A FRAMEWORK FOR THE USE OF GIS FOR NATURAL RESOURCE MANAGEMENT: THE CASE OF FERNCLIFFE CATCHMENT CONSERVANCY

by

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ABSTRACT

The Ferncliffe Catchment Conservancy has been identified, within the context of Pietermaritzburg, KwaZulu-Natal, for its important geographical and ecological features. The mapping and communication of these features to the broader community resident within the Conservancy have been envisaged as an important undertaking. A most effective way of achieving this goal was to use a Geographic Information System in the mapping exercise and in creating an inventory of the resources in the Conservancy and a monitoring database. Such spatial information would then provide stakeholders with a spatial context within which to appreciate the natural resources available and the problems associated with them.

In undertaking this task, spatial data were acquired in digital form as well as from aerial photographs and 1:50 000 topo-cadastral maps. These data were imported into ArcView GIS Version 3.1 where the mapping of the various resources was done. An inventory of the resources was created and a spatial database linking attributes that describe the physical environment, the natural vegetation, agricultural activities and the built environment, was set up.

It became evident that using a Geographic Information System for natural resource management provides for integration of spatial information which would otherwise be contained in several separate databases and maps. Further, these data can be readily accessed, queried, upgraded and manipulated. For conservancies in urban and rural KwaZulu-Natal, and indeed, the rest of South Africa, to achieve their aims in natural resource management and monitoring, such an approach would be most efficient and effective.

PREFACE

The work described in this dissertation was carried out at the Centre of Environment and Development, University of Natal, Pietermaritzburg and at Umgeni Water, Pietermaritzburg, from August 1999 to January 2000. The research was supervised by Dr. F. Ahmed (School of Environmental Sciences), Mr. Brent Steyn (GIS Section, Umgeni Water) and Mr. Mark Graham (Water Quality Department, Umgeni Water).

The research reported in this dissertation represents original work by the author except where acknowledged and has not otherwise been submitted in any form for any degree to any other University.

Signed..

K.M. Nsanzya.

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ABBREVIATIONS

BRG	Bioresource Group
BRU	Bioresource Unit
CAD	Computer Aided Design
.DGN	MicroStation Design files
.DWG	AutoCAD Drawing files
.DXF	Drawing Interchange Files
ESRI	Environmental Systems Research Institute
FCC	Ferncliffe Catchment Conservancy
GIS	Geographic Information Systems
ICM	Integrated Catchment Management
IEM	Integrated Environmental Management
KZN	KwaZulu-Natal
lut	Look-up Table
MDEP	Mojave Desert Ecosystem Program
NCMP	Ntshongweni Catchment Management Programme
NGO	Non-governmental Organization
NTC	Natal Timber Corporation
PCM	Participatory Catchment Management
PMB	Pietermaritzburg
WCED	World Commission on Environment and Development

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CHAPTER 1: INTRODUCTION

1.1 Introduction

There has been a marked growth of interest in the quality of the environment, the disruption of the earth's natural ecosystems and the depletion of resources. The speed and nature of environmental change in recent years have brought about a series of environmental problems of global magnitude. It has become important that decision makers and planners fully understand the concepts of natural system processes, integrity and sustainability so that their objectives promote true system management. Environmental management at the catchment level is distinguished by its concern for characteristics of the whole system. Past resource management efforts have often failed to provide for sustainability or productivity because their focus was at the individual unit level.

Effective environmental management demands that key geographic and ecological features, as well as potential problems and resources, be examined in the context of the overall catchment and its surroundings. Integrated Environmental Management (IEM) is referred to as "a systematic approach developed for ensuring the structured inclusion of environmental considerations in decision making at all stages of the development process" (Fuggle, 1989). The Department of Environmental Affairs (1992) describes IEM as "a philosophy which prescribes the code of practice for ensuring that environmental considerations are fully integrated into all stages of the development process in order to achieve a desirable balance between conservation and development". Hence, IEM gives a broad meaning to the term environment. The meaning includes the physical, biological, social, economic, cultural, historical and political components.

For decision makers and planners to have a better understanding of catchment functions and interactions, they need accurate and available data describing the dynamics of catchment processes. It is only then that appropriate management solutions that minimize unexpected and undesired results will be made. It is for this reason that data for the Ferncliffe Catchment Conservancy (FCC) were collected for the purpose of setting up a resource inventory.

Ferncliffe Catchment Conservancy is situated between Woodlands and Hilton Gardens in the Pietermaritzburg and Hilton areas in KwaZulu-Natal. There are various important ecological and geographical features which make the catchment unique within the context of Pietermaritzburg. These include the indigenous vegetation, streams, and the landscape. Developments within the catchment have led to major threats to land and water resources and a general degradation of environmental quality due to the following:

a) poor planning and development site selection;

b) removal of vegetation cover;

c) enhanced flooding;

d) poor control of alien plants;

e) afforestation; and

f) expanding transport networks

(Scotney, 1999a).

Implementation of an environmental monitoring programme would pinpoint problem areas and would accurately gauge the success, or otherwise, of the integrated catchment management that is to be introduced. The mapping and communication of ecological and geographical features to the broader community resident within the catchment as well as to those in the surrounding areas would go a long way in bringing about community awareness and participation in the conservation of the catchment. A Geographic Information System (GIS) mapping exercise would provide the community and the city council with a spatial context within which to appreciate the unique features, as well as to understand current and potential future problems and importance of this catchment to the city as a whole.

The development and implementation of a GIS database would facilitate collection, storage, retrieval and analysis of information regarding inventories, resource assessment, scientific documentation and land management by the authorities and other interested parties. This study aims to aid the management process of the catchment and to enable more accurate modeling of the conservancy's ecological system and to facilitate decision making about its use and management. Emphasis is therefore on the design and implementation of a GIS database that can yield appropriate data upon which planners can base their decisions. The implementation of the system in such a manner would encourage stakeholder participation in the design and construction of the database, as well as in the use of the database to make management decisions.

1.2 Aim and objectives

The aim of the project is to lay out a preliminary study for the promotion of environmental sustainable resource management in the Ferncliffe Catchment Conservancy. It is envisaged that sound land use planning and active community participation would enhance the quality of life within the catchment. This would be realized by setting up the following:

a) structure for the creation of an inventory of the biophysical and socio-economic environments of the FCC;
b) framework for the design and implementation of a GIS database;
c) framework for the formulation of management options;
d) outline for the implementation of a monitoring programme; and
e) foundation for encouraging community participation and awareness through communication via the Internet and display of maps in public places.

Given the time and resource constraints, this study could not conduct detailed surveys of the FCC and therefore relied much on field trip observations and on consultations with the management of the FCC and the NTC. Specialist surveys must be undertaken to deal with the extent of the environmental problems that have been noted in this study. This project therefore serves as a prototype on which a management and monitoring program can be built on.

CHAPTER 2: LITERATURE REVIEW

2.1 Natural Resource Management

Natural resources have been defined in many different ways. The ecological point of view defines natural resources as anything that occurs in nature that humans use to provide any form of energy (Park, 1981). The economic perspective sees natural resources as anything occurring in nature from which humans gain any form of utility (Ryding, 1992). From a political perspective, a natural resource is anything that occurs in nature that one social class uses to its own advantage, either relative to the previous situation or relative to some other social class (Hart, 1992).

2.1.1 The environmental crisis

The speed and nature of environmental change in recent years have brought about a series of environmental problems of global magnitude. General environmental degradation includes the various forms of pollution, the depletion of natural resources, an increased reliance on energy consuming and ecologically-damaging technologies, just to mention a few. The ecological crisis includes the reduction and loss of ecological populations from toxic substances, the loss of habitat to urban, industrial and agricultural expansion, and the loss of genetic variety due to mono-cultural practices and habitat removal (Ryding, 1992). The ecological resources affected are all plant and animal resources in terms of individuals, species, communities, habitats and ecosystems. Among the earliest recognized environmental problems are the pollution of air by products of combustion, the pollution of water by organic and solid wastes, and the physical, chemical and biological degradation of soil (Fuggle, 1992).

The urbanization of formerly rural environments has caused the removal of numerous ecological habitats and the disruption of large numbers and varieties of ecosystems. Urban expansion has adverse environmental effects of pollution of air, water and soil associated with urban and industrial activities which tend to concentrate around urban areas. Of similar impact on ecological resources is agriculture. Commercial agriculture and commercial forestry cause loss of habitats - such as indigenous forests and wetlands - which are most important to wildlife. As a result there has been a reduction in the range of faunal and floral species related to habitat loss. Other agricultural impacts include soil pollution, land cover loss, erosion, sedimentation and chemical pollution (Armstrong and van Hensbergen, 1996; Armstrong *et al* 1998).

The growth in transport activities and in road transport in particular is of great concern over a range of environmental issues such as pollution, loss of habitats and possibilities of global environmental change. The following have been major environmental impacts of transport infrastructure development:

a) land-take, fragmentation and displacement;
b) landscape damage, loss of aesthetic quality;
c) disruption of hydrological processes and water pollution;
d) ecological degradation;
e) air pollution;
f) noise; and
g) traffic accidents.

(Hoyle and Knowles, 1998).

2.1.2 Conservation and development

The requirement for sustainable development is meeting the basic needs and extending to all people the opportunity to satisfy their aspirations for a better life. The promotion of values that encourage consumption standards that are within the bounds of the ecologically possible and to which all can aspire is of importance if sustainable development is to be achieved. Development and consumption standards therefore have to regard long-term sustainability. Both the incidences of poverty and of high productivity have an impact on the environment and so the notion of sustainable development requires that societies meet human needs both by increasing productive potential and by ensuring equitable opportunities for all. Natural systems that support life on earth such as the atmosphere, the waters, and the soils should not be endangered by development processes. Sustainability requires equitable access to these constrained resources long before their ultimate limits are reached (Yearley, 1996).

Sustainable resource use requires that the rate of depletion of non-renewable resources should foreclose as few future options as possible. Plant and animal life should be safeguarded against development trends that simplify ecosystems and reduce biodiversity. Adverse impacts on the quality of natural elements, especially air and water, need to be minimized so as to maintain an ecosystem that can be self sustaining. In other words, sustainable development is a "process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations" (World Commission on Environment and Development, 1987).

The earth summit in 1992 at Rio de Janeiro, Brazil made it clear that it recognizes the right to development of the poor countries and the duty of the rich to alleviate poverty. It saw that developing countries have special needs and so the promotion of supportive and open international economic systems was of essence. Poverty was seen as an indispensable component of sustainable development and its eradication therefore was a matter of great urgency. The Rio declaration committed national states to "reduce and eliminate unsustainable patterns of production and consumption" and to adopt the "precautionary approach by preventing environmental degradation, even before comprehensive scientific proof is available" (Wynberg, 1993).

Wynberg (1993) introduced Agenda 21 as a "comprehensive plan of action which seeks to integrate developmental and environmental issues" and that is "based on the premise that all nations share responsibility for the environment".The major emphasis of Agenda 21 is to achieve a prosperous, just, habitable, fertile, clean, shared, cooperative and secure world. "Each country is supposed to adjust its national policies to be in line with the commitments of Agenda 21 which reflects a global consensus and political commitment at the highest level on development and environment cooperation"(Wynberg, 1993). The principal issues at Rio were global warming, biological diversity, and the depletion of the stratospheric ozone layer. These problems cannot be solved by one country alone (Brown, 1992). The successful implementation of Agenda 21 is therefore the responsibility of governments. Agenda 21 acknowledged "the importance of international cooperation, broad public participation and the active involvement of NGOs and other groups" for a global partnership for sustainable development to be effective (Wynberg, 1993).

2.1.3 Environmental management

According to Bridgewater (1993), there are two major objectives for nature conservation. The first objective is maintaining the maximum degree of biodiversity. The second is developing, managing, and maintaining the ecological infrastructure through the designation and management of protected areas (cited in Aspinall, 1999).

In both the developed and the developing worlds, human beings are engaged in massive transformations of the natural and semi-natural vegetation cover of the earth. In some areas, natural landscape patterns which have been largely stable or only slowly changing for many generations, are now being rapidly altered.

It is increasingly essential to take an integrated perspective when seeking to understand the significance of environmental change. The solution to environmental problems requires both an understanding of the physical and ecological aspects of environmental systems and the way in which they interact with economic, social and political factors (Haines-Young *et al*, 1993). The same view is expressed by Rapport (1998) who contends that the larger problem facing the challenges of biodiversity is the lack of integration between the social and natural sciences. Mainstream science continues to reject the notion that solving environmental problems requires an integration of values and processes. Rapport (1998) suggests a conceptual model that shows how these facets may be brought together. Rapport argues that mainstream ecologists, atmospheric scientists, and economists "continue to reject the notion that grappling with environmental problems requires at a minimum an integration of values and process". Values may either be economic or market value; human benefit from the ecosystem; and value in the sense of goals or morals that govern a social unit. Hence, in articulating a holistic vision for environmental management, "the integration of the natural science, social science and health science is an absolute requirement" (Rapport, 1998).

The typical role of conservation is the maintenance of biodiversity. Biodiversity is reduced as a result of habitat loss and degradation, pollution, and the introduction of exotic plantation species. Pott (1997) on the other hand has argued that "much of the criticism of plantation forestry as a form of land-use is based on emotional bias rather than on hard evidence". He asserts that there is no evidence suggesting that forestry has an impact on biodiversity. This view has been challenged by Armstrong *et al* (1998) who point out that most plantations in South Africa are in the grassland biome, which does not have extensive areas of wooded vegetation:

> "This biome has relatively small, scattered forests composed of many tree species, and not large tracts of woodland composed of one species. Therefore, timber plantations affect biodiversity structure by changing vegetation structure in the planted areas from an open graminaceous form to a woodland form, by altering the distribution, biomass and abundance of grassland plants, animals and micro-organisms (which do not live in the planted areas and vicinity), by reducing habitat heterogeneity because plantations are of one timber species and therefore are uniform, by reducing connectivity between unplanted areas, and by increasing patchiness and fragmentation of the landscape" (Armstrong *et al*, 1998).

The objectives of conservation cannot however, be adequately met by emphasizing biodiversity alone. A more encompassing approach is to look at ecological infrastructure which is what allows biodiversity to occur, maintain and change within the wider environment. For example, Lister (1998) examines the implications of a systems-based perspective of living systems as resting on the central principle of complexity and uncertainty, and necessitates flexibility, anticipation and adaptation rather than prediction and control in conservation planning and management. Lister explores new perspectives on biodiversity and discusses the emergence of a new ecological context for biodiversity conservation. The conclusion is that conservation planning and management approaches should reflect the essence of living systems, i.e., they should be diverse, adaptive, self-organising, and accepting the realities of ecological change (Lister, 1998).

2.2 Integrated Catchment Management

Integrated catchment management (ICM) is a holistic approach to the management of water resources. It encompasses water quality and quantity, aquatic ecology, and the processes that impact on the water resource including land-use, water-use and pollution. The objectives of ICM are to:

a) control, conserve and monitor water and land resources;

b) reduce the degradation of the land;

c) ensure biodiversity; and

d) achieve specified water and land management as well as social objectives.

(Umgeni Water, 1997; O'Keeffe *et al* 1992)

Integrated catchment management is based on the view that the entire catchment is a fundamental environmental unit and so takes into account the impacts of development and other resources on water resources. The management of resources is holistic and emphasis is placed not on the treatment of problems, but on management of the source of the impact on the water (Scotney, 1999a). Sustainable balance between utilisation and protection of all environmental resources within the catchment are ensured by coordinating the management of land-use activities. To this end the following processes are taken into account:

a) preparation of an inventory of available resources;

b) identifying ecological and socio-economic factors which cause degradation of resource and the ecosystem;

c) establishing precisely the water resource quality, the status of soil and vegetation, and the functioning of the ecosystem;

d) predicting the results of different resource management programmes; and

e) identifying organisational structures, institutional arrangements and individual actions that can be of use in managing resources in such a way as to enhance improved resource condition and ecosystem functioning.

(Scotney, 1999a)

Integrated Catchment Management involves a participatory approach which tries to put people and their needs in the centre, balancing individual short-term needs with society's longer term needs (Auerbach, 1997). It is a participatory approach in that water managers, ecologists, agriculturalists and social scientists come together to manage a catchment from their different perspectives. Historically this was not the case as most catchment programmes, driven by hydrologists and water managers, focused on water rather than on people (Auerbach, 1997). A World Bank Policy Paper on Water Resources Management described participation as "a process in which stakeholders influence policy formulation, alternative designs, investment choices, and management decisions affecting their communities and establish the necessary sense of ownership" (The World Bank, 1993).

In emphasizing the centrality of people, the Nsthongweni Catchment Management Programme (NCMP), states as its first and foremost objective, the need "to assist local residents in implementing ecologically and economically sound land-use practices" (Farmer Support Group *et al*, 1997). The NCMP further saw the need to help build the institutional capacity needed for informed local control of the planning and use of natural resources in the catchment. Of importance too, was to help appropriate agencies to understand local attitudes to the catchment and its resources. To this end, the Programme's activities included, among others, participatory land use planning with local communities, formation of conservation groups, establishment of parks and community open spaces, and working with industry to reduce water pollution. (Farmer Support Group *et al*, 1997).

2.3. Geographic Information Systems

2.3.1 A Generic Definition

GIS are special-purpose digital databases in which common spatial coordinate system are the primary means of reference (Burrough and McDonnell, 1998). GIS require a means of:

1. data input, from maps, aerial photos, satellites, surveys, and other sources;
2. data storage, retrieval, and query;
3. data transformation, analysis, and modeling, including spatial statistics; and
4. data reporting, such as maps, reports, and plans

(Foote and Lynch, 1997).

Perhaps a more comprehensive definition of GIS is the tool base definition provided by Burrough and McDonnell (1998):

> "*A powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes.* The geographical (or spatial) data represent phenomena from the real world in terms of (*a*) their position with respect to a known coordinate system, (*b*) their attributes that are unrelated to position (such as colour, cost, pH, incidence of disease, etc.) and (*c*) their spatial interrelations with each other which describe how they are linked together."

While GIS are related to other database applications, there is an important difference in that all information in GIS is linked to a spatial reference. Other databases may contain locational information such as street addresses, but a GIS database uses geo-references as the primary means of storing and accessing information (Foote and Lynch 1997). Besides, GIS integrate technology.

Whereas other technologies might be used to analyze aerial photographs and satellite images, to create statistical models, or to draft maps, these capabilities are all offered together within a comprehensive GIS (Haines-Young *et al*, 1993).

GIS, with their array of functions, should be viewed as a process rather than as merely software or hardware. GIS are for supporting decision making (Ahmed, 1999b). The way in which data are entered, stored, and analyzed within GIS must mirror the way information will be used for a specific research or decision-making task. The importance of GIS as an integrating technology is also evident in its pedigree. The development of GIS has relied on innovations made in many different disciplines: Geography, Cartography, Photogrammetry, Remote Sensing, Surveying, Geodesy, Civil Engineering, Statistics, Computer Science, Operations Research, Artificial Intelligence, Demography, and many other branches of the social sciences, natural sciences, and engineering which have all contributed (Burrough and McDonnell, 1998; Foote & Lynch, 1997).

2.3.2 The Use of GIS

GIS have emerged as very powerful technologies because they allow users to integrate their data and provide methods in ways that support traditional forms of geographical analysis, such as map overlay analysis as well as new types of analysis and modelling that are beyond the capability of manual methods. With GIS it is possible to map, model, query, and analyse large quantities of spatial data all held together within a single database (Martin, 1996).

GIS provide powerful tools for addressing geographical and environmental issues. GIS allow us to arrange information about a given region or city as a set of maps with each map displaying information about one characteristic of the region. For instance, if a set of maps that would be helpful for urban transportation planning has been gathered, each layer can be easily overlaid on the others so that every location is precisely matched to its corresponding locations on all the other maps. Each of these separate thematic maps is referred to as a layer, coverage, or theme (Burrough and McDonnell, 1998). Once these maps have been registered carefully within a common locational reference system, information displayed on the different layers can be compared and analysed in combination. Transit routes can be compared with the location of shopping malls, population density with centres of employment, etc. In addition, single locations or areas can be separated from surrounding locations by simply cutting all the layers of the desired location from the larger map. Whether for one location or the entire region, GIS offer a means of searching for spatial patterns and processes (Burrough and McDonnell, 1998; Foote and Lynch, 1997).

Not all analyses require using all of the map layers simultaneously. In some cases, a researcher will use information selectively to consider relationships between specific layers. Furthermore, information from two or more layers might be combined and then transformed into a new layer for use in subsequent analyses. This process of combining and transforming information from different layers is called map "algebra" insofar as it involves adding and subtracting information. For example, if the effects of widening a road were to be considered, the GIS process could begin with the road layer, then widen a road to its new width to produce a new map, and finally overlay this new map on layers representing land use (Foote and Lynch, 1997).

2.3.3 The Appeal and Potential of GIS

The great appeal of GIS stems from their ability to integrate great quantities of information about the environment and to provide a powerful repertoire of analytical tools to explore these data. GIS have the potential in which dozens or hundreds of map layers can be arrayed to display information about transportation networks, hydrographs, population characteristics, economic activity, political jurisdictions, and other characteristics of the natural and social environments. Such a system would be valuable in a wide range of situations; for urban planning, environmental resource management, hazards management, emergency planning, or transportation forecasting, and so on. The ability to separate information in layers, and then combine it with other layers of information is the reason GIS have such great potential as research and decision-making tools (Foote and Lynch, 1997; Chou, 1997).

2.3.4 Application Areas

GIS are now used extensively in government, business, and research for a wide range of applications including environmental resource analysis, land use planning, locational analysis, tax appraisal, utility and infrastructure planning, real estate analysis, marketing and demographic analysis, habitat studies, and archaeological analysis.

One of the first major areas of application has been in natural resources management, including management of wildlife habitat, flood plains and wetlands, aquifers, agricultural lands, forests, water quality, and environmental impacts (Ahmed, 1999b; Ahmed *et al*, 1999). One of the largest areas of application has been in facilities management. Local, regional and national planners have found GIS particularly useful in land management. Yeh (1999) observes that GIS serve both as a database and as a toolbox for urban planning. The author states the importance of a GIS in the following areas:

a) resource inventory;
b) analysis of existing situations;
c) development of planning options;
d) selection of planning options;
e) plan implementation; and
f) plan evaluation, monitoring, and feedback.

More recent and innovative users of GIS have used information based on street-networks. GIS has been found to be particularly useful in address matching, location analysis or site selection and development of evacuation plans. The range of applications for GIS is growing as systems become more efficient, more common, and less expensive. Some of the newest applications have taken GIS into unexpected fields such as the Global Change and Climate History Project, Emergency Response Planning, Site Selection of Water Wells and wildfire hazard identification and mitigation (Foote & Lynch, 1997).

2.4 GIS in Natural Resource Management

GIS has an important role in developing, managing, maintaining and analysing a database that supports strategic and local planning related to biodiversity. Aspects to which GIS can be applied include the integration of biological records, an inventory of resources, and the evaluation of geographical patterns of diversity at different geographical scales. The need to link conservation and development and human activity with environmental quality for planning and management calls for the development of GIS so that they can fully explore the concept and practice of sustainability in ecological systems (Aspinall 1999).

Designations based on criteria such as diversity, rarity, position in an ecological and geographical unit, fragility and so on have been applied at all levels including the global scale (such as the World Heritage Sites). GIS are being employed to manage data for these sites, analyze and evaluate their characteristics, develop management plans, and examine their significance in relation to the wider geographical context of site protection (Aspinall, 1999).

2.4.1 Water Resources

GIS are capable of correlating land cover and topographic data with a variety of environmental parameters relating to such indicators as surface runoff, drainage basin area, terrain configuration, etc. This permits the integration of water quality data from various sources into a comprehensive system capable of combining and cross referencing diverse data such as conventional maps, remote sense imagery, and tabular data obtained from ground surveys (Walsh, 1987). The author found the need to estimate runoff as a function of soil, vegetation, and antecedent moisture. By organizing these data in GIS, nonpoint pollution over extensive areas would be appraised frequently. This also helps in identifying and managing areas that contribute in relative amounts to runoff problems.

In assessing surface water, a Relative Non-point Source Pollution study was conducted in Minnesota (Robinette, 1999). The study defined potential problem areas by correlating water quality records with geographical characteristics of catchments. Profiles were developed for each catchment based on GIS inventories of the extent of urban land, forest lands, cultivated land, stream shore, lake shore, silt soil, sand soil, areas of 3-6 per cent slope, those where the slope was greater than 6 per cent and other parameters. Regression analysis was applied and this showed that the extent of forests and sand soils had a negative correlation to water quality while all others were positive. The objective of the model was to obtain uniform and accurate estimates of runoff quality with emphasis on sediment and nutrients, and to compare the impacts of a number of conservation alternatives and management practices in the catchments.

MacMillan *et al* (1993) describe the use of digital elevation data, hydrological simulation modeling and GIS in water resource management. These have been used in assessing time-varying distribution of non-permanent water at a small scale and to estimate the possible patterns of redistribution that might arise from drainage or consolidation. GIS tools were found to be essential for acquiring, collating, and storing the data needed for the models. GIS were used to collate the data in a common format and spatial reference, and to integrate the data and models to facilitate model operation. Johnston (1998) adds that catchment modeling predicts the location, direction, and magnitude of water flow within a catchment. Catchment models have become increasing useful to ecologists who use them to investigate how ecosystems affect and are affected by water and nutrient distribution in a landscape (Johnston, 1998).

2.4.2 Soil conservation

Burrough (1999) has stated that "GIS are now firmly established in soil survey practice and are used for map production, deriving suitability maps to meet user's requests for special-purpose information and for modelling environmental processes". GIS are capable of manipulating soil data in several ways even if only digital soil maps and associated attributes are used. Soil scientists have come to grips with the difficulty of describing the spatial variation of soil and they are now providing useful information services to a wide range of different kinds of users.

Best and Westin (1987) argue that conventional field survey techniques for identifying and monitoring problem areas are not adequate or cost efficient, especially if Landsat imagery is available and reasonably cheap. In countries with large areas of potentially arable land, conventional methods would require extensive labour and long periods of time. The authors demonstrate how GIS can be used in an operational soils and rangeland management program. The authors identified areas of rangeland that were cultivated on soils not suitable for cultivation by compositing a land use map derived from Landsat imagery and soil capability and slope maps produced from a soil survey map. The GIS composite map showed the location and distribution of problem areas. GIS were also used to generate quantitative areal summaries to determine the magnitude of the problem. The resulting map showed the spatial distribution of regions that had minor limitations to cultivation, those that were marginal to cultivation and those that had severe limitations to cultivation. With this in place, a soil conservation program would identify areas under cultivation in order to concentrate management efforts.

2.4.3 Vegetation

Writing about the Flow Country of Caithness and Sutherland in Scotland, Lavers, Haines-Young and Avery (1993) point out that despite the area's ecological value, it has been under development pressure, especially a large amount of afforestation which many felt was undermining the area's ecological value. Afforestation has a negative effect in as far as water quantity is concerned. Replacing natural vegetation with alien timber has severe impacts on catchment runoff and hence the maintenance of riverine biodiversity and ecosystem functioning (Hoffman, 1997; Macdonald, 1989; Richardson *et al*, 1997).

Afforestation in most cases leads to fragmentation of indigenous vegetation. Rivers-Moore (1997) suggested using conservation corridors of grassland to link indigenous forest patches in the Midmar catchment. Using GIS to create buffers, conservation corridors would allow for the creation of larger patches of indigenous forests in KwaZulu-Natal and would help to reduce the area under afforestation and give greater heterogeneity to the landscape.

2.4.4 Land use

Bibby and Shepherd (1999) identify the concept of 'land use' as defining a social purpose and not a set of physical qualities (i.e. as opposed to the term 'land cover'). Land use is the human-imposed function of a land area, and distinguishing it requires the knowledge of human behavior that only another human can provide (Johnston, 1998). Bibby and Shepherd (1999) therefore contend that many data sets can be used to investigate land use issues than is generally understood and that GIS have a key role to play in the processing and integration of such data. The authors point out that "if GIS is treated as a constructional system, even data presented in the form of address lists may be used to generate information about policy-relevant constructs in relation to a range of other applications including local employment analyses, urban sectoral maps, and a classification of rural settlement patterns". This is a move towards perceiving land use with reference to social purposes other than confining it to biophysical elements.

An example of the application of GIS in land use is the LANDCARE GIS, a spatial information system developed to assist with the evaluation of land management programs in Australia by providing an integrated analytical approach. It has been used to identify and analyze the spatial relationships between the National LANDCARE Program, land resource condition and land use practices (East and Wood, 1998). LANDCARE, a community-based approach to sustainable natural resource management, is an approach to sustainable management of land, water and related vegetation resources, which maintains and enhances their long-term productive and environmental values.

East and Wood (1998) discussed the requirements of program evaluation and explored advantages of introducing GIS into evaluation methodologies. The purpose of evaluation was to ensure that the "program's aim of efficient, sustainable and equitable management of natural resources is being achieved". This project put together a GIS database of the locations, dates, and funding of LANDCARE projects; surveys of national and state environment conditions; surveys of landcare groups and land management practices; and additional biophysical and socio-economic data. These data were stored as point features in the GIS and attributes were attached for describing or querying the data. This information was found to be vital in the effective evaluation of the National Landcare Program's aim. It allowed policy makers "to 'view' their (spatial) data for the first time and to identify relationships, trends and anomalies which may have remained hidden".

Similarly, the Mojave Desert Ecosystem Program (MDEP) of the United States of America, is an attempt to create a regional scale database that can be utilized to effect dynamic and sustainable land management. In emphasizing the importance of both maintaining and improving the native biodiversity and sustainability of ecosystems, the project, through the use of GIS and Internet technologies, accomplished an electronically linked distribution system, and a series of comprehensive and fully integrated environmental spatial databases that span the Mojave Desert eco-region. This has facilitated the sharing, management, and monitoring of the eco-region by various stakeholders including the Department of Defense, the California Desert Managers Group, the Bureau of Land Management, the U.S. Geological Survey, and the Utah State University (Mojave Desert Ecosystem Program, 1998).

2.4.5 GIS and Biodiversity

Biodiversity refers to the quantification of organismic kinds that coexist within a specific region (Rapport, 1998). Steinitz (1997) discusses a two-year research program on biodiversity and landscape planning that explored how urban growth and change in a rapidly developing area might influence the biodiversity of the area. A GIS was organized to contain spatially detailed and explicit data on the region. Information generated included terrain, soil type, annual rainfall, vegetation, hydrology, land use, and land ownership. The future change of the area was represented via the complete implementation, or "build-out", of the area's current plans as summarized by the regional planning agencies. Steinitz's study found that there were several locations where projected development threatened the maintenance of biodiversity. The findings suggested that the highest priority for conservation be assigned to public and privately owned lands. To facilitate change, three decision-related conditions were recommended:

1) recognition of the values of biodiversity;
2) establishment of means to protect it; and
3) institutional changes needed to guide future development.

(Steinitz, 1997).

The ability to document information and develop models over large areas is vital if an attempt is made to develop an understanding of ecological infrastructure. It is here that the use of GIS comes into play. GIS can best serve nature conservation when there are adequate databases of biology, geology and pedological information (Bridgewater, 1993).

In conclusion, GIS and the various analytical tools associated with them, are increasingly able to provide sources of data and the means of manipulating data appropriate for the large scale management of natural resources. As such GIS would aid the management of the unique geographical and ecological features in the Ferncliffe Catchment Conservancy through the creation of an inventory, setting up a GIS database and creating corridors of conservation.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area

3.1.1 Geographic location

The Ferncliffe Catchment Conservancy lies between 30°18' and 30°24' east, and between 29°32' and 29°36' south. It is situated between Pietermaritzburg and Hilton and encompasses the residential areas of Woodlands, Chase Valley, Chasedene, Oak Park, Athlone, Northern Park, Montrose, Mount Michael and Hilton Gardens (Fig.3.1).

3.1.2 Resource Information

The natural resources of the Ferncliffe Catchment Conservancy will be described according to the Bioresource Classification Programme of KwaZulu-Natal (Camp, 1999a). This programme classifies the natural resources into agro-ecological zones at three levels. The first level of classification is the Bioresource Group (BRG) which is a particular vegetation type influenced by a combination of climatic and biotic factors such as soils and altitude. BRGs are further divided into sub-groups and sub-groups into sub-divisions where there are significant soil or climatic changes requiring different management and where there are natural resources which are identical in description (Camp, 1999b).

The second level of classification is the Bioresource Unit (BRU). This class is of land within which the environmental factors such as vegetation, soil type, climate and terrain form are sufficiently homogeneous such that uniform land use practices and production yield and techniques can be defined. The third and smallest level is the ecotope which is defined in terms of soil, that is, texture, form and depth, and soil surface characteristics such as rockiness (Camp, 1999b).

The Ferncliffe Catchment Conservancy is made up of five different BRUs (Fig.3.2), namely Hilton - Zc7, Oak Park - Zb2, Chase Valley - Yb9, Bishopstowe - Wb12 and Pietermaritzburg - Vb14 (Table 3.1). The BRG under which the Hilton - Zc7 falls under is BRG 5 - Moist Midlands Mistbelt. The vegetation pattern here is mostly grassland and forest. Oak Park - Zb2 is in BRG 3 - Moist Coast Hinterland Ngongoni Veld characterized by forest and bushed grassland

Figure 3.1: Study Area

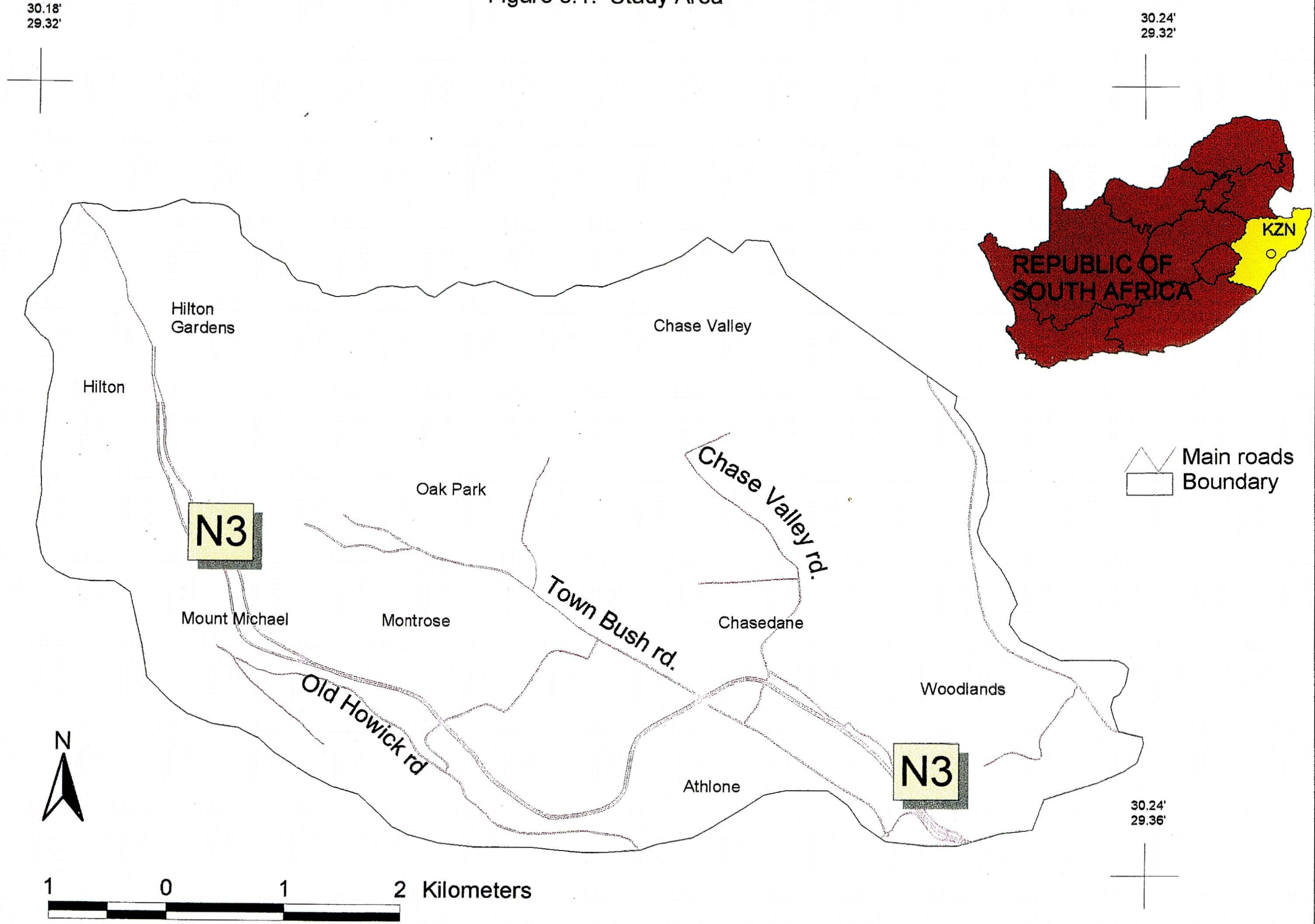
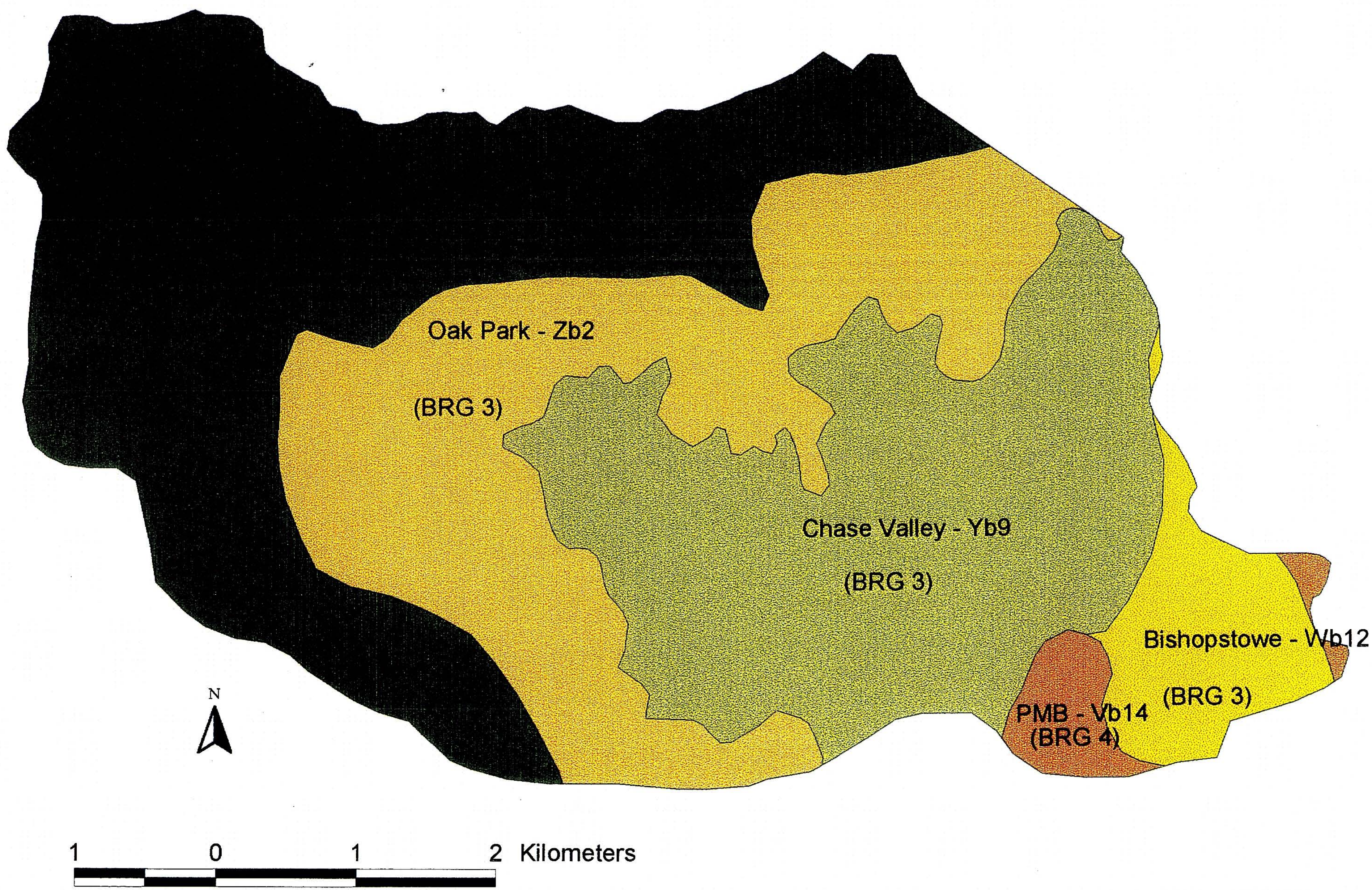


Figure 3.2: Ferncliffe Catchment Bioresource Units



vegetation. Chase Valley - Yb9 and Bishopstowe - Wb12 BRUs also lie in BRG 3 - Moist Coast Hinterland Ngongoni Veld but their vegetation pattern is bushed grassland and grassland and bushed grassland respectively. Pietermaritzburg - Vb14 falls under BRG 4 - Dry Coast Hinterland Ngongoni Veld with grassland vegetation - Table 3.2 (Natural Resource Department, Cedara, 1999).

Table 3.1: BRU Codes used in the classification of natural resources

BRU code	**BRG**	**Rainfall (mm)** 1st letter of code	**Altitude (m)** 2nd letter of code	**Occurrence** (of code in KZN)
Hilton - Zc7	5	**Z** > 1100	**c**: 900 - 1400	7th
Oak Park - Zb2	3	**Z** > 1100	**b**: 450 - 900	2nd
Chase Valley - Yb9	3	**Y**: 900 - 1100	**b**: 450 - 900	9th
Bishopstowe - Wb12	3	**W**: 800 - 850	**b**: 450 - 900	12th
Pietermaritzburg - Vb14	4	**V**: 750 - 800	**b**: 450 - 900	14th

Table 3.2: General Resource Information

BRU CODE	SLOPE	BIORESOURCE GROUP	VEGETATION PATTERN	INDICATOR SPECIES
Hilton - Zc7	Moderate/Steep	BRG 5 - Moist Midlands Mistbelt	Grassland/Forest	*Aristada junciformis; buddleja salviifolia; Greyia sutherlandia; Leucosidea sericea; Pteridium acqualinum; Rubis cuneifolia; Solanum mauritianum*
Oak Park - Zb2	Steep	BRG 3 - Moist Coastal Hinterland Ngongoni Veld	Forest/Bushed Grassland	*Aristida junciformis; Rubis cuneifolia; Solanum mauritianum*
Chase Valley - Yb9	Steep	BRG 3 - Moist Coastal Hinterland Ngongoni Veld	Bushed Grassland	*Aristida junciformis; Rubis cuneifolia; Solanum mauritianum*
Bishop-stowe - Wb12	Moderate/Steep	BRG 3 - Moist Coast Hinterland Ngongoni Veld	Grassland/Bushed Grassland	*Aristida junciformis; Acacia mearnsii; Acacia sieberiana; Lantana camara; Solanum mauritianum*
Pieter-maritzburg - Vb14	Moderate/Steep	BRG 4 - Dry Coastal Hinterland Ngongoni Veld	Grassland	*Aristada junciformis; Acacia sieberana; Acacia nilotica Eragrotis curvula*

Source: Natural Resource Department, Cedara (1997; 1999).

3.1.3 Land use

The terrain of Ferncliffe Catchment is both rolling and broken. The topography rises gently from the south-east at an altitude of 450 metres above sea level and increases to 1360 metres in the north-west, rising steeply over a short distance at an average slope of 12 per cent (Fig. 3.3). The extent of cultivation is widespread with the exception of Pietermaritzburg - Vb14. Commercial forestry is the main type of agricultural activity in the catchment. A number of plots in the Conservancy are categorised as farmland by the Land Survey section of the City Engineer. Sugar cane and other agricultural crops are cultivated on these especially to the north of the Conservancy. There is an extensive network of untarred commercial forest service roads in the plantations. There are a number of hiking trails to the north of the catchment in the Ferncliffe Nature Reserve.

All five BRUs (Fig. 3.2) have residential areas in them, mainly Montrose, Chase Valley, parts of Hilton and Woodlands (Fig. 3.4). According to the 1996 census the total population of Montrose and Chase Valley only is 7167. Roads servicing these areas are tarred and the national road, the N3, passes through from the south east to the north west. Adjacent to Montrose is the Country Club Golf Course with eighteen holes. North of this is the Queen Elizabeth Park, a nature reserve. There are a number of environmental problems associated with land use and these are dealt with later in section 4.4.

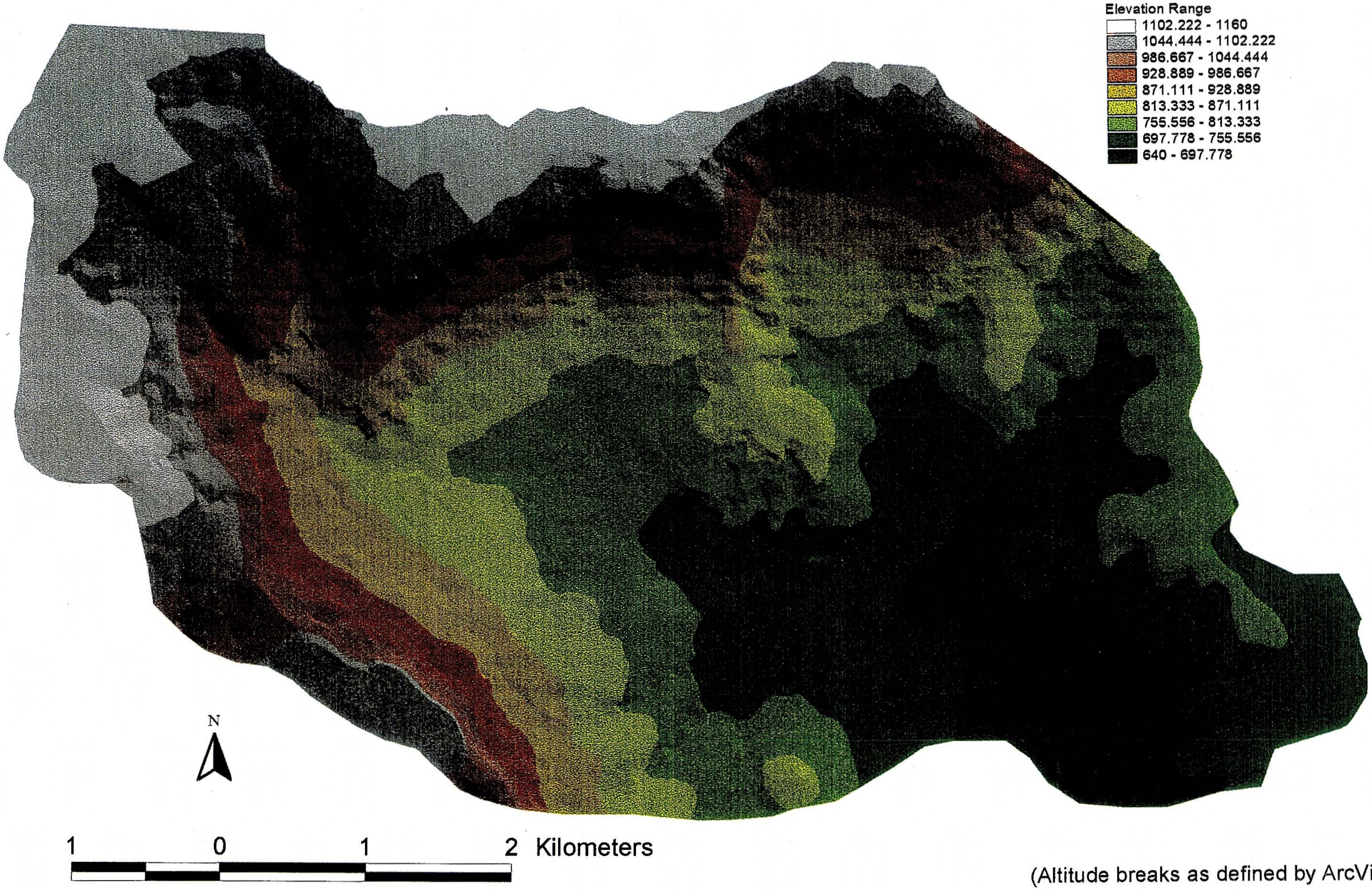
3.1.4 Hydrology

There are two main streams in the Conservancy, the Town Bush and the Chase Valley streams. These are fed by a number of tributaries before they meet and flow into the Dorpspruit river, which in turn flows into the Msunduzi. The Ferncliffe catchment is therefore a sub-catchment of the larger Duzi-Mgeni catchment. The Ferncliffe Catchment Conservancy has ten water quality monitoring points in the whole catchment (Fig. 3.5). Sampling at these points is conducted by the management of the Conservancy with the assistance of the Umgeni Water Board. This sampling facilitates comparisons of water quality in both sub-catchments and between seasons, and is also conducted during incidents such as chemical spillages from the N3 highway or burst sewage pipes within the Conservancy (Scotney, 1999a).

3.1.5 Climate

Table 3.3 summarizes some of the most influential climatic parameters in the study area. The Hilton - Zc7 BRU is the largest in the catchment. Rainfall in this part of the catchment is more than 1100mm per annum. The altitude here ranges from 900 to 1400 metres. Oak Park - Zb2 also has an annual rainfall greater than 1100mm but its altitude range is from 450 to 900 metres. Rainfall becomes less to the east of the catchment with 900 to 1100mm in Chase Valley - Yb9, 800 to 850mm in Bishopstowe - Wb12 and 750 to 800mm in Pietermaritzburg - Vb14. The altitude range in these BRUs remains at 450 to 900 metres.

Figure 3.3: Terrain of the FCC



(Altitude breaks as defined by ArcView)

Figure 3.4: Landuse in the Fencliffe Catchment Conservancy

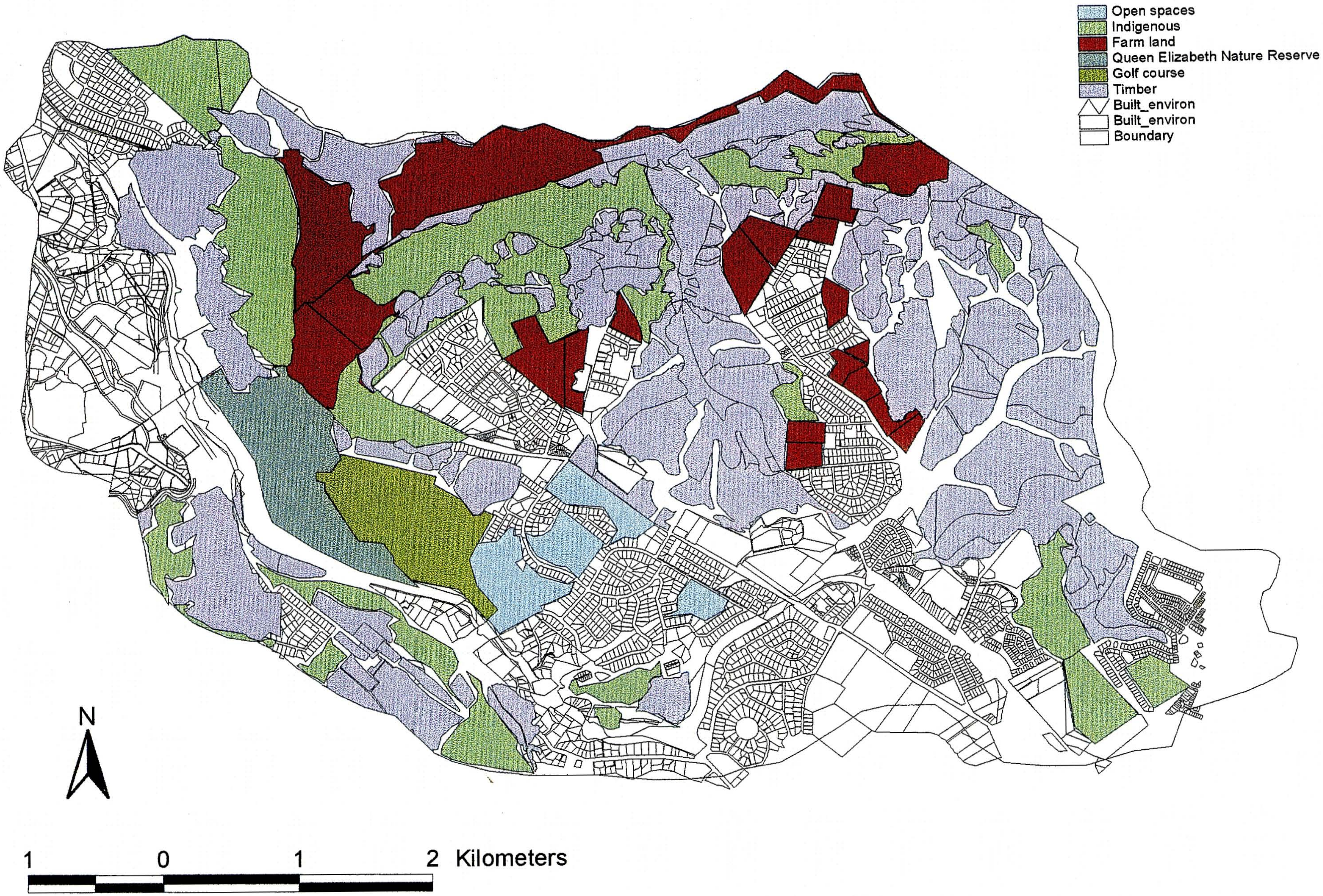


Figure 3.5: Streams and water quality monitoring points in the FCC

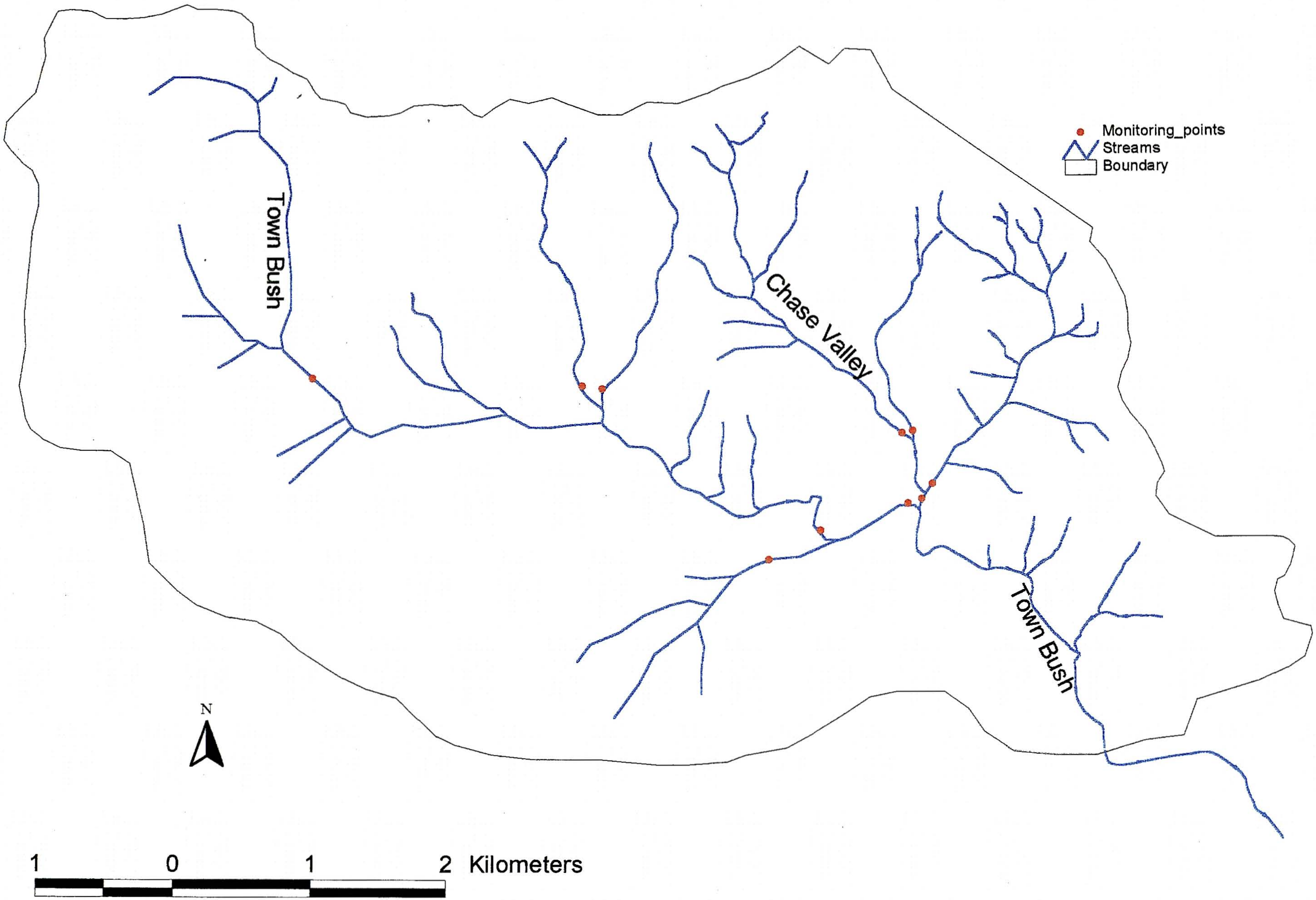


Table 3.3: SUMMARY OF SOME MOST INFLUENTIAL CLIMATIC PARAMETERS FOR EACH BRU IN THE STUDY AREA

BRU		Annual	Jan	Feb.	Mar	Apr.	May	Jun.	Jul.	Aug	Sep	Oct	Nov	Dec
Hilton - Zc7	mean rainfall (mm)	1141	195	146	127	85	32	17	14	32	65	116	143	169
	mean °c	16.3	19.8	19.9	19	16.8	14.5	12	12	13.6	15.4	16.4	17.5	19.2
	maximum °c	22.4	25.2	25.2	24.5	22.7	20.8	18.5	18.8	20.3	21.8	22.4	32.1	24.9
	minimum °c	10.4	14.5	14.6	13.6	10.8	8.2	5.5	5.3	7	9.1	10.5	12	13.6
Oak park-Zb2	mean rainfall (mm)	1157	208	150	146	63	32	14	17	35	59	120	156	157
	mean °c	17.2	20.6	20.7	19.9	17.7	15.4	13	13	14.5	16.2	17.2	18.3	20
	maximum °c	23.1	25.9	26	25.3	23.5	21.5	19.4	19.5	21	22.5	23.1	23.8	25.6
	minimum °c	11.4	15.4	15.5	14.6	11.9	9.4	6.7	6.5	8.1	10	11.4	12.9	14.5
Chase Valley-Yb9	mean rainfall (mm)	911	142	120	115	54	26	14	15	28	54	93	115	135
	mean °c	17.8	21.3	21.4	20.6	18.3	15.8	13.3	13.3	15	16.8	17.8	18.9	20.7
	maximum °c	23.8	26.5	26.6	26	24.3	22.3	20.1	20.3	21.7	23.1	23.7	24.4	26.2
	minimum °c	11.8	16.1	16.2	15.2	12.4	9.4	6.5	6.4	8.3	10.5	12	13.6	15.2
Bishopstowe - Wb12	mean rainfall (mm)	832	144	119	91	58	32	12	15	26	54	77	95	109
	mean °c	17.8	21.4	21.5	20.6	18.3	15.8	13.2	13.2	14.9	16.8	17.9	19	20.8
	maximum °c	23.9	26.7	26.7	26.1	24.4	22.4	20.3	20.4	21.8	23.2	23.8	24.5	26.4
	minimum °c	11.7	16.2	16.3	15.2	12.3	9.1	6.2	6.1	8.1	10.5	12	13.6	15.2
Pietermaritzburg Vb14	mean rainfall (mm)	786	145	112	99	44	23	9	11	27	48	75	87	106
	mean °c	18.1	21.9	22	21.1	18.6	15.8	13.2	13.2	15	17.1	18.4	19.6	21.3
	maximum °c	24.5	27.3	27.4	26.8	25	22.9	20.7	20.9	22.2	23.7	24.5	25.2	27.1
	minimum °c	11.8	16.6	16.6	15.4	12.3	8.8	5.6	5.6	7.9	10.5	12.3	13.9	15.6

Source: Natural Resource Department, Cedara (1999)

3.2 Methods

3.2.1 Data acquisition

Two sets of digital data covering the catchment were acquired, one from the City Engineer, Pietermaritzburg, and the other from the Natal Timber Corporation (NTC). The data from the City Engineer (Land Survey) were CAD drawings in .DWG format of residential plots in suburbs, schools, public open spaces, health centres, sports fields, business areas and roads (Fig.3.6). The NTC data were CAD drawings in .DGN format of timber plantation stands, timber species, public roads and forest roads (Fig.3.7). The CAD drawings were converted into coverages by firstly converting the file formats to .DXF. The .DWG file was converted into .DXF format in AutoCAD (AutoCAD, 1997) while the .DGN file was converted into .DXF format in Microstation (MicroStation, 1995).

The files were brought into ArcInfo (ESRI, 1995) where they were converted into coverages and cleaned. ArcInfo's DXFINFO command was used to read the .DXF files and display the information about them. This information was then used to decide which layers and DXFARC options to use when converting the .DXF files. After the DXFARC command line was entered, the layer names and the layer options to be converted to <out_cover> were specified. Once the .DXF files were converted into ARC/INFO coverages, the BUILD command was used to generate line coverage topologies and the CLEAN command to build polygon topology (ESRI, 1995).

The process of cleaning involved correcting the spatial errors using ARCEDIT. The errors were mostly missing arcs, arc overshoot and undershoots, and open polygons. These errors where created when digitized arcs stopped short of, or extended past, an intended intersection point. The correcting of errors involved adding missing arcs, and removing and replacing inaccuracies with correct data. Correcting errors is important in that subsequent calculations, analyses and maps will not be valid (ESRI, 1995). Once this was done and all the polygons had been formed, the data were transferred into ArcView (ESRI, 1996) where shape files were created.

The data from the City Engineer had a different map projection and did not match with data from other sources. When imported into ArcView, these data appeared rotated at 180° (Fig.3.6) and it had to be transformed to the right position. This was done in ArcView (ESRI,1996) by way of

Figure 3.6: CAD drawing from the City Engineer

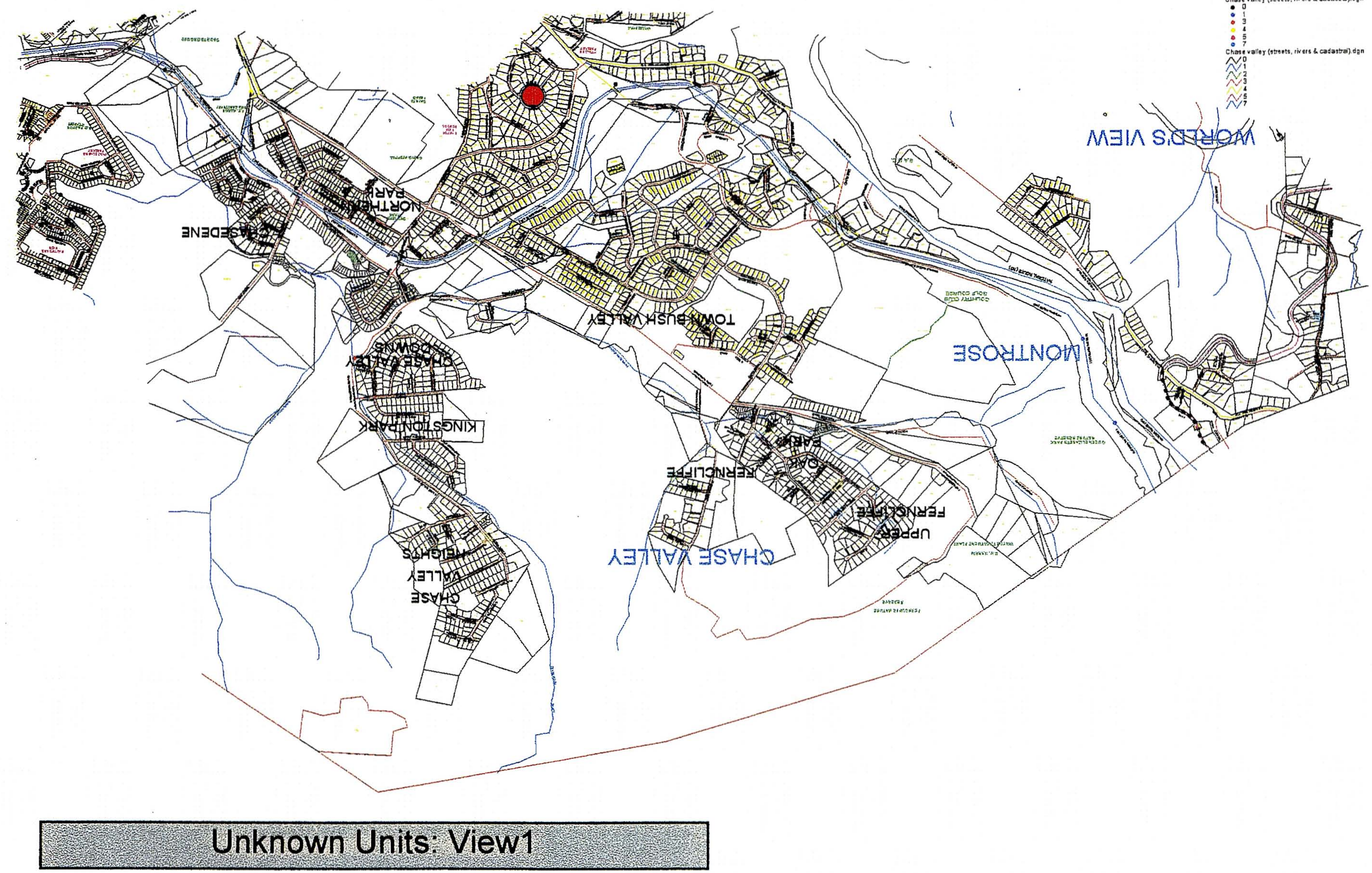
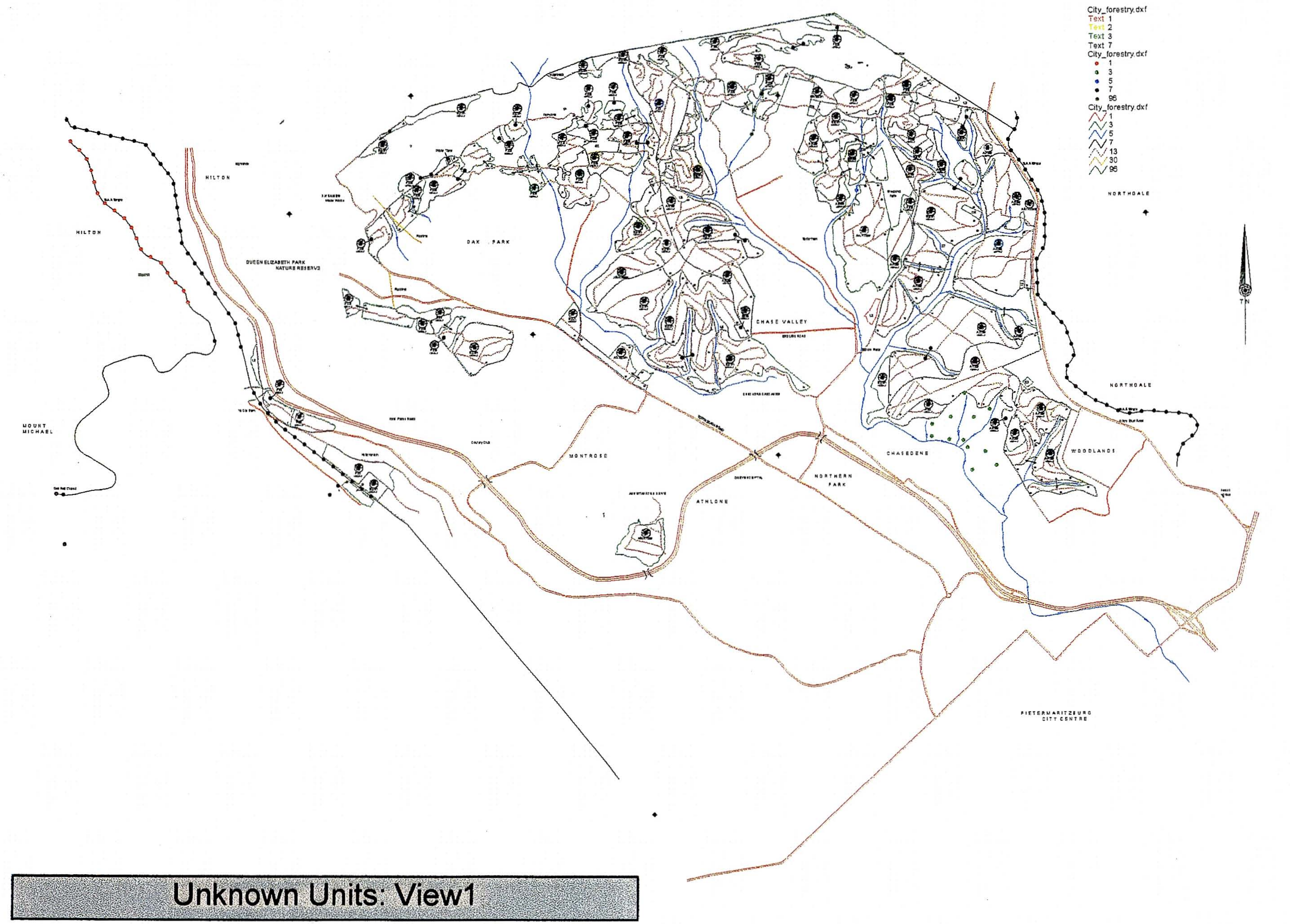


Figure 3.7: CAD drawing from the Natal Timber Corporation



two-point transformation. This process uses a transformation matrix that applies a coordinate offset, scale, and rotation uniform to all coordinates read from the drawing source. A world file was created to apply the coordinate transformation. A world file contains two pairs of X,Y coordinates of which the first pair is the actual X,Y location of known control points in the CAD file. The second pair is a new location in geographic space where the CAD drawing control point is placed in ArcView (ESRI, 1996). The map projection used was the Transverse Mercator.

3.2.2 Data Editing

The data from the City Engineer were mostly polygons of residential plots while those from the NTC were of commercial forest polygons. Both had line themes of roads and streams but these did not overlay precisely. Some sections of these line themes were missing. The missing vertices were added by using a 1:50 000 topo-cadastral (Chief Directorate, 1995) digital map backdrop (2930cb supplied by Umgeni Water) to trace the lines using mouse entry in ArcView.

Polygons of natural areas such as patches of indigenous forests, open spaces and the Queen Elizabeth Nature Reserve were created as new polygon themes using the 1:50 000 backdrop and 1996 aerial photographs supplied by the Surveyor General. The boundary of the catchment as demarcated by the Conservancy was also created as a polygon.

Digital data for the Hilton part of the catchment were acquired from the Hilton Transitional Local Council and the same process was used to convert the data into shape files.

Contour lines (20m) covering the Conservancy were clipped off a 1:50 000 sheet supplied by Umgeni Water. The clipping was performed using the MBB Tools and More extension clip tool (ESRI, 1998).

3.2.3 Assessment of data accuracy

In order to get some indication of the accuracy of the digital data, groundtruthing was performed. The coordinates of fifty randomly selected locations in the Conservancy were determined using a Global Positioning System receiver. These coordinates were then used to check the accuracy of the geographical representation of data in the different themes in ArcView. Accuracies were within acceptable units of one and a half metres.

3.2.4 Analytical Operations

The analytical operations that were employed included spatial overlay, proximity analyses, and distance analyses. These analyses were central in the creation of buffer zones and corridors that would link up the various patches of indigenous areas.

ArcView's 3D Analyst and Spatial Analyst extensions were used extensively, especially in the creation, display and editing of a Digital Elevation Model (DEM) and Triangulated Irregular Network (TIN), 3D shapefile generation and 3D visualisation and animation. The data for the TIN were specifically following stream lines, ridges and other topographical features such as roads. The TIN structures were used to generate maps of slope, shaded relief, contour maps and line of sight maps. The 3D Analyst provided for easy surface analysis that is important in natural resource management.

3.2.5 Field Trips

A number of trips were made to the catchment. The first of these was under the guidance of the Natal Timber Corporation who manage the timber plantations within the Pietermaritzburg/Msunduzi boundary. Information gathered included the ownership of the commercial forest stands in the Conservancy, and major problems facing forestry (such as fires started by neighbouring informal settlers, dumping of solid waste by hikers, among other things). New efforts by the NTC to clear commercial forest stands as far as fifty metres from riparian zones was mentioned (Dixon, 1999). The second major field trip was conducted with a member of the Conservancy in charge of water quality sampling. The locations of the ten water quality monitoring points were identified, as well as noting the various geographical and ecological features such as the indigenous forests. Riparian zones most invaded by alien plants were recorded as were places of serious soil erosion (Scotney, 1999b).

The third major field trip was under the guidance of the study supervisor. During this field trip, a number of sites were visited, and these included points along the streams and roads, stands of commercial plantations, abandoned land, indigenous forests and residential areas. These and the subsequent trips aimed at collecting information about the resource base in the FCC and identifying current and potential environmental problems in the Conservancy were undertaken. This information (see section 4.4) has been compiled into a spatial database. Among the current environmental problems were those associated with the road network, exotic plantation species, alien invasive plant species, soil erosion, land degradation, and fragmentation of indigenous vegetation.

3.2.6 Creation of spatial database

The creation of the spatial database included the collection of resource data, i.e., the natural, the semi-natural, and the built environments. The natural resource data included indigenous vegetation, open spaces and the Queen Elizabeth Nature Reserve. Commercial plantation, the Country Club Golf Course and farm land made up the semi-natural resource data, while built environment resource data included residential areas, schools, play grounds, health and business centers. Given the time limit of the study, only information gathered from those sites that were visited during field trips and through consultation, and the information supplied by the NTC was entered in the spatial database. This information included, among others, the following:

1) condition of the riparian zone along sections of streams;
2) condition of sections of streams;
3) condition of sections of roads;
4) species, date of planting, stand size and condition of plantation stands;
5) condition of abandoned commercial forest stands; and
6) names and description of the built environment, etc.

These data were then compiled in the attribute tables of the various themes in ArcView. Fields pertaining to sustainable resource management strategies were also added to the tables. (See Table 4.1: An example of a GIS database.) These fields were created using the edit function of the Table menu in ArcView and examples of impacts and management strategies were entered. A relational database was then created by "linking" the various tables to one another. Codes were assigned to specific information such as species of exotic timber and "look-up" tables (lut) were created to identify these.

3.2.7 Interviews and consultations

Unstructured interviews with people involved in the Conservancy were carried out. These interviews centered on the concerns that interested parties have regarding the management of natural resources in the catchment. The Conservancy's annual general meeting was attended and this provided an arena for meeting the people involved in the conservation of the catchment. The consultation revealed that the residents of the Conservancy are aware of the aims of the Conservancy but participation in management activities was minimal. Individual efforts in the eradication of alien species were pointed out (MacKenzie, 1999), as well as the fact that NTC was currently engaged in the clearing of these species from riparian zones.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Resource inventory

The bioresource units that cover the Conservancy have been described in the previous chapter and the indicator plant species and geographical features mentioned. In creating an inventory of the resources of the Conservancy, two major shapefiles were created in ArcView. (A shapefile is the format used for spatial data in ArcView). The first of these is the **Resource Inventory** shapefile and it comprises polygons of the following features:

1) commercial forest stands;
2) farmland;
3) indigenous vegetation;
4) scrub vegetation;
5) nature reserves; and
6) open spaces.

(See Plate 4.1)

Polygon features represent homogenous or relatively homogenous areas such as indigenous vegetation (ESRI, 1996). Apart from the commercial forest polygons, which were on existing data from NTC, the other features had to be created using the editing functionality in ArcView (as described in Section 3.2.2).

The second shapefile created was the **Spatial Features** shapefile, and was made up of the following features:

1) suburbs;
2) business;
3) education;
4) health; and
5) public open space.

(See Plate 4.2)

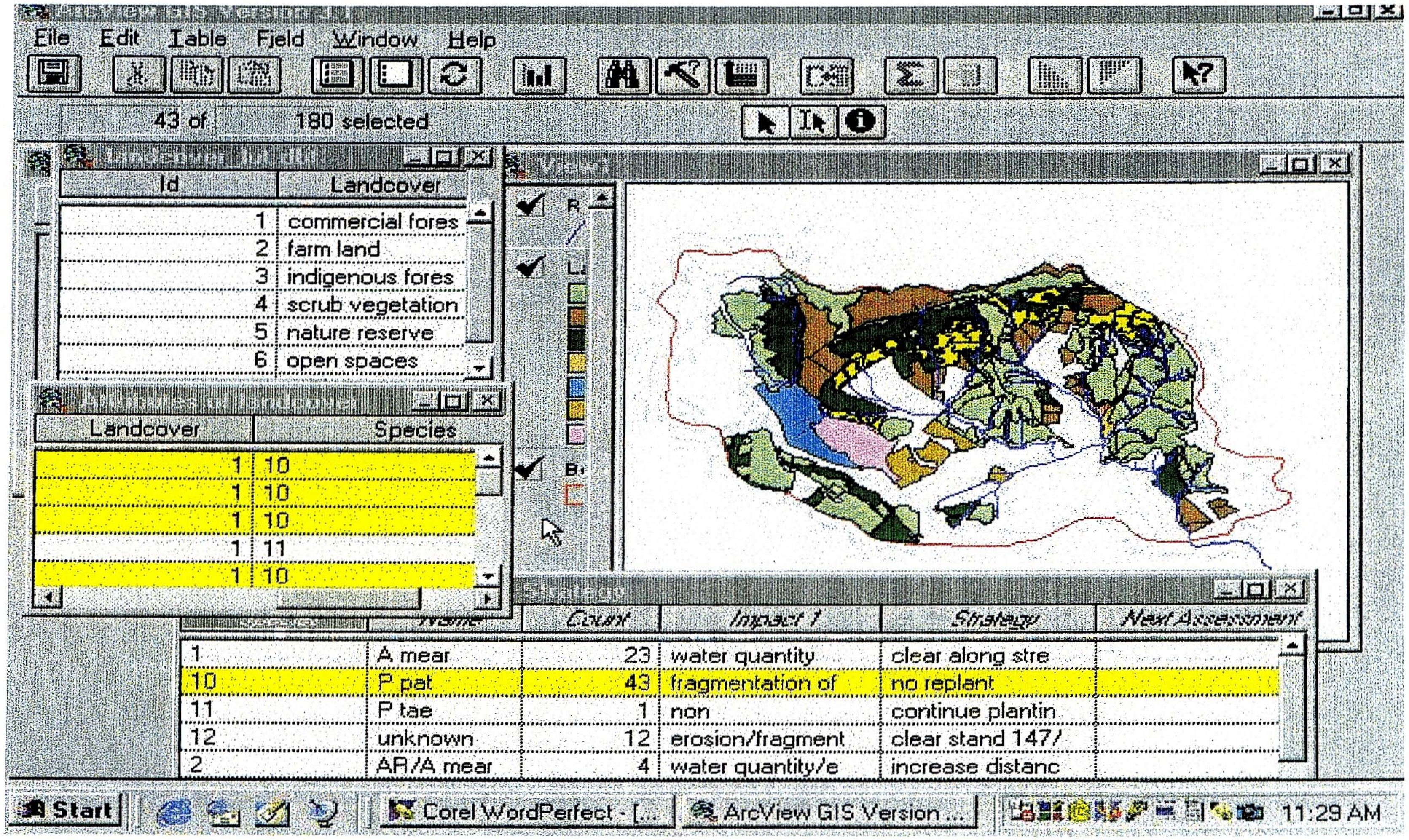


Plate 4.1: Resource Inventory

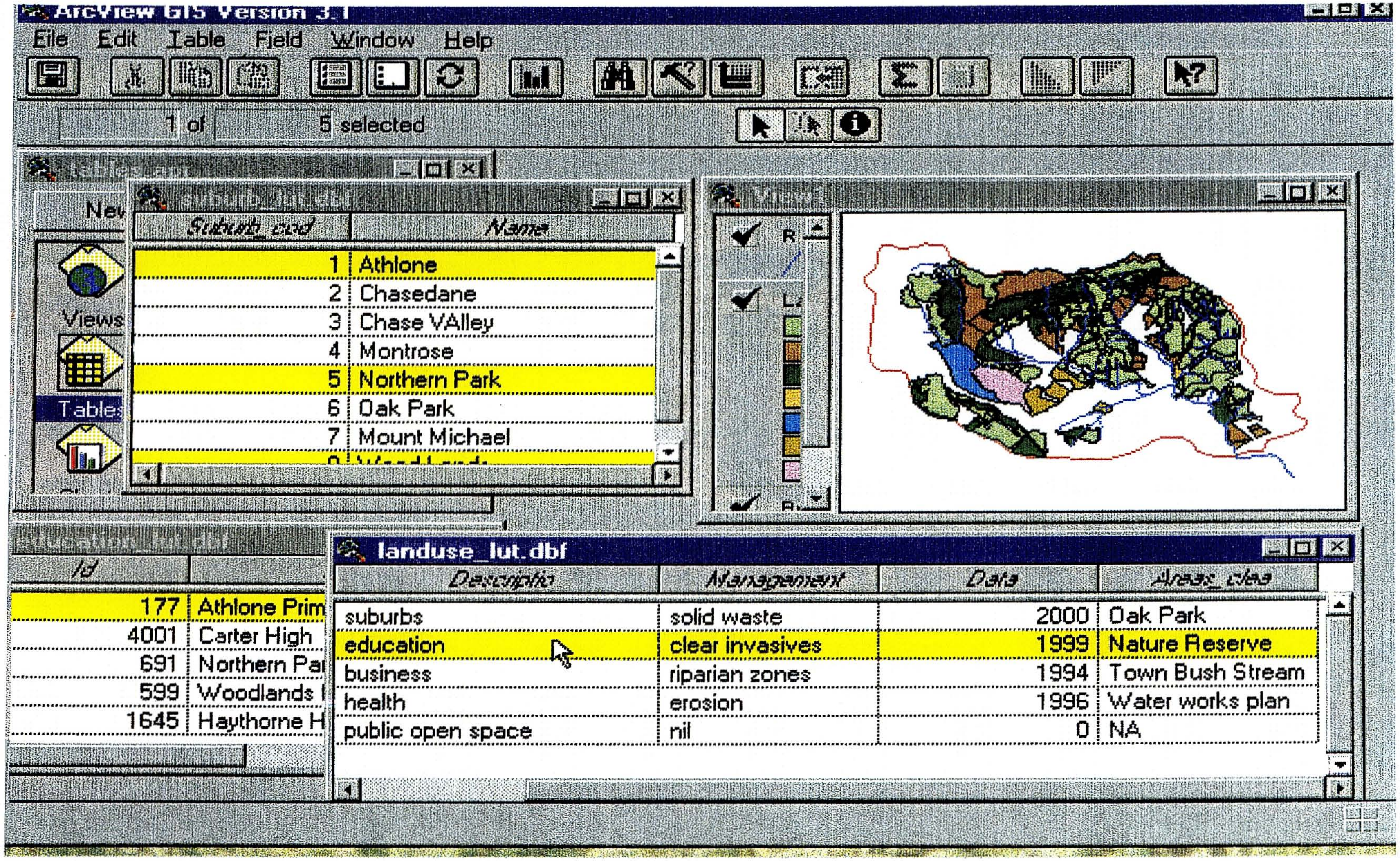


Plate 4.1: Management and monitoring database

The other shapefiles created were the line themes of **Streams, Forest Plantation Service Roads, and Main Roads.** All these shapefiles, when overlayed, completed the land use in the FCC (Fig.3.4). Overlaying is the process of stacking digital representations of various spatial data on top of each other so that each position in the area covered can be analysed in terms of these data (Burrough and McDonnell, 1998).

4.2 Management and Monitoring Database

Integrated Environmental Management requires that a structured system is developed which includes all environmental considerations. A database was created that would enable the collection, storage, retrieval and analysis of information regarding the resource inventory, resource assessment and management strategies. Sample polygons were visited and all the relevant attributes were recorded. Environmental problems were identified and added to the database (Table 4.1). A GIS database is a collection of interrelated information and includes data about the position and the attributes of geographical features that have been coded as points, lines, or polygons (Burrough and McDonnell, 1998). In the **Attribute Table** of the Resource Inventory shapefile, a field containing resource IDs was added. A "look-up" table (lut) was created with one field containing the resource ID and another containing the resource name. The attribute and "lut" tables were "linked" to one another, that is, a two-way relationship was defined between the two tables. By linking two tables, a *one-to-many* relationship is established between the destination table (attribute table) and the source table (resource_lut). This implies that when a record is selected in either of the tables, its related record or records will automatically be selected in the other tables (ESRI, 1996). Since the **Attribute Table** is the feature attribute table of the resource inventory theme, selecting a feature in the theme's view selects that feature's record in the attribute table, and therefore automatically selects the records related to it in the source table and vice versa (Plate 4.1).

A new table, **Plantation Management Strategy Table,** was created with the *species code, name, count* (i.e. number of stands in the Conservancy), *impact 1,* management *strategy and next assessment* (Plate 4.2). An extra field containing the code of the timber plantation species was added to the **Attribute Table** and the two tables were linked using the common field *species*. A number of other fields can be added to the Plantation Management Strategy table and any further relevant data collected and stored, retrieved at will, transformed and displayed (Burrough and McDonnell, 1998).

The similar process was used in creating an inventory of the built environment spatial features and the management and monitoring database. Plate 4.2 shows the attribute table of the spatial features theme. Selecting education in the landuse_lut automatically selects the suburbs in which education institutions are located. Again, the tables can have as many fields as would suit monitoring and management plans. The GIS database can be regularly maintained and updated by the Ferncliffe Catchment Conservancy Management. It can also be used for decision making or as a spatial decision support tool.

Table 4.1: AN EXAMPLE OF A GIS DATABASE

SPATIAL AND ATTRIBUTE QUERY				MANAGEMENT STRATEGIES			MONITORING STRATEGIES		
Feature ID	**Resource**	**Resource name**	**Condition**	**Actions to be taken**	**Actions taken**	**Date**	**Was action taken effective?**	**What is the status quo?**	**Actions for the year 2001**
305	Stream	Town Bush lower	Sedimentation Low quantity	Reduce erosion	Cleared riparian zone	June 1999	No	Poor	Clear alien plant species
95	Stream	Chase Valley middle	Solid waste deposition						
129	Forest	129 - Wattle	Too close to Town Bush upper	Remove 20m from riparian area	Cleared	Jan. 2000	Yes	Good	None
509	Forest	509 indigenous	Pristine	Clear abandoned wattle from edges	None			Pristine	Replace abandoned wattle with indigenous
101	Stream	Town Bush Upper	Not flowing						
735	Forest	Q.E. Nature Reserve	Pristine						

4.3 Corridors for expansion of indigenous vegetation

The fragmentation of the indigenous vegetation has certainly been caused by a number of land use practices such as expansion of residential areas, afforestation, and infrastructure such as roads. It is however evident that much of the fragmentation has been a result of afforestation. The results of the study have shown that if some commercial forest stands were cleared and indigenous vegetation encouraged to take their place, the fragmentation would be reduced, allowing for efficient monitoring and management of these areas (Ahmed, 1999a).

The most effective method of implementing an efficient monitoring and management plan is to divide the FCC into management units (Ahmed, 1999c). While the Bioresource Units cover relatively large areas in the context of KwaZulu-Natal, some even larger than the Conservancy itself, they are nevertheless small enough within the boundaries of the FCC and are the most effective units to use as they are based on homogeneous ecological features. Other management units may not be effective especially if they traverse ecological boundaries. Fig. 4.1 shows the indigenous areas in relation to the BRUs. Most of the indigenous areas are found in the Hilton - Zc7 BRU and it is here that expansion corridors would reduce the fragmentation of indigenous areas. Complete compactness would be inhibited by physical barriers such as the network of roads and residential building. The highlighted areas (Fig. 4.2) are possible corridors which would best support the expansion of indigenous areas and bring about some degree of compactness.

In conclusion, it is important to point out that almost all of the highlight areas in Figure 4.2 are commercial forest stands which not only cause fragmentation but impact on various aspects of natural resources. These impacts will be discussed below, together with the other factors affecting the natural resources of the Conservancy.

4.4 Main environmental problems

The environmental problems listed in this section are based on the information gathered during field trips to the study area and from interviews conducted with the FCC management during the study period. This study had time constraints and could not gather detailed data regarding the problems within the FCC. Specialist investigations would be required to inform on the magnitude

Figure 4.1: Proportion of indigenous areas in BRUs

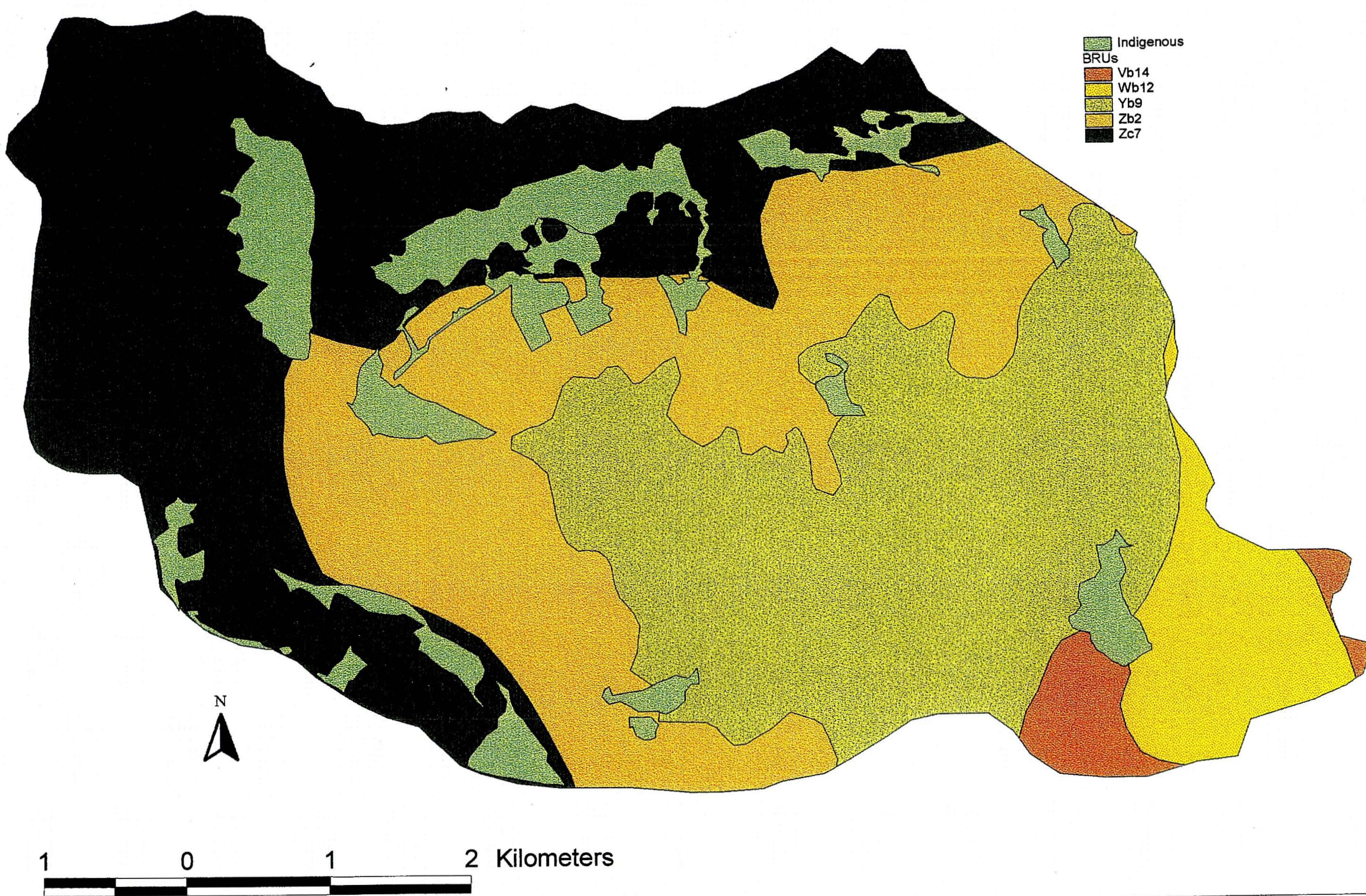
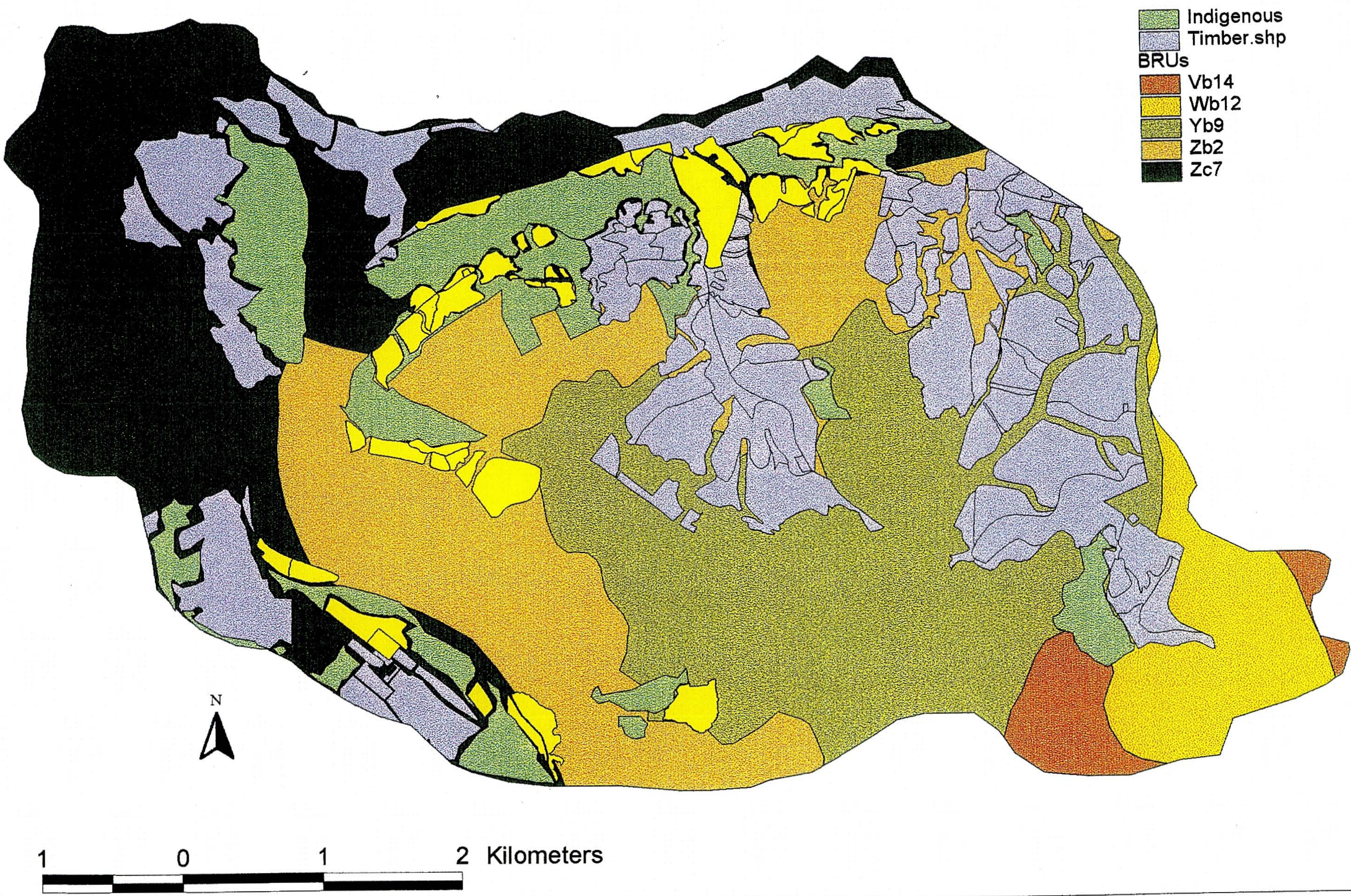


Figure 4.2: Possible indigenous areas expansion corridors (highlighted) based on BRUs



of the environmental degradation in the area and to detail mitigation measures that would be most effective in dealing with these problems.

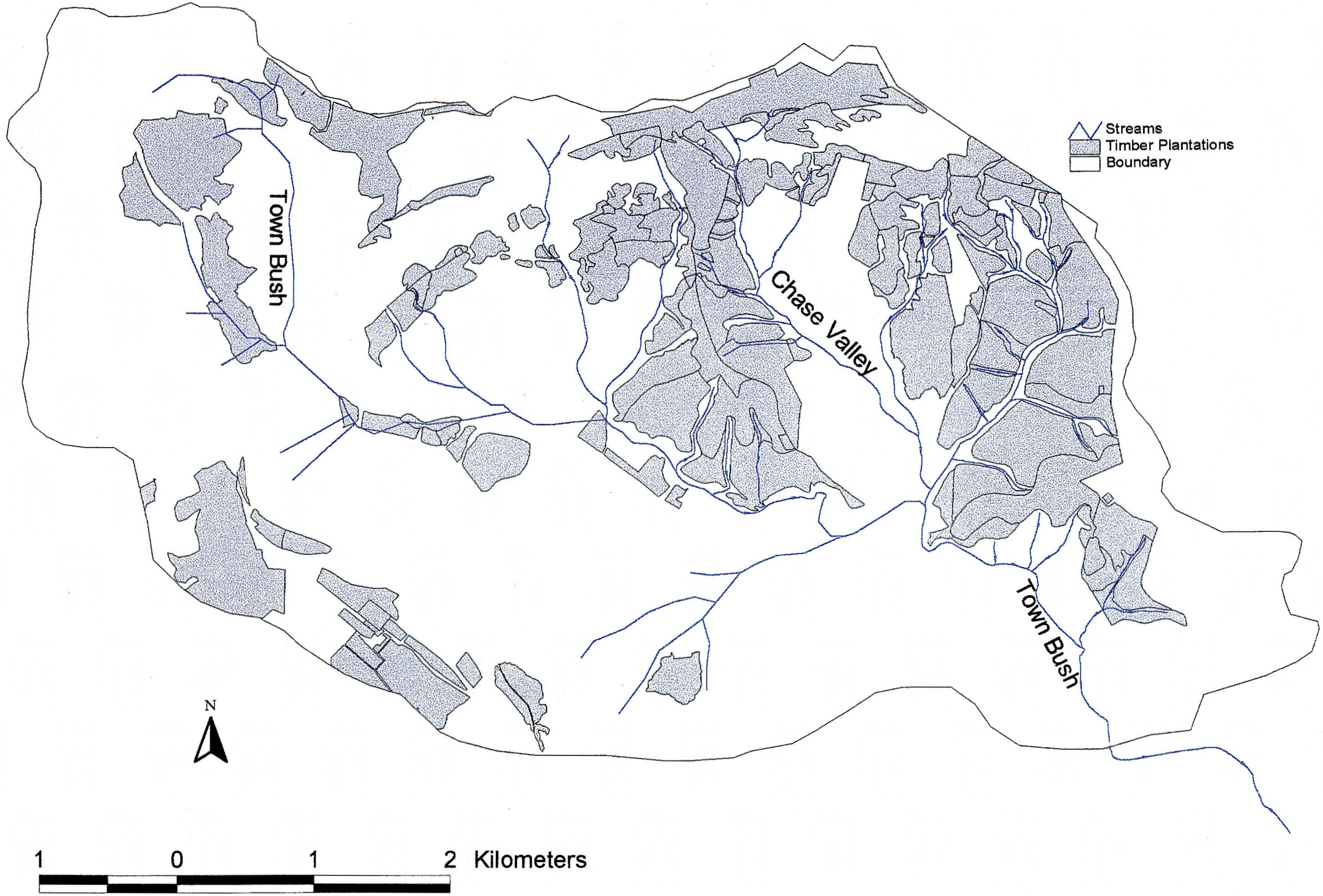
4.4.1 Afforestation

A number of commercial plantation stands were visited during the course of the study and it was noted, on the positive side, that these provide the FCC with aesthetic vegetation cover especially to the northwestern part of the Conservancy. However, 43 per cent of the exotic plantations are of the *pinus* species and those stands visited had no undergrowth. *Pinus* species do not allow undergrowth and so leave the soil bare when they are harvested. This undoubtably exacerbates erosion and run-off especially since the terrain of the FCC is steep. The problem continues even after replanting until the trees reach the age when they can cover the land adequately. Besides, exotic species do not filter out pollutants as well as indigenous plants do (Ahmed, 1999c). Generally, a large amount of afforestation undermines an area's ecological value (Lavers et al: 1993).

4.4.1.1 Impact of afforestation on water quality and quantity

Consultations with the FCC and NTC management revealed that until recently, the forest stands in the Ferncliffe Conservancy have been very close to the streams thereby reducing the amount of flow (Dixon, 1999; Scotney, 1999b). It was noted during field visits that *Acacia* timber species in some areas of the Conservancy are still grown close to the streams. The FCC management pointed out that extensive afforestation (Fig. 4.3) impacts on water quantity and quality as well as sediment yield (Scotney, 1999b), highlighting a greater need for environmentally sensitive planting in the catchment in relation to water supplies and the streams (Aspinall, 1993). The NTC has now started to clear trees that are very close to the streams (Dixon, 1999). It was also observed during field visits that newly planted stands were about 20 metres from the streams. However, this will stop but a small percentage of water lost to afforestation as the replacement of indigenous vegetation by alien timber species has severe impacts on catchment runoff (Hoffman, 1997).

Figure 4.3: Extent of afforestation in the FCC



The plantations reduce the flow of water as they consume a lot of water. One stream in the area is totally surrounded by trees (Plate 4.3) and only managed to flow once in 1998 (Scotney, 1999b). Quality of water in some sections of the streams was observed to be poor. Solid waste was found along, and in the upper Chase valley streams. Exotic plant species do not filter solid waste as well as indigenous species do (Ahmed, 1999c).

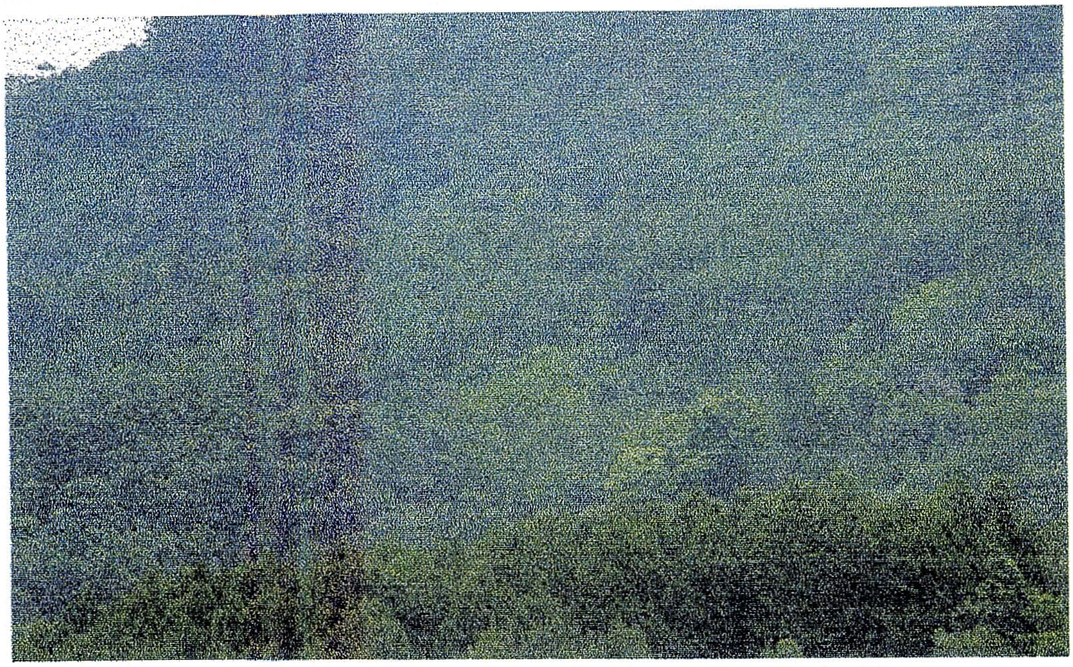


Plate 4.3: Afforestation in the FCC

4.4.1.2 Impact of afforestation on biodiversity

Afforestation has simplified the complexity of biodiversity in the Conservancy (Scotney, 1999b). The patches of indigenous forests in the FCC are not what it used to be. Indigenous plant species such as yellowwood (*Podocarpus latifolius*) and stinkwood (*Ocotea bullata*) have been drastically reduced. The reduction of the indigenous vegetation has made way for invasive alien species such as the Mexican Thorn, the Black Jack forb (*Bidens pilosa*) and *Lantana Camara*. The plantations that are on the Hilton side of the Conservancy are planted on what used to be grassland (Scotney, 1999b).

The view that plantation forestry has a negative impact on biodiversity has been supported by many others. Christie and Gandar (1995) point out that "biodiversity in plantations is lower than otherwise, except in comparison with other mono-crops, such as many agricultural crops, and degraded land". Saville (1994) mentions that the burning of plantation slush, which is permitted only in the wetter months to reduce the chance of runaway fires, has serious adverse implications for plants and animals, since the wetter months are typically the growing season for plants and breeding season for animals.

Another problem that stems from exotic plantation in the FCC is that of land management. When the trees are felled, the brushwood is stacked and then burnt before planting the next lot (Scotney, 1999b). This enhances soil erosion. The brushwood was never stacked along the contour but up and down such that when they got burnt and the rains came, there was increased sedimentation and organic matter loss. Important also is that the riparian zones have not always been left clear, increasing the impact on water (Scotney, 1999b).

4.4.2 Invasion by alien plants.

Invasive alien plants are agents of land transformation. They are disrupters of ecosystems and their threat to biodiversity has increased throughout the world (Richardson *et al* 1997). The current state of the FCC as observed during field trips clearly indicates that alien plant invasion has largely resulted from human activity. Aliens occur where the natural vegetation has been disturbed, particularly by human habitation and planting, abandoned lands, roads, railways and fence lines (Richardson *et al* 1997). All these factors that support invasion are to be found with varying degree in the Ferncliffe Conservancy.

4.4.2.1 Impact of alien plants on abandoned land

The major invaders of abandoned lands are the *Pinus* and *Eucalyptus* species. These abandoned lands are to be found mostly between the Queen Elizabeth Park to the west of the Conservancy and Oak Park to the east. As these abandoned lands are adjacent to indigenous areas, the *Pinus* and *Eucalyptus* species have gradually moved into the indigenous forests especially since they have the advantage of growing fast. Other trees that have invaded these areas are the *Acacia mearnsii* and the climbing shrub *Caesalpinia decapetala.* The area around the Umgeni Water waterworks is vegetated by scrub. This gradually changes into indigenous vegetation which is infested with a lot of exotic timber to the north of the waterworks. Patches of indigenous forests are scattered from here to the Hogsback beacon. It is imperative that timber which has grown in the former NTC forest stands be removed to give conditions for the expansion of the indigenous forests.

4.4.2.2 Impact of alien plants on riparian zones

A number of stretches of the Conservancy's riparian zones have been invaded by alien plants. This is a problem in that these weeds are not capable of offering the catchment the protection that indigenous species provide. The most affected area is that along the eastern bank of the Town Bush Stream along the Queen Elizabeth Park and the Country Club golf course. Here, alien species cover an area up to fifty metres from the bank of the stream. The most common of these is *Lantana camara.* Plate 4.4 shows some clearing of alien plants along the riparian zone.

Plate 4.4: Some clearing of alien plant species

Riparian zones in the Conservancy have attracted invasive species in that they provide a moist environment. The Occasional flooding enables the dispersal of seeds, aids germination, provides seed beds and removes competing plants. This results in dense alien stands which then obstruct water flow, especially during floods. The consequences of this are well defined by Hoffmann and Moran (1988 - cited in Richardson *et al*, 1997).) who point out that this leads to the erosion of the watercourses and to the conversion of well-defined rivers into diffuse systems of shallow streamlets and trickles. The resulting sedimentation and widening of the stream bed create ideal substrata for expansion of the alien stand. Heavy thunderstorms create powerful flood flow during which the force of water breaks off branches and deposits them downstream for propagation. Henderson and Wells (1986) have noted that "water has been of particular significance in transporting the otherwise rather immobile seeds of several alien species belonging to genera such as *Acacia, Caesalpinia, Sesbania* and *Prosopis.* Rivers and streams not only provide routes for the invasion of alien species but their banks also serve as a seed reservoir from which further spread can take place".

4.4.2.3 Other impacts of alien plants

The impact of invasive plants to the natural ecosystem of the FCC can be summarized using categories identified by Richardson *et al,* (1997):

a) replacement of diverse systems with single or mixed species stands of aliens;
b) alterations of soil chemistry;
c) alterations of geomorphological processes;
d) alterations of fire resumes;
e) alteration of hydrology;
f) invasions leading to plant extinctions;
g) threat to native fauna; and
h) destruction of riparian habitats.

Efforts by the FCC management and by individuals are under way in trying to eradicate alien invasive species in the Conservancy. However, these efforts need to be supported by the NTC as managers of the commercial forests, and the Pietermaritzburg/Msunduzi Municipality as the owners of the commercial forests. Such joint effort, coupled with the implementation of legislation, would be most effective to combat the above environmental problems brought about by the invasive plant species.

4.4.3 Soil Erosion

It is well understood that soil is a crucial life-support system on which living organisms depend. While under natural conditions soil loss occurs at more or less the same rate as new soil is formed from the parent material, the activities of human beings tend to increase the rate of soil loss (Liggitt, 1988).

Through consultation and though examination of the problem during field trips, the following were identified as major causes of soil erosion in the Ferncliffe Catchment Conservancy:

a) afforestation;
b) development; and
c) roads.

The major impact of soil erosion in the FCC is on the following:

a) water quality and quantity;
b) sedimentation;
c) vegetation;
d) soil; and
e) land use.

4.4.3.1 Impact of afforestation on soil erosion

About 34 percent of the FCC land cover is taken up by commercial forestry (Plate 4.3 and Fig. 4.3). There are various species of *Pinus, Eucalyptus* and *Acacia* on scattered stands. These stands vary in age, some planted as far back as 1974 while others as recently as 1999. The most recently planted stand is located to the east of the Chase Valley residential area, opposite Kingston Park. This stand, which borders the Chase Valley Stream, has no vegetation cover at all except for the young trees because it was completely cleared before planting. It is possible that a lot of erosion could occur with the coming rains and could cause heavy sedimentation in the Chase Valley stream. Plate 4.5 shows a pine stand that has been harvested and burnt out before the next planting. Clear-felling causes periodic catastrophic changes in runoff, sediment loads and organic input (O'Keeffe *et al*, 1989). It is not so often that the stands are replanted immediately after clearing and so the process of erosion has a long period of time to take its toll. This particular stand in Plate 4.5 borders the Town Bush Stream and therefore soil would easily be eroded into the stream during a storm.

Plate 4.5: Harvested plantation stand

4.4.3.2 Impact of development on soil erosion

Another area of concern in the Conservancy is development. As population grows, there is increased demand for housing, and therefore an increased demand on land. Given the terrain of the Conservancy, the building of houses demands that the landscape be cut to level off a single plot. The loose soil that is removed has to be placed somewhere, and in most cases, the riparian zone (Scotney, 1999b).

Plates 4.6 and 4.7 show the results of some development taking place along the Town Bush Stream where it borders the Country Club golf course. This loose soil will inevitably be flushed down the stream during heavy rainfall and will result in increased sedimentation, which will in turn impact on water quality and quantity. Wherever the soil has been dumped, vegetation will take a long time to grow as the soil will be upturned, losing the top soil in the process. The lack of vegetation in turn enhances the process of erosion. An erosion control measure recommended by specialists has to be undertaken by developers and this would have to be included in the database by the FCC management, as exemplified in Table 4.1.

Plate 4.6: Displaced soil dumped in riparian zone

Plate 4.7: Loose soil dumped on steep stream bank

4.4.3.4 Impact of roads on soil erosion

The vast network of untarred commercial forest service roads in the Conservancy is one of the major contributors to soil erosion (Scotney, 1999b). This again is exacerbated by the steep terrain of the area (Fig. 4.4). While runoff gullies have been made along a number of these roads, much more can be done to reduce erosion. Slope has been identified as particularly important, together with soil parent material (geological type) and drainage density, when considering erosion potential (Liggitt, 1988).

4.4.4 Built Infrastructure

4.4.4.1 Impact of built infrastructure on the landscape

It was observed during field trips that the residential areas in the FCC are expanding with the rise in the demand for houses. New sites for houses are evident in the catchment, especially along the Nonsuch Road which runs along the Town Bush Stream. With new buildings coming up, the landscape is continually being changed and degraded. But perhaps the most serious infrastructure that has deformed the landscape in the FCC is the forest road network (Plate 4.8). This network has cut the landscape, leaving it with rugged bare strips of land that crisscross the northern part of the Conservancy.

4.4.4.2 Impact of built infrastructure on the ecological

Ecological degradation can be measured by indicators such as reduced habitat and species diversity and the areal extent of ecologically valuable plant and animal communities (Hunter *et al*, 1998). The commercial forests service roads have fragmented the Conservancy into many pieces. The roads have also made the boundaries of indigenous areas more convoluted, making them less efficient to conserve. This has been worsened significantly by the "islands" of commercial timber within the natural vegetation - Plate 4.9 (Ahmed, 1999a).

The roads act as boundaries between the natural vegetation and the commercial forests. Since the roads are a physical division of natural and semi-natural ecosystem, they inhibit the spread of indigenous plant species. The consequence of this is that the associated reduction in size can threaten the viability and/or biodiversity of smaller remnants (Hunter *et al*, 1998).

Plate 4.8: Roads Degrade the landscape and enhance erosion

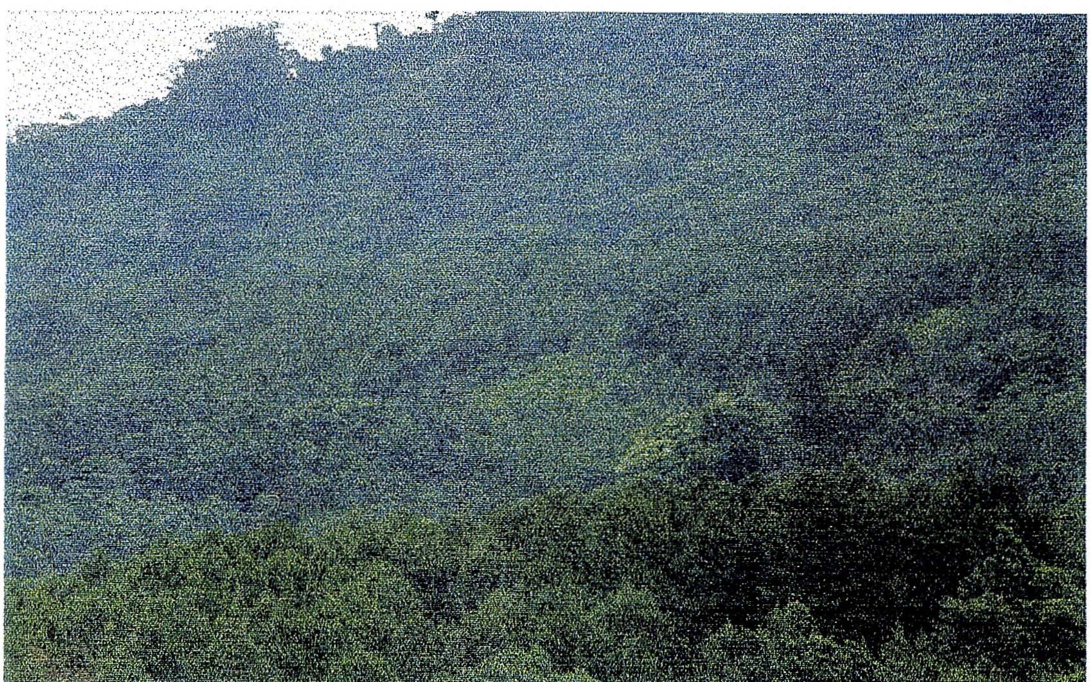


Plate 4.9: Fragmentation of indigenous vegetation by "islands" of plantations

4.4.4.3 Built infrastructure and land consumption

The transport infrastructure that is in place in the conservancy gives rise to environmental impacts first and foremost due to its physical presence. The road network shown in Fig. 4.4 gives an idea as to how much land has been consumed by roads. The consumption of land is not just a direct consequence of transport development but it may also occur indirectly as land is utilized for the extraction of raw materials required for construction (Hunter *et al* 1998). The map also shows how large areas have been effectively divided into smaller ones.

Once the land has been lost to road infrastructure, which is, in itself, a change in land-use, there is a decline in the visual amenity or aesthetic appeal of the landscape (Plate 4.8). However, Hunter *et al* (1998) point out that there are difficulties with the judgement involved in assessing the significance of the visual impact. Individuals and groups are likely to have varying perceptions of any particular piece of transport infrastructure. These groups include developers, planners and transport operators, local residents and interested groups. It is therefore unlikely to get complete consensus.

4.4.4.4 Impact of built infrastructure on runoff

Residential houses are still being built in the conservancy (Fig.4.5). Many impacts, direct or indirect, are associated with this kind of development. Plate 4.10 shows the amount of concrete that is used to cover natural areas. This and the many roofs increase run-off, and hence, erosion. Given the terrain of the conservancy, there is enhanced flooding due to the increase channel flow from the concrete, tar and roofs.

Figure 4.4: Road network and streams in the FCC

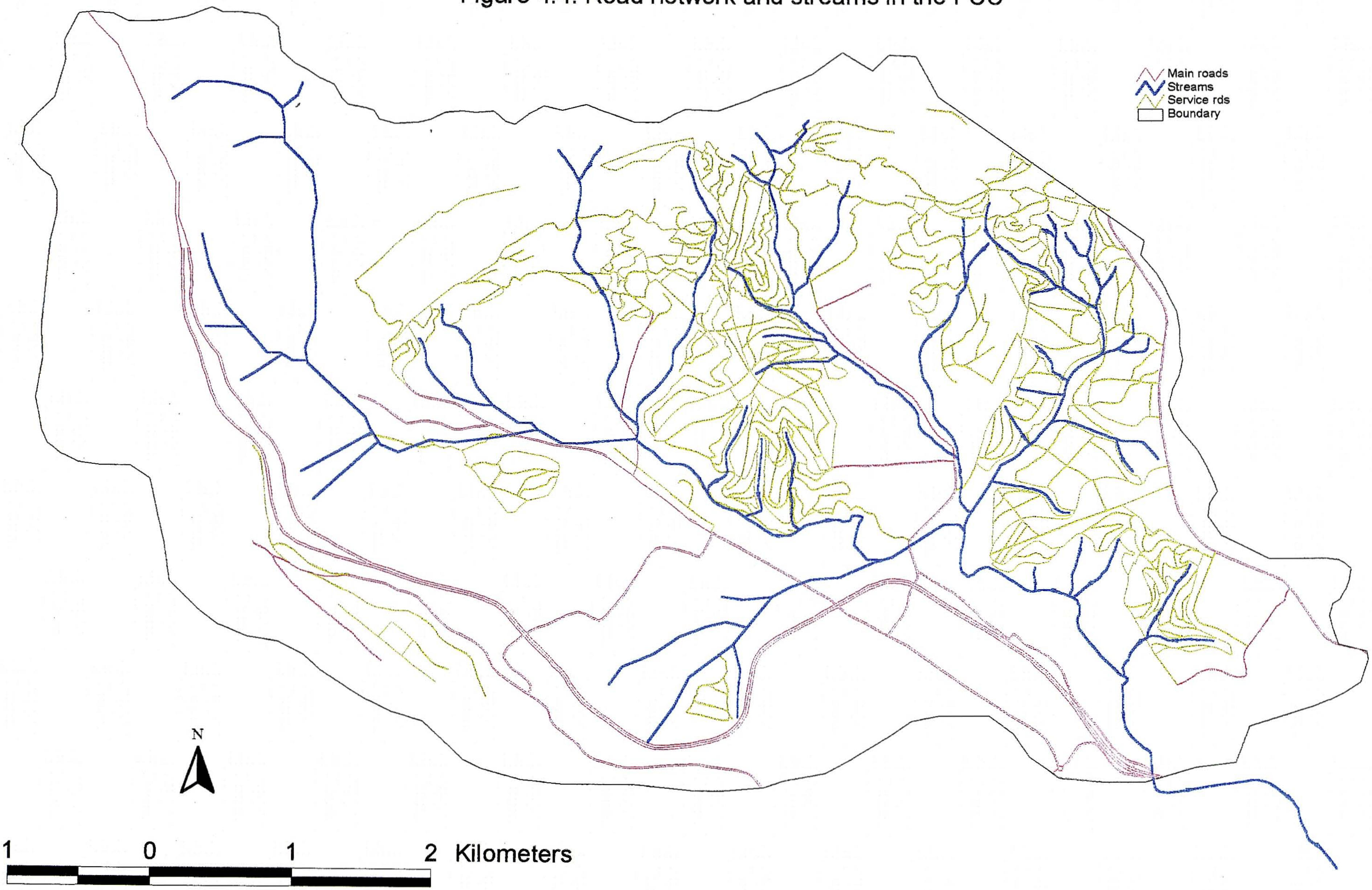


Figure 4.5: Built environment of the FCC

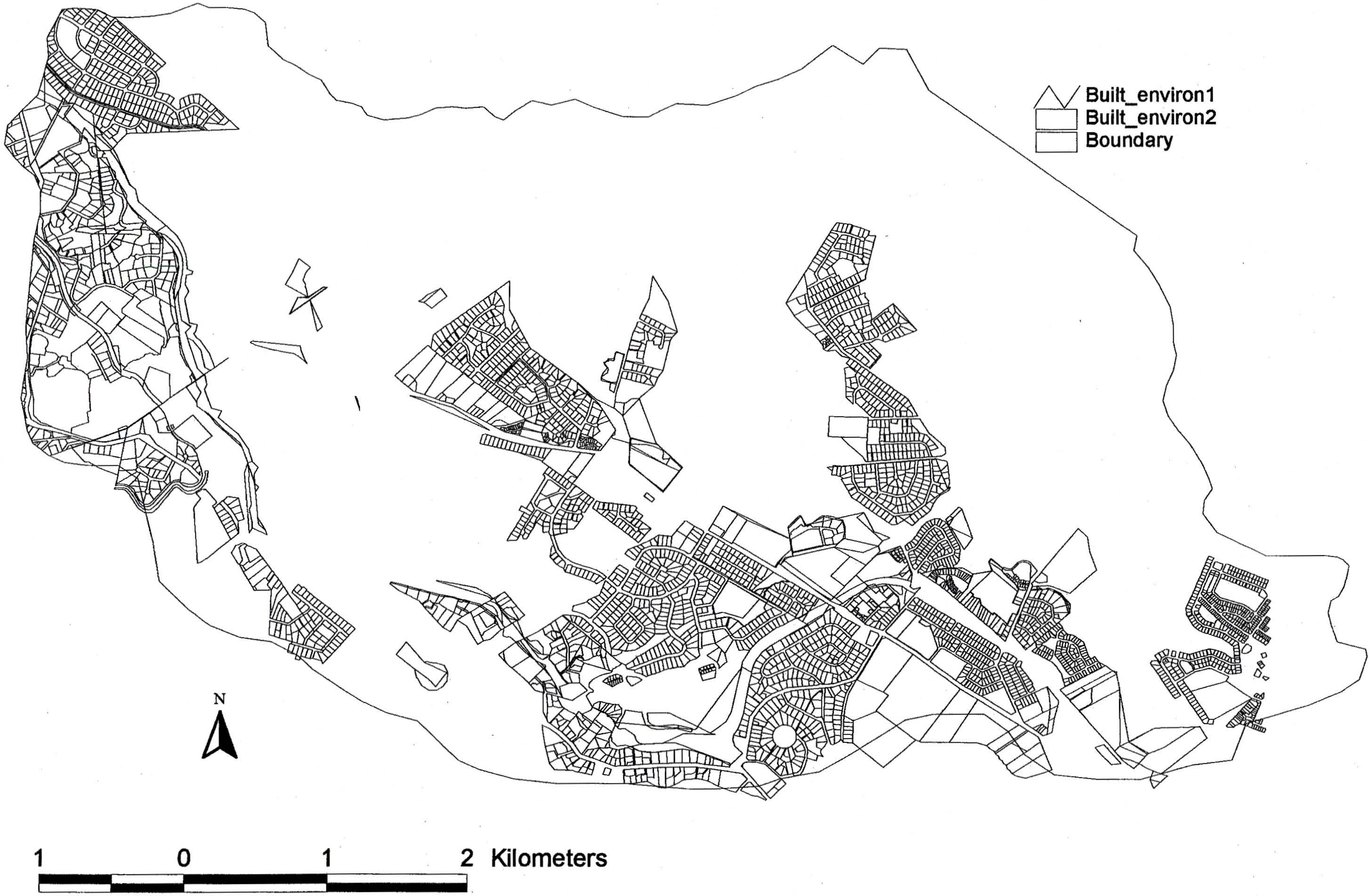


Plate 4.10: Enhanced runoff due to development

Plate 4.11: Soil displaced from building site

The earth that is removed has to be taken elsewhere. Plate 4.6 shows loose soil removed from a building site along the Nonsuch road and dumped in the riparian zone of the Town Bush stream. This soil is being eroded into the stream, causing increased sedimentation which will in turn enhance flooding.

4.4.4.5 Water Pollution and disruption of hydrological processes

Given the terrain of the conservancy, rain water that falls on road surfaces is often drained rapidly to the nearest watercourse. This enhances the risk of downstream flash flooding in the recipient stream shortly after large storms as the channel may be unable to cope with large volumes of water being discharged into it over short time periods (Hunter *et al,* 1998). As has been mentioned above, the roads, especially the forest service roads, together with increased channel flow from residential roofs and the concentration of storm water flows, are channels of soil erosion, and consequently, the deposition of sediments into watercourses (Plate 4.12).

Plate 4.12: Impact of roads on soil erosion

Runoff, especially from tarred roads, allows for the easy transportation of deposited materials into adjacent streams. These materials would be vehicle-related such as petrochemicals, hydrocarbons from exhaust fumes, petrol and oil, rubber and spills from any type of transported load. The national road, the N3, is the route for major chemical transporting vehicles. If an accident occurred involving one of these, chemicals would spill into the Town Bush catchment if the spillage was not immediately contained. Solid waste from residential and business areas are further sources of pollutants that can end up in the streams. There have also been incidents when sewage pipes have burst and discharged effluent (Scotney, 1999b; Mackenzie, 1999).

4.4.5 Possible impacts on biodiversity

4.4.5.1 Impact of development on biodiversity

The patches of indigenous forests (Fig. 4.6) are an important feature in the Ferncliffe Catchment Conservancy (Plate 4.13). They are however highly degraded now. A number of alien species, such as the Mexican Thorn, have invaded these Mistbelt forests. This is an indication that some parts of the forests were cleared to such an extent as to allow the invasion by alien species. There is a possibility that in the early days yellow wood was removed from the forests to provide timber needs for the city of Pietermaritzburg. (Scotney, 1999b).

Figure 4.6: Patches of indigenous vegetation

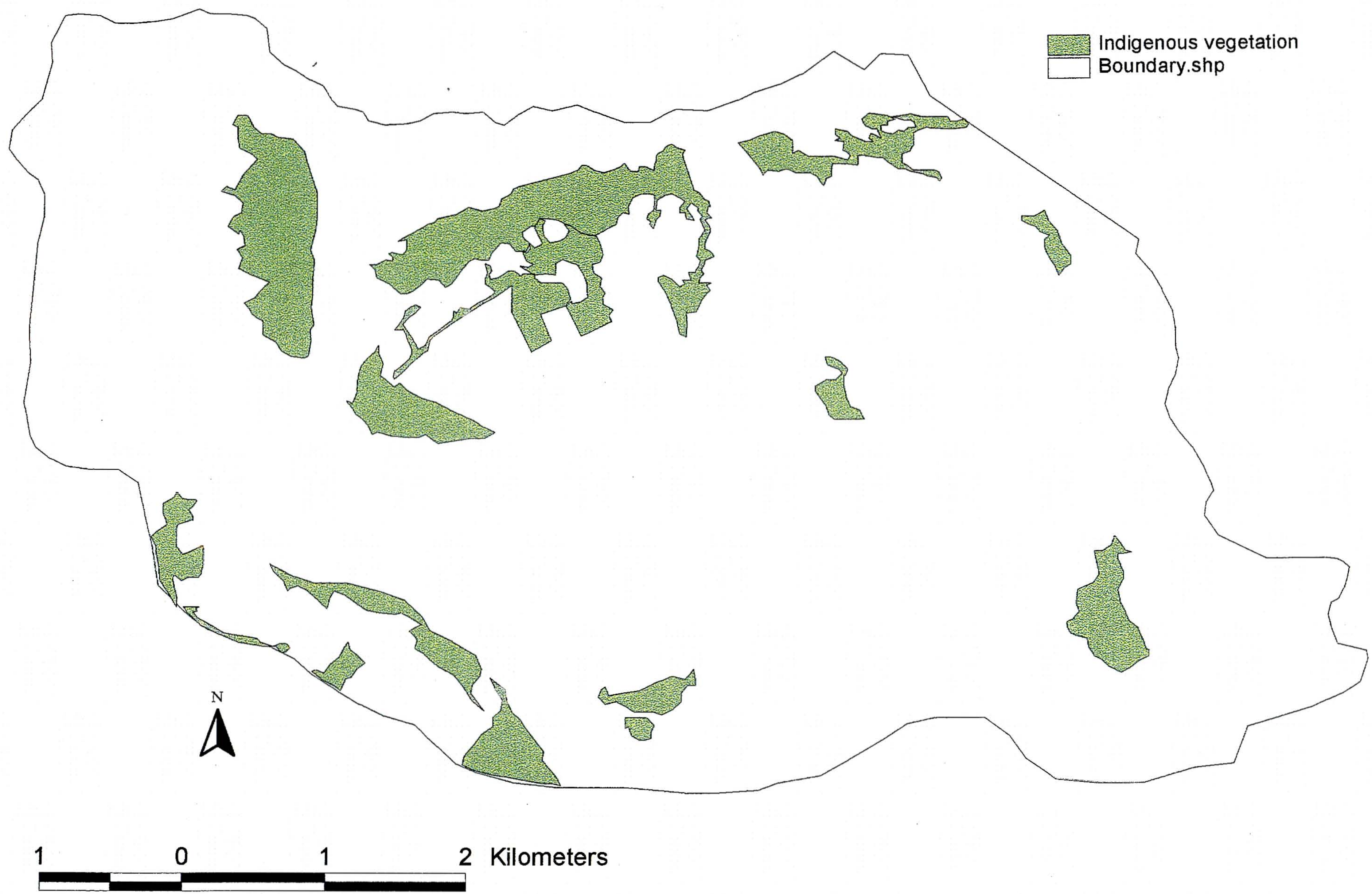


Plate 4.13: A patch of indigenous forest

4.4.5.2 Impact of afforestation on biodiversity

By about the 1950s, permission was given to timber growers to plant up exotic timber in all the grassland areas surrounding the forests. These plantations continue today with one stand being felled only to be planted again the following day. On the positive side, these exotic trees form some kind of protection. The growers will not allow fire, they have very good fire protection mechanisms which benefit the indigenous forests as well.

4.4.5.3 Impact of human activity on biodiversity

There is a threat to the indigenous forests from human activity, for instance, poaching and picking medicinal plants. It is difficult to determine the extent of the problem. There are some animal species in the catchment such as bush buck, duiker, red duiker, hedge hog and wild pig. The exotic plantations have formed some kind of protection for these animals but have made it easier for the poachers who find it easier to hunt in the plantations than in the indigenous forests. These plantations have provided shelter for problem animals such as monkeys, which are on the increase and becoming a nuisance to residents and neighbouring farmers.

4.5 Management and Monitoring Strategies

As has been mentioned above, about a third of the Ferncliffe Catchment Conservancy is afforested by three types of timber species, that is, *Pinus* (43 per cent), *Acacia* (26 per cent), and *Eucalyptus* (29 per cent). The management of the exotic forests should emphasize site selection and correct species matched to each site (Herbert and Musto, 1993). Digital Terrain Modelling is an option that can aid the characterisation for site mapping and for other site related matters. Map data can comprise site units, geological boundaries and plantation site map with roads and streams. These classes of data could then be overlayed on to the digital model. Other surfaces or features, such as soil horizons, geological strata, tree canopy surface could be used in the evaluation of rootable soil, exploitable gravel, and biomass (Thwaites, 1988).

The containment of alien plantations to areas set aside for their cultivation must become an integral part of silviculture (Richardson, 1998). The South African Forest Act requires that forest stands lie at a distance of 20 metres from water courses. For improved water quality and quantity, the 200 metres recommended by Kienzle and Schulze (1993) would be more appropriate. The clearing of alien invasive species from, and maintenance of riparian zones, is hydrologically beneficial. The further down the stream a commercial forest stand is situated the less impact it has on the hydrology of the Conservancy (Forsyth *et al*, 1997).

Alien vegetation in abandoned land and riparian zones is a matter of great concern. Management objectives should aim at the removal and replacement of aliens with indigenous vegetation, and to limit further riparian destruction. Strategies could involve educating land owners, developers, the public, and authorities about the benefits of riparian zones (Scotney, 1999c). The implementation of effective control measures, guidelines and legislation would ensure the limit to further riparian destruction.

Through field visits and consultation with the FCC and NTC management, soil erosion has been identified as one of the major problems in the Ferncliffe Catchment Conservancy. Management objectives should aim at reducing sediment loads and at constructing viable sediment management strategies. To achieve this, there is need for improved land management strategies. It is essential to identify and map the source and potential problem areas and store the data in the inventory as in the example given in Table 4.1. The GIS database will provide for an effective and efficient management and monitoring programme over time. Water quality data from the 10 strategic water quality monitoring points will monitor key water quality parameters and such results can be included in the database. The monitoring of the streams in the FCC will facilitate the monitoring of impacts resulting from developments and land management at a more detailed scale within the Conservancy (Scotney, 1999a).

It is clear that a riparian zone that is vegetated by indigenous plant species is beneficial not only from a water-use point of view, but also from ecological and aesthetic perspectives (Ahmed, 1999c). The maintenance of indigenous vegetation is a valid and realistic management option within the Conservancy. This vegetation maintains excellent water quality, and is suited for the protection of soil and water-yielding characteristics of the riparian zones (Scott and Lesch, 1996).

4.6 Community Participation

The mapping of the Ferncliffe Catchment Conservancy will provide the residents of the Conservancy with an information level from which they would orientate themselves and see the location of ecological and geographical features, as well as developments, trends and problems in the Conservancy. This will make the public aware of their environment and instill a sense of being part of the larger whole and so facilitate participation in the management and monitoring programme.

Murphree (1993) pointed out that "people seek to manage the environment when the benefits of management are perceived to exceed its cost". Murphree further stated that the issue of cost was a fundamental dimension of environmental management since people may want to manage natural resources for better production or to prevent the effects of its destruction. It would therefore be the FCC's Management undertaking to assess the value of the FCC resource base. The cost of monitoring, and of any action that is to be taken also need to be assessed. Table 4.2 shows an example of a summary management plan for the FCC.

The inventory management and monitoring database will be regularly updated with changes in land use, developments, problem areas, water quality status and the condition of the natural resource base. These will be available to the public by permanent display of maps, graphs and tables in the Cascades Shopping Complex located within the FCC. This should foster community participation, especially in reporting issues regarding the condition of the natural resources, waste management, clearing of alien vegetation in riparian zones and abandoned land, planting of indigenous vegetation, waste management, and so on. Most important though, will be to have the community participate in decision making regarding environmentally sustainable resource management in the Conservancy.

TABLE 4.2

AN EXAMPLE OF A MANAGEMENT PLAN FOR THE FCC.

Issues	Objectives	Strategies	Cost
Flooding	Reduce flood risk	Optimal vegetation usage (conservation) Attenuation (legal, structures, planning disposal systems Identify high risk areas	
	Flood management	Warning/evacuation Emergency teams - blockages Publicize principles and guidelines Evaluate events	
Aquatic health	Maintain / improve health	Monitor Educate Empower own monitoring	
Riparian Vegetation	Remove and replace aliens	Working for water project Education and monitoring Riparian audit Control/guidelines/legislation	
Sedimentation	Reduce loads	Rehabilitation of degraded areas Identify and map source/potential problem area Monitoring programme/control	
Pollution	Eliminate future pollution/contain current pollution	Legislation/enforcement of regulations Education Monitoring	
Land-use/ development	Consultation on changes in land-use plan	Identify/map development information Clarify/refine legal aspects Monitor change, network with developers etc.	
Environmental ethics/ responsibility	Maintain and improve quality of FCC/aesthetics and biodiversity	Appropriate landscape monitoring Monitor land values Establish criteria and guidelines	

(Adapted from FCC ICM Draft Proposal, Scotney 1999a.)

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

The Ferncliffe Catchment Conservancy is indeed an area of unique ecological and geographical features within the context of Pietermaritzburg and Hilton. While it was not the aim of this study to investigate land use changes in the Conservancy over time, the fragmentation that has been made evident by the GIS mapping suggests that land use practices have transformed the area's natural resources, especially by the introduction of alien plant species. It would however, be inconceivable to suggest that stakeholders strive to restore the Conservancy to its former natural, pristine state. As such, environmentally sustainable resource management would only be achieved by promoting efficient land use planning and effective community participation. The objectives of this study have hence been aimed at achieving this goal.

While a third of the land cover of the Conservancy is now under commercial agriculture and commercial forestry, there are patches of natural forest that have been identified and listed in the inventory.The creation of an inventory of the resources within the Conservancy did not take into account the natural resources only, but included the built environment as well. By so doing, the sustainable resource utilization and management and monitoring would be undertaken in a holistic manner.

Some samples of the database set up to monitor and conserve the Conservancy over time have been illustrated in Chapter 4. Only some aspects of environmental problems in the Conservancy were dealt with, but this was meant to kick-start the process of building, maintaining and upgrading the database. The potential of GIS as an integrating technology can be realized when used as a tool in natural resource management (Aspinall, 1999). The state of the major issues in the FCC, in particular erosion, riparian vegetation, land use, aquatic health, and so on, will be more readily monitored and queried. More important is that in designing the database, community awareness and participation will be encouraged in that people will have access to information contained in the database. Access can be through the World Wide Web or through display at public places of maps and other visual materials such as graphs and tables and illustrations of the GIS database such as those in Plates 4.1 and 4.2.

Active community participation is crucial for effective management strategies (Murphree, 1993; Mander, 1991). Auerbach (1997) has pointed out how Participatory Catchment Management (PCM) has been applied in a number of Asian countries in the past two decades. An important element of catchment management is creating communication networks which allow for democratic decisions. The Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) among communities of Zimbabwe has demonstrated the dynamics of successful implementation of decentralized natural resource management (Murphree, 1993). As yet, members of the FCC community have not shown interest in the activities that the management committee is doing in trying to encourage sustainable resource management (MacKenzie, 1999).

The results of subsequent monitoring will be displayed in a public place in visual material such as maps, tables and tables from ArcView. It is hoped this will go some way towards providing the community and authorities with a spatial context within which to appreciate the unique features as well as the current and potential future problems and the importance of the Conservancy to the city as a whole. There will be a need for further study on the community's response, from the moment of display onwards.

Another important aspect to encourage is the introduction of Participatory Catchment Management to the Conservancy. This would entail finding avenues through which different stakeholders such as the rate-payers, FCC management committee and the city council could form communication networks to facilitate cooperation and envision a common goal. Other potential role players could include schools, religious groups, boy scouts and girls' brigades, as well as other social and sports clubs such as the Country Club golf club.

A programme that has demonstrated multi-agency cooperative effort that transcends both administrative and geopolitical boundaries is the Mojave Desert Ecosystem Program (MDEP) in the United States of America. The role of the project is data collection, interpretation, documentation, and sharing. MDEP offers an important model for the sharing, interpretation, and use of data for management purposes by a broadly varied group of participants (MDEP, 1998). Drawing from such a model would be beneficial to the Conservancy and any other natural resource for that matter.

While the community would be able to actively participate in environmentally sustainable resource management, issues of land ownership would likely hinder the process. The aspect of land ownership is crucial in determining the success of integrated environment management. For instance, this study found it difficult to design possible corridors that would link up indigenous vegetation because land is owned by different parties within the Conservancy.

If commercial forest stands were cleared to allow for the expansion of indigenous vegetation, there are two options to follow. The first option is to clear the land and then introduce indigenous seedlings. The second option is to leave the land fallow so that indigenous vegetation is reestablished. The latter may not be the best option to take as it would take a long time for the indigenous vegetation to be established and therefore the aesthetic value which is currently enjoyed from afforestation would be lost, to be replaced by bare patches certainly not attractive to the residents in the Conservancy. Corridor creation can only be viable if it is going to be a long term initiative that rehabilitates land portion by portion.

Major issues in the Conservancy have been identified and individual efforts in dealing with these problems are evident (MacKenzie, 1999). Again the question of land ownership plays a significant role when responding to land degradation and resource management at the level of the Conservancy. For instance, alien plant species could be growing on a privately owned land and if the owner sees nothing wrong with that, the invaders will continue growing. No one will have the right to enforce the eradication of these species unless they are banned by law. It is therefore important to determine the benefits resulting from the clearing of invasive species (Forsyth *et al*, 1997) and to communicate the information to the community.

This study has paved the way for the use of GIS for environmentally sustainable management at two levels, namely at a public information level and at a management level. The public information level would include the catchment boundary and major geographical features (such as the streams, roads), beacons, land use categories and water quality monitoring points. This is so that the community can orientate themselves and see the location of major developments, trends and problems in the Conservancy (Scotney, 1999c).

The mapping for the management level was envisaged to be of finer resolution on all of the above so that it included dams (if any), flood lines, flood problem areas, wetlands, contours, hiking trails, "green" open spaces, afforestation and other land uses, and land ownership, among others. The study also suggests investigation into the possibility of creating corridors that would link up green spaces. Most important, it is envisaged that this would be more informative if it were linked up with the other urban conservancies within the city limits to show the continuity of open green spaces.

Such insights expressed by the FCC Committee certainly point out the need for the use of GIS in natural resource management. Most of the major aspects of the GIS mapping proposed by the FCC Committee have been accomplished by this study. There were limitations in terms of time and availability of digital data. However, as more and more institutions are using geographic information systems, such data will become more readily available. The framework that has been designed by this study can be applicable to any conservancy, be it urban or rural. Inventories and databases created for small geographic areas can then be used to build a local, regional, and eventually a national database. Luckily, geographic information systems are capable of handling massive data sets. Perhaps a word of caution here is imperative, as Larsen (1999) rightly points out that: "Much too often the use of GIS for environmental monitoring is restricted to the presentation of data and the creation of 'pretty maps'. The inherent powers of GIS as a tool for data integration and analysis are often underutilised" (Larsen, 1999).

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