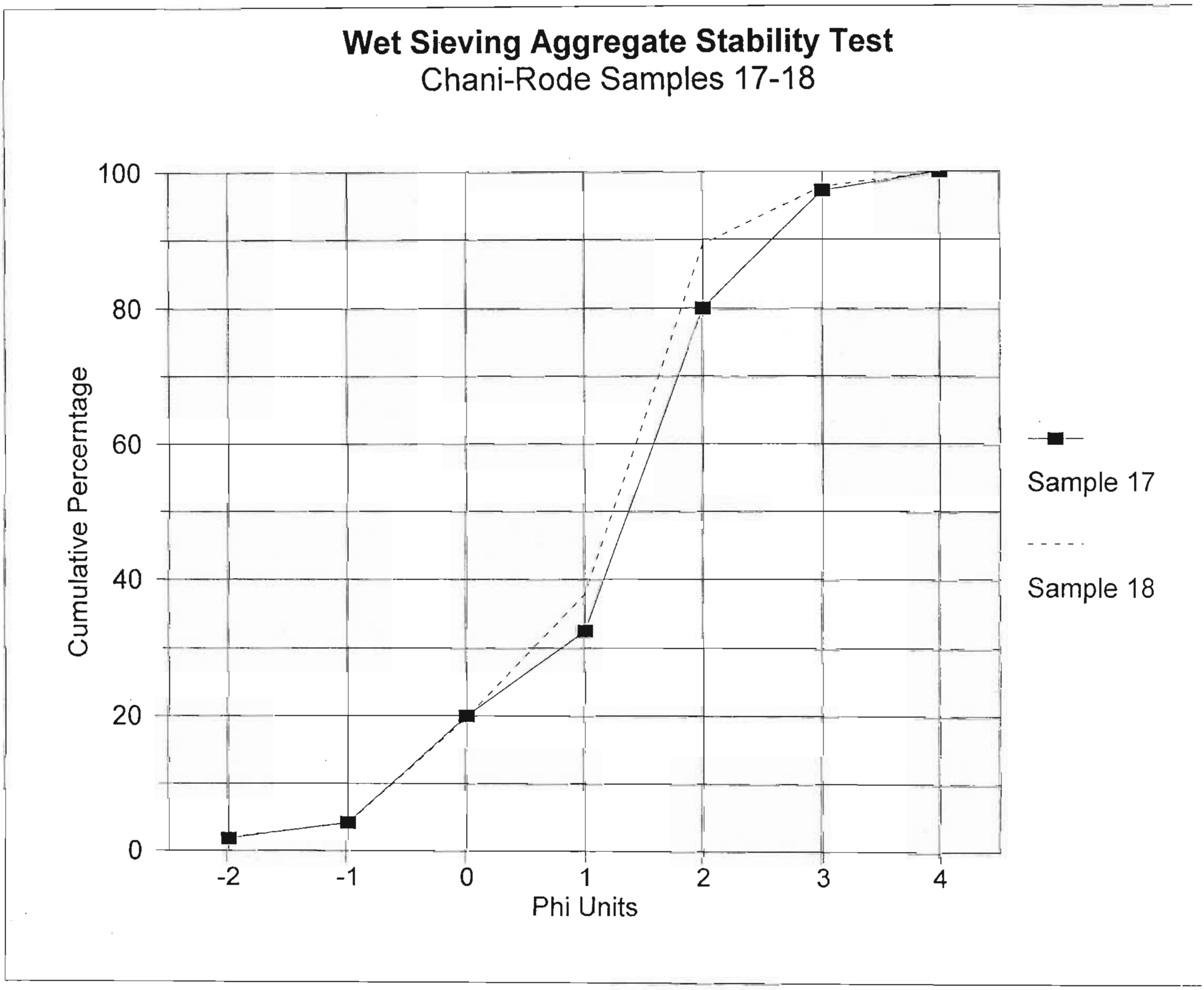

Dry Sieving Particle Size Analysis
Chani-Rode Samples 23
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
5
Phi Units
Sample 23


Dry Sieving Particle Size Analysis
Chani-Rode Samples 24-25
Cumulative Percerntage
0
20
40
60
80
100
-2
-1
0
1
2
3
4
5
Phi Units
Sample 24
Sample 25

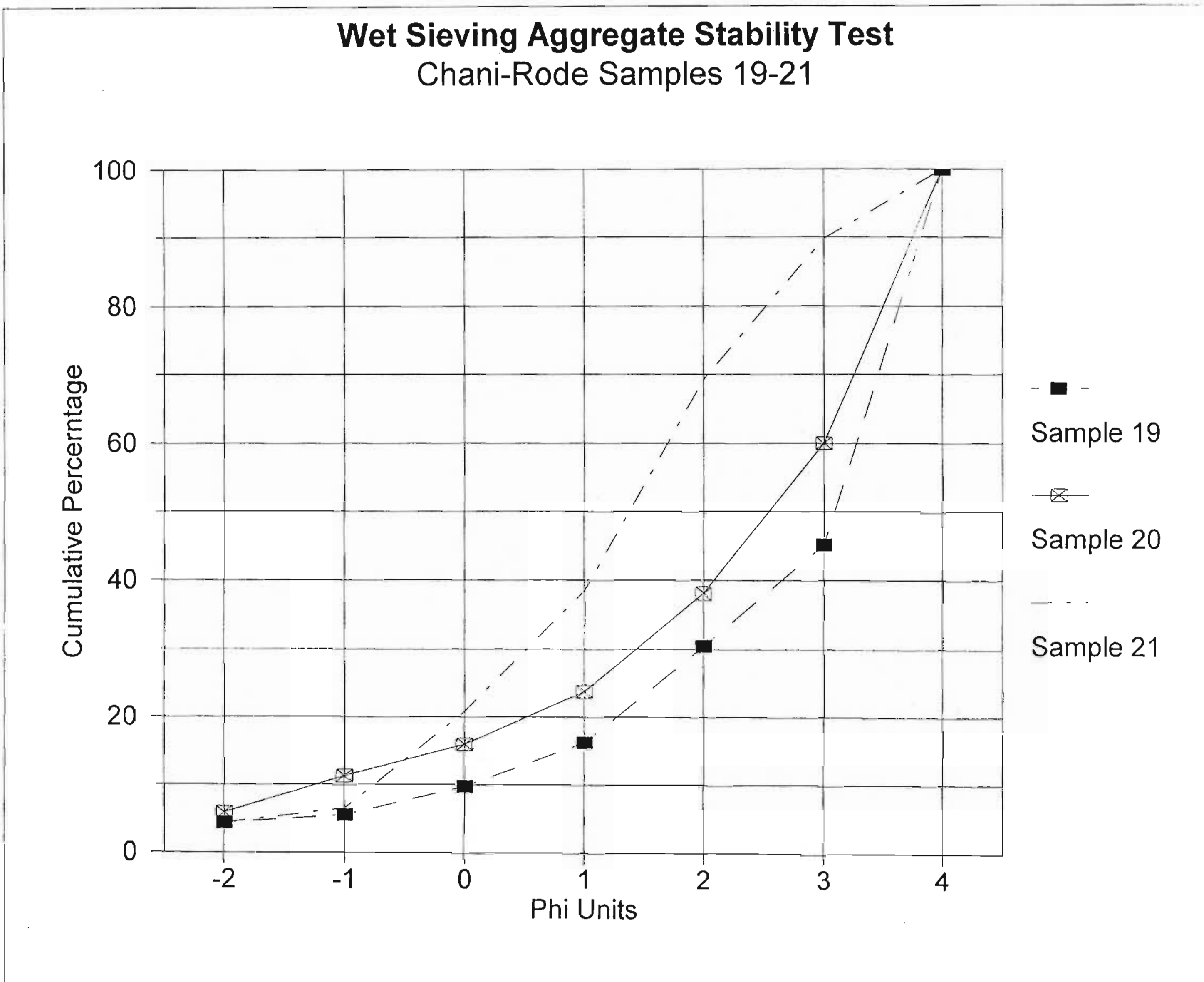
Appendix C-2: Wet Sieving Aggregate Stability Test

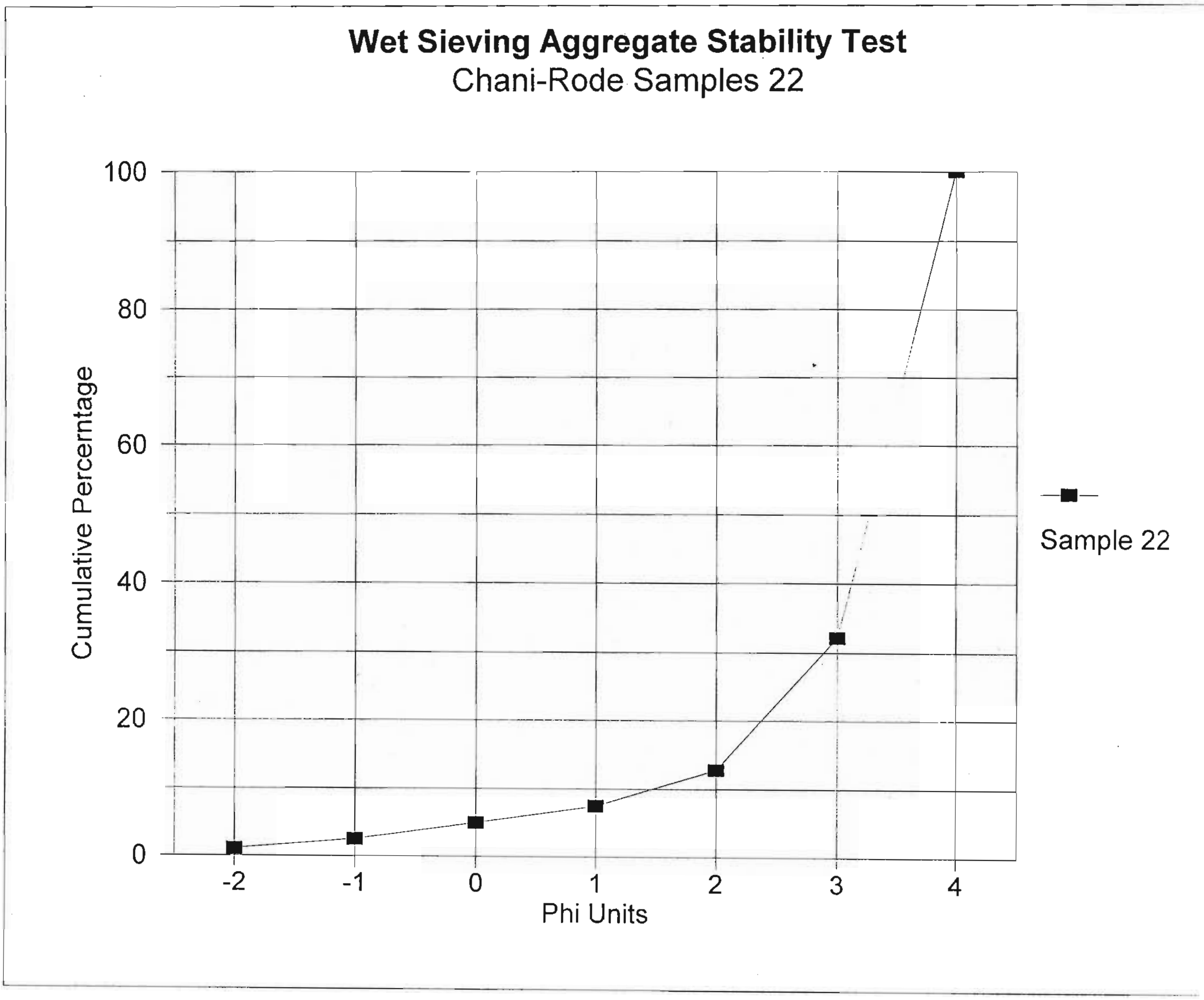

Wet Sieving Aggregate Stability Test
Chani-Rode Samples 12-14
Cumulative Percerntage
100
80
60
40
20
0
-2
-1
0
1
2
3
4
Phi Units
Sample 12
Sample 13
Sample 14

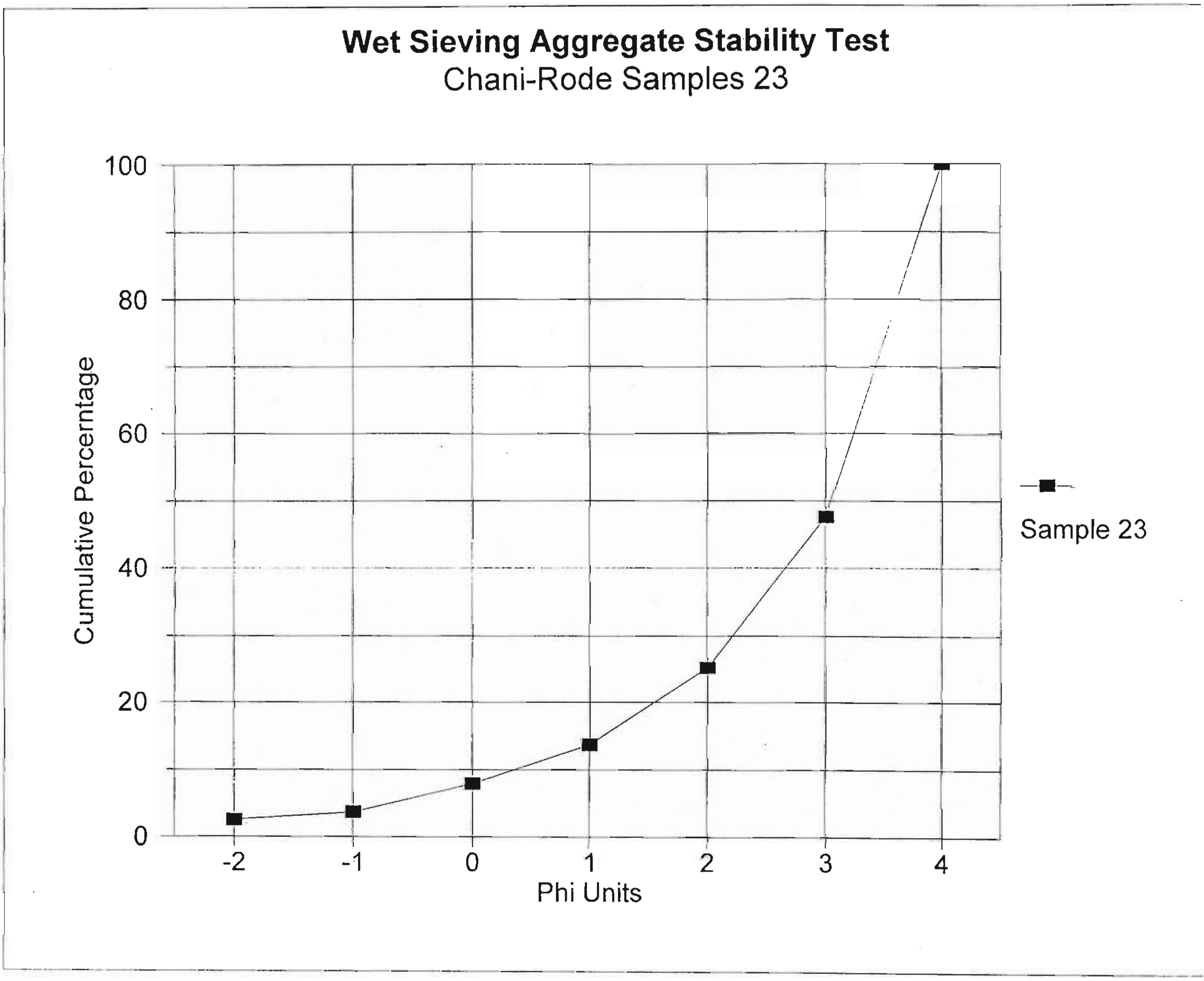

Wet Sieving Aggregate Stability Test
Chani-Rode Samples 15-16
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
Phi Units
Sample 15
Sample 16



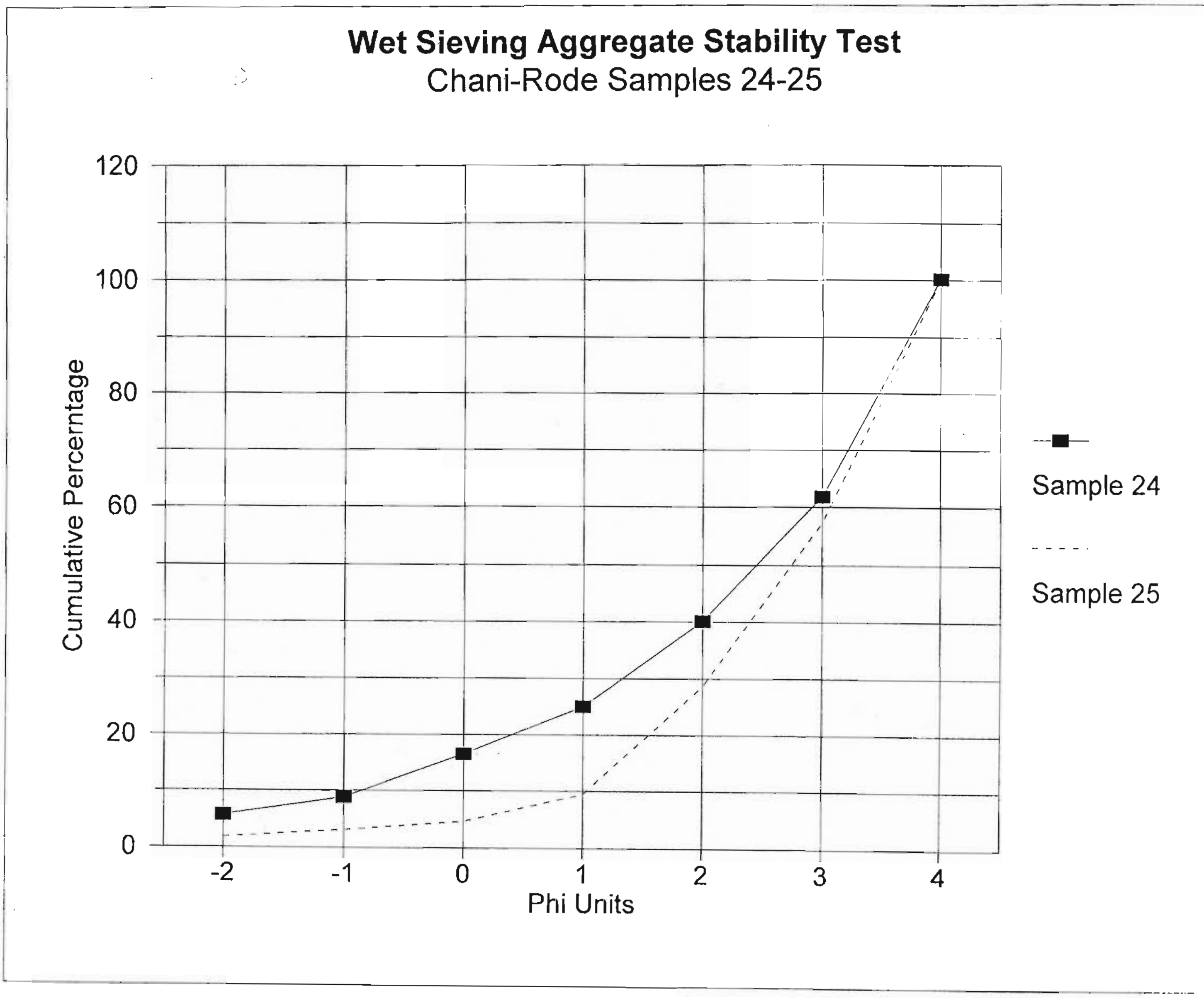
Wet Sieving Aggregate Stability Test
Chani-Rode Samples 17-18
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
Phi Units
Sample 17
Sample 18


Wet Sieving Aggregate Stability Test
Chani-Rode Samples 19-21
Cumulative Percerntage
100
80
60
40
20
0
-2
-1
0
1
2
3
4
Phi Units
Sample 19
Sample 20
Sample 21


Wet Sieving Aggregate Stability Test
Chani-Rode Samples 22
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
Phi Units
Sample 22



Wet Sieving Aggregate Stability Test
Chani-Rode Samples 23
100
80
60
40
20
0
Cumulative Percerntage
-2
-1
0
1
2
3
4
Phi Units
Sample 23



Wet Sieving Aggregate Stability Test
Chani-Rode Samples 24-25
120
100
80
60
40
20
0
Cumulative Perceentage
-2
-1
0
1
2
3
4
Phi Units
Sample 24
Sample 25