THE APPLICATION OF ROUTE NETWORK ANALYSIS TO COMMERCIAL FORESTRY TRANSPORTATION IN THE NORTH COAST OF KWAZULU-NATAL

By

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ABSTRACT

Transportation costs of commercial forestry farms in South Africa are generally very high, causing great economic concern. The current roads of the majority of commercial farms, used to transport timber from the compartments to the market (mill), form part of a 'cob-web', high density network. In order to optimise transportation, it is beneficial to eradicate such a high density of road, achieved by adopting the most effective methods and technology. Such methods include that of Route Network Analysis (RNA) which designs a minimalist, yet cost-effective road pattern of a forestry farm. The aim of the study was to determine what data are required to optimise economic and timber transportation, based on the commercial forestry farm of Ntonjaneni, located in Zululand, KwaZulu-Natal.

Route Network Analysis, which incorporates Geographical Information Systems (GIS) in addition to the current information pertaining to a network, was applied to the Ntonjaneni Farm. The existing data consisted of cadastral shapefile data containing relative attribute data, as well as Digital Elevation Models (DEMs), which were manipulated in order to create a realistic spatial representation of the farm's current transportation network. In addition, the development of project management guidelines to assist the efficient implementation and completion of the analysis was undertaken.

The most ideal route from the plantations to the mill was created, avoiding the environmentally buffered rivers and those slopes which were too steep. As a result, the network was greatly improved. The irrelevant roads were removed, and replaced with a less dense route for timber transportation. The results of the RNA reveal that RNA, completed by the project management guidelines, is an effective and environmentally-sound means of optimising commercial forestry transportation. However, data relating to the rivers and road slope need to be updated in order for RNA to be effectively performed during future studies.

PREFACE

The experimental work described in this thesis was carried out in the School of Life & Environmental Sciences, Faculty of Science, University of KwaZulu-Natal, Durban.

The work was supervised by Dr H.K. Watson, of the School of Life and Environmental Sciences, University of KwaZulu-Natal, and co-supervised by Dr F.B. Ahmed, of the Forestry & Forest Products Research Centre, University of KwaZulu-Natal, CSIR. The duration of the study was from September 2003 to September 2004.

These studies represent original work by the author. Where use has been made of the work of others, it is duly acknowledged in the text.

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September 2004

We certify that the above statement is correct:

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LIST OF ABBREVIATIONS AND ACRONYMS

amsl	above mean sea level
AVNA	ArcView 3.3 Network Analyst (AVNA)
CPM	Critical Path Method
DEM	Digital Elevation Model
EF	Early Finish
EIA	Environmental Impact Assessment
ES	Early Start
FSC	Forest Stewardship Council
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GIS-T	Geographical Information Systems for transport
GPS	Global Positioning Systems
IEM	Integrated Environmental Management
Km/hr	Kilometres/hour
LS	Late Start
LF	Late Finish
NGOs	Non government organisations
PCI&S	Principles, Criteria, Indicators and Standards
$R/ t^{-1}km^{-1}$	Rand per ton per kilometre

RNA	Route Network Analysis
SMZs	Species of Special Conservation Significance
TIN	Triangular Irregular Network
WBS	Work Breakdown Structure
3D	Three Dimensional

CHAPTER 1
INTRODUCTION

1.1 Introduction

Transportation problems necessitate the search for methods or alternatives that ensure efficient, feasible and faster means of transport (Guruswamy & Thirumalaivasan, undated). Transportation costs are of great concern to commercial forestry farms, that contribute significantly towards South Africa's economy. Therefore the latest techniques to reduce such costs are sought. This chapter motivates the reason for the selection of the transportation technique, Route Network Analysis, (RNA) and the study site, discussing the aims and objectives, assumptions relating to the study and the structure of the dissertation.

1.2 Background

Commercial plantation forestry in South Africa involves extensive agricultural activity, generating a large capital from its resources and products. According to the Department of Water Affairs and Forestry (2004) the formal commercial forest sector contributes 2% to the national Gross Domestic Product (GDP), and accounts for 9% of agricultural output in South Africa. In addition, forestry provides 4% of South Africa's total annual exports, contributing R 6 billion (net) to the country's foreign exchange earnings. Large commercial forestry organisations, therefore, endeavour to ensure that their practices are environmentally sound and economically just and cost-effective (Douglas, 1999). Such practices include the planning and implementation of planting, maintenance, felling of the timber as well as the transportation of such timber from the plantation compartments to the mill (market).

Although each of these practices hold equal weight in terms of producing pulpwood and a final wood or paper product; the transportation of timber has been overlooked in the past (Morkel, 2000). Existing literature suggests that more research and deliberation should be applied to the process which involves the acquisition of timber from the plantation as well as the delivery of timber to the market. What has halted such research in the past, according to Lee (undated) is the lack of in-depth knowledge and the ability to allow the most sophisticated techniques to be incorporated within strategic planning.

Morkel (2000) asserts that transport is the largest cost associated with delivering pulpwood, and that people in the forestry industry usually forget that roads are an inseparable part of the road transport. Transportation costs have proved particularly exorbitant, especially if the logistics are numerous, incorporating different contracted companies and a variety of machinery and delivery vehicles. Therefore, in order to minimise or possibly eradicate irrelevant facets, a cost effective logistic line is essential to ensure that planners within the industry incorporate the most modern and applicable models to allow for accurate decision-making relating to timber transportation. Guruswamy & Thirumalaivasan (undated) suggest that recent developments in Geographic Information Systems (GIS) have allowed organisations to perform and provide 'what if' scenarios and sophisticated solutions to pertinent problems within the forestry industry.

The argument exists whether to apply modern methods of analysis to commercial forestry transportation. One such method is RNA, which using a range of data including the existing depots and transportation road network, enables the design of an entirely new route system based on the most cost-effective and economically viable option. One considers information regarding the length, segment, intersections and slope of the road. An enquiry undertaken by ESRI (1996) involves investigating whether the 'best-route' for transportation of the timber from the plantations to mills, is the shortest and quickest route, or the longer route that takes more time, is less costly because steep inclines are avoided. Such decisions are provided by spatial database and Three Dimensional (3D) Modelling.

Route Network Analysis has been extensively used in urban and industrial logistic applications particularly in the Northern Hemisphere, for example, Calicut City in India. Its use in agricultural and forestry logistic applications is in its infancy, especially in South Africa. The findings of Musa & Mohammed (2002), when applying RNA to a forestry farm in Malaysia, suggest that RNA needs to be considered in South Africa.

This study seeks to establish whether databases of forestry farms, typically maintained by commercial forestry companies in South Africa, allow for RNA's potential value to be more fully exploited.

The need for analysis of the existing road structure within plantation forestry came to pass when viewing the current 'cob-web' structure of existing roads within the forestry plantations of the Ntonjaneni forestry Farm, Melmoth, Zululand. The haphazard display of roads provides a link to transport the timber from the road-side to the existing loading zones, (or more commonly known as depots), and furthermore, to the mill at Richard's Bay. The Ntonjaneni area has been selected as the study site as its transportation system is an area of economic concern. *Eucalyptus sp.* and *Pinus sp.* are grown in this region, and as a result contribute a means of commercial benefit towards the paper and pulp industry of South Africa. In addition, the existing data is current, assumed accurate and provides a variety of criteria including varying slope and environmental considerations, which need to be considered. Ntonjaneni is a hazardous area, due to the steep gradient of the roads as well as the varying seasonal climatic changes. In addition, this area requires a new and cost-effective approach to the management of roads and transportation, as a large amount of capital is assigned to such practices.

In order to perform RNA of an area, a modern technique needs to be designed, which will include all the relevant data of the patricular area. The final routing model will contain a spatial model, which will determine whether applying RNA, based on existing data, is deemed economically quantifiable. From an economic perspective, a project management plan, based on the principles initiated by Burke (2003), will minimise the cost and time required for a RNA project, as well as to maximise the quality of the analysis. Project management is becoming increasingly useful in all current business concerns.

GIS-based applications and methodology allow for an immediate access to large amounts of data. Although this is exceedingly advantageous, the validity, reliability and redundancy of data need to be considered (Goodchild & Gopal, 1989). In addition, Foody and Atkinson (2002) suggest that although efforts may be made to eradicate each or all of these factors, one needs to realise that the data is supplied by a variety of sources as well as the fact that particular knowledge is needed in order to manipulate the data.

1.3 Aim and Objectives

1.3.1 Aim

To demonstrate what data is necessary to perform Route Network Analysis which designs an environmentally sensitive, cost-effective and economically viable route system in a forest plantation.

1.3.2 Objectives

The explicit objectives of the study are:

- To identify the most appropriate software model and data sets for carrying out RNA in the study area.
- To apply RNA analysis to develop a revised depot network within the plantation, and establish the closest route from the plantation to the forestry mill.
- To perform the RNA to identify the best route from depots to the mill, and from the plantations to the depots.
- To provide a project management plan for the implementation of the RNA project.
- To identify parameters and conditions, including additional data sets, that need to be in place for the successful application of the RNA.

1.4 Assumptions relating to the study

It is assumed that the timber varieties of *Eucalyptus sp.* and *Pinus sp.* are not transported on the same vehicle. Should this occur, the cost relating to each haulage trip would be altered, and will not be accounted for in this study. In addition, it is assumed that both short-haul and long haul transportation vehicles are able, according to the turning and axle angle, to travel on each portion of the Ntonjaneni roads as well as the Department of Transport roads. The road design needs to consider the angle required for a vehicle to turn completely without causing any damage. Assumptions are made that the Ntonjaneni and Department of Transport roads are able to withstand the weight of the trucks with varying climatic conditions. Without assuming so, more capital would need to be assigned towards the type of material used to construct the roads, ensuring that roads would be able to withstand a certain amount of traffic pressure. It is assumed that the project management plan for RNA for the Ntonjaneni Farm incorporates employees who are knowledgeable and are able to provide useful information within their area of expertise. A lack of suitable employees would alter the time and cost constraints for the project management plan. Lastly, it is assumed that the data used for a RNA is in the same state that the Ntonjaneni Farm data was at the start of the study. If the data is not accurate and has not been manipulated according to what has been previously mentioned, once again the time and cost for the project will be dramatically altered, and as a result, there will be a lack of resources for the effective completion of the study.

1.5 Structure of Dissertation

Chapter 2 reviews and considers the relevant literature pertaining to RNA and project management within transportation planning. The study area of Ntonjaneni is described in Chapter 3. Ntonjaneni is situated on the North Coast of KwaZulu-Natal, in close proximity to Melmoth, and provides an ideal location for RNA, with ideal conditions and availability for the existence of farm roads. Chapter 4 examines the materials and methods used to perform RNA. Network Analyst, an extension of ArcView 3.3 (2001) is a modern technique used to manipulate the available data, in addition to the project management guidelines developed by Burke (2003), for the effective implementation of a project management plan for RNA. The results of the RNA are revealed and discussed in Chapter 5, with an ideal route established for the transportation of timber from the depots to the mill, and from the plantations to the depots. Chapter 6 concludes that RNA provided the most ideal route for transportation but failed to include all the factors within a forestry transportation system. Therefore future studies relating to RNA need to include more comprehensive data of rivers, to meet environmental concerns, and data describing the speed travelled along the roads which is affected by a change in slope.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Forestry transportation in South Africa is believed to be the most important phase of all commercial forestry components. This chapter focuses on the time and effort spent on developing and maintaining the most modern techniques to ensure that new roads which are designed, using the most modern techniques, are environmentally and economically sound. In addition, tactical and operational planning is discussed, which assists the application of GIS and transportation modelling to allow RNA to be applied to commercial forestry. Examples of how RNA have been applied to both urban and rural environments are discussed. This emphasises the need to implement RNA to commercial forestry in South Africa, with the assistance of a project management plan (Burke 2003), to improve the economic status of the transportation system, which will in turn reap economic rewards.

2.2 South African Transport

According to The National Department of Transport (2002), transport in South Africa is central to economic development. It is therefore imperative that transportation infrastructure is extremely flexible as well as reliable, allowing access to services provided by a road network. Transport efficiency is a logic design, based primarily on a clear understanding of both service demands as well as the expectations placed on the system by both future and current needs.

Forest roads are constructed to serve their primary purpose of providing easy access to a forest, and transport is usually cheaper by road than over forest terrain. (Plate 1, Appendix 2) Tann (1999) suggests that a forest road network should minimise the total cost of wood extraction, wood transport and road construction, in addition to minimising adverse environmental impacts. Locating a forest road network is determined by optimising road spacing. Road spacing takes into consideration the spatial diversity of terrain conditions within a forestry plantation.

2.3 Forestry Road Infrastructure

Currently, an excess of 100 000 km of road network are managed by the South African forestry industry. The main function of a forestry road network is to provide admittance to the felled timber during the transportation phase, which is based on an adequate plantation management plan and in turn a high profit turn over for the industry (Lee, undated). In South Africa, it is estimated that roughly 60 % of the industry's costs are attributed to the transportation phase, as opposed to the growing and harvesting. Profit margins of forestry companies may be greatly improved by improving the quality of the road network, and in turn increasing optimisation. Guruswamy & Thirumalaivasan (undated) purport that many forestry companies have made route planning a priority, although the present condition of forest road networks as a whole, can be seen as poor. Lee (undated) suggests that the reason for the poor quality of roads is that in the past, minimal expertise was employed to improve road networks. Alternatively, a road network could be improved using modern technology and highly qualified and knowledgeable expertise, which is currently associated with a high cost. Even so, commercial forestry companies are prepared to expend, if the technology will reap the correct economic rewards.

Forestry plantations in South Africa have a fairly well-developed road infrastructure, although 98% of the network is unsealed, which causes significant expenditure with regards to road maintenance and increased vehicle costing, compared to the value of the timber being harvested. Therefore, techniques which can improve the unsealed roads need to be implemented to ensure that improvements are made for the future.

Lee (undated) argues that the major downfall associated with forestry road planning in South Africa, is that most forest road networks are planned and constructed at planting, with the main purpose being to provide access for immediate plantation management needs. It is evident that road design fails to consider criteria such as available and suitable material for the prevailing conditions and to allow effective drainage. In addition, roads are constructed at the lowest cost possible and carry large volumes of timber.

Further suggestions made by Lee (undated) are that during the first harvesting phase, certain roads are upgraded at a huge cost, and therefore form the 'back-bone' for the road network, when in actual fact the chosen roads may not be adequate to withstand future transportation. These roads, therefore, form the basis of forest management and will determine the effectiveness and profitability of future resource management. Such profitability is greatly reduced due to the maintenance and upkeep of the roads, which is caused by poor drainage. This in turn causes the development of ruts and potholes, corrugations, loose surface material ravelling and dust. Such problems may be overlooked as the traffic densities and speeds are low; however heavy gross vehicle or combination mass traffic and high-axle loadings are common. Deterioration to the road is often exacerbated by a harsh climate as well as operating conditions on the road, which are often used for the initial processing and stockpiling. Lee (undated) emphasises the need for careful consideration towards environmental issues, as plantations often exist near to or surround environmentally sensitive areas which are very commonly the source of erosion and sedimentation.

2.4 Forest Road Design

Lee (undated) explains that the function of roads is to provide a safe route which can be travelled under varying conditions, with minimal damage to the vehicles or alterations to the structural integrity of the road. Although the purpose of all roads remain the same, very little has been done to modify the materials and techniques used for unsealed road construction. Modern road design seeks to enumerate and to estimate the future performance of roads, based on the past performance of roads as well as proven methods performed in the past.

According to Lee (undated), the design of roads may be categorised into five main areas, namely network planning, geometric design, drainage design, pavement design and material selection. The focus of this study is on network planning.

Network planning allows for the optimisation of existing networks, and considerations are made for a new road design before an area is replanted after harvesting. Network planning should incorporate a variety of considerations including functionality, access needs, environmental impact and transportation costing for a general area, eg. a plantation. Transportation considerations include:

- The density of roads within a network (km/ha);
- The layout of roads and what the routing alternatives should be;
- The level of efficiency which the roads provide; and
- The type of vehicle considerations the roads can be designed for.

In order to achieve the best efficiency within a network, an attitude of 'less is better' should be adopted, in that the best efficiency can often be achieved with a relatively low density. In short, achieving an effective and efficient network stems from a well planned network which is achieved by the collection of relevant information; determining the planning units, the main node points and a detailed design (Lee, undated).

2.4.1 Forestry Engineering South Africa Guidelines

Forestry Engineering South Africa (1999) suggest guidelines for the design of roads, based on the proposed objectives within forestry transportation to transfer a particular volume of timber from the plantation to the depot or to the mill. Regardless of the type of transportation used, certain parameters influencing road design remain fixed. These include the gradient of the terrain; the geology and soil variety; the timber quantity to be transported; the choice of vehicle for transportation and its associated characteristics; weight and enormity of the load; travel rates; road usage related to the duration of use and the influence of climatic conditions (rainfall) on drainage and lastly, the available materials for road establishment.

Once these factors have been considered for a road design, Forestry Engineering South Africa (1999) asserts that a well-constructed road can only render positive results within a plantation. Such impacts include a reduction in sedimentation and run off from roads; a time effective road enhancing safe speed; transportation costs are greatly reduced; sustainable and environmentally sound plantations are developed as road design efforts are improved and upholding and refurbishment costs are greatly reduced.

However, Forestry Engineering South Africa (1999) highlights that the numerous negative impacts that roads have on the surrounding environment need to be considered, which are often inconspicuous, and if not correctly monitored and prevented, can cause drastic time and cost implications to timber transport. In order to prevent inadequacies, planning is essential. One needs to carefully plan for the type of road use (ie. crowned, inslope or outslope); cut and fill utilisation (employing material from cuts to be used on fills, to reduce handling); and benching of banks.

2.4.1.1 Environmental considerations

Forest roads and structures may leave significant scars on the environment which are visibly distinct due to the linear nature of the routes within the network (Plate 2, Appendix 2). In addition to the aesthetically unpleasant visual impacts, many bio-physical and socio-economic impacts to the environment are induced during the construction, maintenance and use of the plantation roads. Impacts include those to:

- The physical and ecological characteristics of the site and surroundings;
- Current and potential land use and landscape character;
- Cultural resources;
- Adjacent and associated infrastructure services;
- The nature and level of present and future environmental pollution;
- Health and safety;
- Socio-economic characteristics of the affected public; and
- Social and community services and facilities (Forestry Engineering South Africa, 1999).

In addition to these impacts, Figure 2.1 illustrates alternate impacts which transportation has on the environment.

Forestry South Africa (2002) explains that because the adoption of environmental impact assessments (EIA's) is fairly new in South Africa, very little attention was given to the environment in the past. Currently, harvesting codes of practice and international trade agreements are encouraging a more responsible approach to road network design.

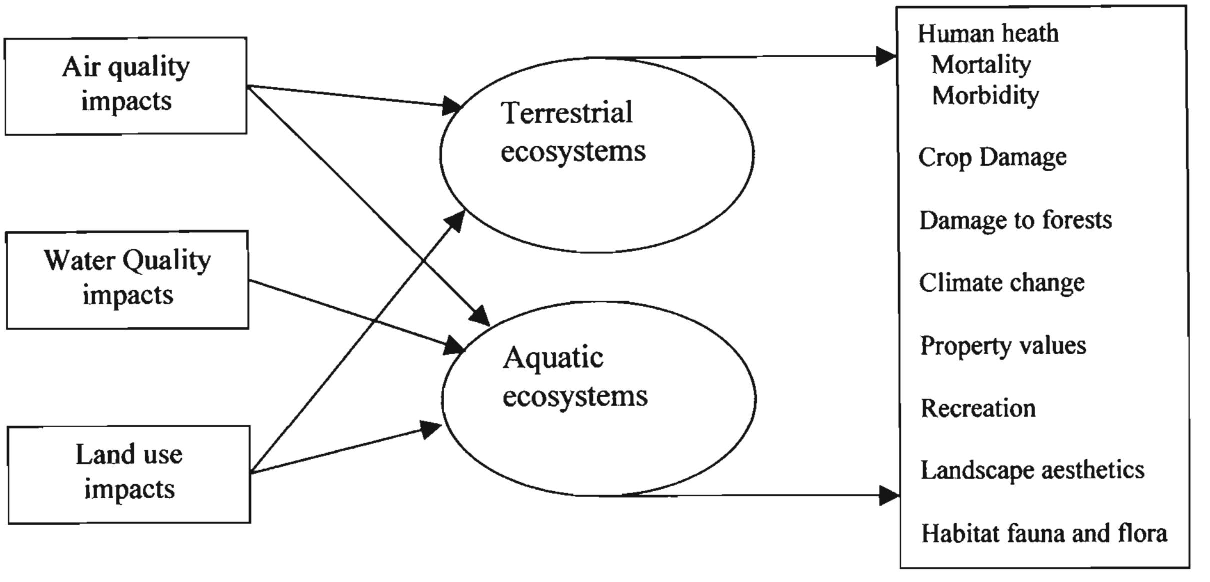


Figure 2.1 Environmental impacts of transportation (Hensher & Button, 2000).

In addition, the need for certification of forests is becoming increasingly important. According to Anon. 4 (undated) certification has been developed to independently verify the quality of forest management, to communicate this to those involved and to improve the market benefits for the products of good management. The influence of the Forest Stewardship Council (FSC) and ISO 14001, are the most recent developments in forestry. FSC have produced principles and criteria for FSC-certified forests. Such criteria includes forests adhering to all laws within South Africa, the documentation of tenure and land-use rights and responsibilities, recognising indigenous people's rights, as well as worker's rights and adhering to maintain environmental standards (Anon. 4, undated). ISO 14001 certification seeks to improve plantation management, forms agreements internationally to ensure that forestry operations are carried out in accordance with current legislation and that forestry companies commit to control significant environmental impacts, to prevent contamination, to train personnel and to maintain a continuous improvement program for the environment. Currently, according to Anon. 3 (undated) 500 000 hectares of commercial plantation forest are covered by ISO 14001.

In addition to EIA's, Integrated Environmental Management (IEM) and certification procedures are designed to ensure that the consequences related to environmental disturbances caused by development are fully understood, and as a result are carefully planned for. Lee (undated) supports the implementation of IEM within forestry, as negative effects are mitigated and probable positive impacts which may result during road use, construction and design, are enhanced.

2.4.1.2 Sustainable Forestry

The twentieth century buzz-word "sustainable development", is a term commonly associated with the forestry industry. Government, industry, Non-government Organisations (NGOs), the informed public and many environmental and social groups insist on enforcing sustainability, but are usually unaware of how it should be implemented and achieved. Forestry practices seek to adopt an attitude of Principles, Criteria, Indicators and Standards (PCI&S) which purport to improve forest management as well as increasing the liability for it. Nussbaum *et al.*, (1996) suggest that forestry management should include retaining yields of goods and services; protracting biodiversity of flora and fauna and reducing the negative socio-economic impacts of forestry.

In summary, Forestry South Africa (2002) emphasises that a road design should take into account the following:

- Avoid re-routing of a road which would include alterations to a steep slope, large rocks and cliffs ('negative cardinal points'). Careful consideration should be made to choose 'positive cardinal points' including flatter and more stable terrain.
- Water courses are very sensitive, especially wetlands and need to adhere towards the legal recommendation. Legally, roads may not be routed within 10 metres of a watercourse or wetland except where they cross. However a 30 metre buffer is recommended. Where current roads do not adhere to this, consideration needs to be made to rectify this.
- Transport costs may be greatly reduced by adhering to the guidelines for gradient slopes. Special surface protection may be necessary for particularly

steep roads (exceeding 12 %). Alternatively, the need for the road and the associated afforestation should be considered.

2.5 Forest Transportation Planning

Forest transport planning consists of both tactical and operational planning activities.

2.5.1 Tactical Planning

Tactical transportation planning focuses mainly on an adequae tactical planning stage in order to provide an adequate timber supply and efficient utilisation of resources during the harvesting period (three to five years). In addition, the timber, volume of timber and the road network are aspired to reach 'level pegging' in order to ensure that the tactical plan can be correctly and efficiently implemented. In order to achieve this, Forestry South Africa (2002) suggest that planning should rely on:

- Effective operating guidelines;
- Theoretical as well as practical planning;
- Flexibility to adjust the plan due to unknown circumstances;
- Accurate information regarding timber volume, market, contractors etc.

Access development refers to the process that involves the scheduling, formation and preservation of all forest road networks including depots, landings and extraction routes. The primary purpose of access development is to allow the workforce and their machinery to reach the trees to collect forestry products from the plantation.

Road tactical planning should be undertaken in conjunction with the harvesting plan to ensure that optimal transportation objectives are met. In other words, a road network needs to be established which is environmentally sound, which can accommodate the demands of the transportation vehicles and is economically viable. During this tactical stage, the topography and terrain need to be considered in order to reduce environmental degradation and for an aesthetically pleasing effect. This is achieved by minimising exposed surfaces and earthworks; by using natural topographical features, for example choosing flatter slope and natural benches; and observing the Species of Special Conservation Significance (SMZ's) areas, to ensure future conservation and biodiversity. In addition, buffer zones should be implemented to reduce visual, noise and environmental effects, and roads need to accommodate for the occurence of floods and land slips (Forestry South Africa, 2002).

2.5.2 Operational Planning

Once the tactical plan has been finalised, the operational planning phase seeks to plan each individual compartment within the harvesting period. Such fine detail includes the best route and direction of timber flow and the delivery, transport scheduling, environmental precautions, cost considerations and human and equipment allocation (Forestry South Africa, 2002). The operational planning phase is implemented by a day-to-day manager who controls the process with the aid of modern logistic methods and computers. The operational planning stage seeks to include the tactical planning objectives by giving them practical weighting to ensure that they are put to correct use. Forestry South Africa (2002) recommends that all roads need to be equipped with a sound and reliable map of the area. Such maps need to depict those areas which are environmentally sensitive, the gradient of the area, and the timing of the operating season.

2.6 Transportation Modelling

Hensher & Button (2000) assert that transportation modelling is a crucial part of any decision making, providing mental methods of how the world would work, based on such decisions. Lee (undated) suggests that environmental and economic pressures in South Africa make it difficult to expand the provision of transportation infrastructure. It is therefore of greater importance to make the best use of existing capacity, including physical maintenance; ensuring that models adapt to advanced production management techniques as well as the existing and unpredictable economy.

A good transportation model associates the movement of commodities with the behaviour of individuals, ensuring that individuals will be able to redeem the best solutions from such models. In this way, the technical efficiency of a transport system is considered and analysed. According to Hensher & Button (2000), determining whether a transportation model is astute or not, depends on the two conflicting ideas.

Firstly, that the success of a model, is based on the extent to which is explains behaviour and promotes understanding. Opposing this idea, the success of a model is dependant on their predictive accuracy. Hensher & Button (2000) conclude that whilst it is true that both of these approaches seem viable, essentially good predications do in fact require good models, and that they often lead to very sound predictions.

It is also clear that there is a gap between the state-of-the-art theory and the application associated with it. This may suggest that since some of the models are designed by researchers, they may have the intellectual interest, but lack the application to real-life decision making (Hensher & Button, 2000). It is therefore essential to design a model, which whilst bearing academic and intellectual theory, may be applied to the forestry industry, to provide answers for existing transportation structures and provide an efficient network.

2.7 The Concept of a Spatial Economy

Butler (1980) explains that the concept of spatial economy, or a spatial economic system, is a fundamental one in economic geography. With this in mind, a spatial model reflects different spatial patterns relating to two significant factors, namely consumers and production establishments. A third and most deciding factor is that of exchange which ensures that the demand and supply of goods, people and/or information are connected via the market place which in turn reduces transportation costs.

"For any change to take place in raw forest product transportation, the technology available at the time has to change. Economics can be seen as the driving force behind the change, while the technology of the day is the limiting force: economics can push, but technology is the brake. Release the brake, and progress can be made" (Douglas, 1999:11).

2.8 Transportation Strategy and Cost Reduction

Two basic approaches are evident within the broad view of effective management and cost control within all forms of transportation. Firstly, and most definitely the most important, is the development of a strategy for the paying of transportation. Therefore an integral plan for the purchase of all the transportation services are developed which meet the needs of the organisation. In this study, a plan for transporting the timber from the plantations to the mill is developed. Secondly, it is beneficial to identify and conduct traditional cost reduction projects which will in turn have high payoff potential for the organisation. Developing a RNA for the existing road system will ensure that the organisation preserves its capital and does not expend inadequately. Dobler & Burt (1996) suggest that this will improve the economic quality within the forestry company.

2.9 Geographical Information Systems

The term GIS has been misconstrued by many, as its functions and varied applications do not present a clear and constructive definition.

GIS may be broadly defined as "tools that allow for the processing of spatial data into information, generally information tied explicitly to, and used to make decisions about, some portion of the earth" (Demers, 2000:30). Whilst this definition does not do justice to what GIS actually is, it is hoped that its application in this study provides a clearer understanding. Figure 2.2 illustrates the application of GIS to provide specific results.

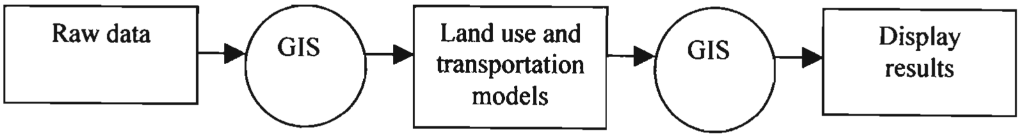


Figure 2.2 GIS used for inputs and outputs (Hensher & Button, 2000).

Geographical Information Systems can be subdivided into data input, data storage and retrieval; data manipulation and analysis; and a reporting subsystem (Demers, 2000). Musa & Mohammed (2002) note four key functions of GIS, namely: 1) digital mapping, 2) data management, 3) data analysis and 4) data presentation.

According to Anjaneyulu et al., (undated) GIS is one of the fastest growing technologies, which has emerged as a powerful and sophisticated means to manage vast amounts of geographic data. GIS provides a mechanism by which information on location, spatial interaction and geographic relationships of various facilities can be assessed and viewed in moments, thus improving decision-making.

Prasad (undated) emphasises that transportation management is a spatial phenomenon and, therefore, GIS can be used as a powerful and useful tool in both the management and planning of transportation. Gokuldas *et al.*, (undated) notes that transportation management is the application of sound management principles and practice. This optimises the use of existing road network, striving to improve traffic flow and road safety without impairing environmental quality. Further observations by Musa & Mohammed (2002), suggest that future transportation planners need to generate a variety of scenarios which consider four guidelines for transport networks: to de-market some of the commodities within the network; to enhance the network using a series of actions, for example the use of additional lines, automatic signalling and higher speed locomotives; to set up and optimise alternative route; and to initiate policy changes.

Gokuldas *et al.*, (undated) makes further suggestions that when implementing transport management within GIS, one needs to have a clear understanding of locations, flow patterns, as well as the existing road network and even more importantly, to be able to analyse the attributes relating to them. This is assisted by GIS, which help to meet the above criteria both efficiently and effectively.

According to Guruswamy & Thirumalaivasan (undated) GIS is seen more and more to be effective in integrating the data which is required to support the transport modelling and allow for efficient data management. The term GIS-T (GIS for transportation) evolved in the 1990s, from the two disciplines of geography and transportation. It has been argued as to whether GIS should become a part of the transportation system, or should the transportation system become a part of the GIS. This has resulted in transportation packages being developed to incorporate the link to a GIS, enhancing the geographical display as well as the transport network editing. In addition, commercial GIS packages have been extended for the use of solving transportation problems, as well as non-transportation applications.

2.9.1 Error in Geographical Information Systems

"Uncertainty is a characteristic feature of research undertaken at the frontiers of science and technology" (Foody & Atkinson, 2002:15). Uncertainty within GIS has

been an underlying problem within applications (Bedhard, 1987). The manner in which uncertainty is resolved can be attributed to its description, evaluation and the user's estimation of the improbability within data, which allows for future research improvements (Foody & Atkinson, 2002).

Foody & Atkinson (2002) make further suggestions that uncertainty may be categorised as being either ambiguous or vague. Uncertainty is to be based on something which is known, in order for uncertainty to become apparent. Certainty, or accuracy can be subdivided into that which is free from bias, that which is precise and contains no errors.

Goodchild & Gopal (1989) suggest that besides basic research, a greater sensitivity to error on the part of GIS users, greater awareness of the kinds of errors which can occur, and techniques for recognizing the impact, would greatly assist in minimising error.

Upon using GIS for decision-support systems, the most current data is manipulated within the database. Although the data used is current, in terms of reflecting the most recent information, it may contain many errors. Such errors may include unreliability, redundancy and repetitive data problems. In order to eliminate and eradicate errors, it is essential that the data being used for a particular application has been ground-truthed, so that the area of study correlates with that of the database.

Goodchild & Gopal (1989) argue that both tabular and graphical data are a result of modelling applications within GIS and decision-support systems. The success of a model's ability to perform a particular function, is measured in terms of its reliability and presents an argument that even though GIS applications are generally of high value, they are often inaccurate and prone to hidden errors.

2.9.2 The Use of Vector Versus Raster Data

Anon. 1 (undated) illustrates that in GIS, the real world is represented by one of two spatial models; vector-based or raster-based. It is important within transportation to determine which spatial model would best represent real world forestry transportation networks. As a result, both models may be used for solving path finding algorithms due to their high accuracy. The preference for a particular medium is usually based on the choice of the user.

2.10 Route Network Analysis

According to Husdal (2000) a network refers to an arrangement of features which are linearly interconnected. The most widely used examples are transportation links (e.g. roads, railways) and various communication networks (e.g. telephone and power lines). Nevertheless, all networks have in common two criteria. Firstly, there needs to be a resource which travels through the network; and secondly, for the resource to travel from one point to another, there needs to be a connected path between each of these points. A basic network model consists of a section of links (arc segments) which have associated attribute values, termed the impedance. The impedance may represent a variety of values, for example the cost of travelling across a link, the time taken to travel or perhaps the resistance caused whilst travelling, for example the road condition or gradient.

2.10.1 Performing a Route Network Analysis

In order to perform a RNA, Musa & Mohammed (2002) suggest the following four formal steps to find the most ideal route for the transportation of timber from the depot to the mill. These include; 1) analysis and survey, 2) identification and evaluation of road routes, 3) model building, 4) simulation, 5) forecast evaluation and 6) improve road route(s) location.

The analysis and survey step can be seen as the input features and rule base, involving a simple analysis in defining the planning policies and the other related factors which come into play. The necessary costs should be incorporated within this stage. The identification and evaluation of road routes phase involves assessing whether the captured routes are in fact realistic and do represent the real world. Mis-capturing may result in errors within the network and should be corrected immediately. The model may be built within the model building phase, using an appropriate model which would create a simulation in the simulation phase, which would create a realistic visual display of the best route available. The forecast evaluation combines the modelled network with personal knowledge of the forest environment and their relationships to each other which allows for the most adequate location, design, construction and maintenance of the forest roads, striving towards improving road route location.

2.10.2 Examples of the Application of Route Network Analysis

No applications of RNA in South Africa, using ArcView's Network Analyst extension, have been identified. This could be attributed to the lack of agricultural and farming route planning or the lack of current and existing data. However RNA, using Arcview's Network Analyst, has been greatly applied to international urban problems (e.g Calicut City in India), and to a lesser extent forestry applications (e.g. Malaysia). According to Prasad (undated) urban areas are usually more well represented and the data more current as many services rely on an efficient transportation network. This includes the delivery of products, emergency routing, navigation and transportation infrastructure. Urban areas are therefore more representative of the type of road system where RNA should be performed.

Calicut City is a developing city, located on the west coast of India. Calicut has seen the effects of large growth due to the population's involvement in industrial activity, but with very little planning. As a result it is connected to many large surrounding cities by rail and road, but within its own boundaries, it is limited by its singly poor road system. Anjaneyulu, *et al.*, (undated) sought to rectify the transportation problem within Calicut City by undertaking a strategic plan of the pertaining transport systems, incorporating the key variables of the existing facilities in addition to the demand of the traffic load. Upon collecting and 'cleaning' the relevant data of Calicut City, Anjaneyulu, *et al.*, (undated) linked the databases based on common identities. This formed the basis for RNA, finding the shortest path along road linkages, taking into consideration the changes in traffic volume. It is evident that the study performed provides a useful RNA for Calicut's city, as well as an adequate idea of what data is required for an analysis to take place. From this study, it is clear that a means of alleviating congestion and traffic flow would firstly be to upgrade or implement a rail system within the city as the rail links to the surrounding cities are inadequate. Thereafter, the roads within Calicut City would be upgraded, based on the findings of the RNA, providing both passenger and good transportation.

Musa & Mohammed (2002) applied GIS to the automated planning process of routing and the alignment of a forest road network in the Malaysian forest of Ulumuda, Kedah State. A model was developed to distinguish the lowest value and the shortest route between the origin and the destination points, with varying surface differentiation within the GIS. In other words, the model depicts the least value pixel each time it moves from one pixel to the next, from a particular starting point. Based on raster data, the analysis models the increased value of movement from one cell to another based upon the frictions which are acting on the movement. Once the analysis had been completed, the best route through the Ulumuda forest was modelled. The road alignment provides useful information with regards to helping the forest manager to judge the efficiency and to determine the most optimal location and route of forest roads, whilst considering technological criteria, gradient and other topographical features within the forest and its surroundings. This, in turn, improves the efficiency of the network and allows for better economic planning and optimisation.

Therefore, upon reviewing the findings of Anjaneyulu, *et al.*, (undated) when applying RNA to Calicut City, India, from an urban perspective, as well as Musa & Mohammed's (2002) findings of Ulumuda forest in Malaysia, from a rural perspective, it is clear that applying RNA to commercial forestry farm in South Africa would be of great benefit. Not only would the economic efficiency of the farm be improved, but planning and optimal locations within the transportation network could be established.

2.11 Route Network Analysis in South Africa

In order to apply RNA to South Africa's commercial forestry plantations, the RNA application in this study should focus on depots and both short-haul and long-haul transportation, which are essential to the functioning of the RNA.

2.11.1 Depots

Forestry Engineering South Africa (1999) asserts that depots are storage and handling areas that 'house' large volumes of timber that are stored prior to transportation to the mill. Depots need to be well planned and constructed within the transportation network.

2.11.2 Short-Haul Transportation

Short-haul transportation is the term which describes the transport of timber from the extraction route, forest road or landing to a depot, rail head or secondary storage area. Short-haul takes place over short distances (<10 km) (Forestry Engineering South Africa (1999). Tractor and trailer short-haul is applied most frequently (Appendix 2, Plates 3 and 4). In addition, short-haul transportation refers to primary and extended primary equipment. Forestry Engineering South Africa (1999) suggests that the utilisation of short-haul transportation is affected by transportation potential; the total volume and weight of the load; the dispersal of the load within the vehicle; transportation distance from the plantation to the depot; transportation time and cost restrictions; loading and unloading techniques as well as the availability of vehicles and labour, travelling speeds (road conditions and driver skills) and the slope and condition of the roads.

Short-haul transportation has, in the past, been seen as an effective means of transportation as it is a cost effective. However, short-haul transportation is slowly being ruled out as the multiple handling of timber has caused damage to the timber as well as increased the cost conveyance. In addition, there is a low availability as well as utilisation of short-haul vehicles and overloading is seen as a significant drawback.

2.11.3 Long Haul Transportation

Forestry Engineering South Africa (1999) explains that long-haul transportation, or more commonly referred to as secondary (Rigid and Draw-Bar) has provided a good option to replacing short-haul transportation. Long-haul is used to describe the transport of timber from the forest road, landing or depot to the final destination, usually a mill. Rigid and Draw-Bar long-haul transportation is most frequently used in South Africa. (Refer to Appendix 2, Plate 6) In addition, two types of long-haul are recognised, (1) where the timber is transported from the forest road to a mill over unpaved and paved roads (similar to sawtimber systems), and (2) where the timber is transported from a depot to a mill over predominantly paved roads (similar to the long distance transfer of pulp logs). This type of transportation is performed by high speed vehicles over long distances (>10 km).

2.12 Project Management

In order for a RNA to be efficiently developed, implemented and completed, it is essential to adopt a project management method asserted by Burke (2003), which offers a structured approach to managing projects, emphasising the need to control cost, time, scope and quality; four elements to any project which are of great importance. Therefore, by adopting the principles of project management as a step-by-step guide for each task within RNA, forestry companies would reduce project costs, which would then improve the economic status of the entire company.

According to Burke (2003), project management is a temporary attempt to create a unique service or product. In addition, it is the application of knowledge, techniques and skills to project activities which meet the stakeholder's (people who are actively involved in the project or who may be affected by the project being implemented) expectations and needs of a project. A project consists of distinct features, which include a start and finish; a life-cycle; a budget; activities which are unique and non-repetitive; team roles and relationships; a single point of responsibility (project manager) as well as fast-tracking (getting the product to the market before competitors). In addition, project management strives to achieve deliverable objectives relating to integration, human resources, communication, risk, procurement and contract.

2.12.1 Feasibility Study

Before RNA can be performed, Burke (2003) reveals it is not only imperative to question whether the analysis would be feasible, but also to question whether the forestry company makes the best use of its existing resources. The feasibility study describes the purpose of the project in terms of questioning the viability of the RNA, in terms of the requirements of technical expertise, the appropriate skills and which stakeholders to be involved. In summary, the feasibility study determines whether applying RNA to a forestry farm, will be of benefit to the forestry organisation.

2.12.2 The Project Charter

The Project Charter suggested by Burke (2003), provides information relating to the aim as well as the objectives of the RNA. In addition, the stakeholders are mentioned as well as the milestones of the project, based on an anticipated five day completion plan for the RNA application to the Ntonjaneni Farm.

2.12.3 The Project Life Cycle

The Project Life Cycle (Figure 2.3) has in recent years become the forefront in project management, providing key structures or frameworks for subdividing the scope of work into manageable work packages or phases (Burke, 2003). The RNA is divided into the following four phases:

- Concept and Initiation Phase: This phase establishes the need or opportunity for the project, determining the feasibility of the project to be investigated. Acceptance of the proposal will entitle the next phase to be introduced.
- Design and Development Phase: The second phase of the project life-cycle incorporates the guidelines set out during the feasibility study to design the detailed schedules and plans for implementing the project.
- Implementation or Construction Phase: The third phase actually implements the project, based on the *baseline plan* (underlying plans) developed during the previous phase.
- Commissioning and Handover Phase: The fourth and final phase of the project confirms the implementation of the project and terminates the project.

2.12.4 Project Budget / Estimates

In order for a Project Manager to effectively plan and control a project, Burke (2003) believes accurate budget estimates are essential. The estimate is therefore a prediction of the RNA project's parameters, based on the best approximation of the available time, information, techniques employed, and the expertise and experience of the estimator.

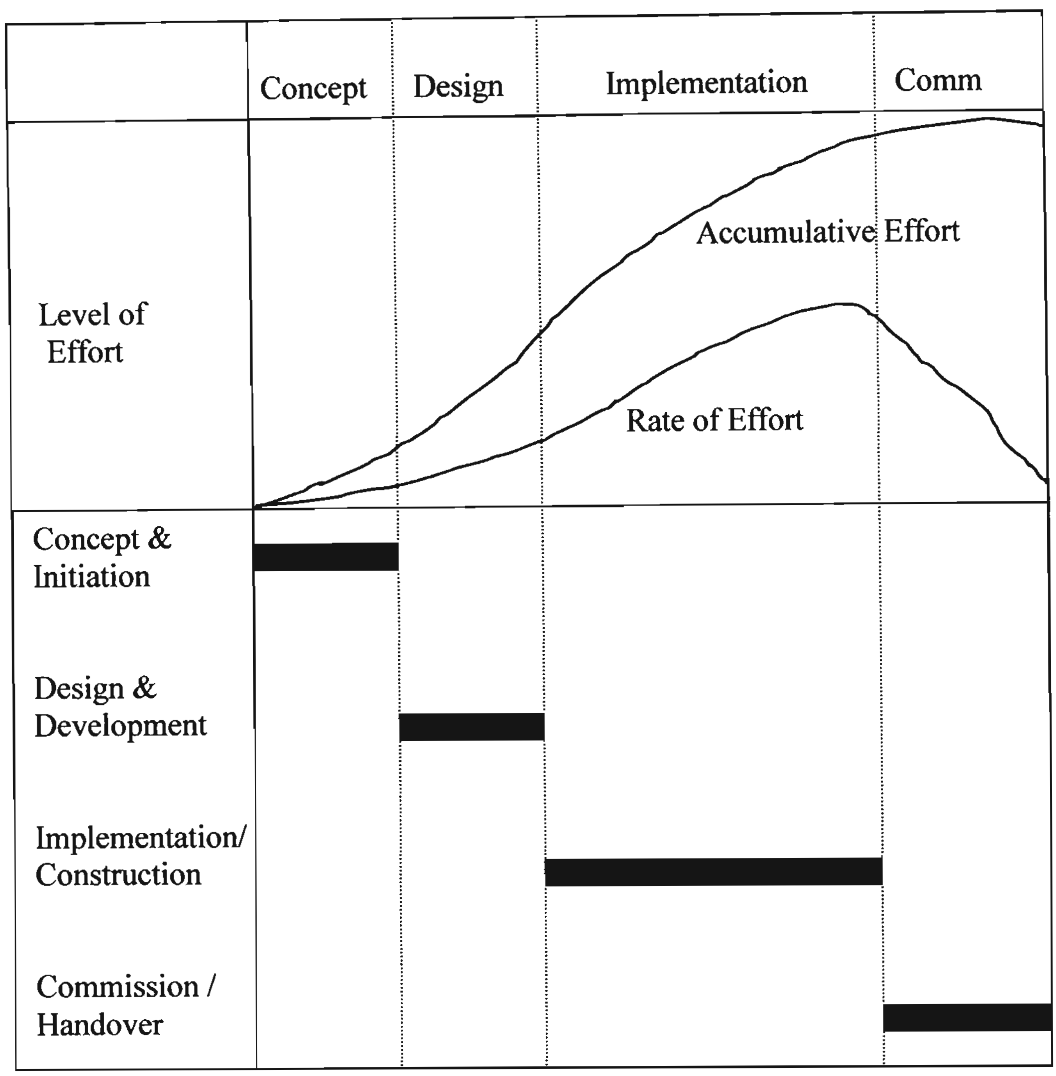


Figure 2.3 Project Life Cycle (Burke, 2003)

The accuracy of the estimate is strengthened by including and analysing the potential project costs. Such costs include: direct, indirect, time-related, labour, material and equipment, transport, preliminary and general, office and team costs. The budget includes all the above factors within the data analysis, the project advisors as well as the project management fee, which includes procurement costs, labour, computers, software etc. The expected profit is included. However the profit will become depleted if unexpected costs, which are unplanned, affect the budget.

2.12.5 Cash Flow

The cash flow relating to a project can be defined by Burke (2003) as a document which models the flow of money in and out of the project, during the anticipated five days in which the project for the Ntonajeni Farm will run. Creating and maintaining control over the project's monetary value, in terms of the project's accounts, is essential to any effective project management. In doing so, an agreeable cash-flow is maintained during the life of a project within the financial limits originally set out at the beginning of the project.

2.12.6 Work Breakdown Structure

Burke (2003) notes that the purpose of a Work Breakdown Structure (WBS) is to subdivide the scope of the work required to be performed within the project, into manageable work packages which can be estimated, planned and assigned to the appropriate person or department, possessing the correct technical expertise for the completion of a particular task/s. The work which needs to be completed is subdivided based upon various elements, including specifications, quality requirements, estimate (manhours), budgets, duration, procurement, resources and equipment requirements. The WBS is a hierarchical structure which is represented by a graphical subdivision of the scope of work into boxes, representing the different needs of the various disciplines and project locations. In short, the WBS depicts what work should be done and by whom.

The Gantt Chart, established by Henry Gantt (Burke, 2003), is a barchart designed as a visual aid for controlling and planning of projects. A Gantt Chart consists of a time scale of days, the activities to be performed, as well as the scheduling of each activity represented by a horizontal line, from the activity's start to finish date.

2.12.7 Critical Path Method

In order for the RNA to be effectively planned and controlled, large amounts of data need to be assessed quickly and accurately, in order to create an order within a complex situation (Burke, 2003). The Critical Path Method (CPM) offers a structured approach to the project planning. The CPM diagram establishes a logical relationship between the activities using a network diagram, ensuring that the tasks are done at the right time. Therefore it incorporates the information required pertaining to a list of activities as well as the logic constraints between the activities. Very often, a project is either ahead or behind schedule. Burke (2003) emphasises the need to incorporate the forward pass backward pass techniques, which will be explained at a later stage, in order to accommodate adjustments to the schedule.

2.12.8 Resource Planning

Within an organisation, it is imperative to ensure that all resources are well managed. According to Burke (2003), resource planning adheres to determine which physical resources (people, equipment and materials) and what quantities of each should be used in order to perform RNA. Therefore, incorporating resource planning, maximum quality versus minimum time and cost, is emphasised.

2.12.9 Project Risk Management

In order for change to occur, decisions need to be made, ideally based on known information. However, this is not always the case as decisions are almost always based on a high degree of uncertainty of the outcome. Burke (2003) asserts the implementation of a risk management plan, as a formal approach to recognising and anticipating risk.

2.12.10 Quality Management

Project quality management, proposed by Burke (2003), is the process required to ensure that the project undertaken will satisfy the needs for which it is undertaken, incorporating both the management as well as the product of the RNA. In addition, quality is achieved by including quality planning, control and assurance.

2.13 Summary

The existing literature indicates that improvements to transportation systems of South Africa's commercial forests would enhance economic and transportation optimisation.

RNA, which has been applied to Calicut City, India, as well as the Ulumuda forest in Malaysia, has improved the transportation systems. Therefore, it is suggested that South Africa looks to apply RNA to the current road systems of forestry farms. Using GIS as a medium and planning as an assistance to transport modelling, RNA should improve the economic and environmental condition of forestry farms. The various steps towards effective project management outlined by Burke (2003), provide a very comprehensive and logical guide as to how RNA should be implemented over a five day period for Ntonjaneni Farm. Not only does project management include the objectives and aim of the RNA, it also emphasises the importance of utilising resources, controlling cost, anticipating risk and striving towards quality. Adhering to each of these steps, will greatly improve the economic competence of the RNA.

CHAPTER 3
THE STUDY AREA

3.1 Introduction

In order for RNA to be performed, it is essential to ensure that a study area is selected which represents many other commercial forestry farms in South Africa, so that RNA could also be performed on other farms if the analysis of the study area is successful. The fundamental requirements are a haphazard road system utilising both short-haul and long-haul transportation, with a network of depots. Steep slopes and environmentally sensitive areas also need to be sought to add various criteria to the RNA.

3.2 Ntonjaneni

The study area is located on the North Coast of KwaZulu-Natal in South Africa. The exact study area is Ntonjaneni Farm, managed by a commercial forestry company. Ntonjaneni is located at 31°34'00"E and 28°55'00"S. The Ntonjaneni Farm is located within proximity to both Durban and Richard's Bay (Figure 3.1).

The Ntonjaneni farm contributes a means of commercial benefit towards the paper and pulp industry of South Africa, through the growth of both *Eucalyptus sp.* and *Pinus sp.*, grown throughout KwaZulu-Natal. The existing transportation system consists of haphazard, dense roads, which are used to transport timber via short-haul and long-haul transportation from the plantation to the mill.

3.3 Biophysiographic Description of the Study Area

3.3.1 Geology, Soils and Topography

Natal Group Sandstone is the dominant geology stratum of Ntonjaneni (Department of Environmental Affairs and Tourism, 2000b).

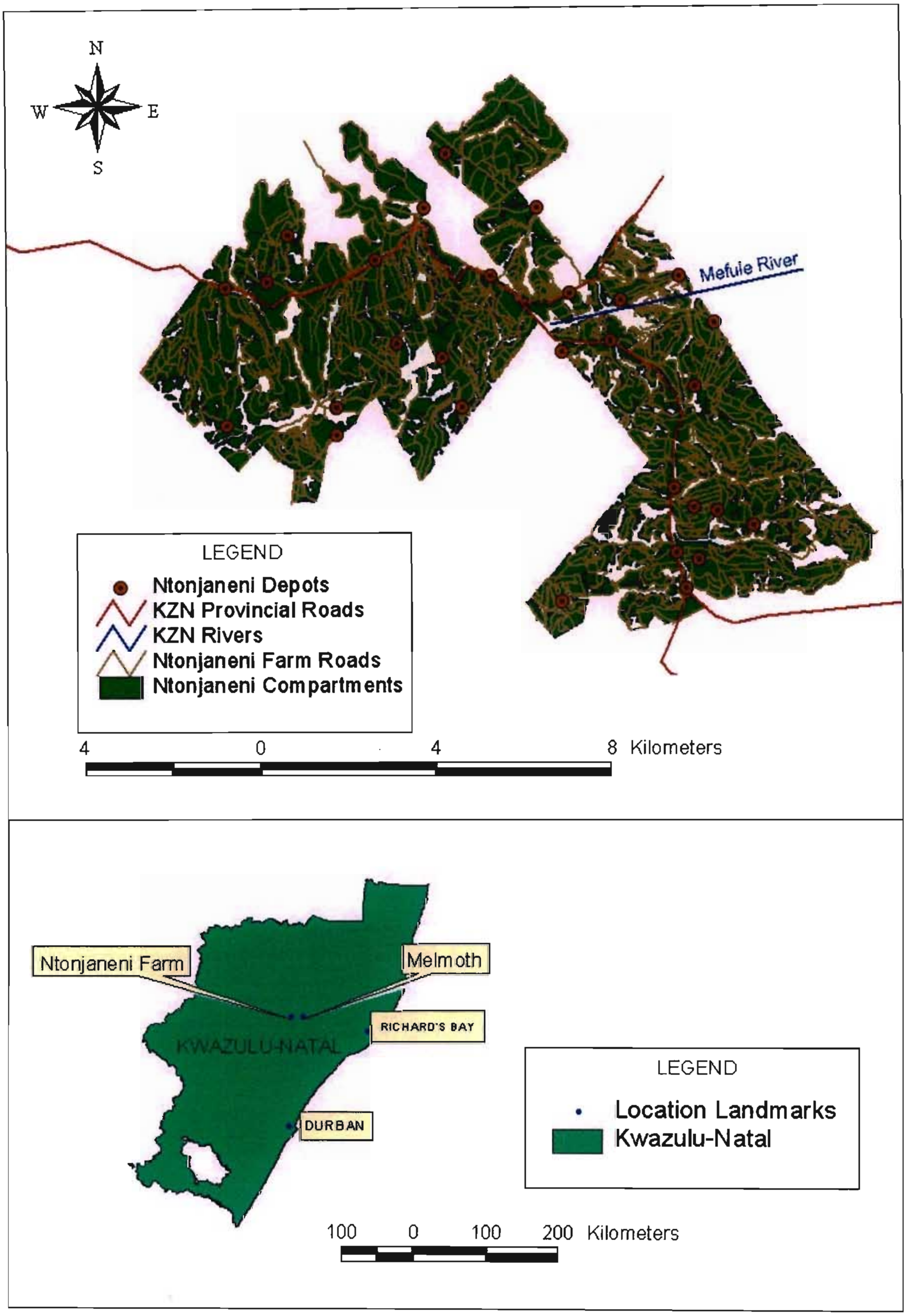


Figure 3.1 Ntonjaneni Farm Location

According to the South African Sugar Association Experiment Station (1999), the dominant soil in the Ntonjaneni region is Avalon Form, with a sandy loam texture and belongs to the Ruston soil series, which indicates that the soil has a moderate erosion hazard.

The terrain type is predominantly rolling, with an altitude ranging from 803 to 1 165m above mean sea level (amsl). In addition the slopes are generally steep (above 12 %), which need to be accounted for during any planning and analysis of forestry processes.

3.3.2 Climate

Ntonjaneni has a humid climate, with heavy mists contributing significantly to moisture required by forests for enhanced growth. Additional moisture is acquired from rainfall, where annual figures range from 800mm to 1280mm (Figure 3.2).

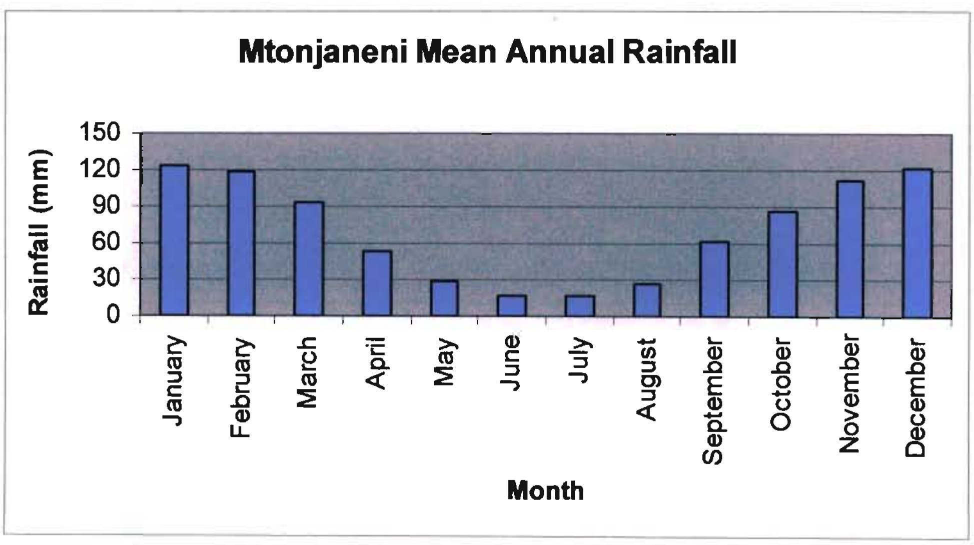


Figure 3.2 Ntonjaneni Mean Monthly Rainfall (Camp, 1997)

The mean annual temperature for the region is 17 ° C (Figure 3.3), with warm, wet summers and cooler, drier winters.

Camp (1997) notes that unfavourable climatic conditions in the Ntonjaneni region include drought and frost with occasional hail. Further unfavourable conditions such as hot, north-westerly winds, more commonly known as berg winds which induce the risk of fires, are of great concern within this region occupied by forestry.

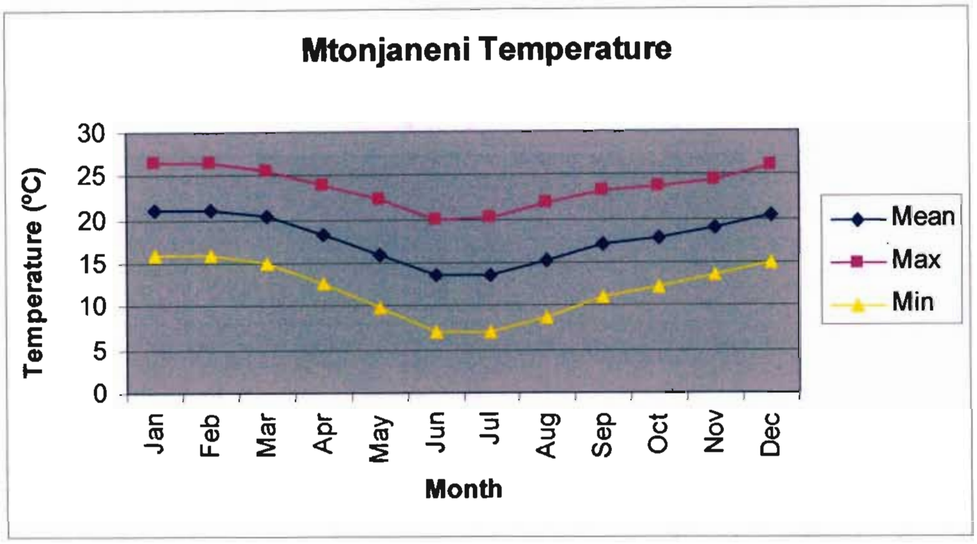


Figure 3.3 Ntonjaneni Mean, Maximum and Minimum Monthly Temperatures (Camp, 1997)

3.3.3 Hydrology

Ntonjaneni lies within the Moist Midlands Mistbelt, which is well-watered, with streams and rivers proving an important source of water to the lower lying areas which they feed and should be taken into great consideration for future planning of the region (Camp, 1997). Most rivers flow through environmentally sensitive areas which are often not adequately accounted for during agricultural activities. The wetland coverage for the area for WXc8 is 76 ha, consisting of one perennial river.

3.3.4 Natural Vegetation

A Bioresource Unit (BRU) is a specific area in which the environmental conditions such as soil, vegetation, climate, and to a lesser degree, terrain form, are sufficiently similar in order to allow uniform recommendations of farm practices and land use to be made, in order to assess the magnitude of crop yields that can be achieved. This provides an adequate framework in which research can be performed, to assist land users to make the correct decisions (Camp, 1997). There are 590 BRU's in KwaZulu-Natal, based primarily on vegetation and climate.

According to Camp (1997), Ntonjaneni lies within the Bio Resource Group 5: Moist Midlands Mistbelt, within the BRG subgroup 5.1a. The Moist Midlands Mistbelt covers an area of 520 212 ha, and in addition, Ntonjaneni lies within the Bioresource unitWXc8, consiting of arable land.

With such a high percentage of arable land, very little emphasis has been placed on the veld and veld management practices. The Veld Type of a particular region may be defined as "a unit of vegetation whose range of variation is small enough to permit the whole of it to have some farming potentialities" (Acocks, 1988:1). According to Acocks (1988) the Ntonjaneni region can be described as the Ngongoni Veld; which together with the Eastern Province Thornveld and the Zululand Thornveld, occupies an irregular belt, positioned inland of the Coastal Forest Belt. The vegetation pattern for the region is Grassland.

3.3.5 Land Use

According to the Department of Environmental Affairs and Tourism (2000a), the land use is predominantly cultivated land. Camp (1997) suggests that the Moist Midlands Mistbelt has a particularly high potential owing to its favourable climate, with 47 % of the land being arable, with 37.7 % of the total area consisting of a high potential soil. Forestry plantations constitute 33.41 % of the land, which including Ntonjaneni is a total area of 3 705 ha. Forestry is an ecologically sound practice within the region and is a widespread land use form, consisting of gum, pine and wattle within selected sites in the valleys. In addition sugar cane constitutes an additional 1.52 % of the total area (ie 169 ha).

3.4 Summary

Ntonjaneni Farm is an acceptable study site because transportation is an economic concern. In addition, the haphazard array of roads which, with the inclusion of depots, form a network for short-haul and long-haul transportation. Steep slopes and environmentally sensitive areas are also of great concern, which will be accommodated within the RNA. These criteria are common to many other commercial farms, particularly in South Africa.

CHAPTER 4
MATERIALS AND METHODS

4.1 Introduction

The materials and methods acquired and used in this study were chosen to ensure that a RNA of Ntonjaneni Farm could be performed, based on the requirements stipulated in the literature. The Ntonjaneni Farm is an applicable study area for forestry RNA, which consists of depots, with both short-haul and long-haul transportation being used on the transportation system. The software used to perform RNA, ArcView 3.3, has proved beneficial in previous studies and is able to manipulate the data of Ntonjaneni Farm. The project management techniques suggested by Burke (2003) are designed in order to offer an assisting guide as to how RNA should be performed on Ntonjaneni Farm, in order to optimise the transportation system from an economic perspective.

4.2 Materials

In order for RNA to be effectively performed, a study area meeting the requirements mentioned previously was essential, as well as the most current and accurate spatial data relating to the routing system.

4.2.1 The Study Area

The Ntonjaneni Farm, located near Melmoth on the North Coast of KwaZulu-Natal, provided an ideal location for the application of RNA. A site visit was essential to ensure that the existing data was in fact up to date and represented the area with as few errors as possible.

4.2.2 Map Units

The data's map units were metres, and the map distance were kilometres.

4.2.3 Data Required for Route Network Analysis

In order for a RNA to be effectively performed, it was imperative that the information was current and was an accurate representation of the Ntonjaneni Farm. Data was supplied in the form of two types of GIS data, including shapefiles (with adjoined attribute data) and Digital Elevation Models (DEM) (Table 4.1).

Table 4.1 Types of data used for Route Network Analysis

SHAPE FILES	**DEM**
Original Plantation Compartments	*Original Dem 110*
Original Non Plantation Compartments	*Original Dem 210*
Original Fell Plan	
Original KZN Roads	
Original Ntonjaneni Forestry Roads	
Original Ntonjaneni Road Slope	
Original Ntonjaneni Rivers	
Original Ntonjaneni Depots	
Original KZN Contours	

4.2.3.1 Spatial and Attribute Data

The spatial and attribute data was provided by a commercial forestry company who manage Ntonjaneni Farm.

Original Plantation Compartments

The data was in the form of shapefiles and was made up of polygons delineating each compartment. Each compartment had a unique identifier (code), and the area of each compartment was also included in the attribute data.

Original Non-Plantation Compartments

The data was in the form of shapefiles and was made up of polygons delineating each compartment. Each compartment had a unique identifier (code), and the area of each compartment was also included in the attribute data.

Original Felling Plan

The data was in the form of shapefiles and was made up of polygons delineating each compartment. Each compartment had a unique identifier (code) as well as the particular date which each compartment would be felled. The felling plan was based on a five year rotation harvesting plan, starting on 1st January 2004, and completing on 1st August 2008.

Original KZN Roads

The entire road network of KZN was obtained in shapefile format. The accompanying attribute data had values describing each road segment's length, name, and unique code. Only roads pertaining to the study area were clipped and used for the analysis.

Original Ntonjaneni Forestry Roads

The data was in the form of shapefile line data, with each line segment represented by a unique code, route number as well as a description of the type of road. Table 4.2 outlines the properties relating to the roads, which should be incorporated within the RNA.

Table 4.2 Forestry Road Description (Forest Engineering Technical Department, 1999)

Description	**Class C**
Traffic Direction	1 lane
Recommended maximum speed (km/hr)	40
Sight distance (m)	60
Road width (m) road reserve construction width wearing course	 6 6 4 (driving surface)
Desirable maximum gradient (%) Mountainous terrain	 12
Road junctions – hazardous sites	Yield / warning sites
Speed restrictions	As appropriate

Original Ntonjaneni Rivers

The data was in the form of shapefile line data, with the attribute data describing the river's unique identity code of each segment.

Original Ntonjaneni Road Slope

The data was in the form of shapefiles and each line segment represented the variance of slope for the Farm. In addition, the attribute data described the individual length and gradient of each road segment.

Original Ntonjaneni Depots

The Original Ntonjaneni Depots are areas which have been demarcated within the forestry plantation as loading points, and are used in accordance with short-haul distances as well as volume measurements relating to the timber. In addition, depots act as the middle-medium in order to assist in the switching of loading from short-haul to long-haul transportation. Depots need to be well planned and positioned to allow easy access to the timber stacks and to meet the haulage volume amounts. In addition depots need to be well drained to eliminate flooding and act as a loading ground particularly during wet conditions (Engelbrecht, 2002). The data was in the form of shapefile data, with the accompanying attribute data describing the location of each depot, as well as the amount of timber they can withstand (in tons).

Original KZN Contours

The KZN contours consisted of shapefile data, described by the height of each line segment representing altitude in mamsl.

4.2.3.2 Digital Elevation Models

Digital Elevation Models (DEM) have been developed to reform the spatial data into a Three Dimensional (3D) view. The DEM was not supplied with attribute data.

4.3 Software

ArcView 3.3 (ESRI, 2001) was used in this study to view and manipulate geographic data. The software was used specifically to query, explore and analyse data from a statistical and spatial perspective. ArcView 3.3 extensions were also used in the analysis, including Network Analyst, Spatial and 3D Analyst.

ArcView Network Analyst

The *ArcView 3.3 Network Analyst (AVNA)* extension allows the user to perform *'Find Best Route'*, which solves a network problem by finding the 'least cost impedance' path on the network from one specified stop to one or more stops. Network modelling in ArcView allows the user to include the rules relating to the objects, arcs and events in association with solving transportation problems (Husdal, 2000).

The Pathfinding Algorithm

Network Analyst software determines the best route by using an algorithm which finds the shortest path, developed by Edgar Dijkstra in 1959. Dijkstra's algorithm is the simplest pathfinding algorithm, even though to this day many other algorithms have been developed. Dijkstra's algorithm reduces the amount of computational time and power needed to find the optimal path. The algorithm strikes a balance by calculating a path which is close to the optimal path, which is computationally manageable. The algorithm breaks the network into nodes (where lines join, start or end) and the paths between such nodes are represented by lines. In addition, each line has an associated cost representing the cost (price) of each line needing to reach a node. There are many possible paths between the origin and destination, but the path calculated depends on which nodes are visited and in which order (Anon. 1, undated).

Three Dimensional Modelling

Three Dimensional Modelling is performed using the 3D Analyst and the Spatial Analyst extensions. These extensions are tools which enable the analysis of spatial relationships within data. The fundamental component of the Spatial Analyst is the grid theme, which is the raster equivalent of a feature theme. The Spatial Analyst performed the *Derive Slope* function, appropriate for the analysis of gradients (ESRI, 2001).

4.4 Methods

The methods performed during the RNA are summarised in Figure 4.1, after the RNA has been explained in detail.

4.4.1 Selection of relevant data

The original data set contained a large quantity of data relating to the entire KwaZulu-Natal region. It was therefore essential to select the data which was related to the Ntonjaneni Farm as well as the KwaZulu-Natal roads which connect the Ntonjaneni Farm with the mill at Richard's Bay. Therefore, only data pertaining to the study area was clipped out using Geoprocessing Wizard extension of ArcView. Such data included KZN Roads, KZN Road Slope, KZN Contours and KZN Rivers.

4.4.2 Digitizing

Clipped KZN Roads

The Clipped KZN Roads and the Ntonjaneni Farm Roads were not properly aligned once viewed, and therefore the KZN roads had to be digitized in order to match the Ntonjaneni Farm Roads.

4.4.3 Manipulation of the attribute data relating to the spatial features

KZN Roads

The attribute data of KZN Roads did not include data relating to the true cost, speed or travel time for the transportation of timber along these roads. Such data were sourced from the commercial forestry farm and consequently added to the attribute file of KZN Roads.

Ntonjaneni Farm Roads

The *Ntonjaneni Farm Roads* did not have to be altered spatially, however their attribute table contained a large number of unnecessary fields (columns) and records (data within the rows). These had to be removed. In addition, the roads contained no data relating to the cost, speed or travel time relating to the transportation of timber. These data was obtained from the commercial forestry company and the attribute data was updated accordingly.

Original Felling Plan

In order for RNA to be effectively performed, a start and end point (represented by nodes) as well as a line feature (arc) in order to find the best route, need to be obtained. It was essential therefore to manipulate the Ntonjaneni Felling Plan compartments so that a start point is represented by a node. Each node was based on a central position within each compartment, which was randomly assigned.

Original Depots

Only depots situated on the Ntonjaneni Farm were selected for the analysis. Additional data describing the depots, as well as the location of the forestry mill at Richard's Bay, on the North Coast of KwaZulu-Natal, were obtained from the commercial forestry company.

4.4.4 Buffering

A buffer zone of 30m surrounding the clipped farm rivers was created (Forestry South Africa, 2002). However, roads could cross the buffered areas.

4.4.5 Spatial and Three Dimensional Modelling

The Clipped Farm Road Slope consisted of small segments of road, often only reflecting half a metre. It was therefore necessary to use Three Dimensional Modelling, to determine the complete variation in gradient of the slope, as opposed to the changes of height of each small segment.

Ntonjaneni Farm Contours

The Ntonjaneni Farm Contours provide a measurement of altitude for the study area, represented by a Z value. The Z value of each line represents all contiguous locations which have the same height, (concentration or magnitude) values, stored in the attribute table. Contours form the basis for creating a *Triangular Integrated Network* (TIN).

Ntonjaneni TIN

The surface of the earth was represented by a TIN, in addition to storing specific structures with regards to the surface area, which was divided into a set of contiguous, non-overlapping triangles (ESRI, 2001). A specific height value (gained from the Z value within the Ntonjaneni Farm Contours*)* was recorded for each individual triangle node. Because of this, the height between each node was determined, creating a continuous surface, thus allowing for the representation of a very complex and irregular surface within the data set.

Derived Slope

The Ntonjaneni TIN was used to create a Derived Slope, which identified the slope or more simply, the rate of change from each grid cell to the next. The output slope grid therefore represented the degree of the slope for each cell location, which ranged from 0 to 89.2 degrees, from the horizontal.

Map Calculator

The Map Calculator function creates mathematical statements from grid themes. An output grid using an expression, based on the requirements of a road slope, was created, which was less than 12 %. (Derived Slope < 12%=1, Derived Slope > 12% =1)

The output called *Acceptable Slope* was then converted into a shapefile, using the *Convert to Shapefile* function which converts the data from raster to vector.

4.5 Route Network Analysis

The data required to perform the RNA was corrected and manipulated so that the analysis could be performed, by 'Find Best Route'.

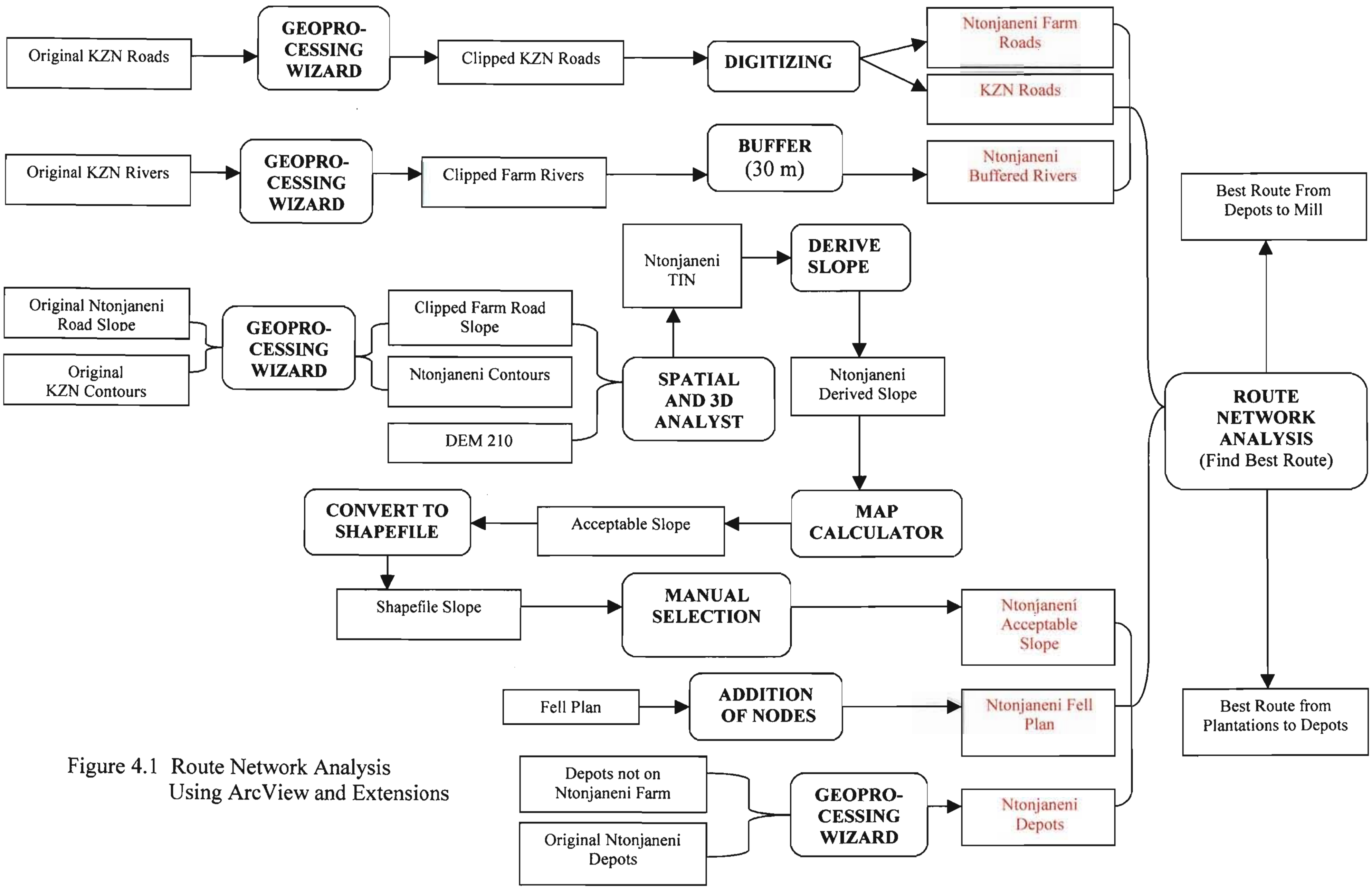


Figure 4.1 Route Network Analysis Using ArcView and Extensions

4.6 Project Management

The methodology behind the RNA has been discussed as well as the key steps which should be followed in order to accurately perform RNA. Because the focus of this study is to perform RNA based on improving the economic efficiency, it is important to source techniques which may assist in the economic control of cost, time and quality. Including such parameters which enhance the economic status of a project. Burke (2003) has noted the economic benefit which all companies will achieve in adopting a project management plan for any form of project. Applying project management to RNA based on techniques to economically improve the Ntonjaneni Farm would be of great benefit, not only controlling cost, but also ensuring that the RNA is implemented, managed and commissioned correctly. In order for project management to be included within the RNA, a unique guide needs to be established, incorporating the application of RNA over a five day period for Ntonjaneni Farm with the project management, adhering to the steps which will be discussed.

4.6.1 The Feasibility Study

Before the RNA of the Ntonjaneni Farm could be performed, it was essential to consider whether the analysis, based on the economic status of the company, will:

- Maximise profits;
- Maximise the utilisation of the workforce;
- Maintain or increase market share;
- Maximise the utilisation of forestry equipment and roads;
- Improve the organisation's image;
- Account for risk and uncertainty; and
- Will meet the expected results and strategic goals of the organisation.

4.6.2 The Project Charter

The aim of the project needs to be established, incorporating the objectives of the organisation and the application of RNA.

4.6.3 The Project Life Cycle

The project life cycle for RNA will be designed in order to divide the work according to manageable work packages which need to be completed in order for the RNA to be successfully completed.

4.6.4 Project Budget (Estimates)

The project budget will be designed according to the amount of capital which needs to be expended during the project (Rand) as well as the description of each activity. In addition, the contingency determines the amount of money accredited for risk, and the profit is also indicated.

4.6.5 Cash Flow

The cash flow for the RNA will be developed as a graph, which indicates the flow of money, based on time (days) against cost (Rand).

4.6.6 Work Breakdown Structure

A WBS needs to be designed for the RNA, based on the requirements of work for each member within the organisation. Work must be divided for the GIS Specialist, Environmentalists, Civil Engineers and Logistic Planners. A Gantt Chart for RNA needs to be developed to link the WBS to each portion of work which needs to be completed. The Gantt Chart will indicate the project duration (days) against the activity description.

4.6.7 Critical Path Method

The CPM is established, based on an activity, logical relationships, and activity duration of the RNA. The WBS can be subdivided into a number of activities, which is represented within the network diagram as an identity number, represented in each box. The activity needs to be described so as to ensure a clear understanding within the workforce. Logical relationships show the flow of activities throughout the project, reflected as activities in series (performed one after the other) or in parallel (performed at the same time). For ease of reading, an activity logic table represents the flow of activities in a tabular format. The activity duration of a project is represented as the time spent to complete an activity, either represented as a calendar or work pattern. The CPM time analysis establishes the start and finish dates for all the activities, using the start date, Early Start (ES), Early Finish (EF), Late Start (LS) and Late Finish (LF), based on the time allocations with regards to the Gantt Chart, which displays the work schedule. The Forward and Backward Pass accommodate changes to the schedule. An activity float, or more commonly referred to as a float, is a measure of flexibility, or inherent surplus time within an activity's scheduling. A float indicates how many working days an activity may be delayed or extended so that the work may be completed before the target finish dates (milestones).

Start Date: The CPM analysis needs a day in which to start the scheduled work which needs to be done. Setting the start date allows the first interaction to take place, allowing the project planner to anticipate an end / finish date, using the activity duration and calendar.

Early Start: The early start may be defined as the earliest date by which an activity may start, assuming that the preceding activities are completed as planned.

Early Finish: The earliest date by which an activity may be completed, assuming that the preceding activities are completed as planned.

Late Start: The latest date that an activity can start in order to meet the planned completion date.

Late Finish: The latest date an activity can finish in order to meet the planned completion date.

Forward Pass: The term forward pass is used to define the process of calculating the early start date (ES) and the early finish date (EF) for all the activities within the project. The early start date is the start of the project, whilst the early finish date of an activity is calculated by adding the duration of the activity to the early start date, using the following formula: $EF = ES + Duration - 1$.

Backward Pass: Upon completion of the forward pass, the backward pass is performed in order to calculate the last start date (LS) and the late finish (LF) of each activity. The last finish date of the final / last activity may be given, otherwise the early finish date of the last activity may be used. Late Start is calculated using the formula:

$LS = LF\text{-}duration + 1$.

Activity Float: The float is calculated using the following formula:

Float = Late Start – Early Start.

4.6.8 Resource Planning

Various resources are used within RNA, both human and physical. Human resources include the employees, the Engineers, the Environmentalists, the Logistic Planners and GIS Specialist. The Physical Resources include data, software and computers. It is during the resource planning phase that a breakdown of which resources need to be used per day is established.

4.6.9 Project Risk Management

During RNA, very little risk is anticipated, as the analysis for the Ntonjaneni Farm takes place over a period of five days, and therefore there is less time for things to go wrong. However one needs to identify the risk, develop a response to such risk, and finally mitigate the risk. The anticipated risk for RNA are employees becoming ill, as well as the data becoming corrupted or any element of the hardware or software crashing.

4.6.10 Quality Management

The RNA will only be expensive the first time it is undertaken, as quality products are only expensive once. Therefore once the RNA has been designed for Ntonjaneni Farm, and is successful, it can easily be applied to other forestry farms within the organisation. With this in mind, the project will strive to satisfy the needs for which it has been undertaken. The RNA project must conform to the QS 9000 Quality standards, as well as the Road Safety Act and Environmental Guidelines for Forestry (Forestry Engineering South Africa, 1999). Each activity will only be recognised as completed once it has passed its specific control, guided by the order of work set out in the Critical Path Network Diagram, or planned method. In this way, Total Quality management is strived for.

4.7 Summary

The Ntonjaneni commercial forestry farm provides an excellent study area for the application of RNA, as the existing road systems is an economic concern when viewing the transportation network. Once the best route has been established, using ArcView 3.3, the economic efficiency of the network will be greatly improved. Including a project management guideline for the application of RNA, the economic status of Ntonjaneni Farm will be improved, by placing considerable emphasis on cost, quality, time and human resources, to name a few factors

CHAPTER 5
RESULTS AND DISCUSSIONS

5.1 Introduction

The results of the study are based on the data collected and the analysis undertaken, previously explained in Chapter 4. The results show a successful completion of spatial and attribute data manipulation, Three Dimensional Modelling, RNA and project management. The final result of the GIS manipulation revealed a best route from the depots to the mill, and from the plantations to the depots, however the data was found to be inadequate relating to the rivers and varying speed of roads, which alters the results of the RNA. However, applying RNA and a project management plan specifically designed for RNA of Ntonjaneni Farm over a five day period, has improved the economic status of the Ntonjaneni Farm, by enhancing the transportation optimisation .

5.2 Route Network Analysis

5.2.1 Spatial and attribute data manipulation

5.2.1.1 Clipping of relevant data

By clipping the KZN datasets, irrelevant data surrounding the Ntonjaneni Farm was clipped and as a result the following shapefiles were created (for use in subsequent analysis): Ntonjaneni Farm Rivers (Figure 5.1), Ntonjaneni Farm Road Slope (Figure 5.2) and Ntonjaneni Farm Contours (Figure 5.3).

5.2.1.2 Digitizing

Digitizing and manipulation of the attribute data relating to the spatial data was performed which resulted in *KZN Roads*, reflected in Figure 5.4 and Table 1, Appendix 1. Table 1 contains information, with appropriate fields including *Roadkey, Roadnumber, Measured Length (km), Class (district/provincial), Rand per ton per km for Gum variety, Rand per km for Pine variety, Speed, and Travel Time (minutes).* In summary, 1 553.10 km or National/Provincial KZN Roads covers the study area, and long-haul transportation in 2003 was estimated at *Eucalyptus sp.* being transported at R 3.96 per $t^{-1}km^{-1}$, and *Pinus sp.* transported at R 3.77 per $t^{-1}km^{-1}$.

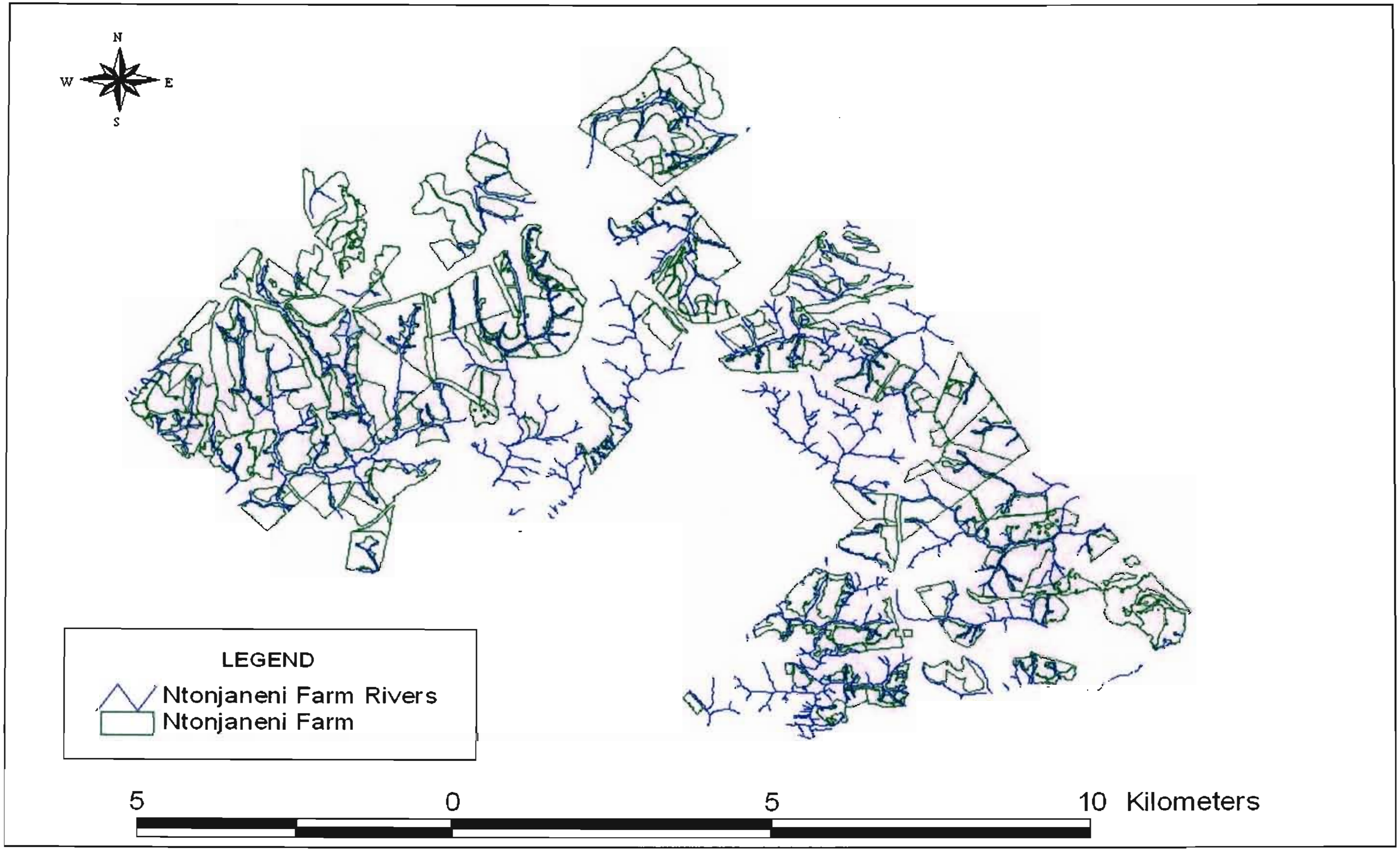


Figure 5.1 Ntonjaneni Farm Rivers

Figure 5.2 Ntonjaneni Farm Road Slope

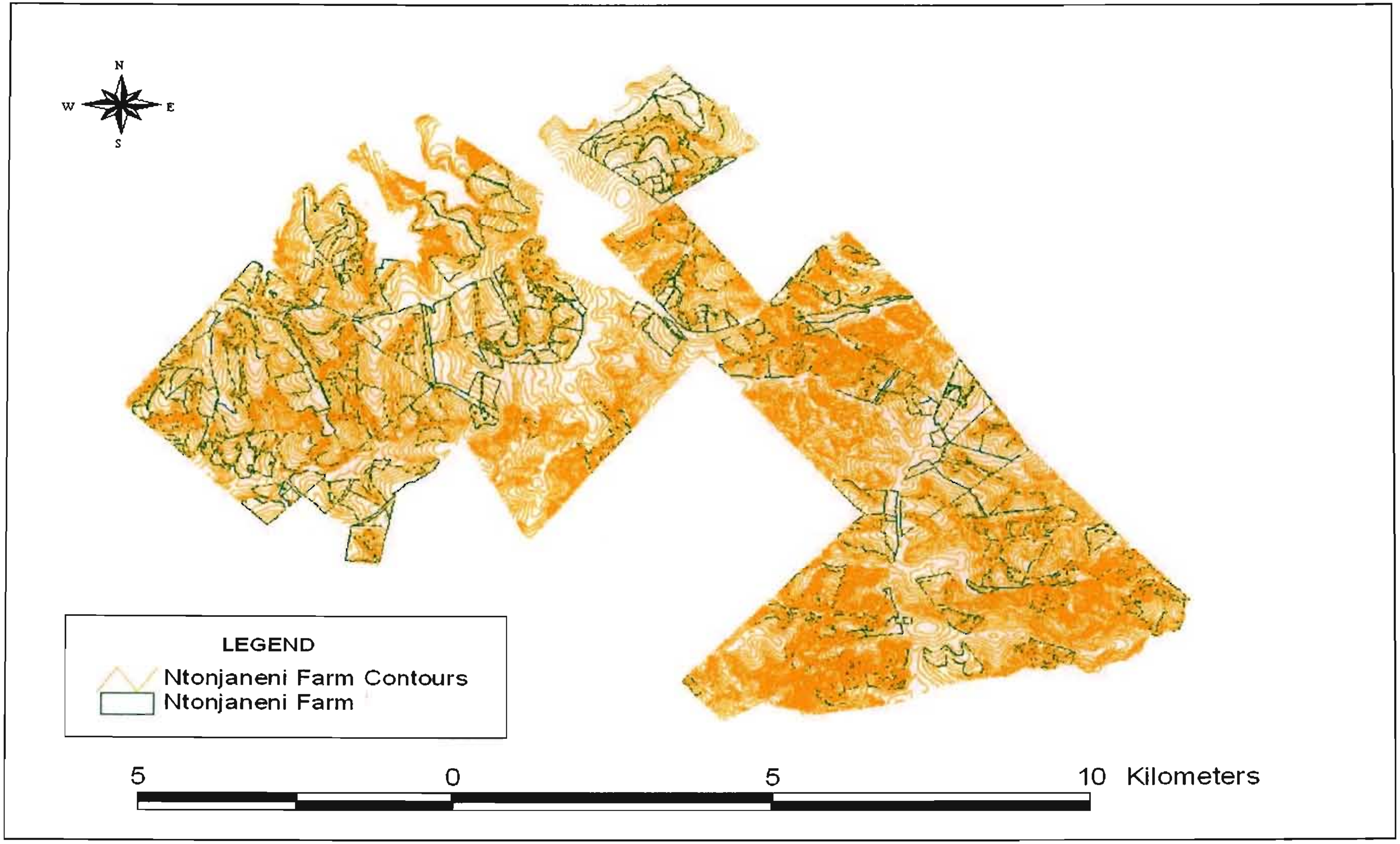


Figure 5.3 Ntonjaneni Farm Contours

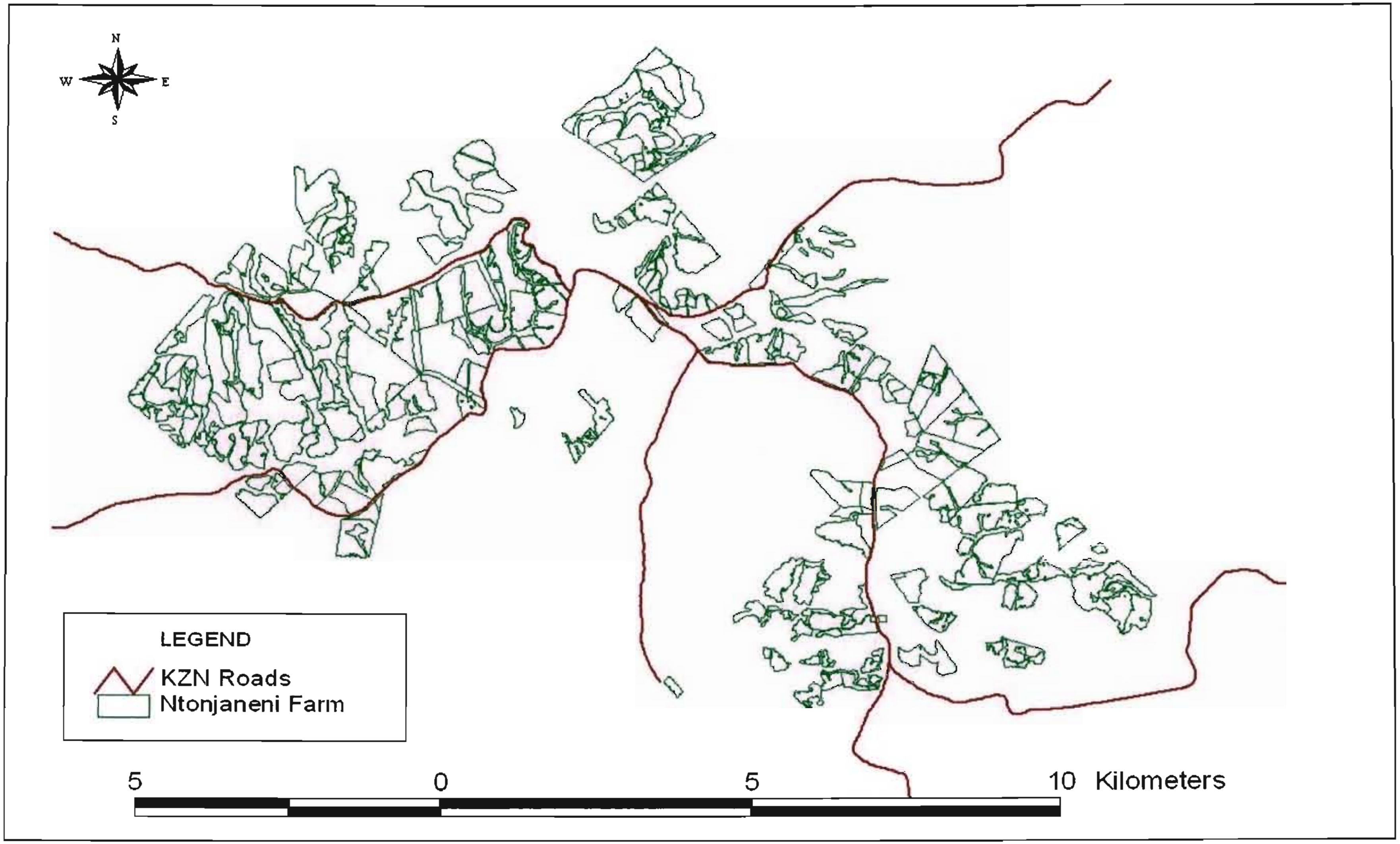


Figure 5.4 KZN Roads

5.2.1.3 Buffering

The buffered rivers within Ntonjaneni, buffered to 30m, are shown in Figure 5.5.

5.2.1.4 Ntonjaneni Farm Roads

The attribute data relating to Ntonjaneni Farm Roads were altered to reflect specific fields displayed in Table 2. Appendix 1. The appropriate fields are *Class, Route Number, Farm Code, Object ID, Rand per ton per km for Gum and Pine* variety, *Speed* (km/hr) and *Travel Time* (minutes). In summary, a total of 4 458 km of road covers the study area, and short-haul transportation in 2003 for both *Eucalyptus sp.* and *Pinus sp.* varieties was estimated as being transported at R 1, 27 $t^{-1}km^{-1}$.

5.2.1.5 Ntonjaneni Felling Plan

The Ntonjaneni Felling Plan, consisting of the Felling Plan and Plantation Nodes, is reflected in Figure 5.6. The attribute data reflected in Table 3, Appendix 1, was manipulated to reveal relevant information consisting of *Farm Code, Compartment, Class, Effected Area, Object ID* and the *Fell Date.*

5.2.1.6 Ntonjaneni Depots

Figure 5.7 depicts the results relating to the *Ntonjaneni Depots*. In addition the attribute data was incomplete, and required manipulation, and the results are revealed in Table 4, Appendix 1. The relevant fields consist of the *Number, Description, Locality, Kilometres to the Richard's Bay Mill and a Route Network Number.*

5.2.2 Three Dimensional Modelling

5.2.2.1 Ntonjaneni Triangular Irregular Network

The *Ntonjaneni TIN*, illustrated by Figure 5.8, represents the surface of the Ntonjaneni farm, revealing an elevation range form 60 to 2500 mamsl. The TIN contains 201 7034 triangles and 1008 570 nodes.

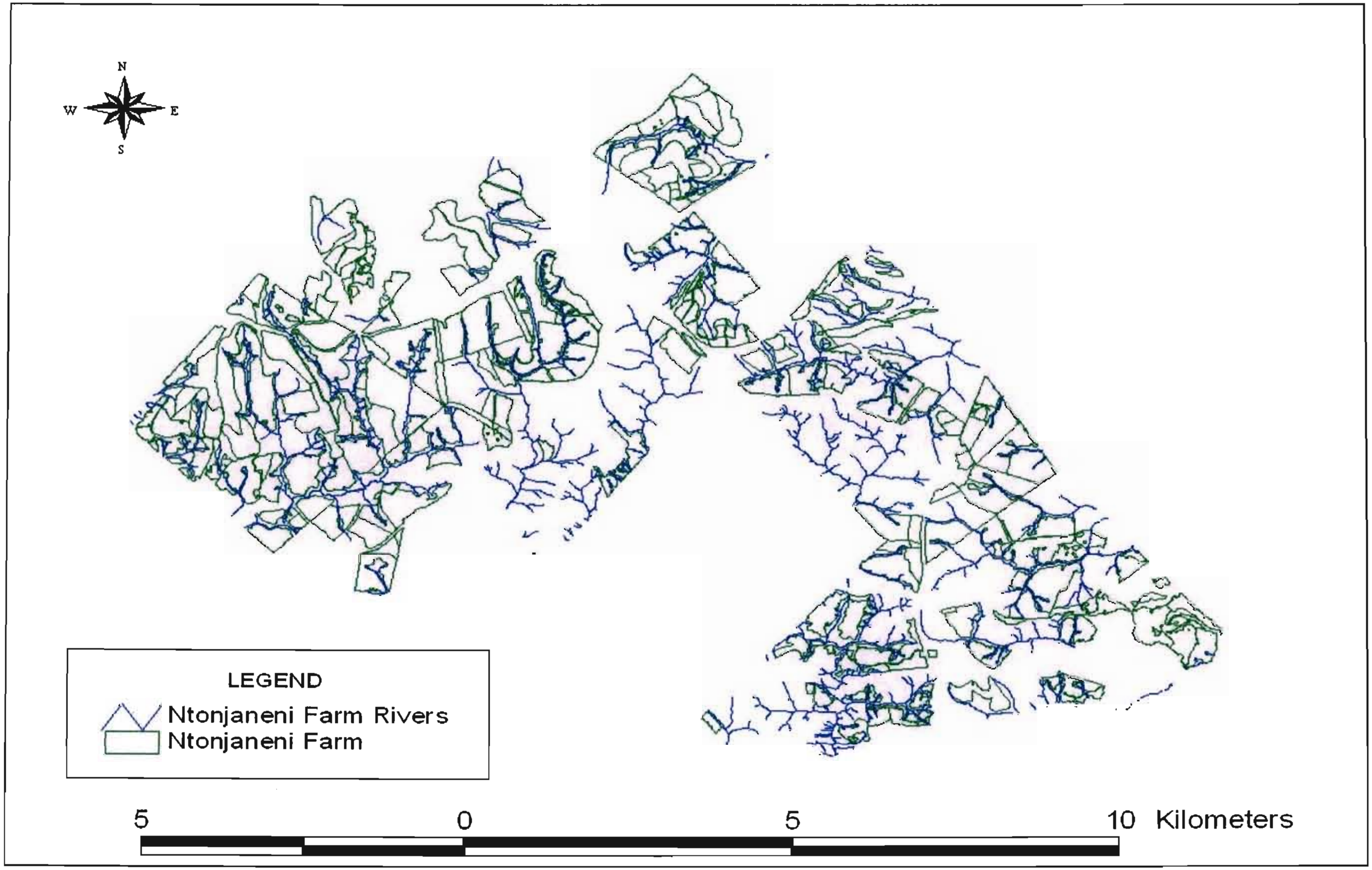


Figure 5.5 Ntonjaneni Rivers (with 30m buffers)

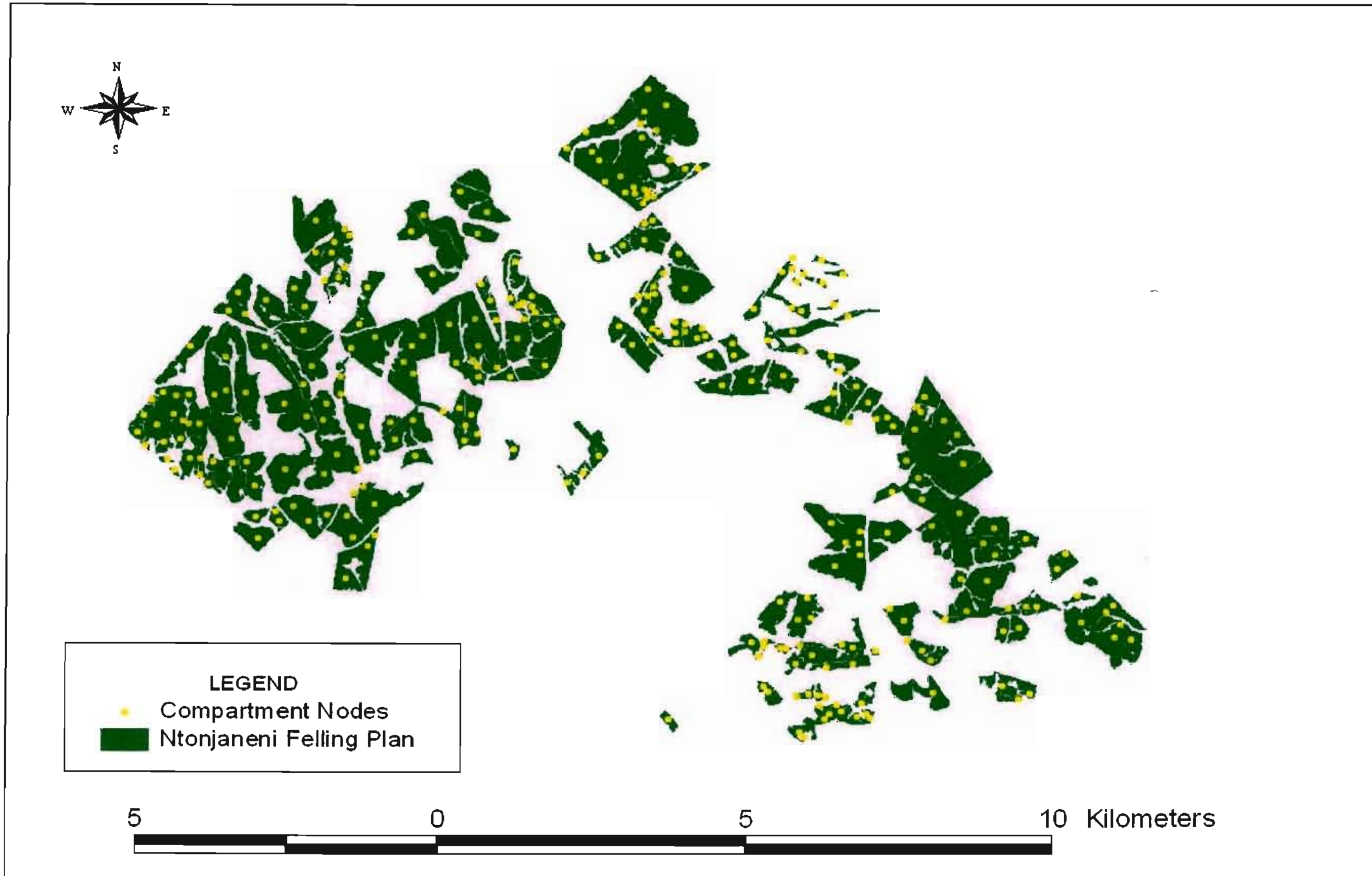


Figure 5.6 Ntonjaneni Fell Plan

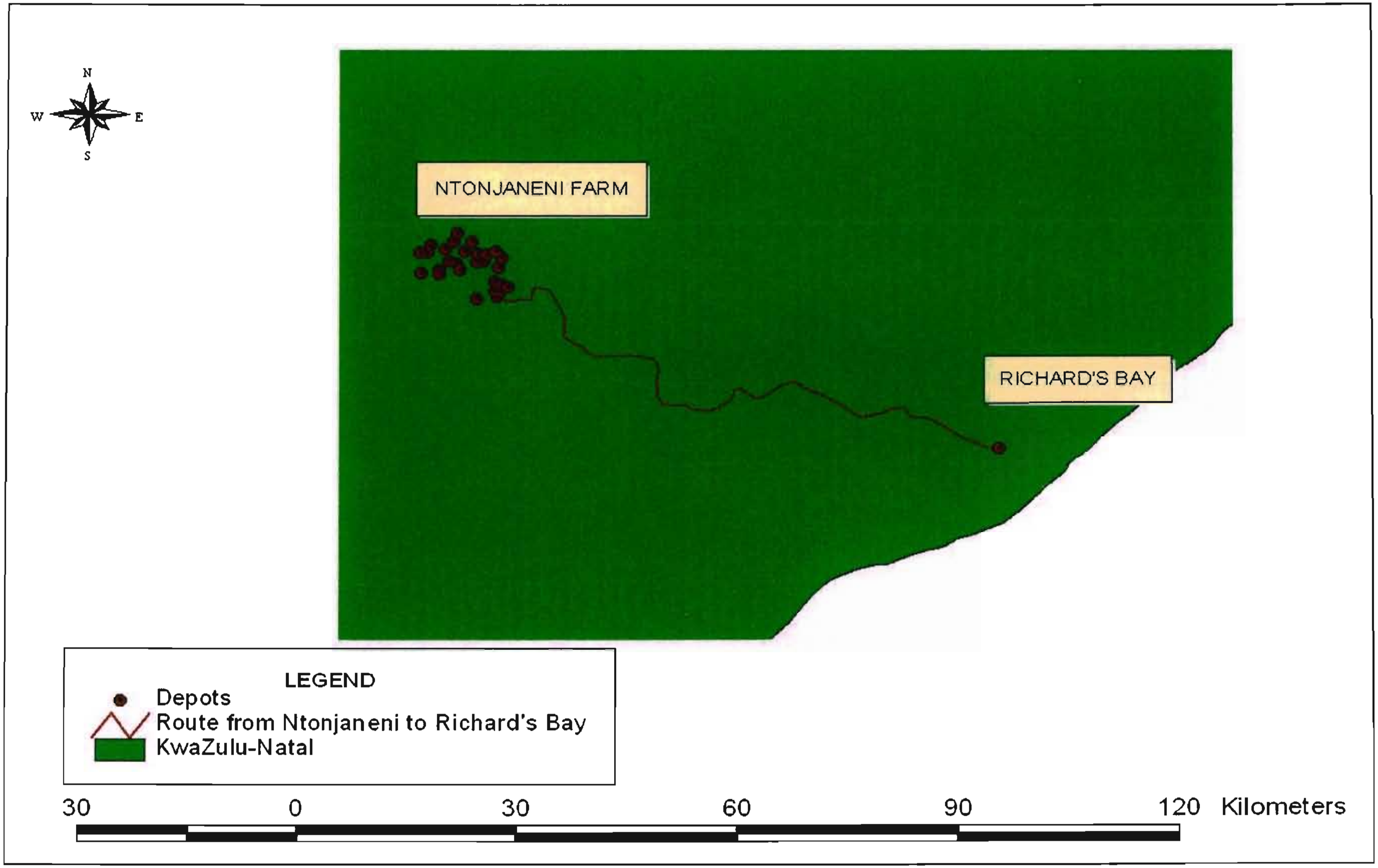


Figure 5.7 Ntonjaneni Depots

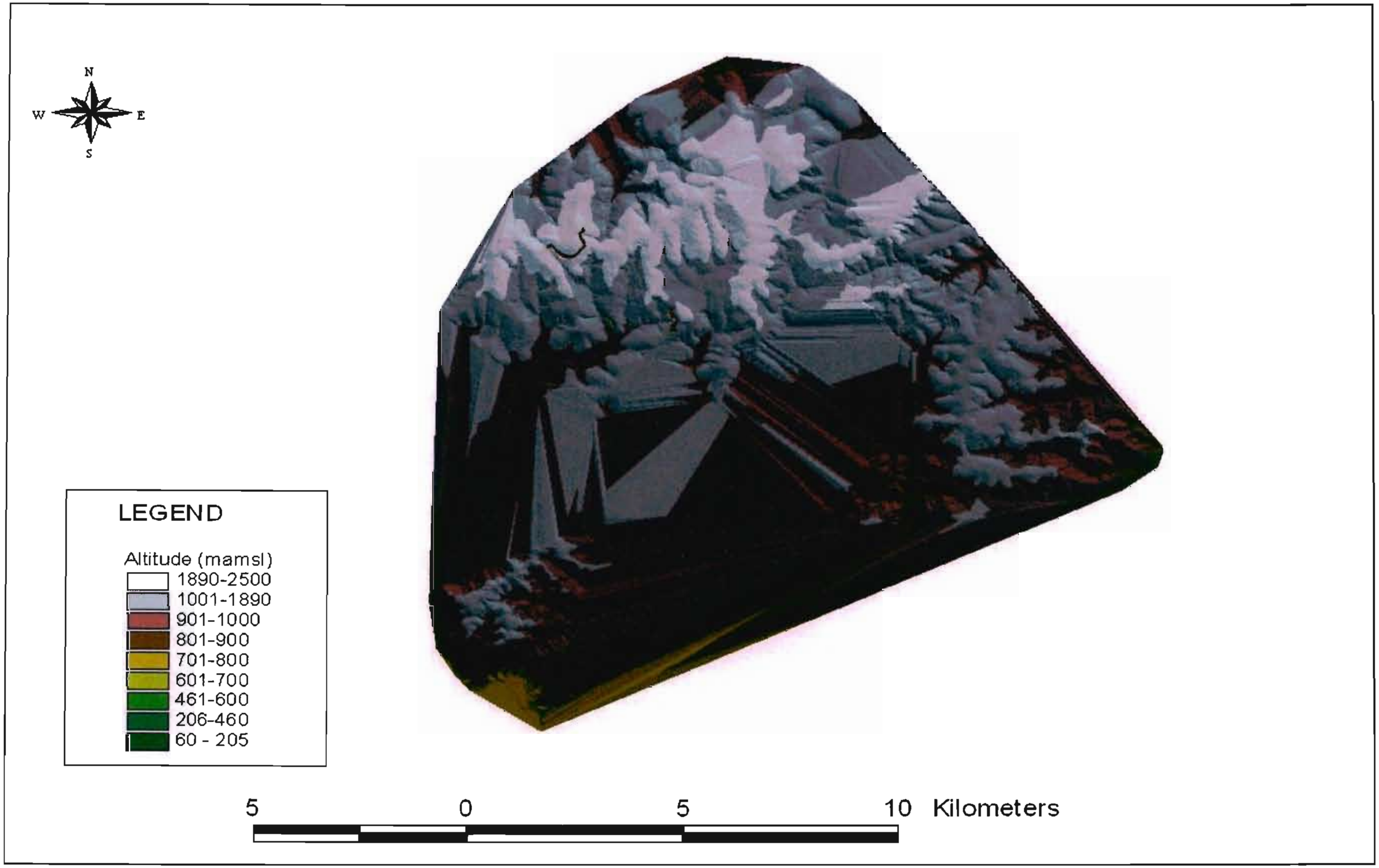


Figure 5.8 Ntonjaneni TIN

5.2.2.2 Ntonjaneni Derived Slope

The *Ntonjaneni Derived Slope* is illustrated by Figure 5.9, with the output slope grid representing the degree of the slope for each cell location, which ranges from 0 to 89.2 degrees.

5.2.2.3 Suitable slope

Based on the slope requirements of an acceptable slope being less than 12 %, a *Suitable Slope* is illustrated in Figure 5.10.

5.2.2.4 Shapefile Slope

Figure 5.11 illustrates the results of the Suitable Slope as it has been converted from a grid to a shapefile, so that it may suit the other data which is in vector format.

5.2.2.5 Ntonjaneni Acceptable Slope

Figure 5.12 reveals the final result of the Three Dimensional Modelling which is an acceptable slope for the Ntonjaneni Farm. The roads lying over this region are acceptable, as the slope is less than 12 %.

5.2.3 Route Network Analysis

5.2.3.1 Best Route from Depots to Mill

Figure 5.13 and Table 5, Appendix 1, illustrate the results of the best route from the depots to the mill. Table 5, consists of the following fields relating to the analysis, namely *Path ID, Origin, Destination, Cost at Origin, Cost at Destination* and the *Travel Cost Between Origin and Destination.* The results reveal an orderly routing from each depot towards the mill. From a cost perspective, it will cost R 508,10 for *Eucalyptus sp.,* to travel from the depots to the mill per trip and R 488.53 for *Pinus sp.,* to travel from the depots to the mill.

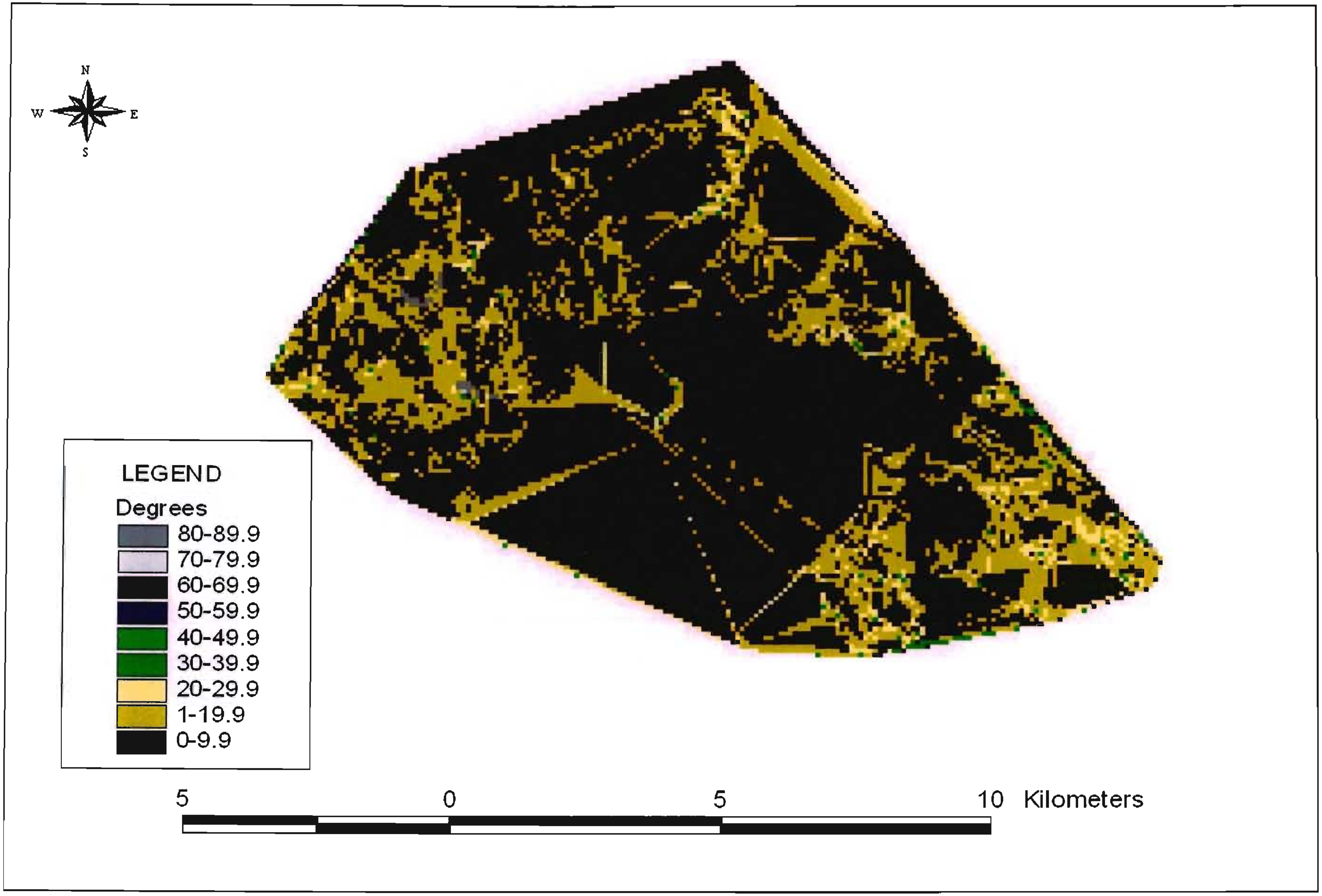

N
W
E
S
LEGEND
Degrees
80-89.9
70-79.9
60-69.9
50-59.9
40-49.9
30-39.9
20-29.9
1-19.9
0-9.9
5
0
5
10
Kilometers

Figure 5.9

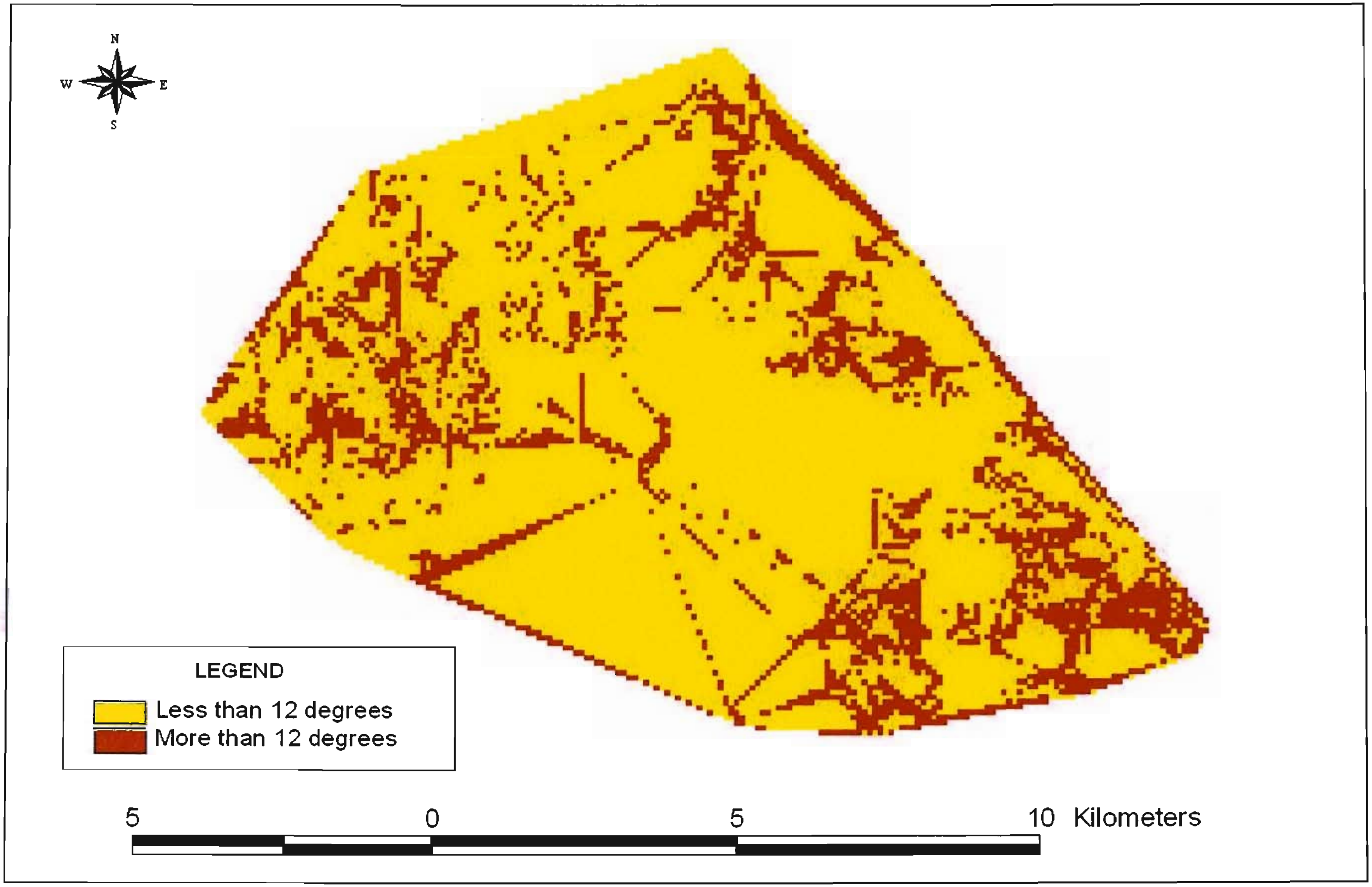

N
W
E
S
LEGEND
Less than 12 degrees
More than 12 degrees
5
0
5
10 Kilometers

Figure 5.10

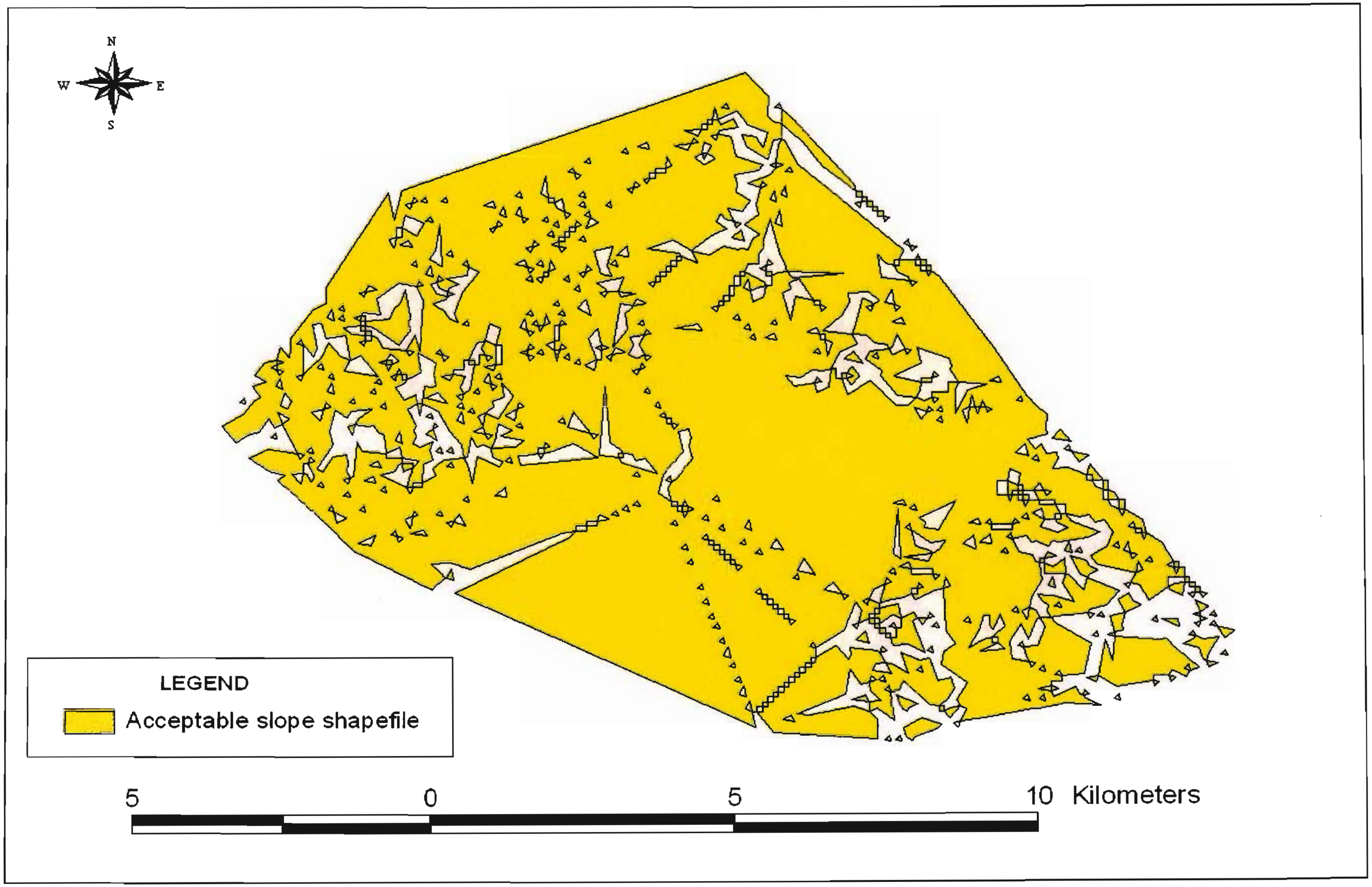
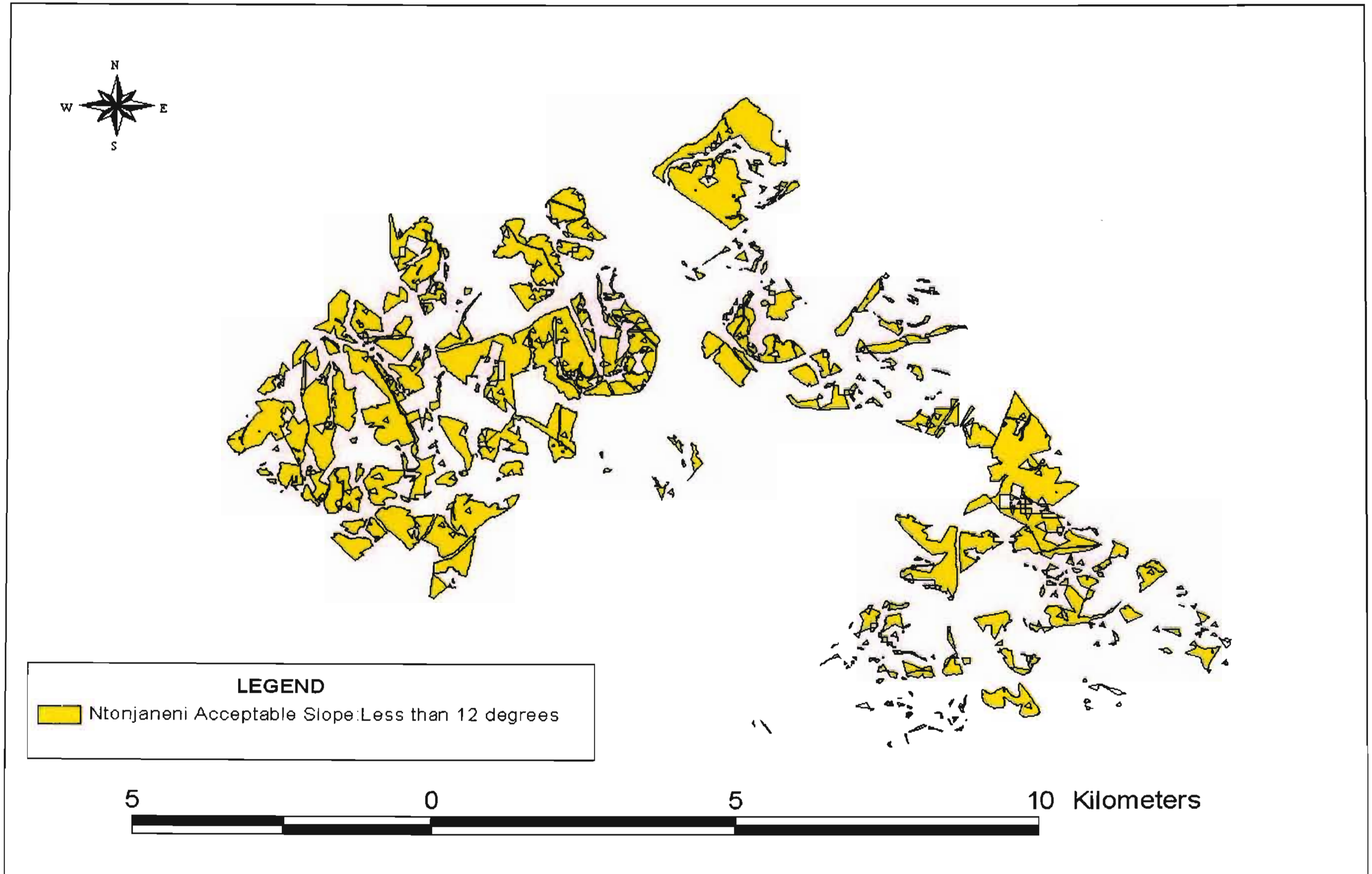


Figure 5.11


N
W
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LEGEND
Ntonjaneni Acceptable Slope:Less than 12 degrees
5
0
5
10 Kilometers

Figure 5.12

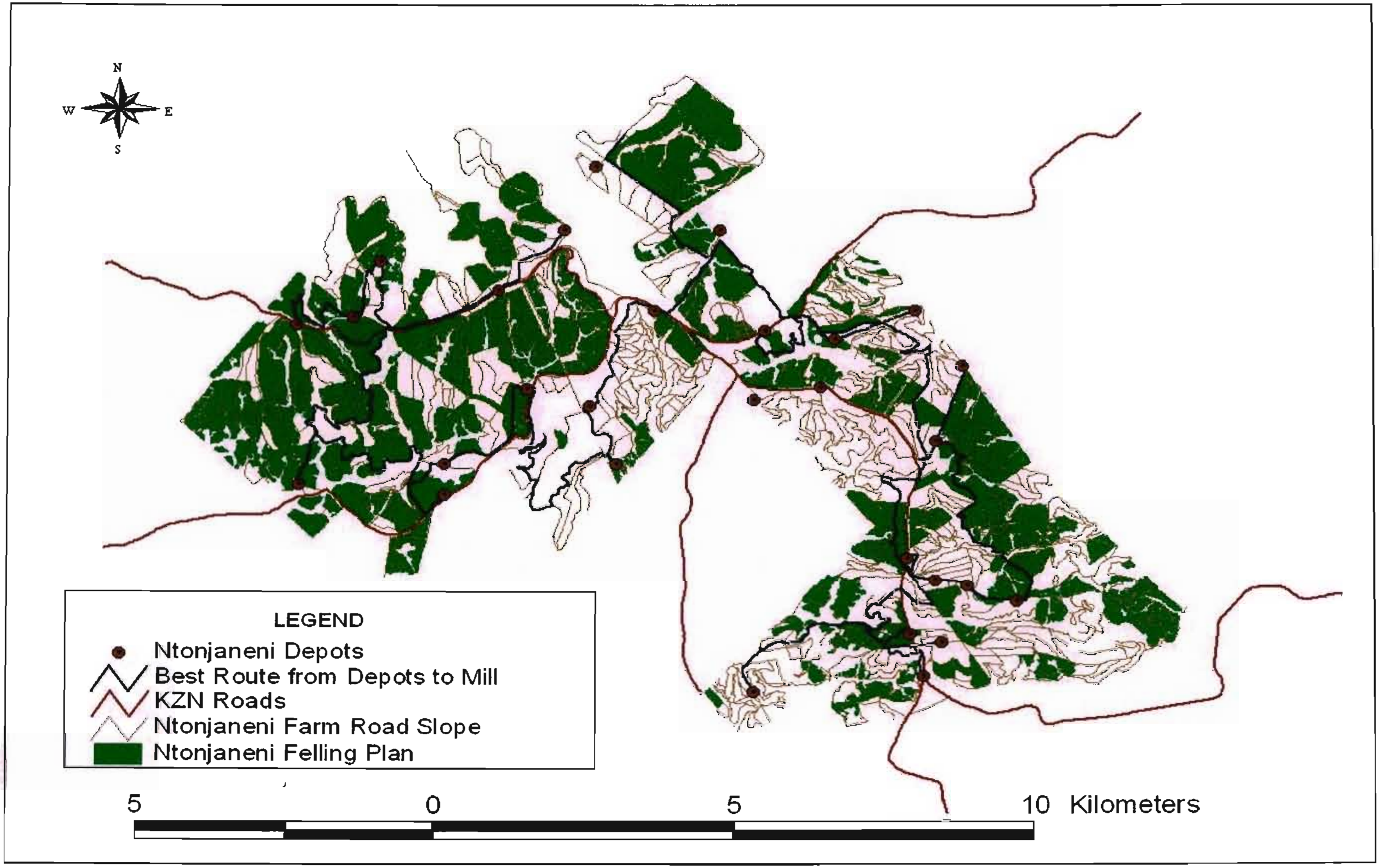

Figure 5.13 Route Network Analysis (Best Route from Depots to Mill)

5.2.3.2 Best Route from Plantation to Depots

Figure 5.14 and Table 6, Appendix 1 illustrate the results of the best route from the plantations to the depots. Table 6 consists of the following fields relating to the analysis, namely *Path ID, Origin, Destination, Cost at Origin, Cost at Destination* and the *Travel Cost Between Origin and Destination.* The results reveal that the total cost of trips required from the plantation to the depots, starting at each plantation and including each depot is R438.81 per trip.

5.2.3.3 Inaccuracy with Route Network Analysis

The RNA was performed, incorporating the Ntonjaneni Rivers (buffered to 30m) as well as the Ntonjaneni Acceptable Slope (less than 12%). Two routes were designed, the best route from the depots to the mill, and from the plantations to the depots. However, of concern is the route from the plantations to the depots, which when designed to include the Ntonjaneni Rivers and Ntonjaneni Acceptable slope, one notices that these two important factors have not been adequately considered by the RNA. Figure 5.15 reveals the inaccuracy indicated by the green circle where it is evident that roads have been designed on slopes which are unacceptable (ie. greater than 12 %) and in some cases lying within the buffered rivers. Originally it was stated that roads may cross the rivers, but not lie within the 30m buffered area. It is from this figure that one is able to determine that data relating to the Ntonjaneni rivers and Ntonjaneni Acceptable slope needs to be more detailed in order for an analysis to be accurate.

5.3 Project Management Plan

5.3.1 Project Feasibility Study

The feasibility study was performed considering what was outlined in the methodology, in order to enquire whether from an economic perspective, would it be beneficial to the organisation to apply RNA to the transportation system:

- The analysis will maximise profits as all costs will be more carefully controlled using RNA;

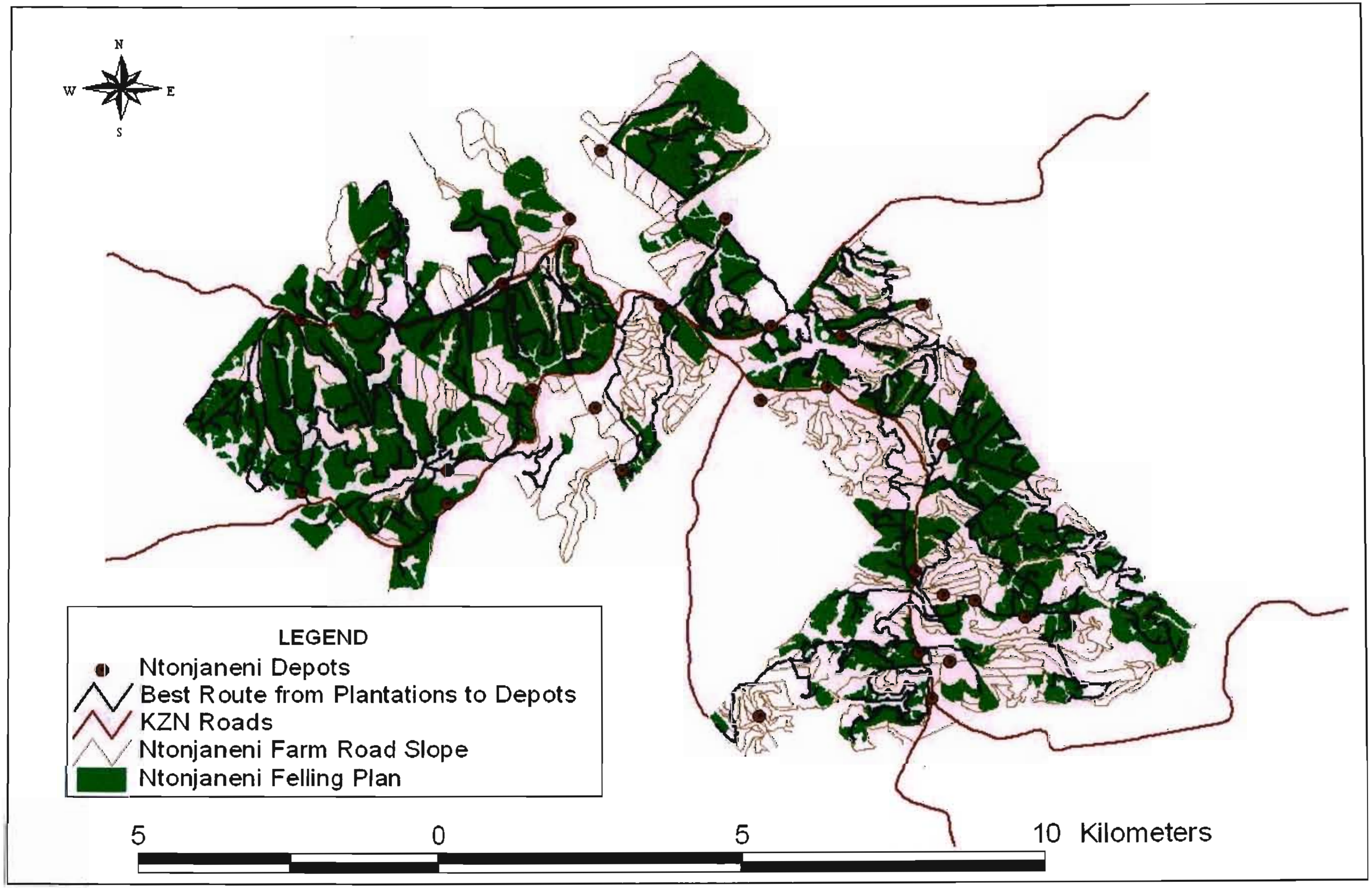

Figure 5.14 Route Network Analysis (Best Route from Plantations to Depots)

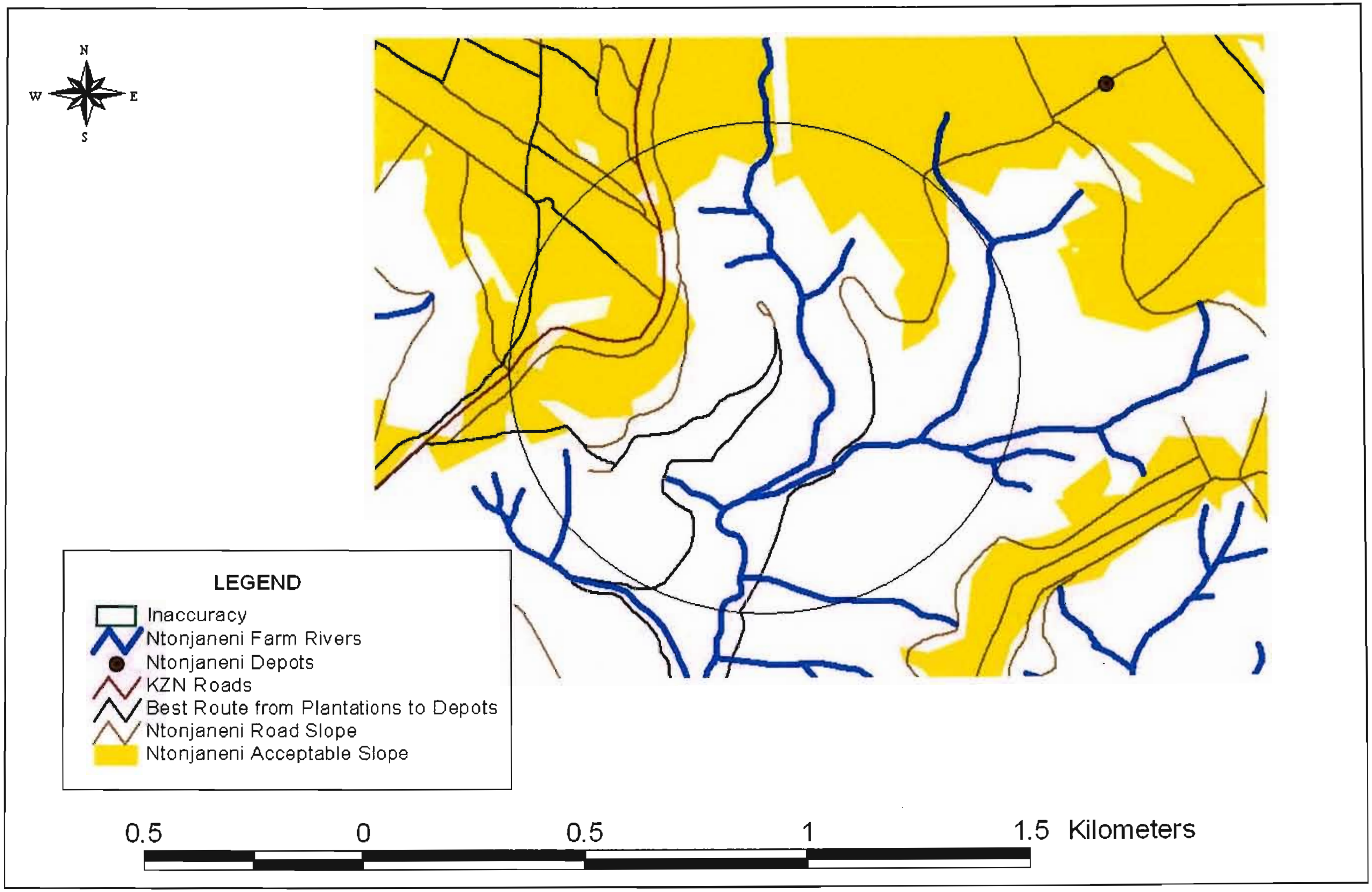

Figure 5.15 Inaccuracy with Route Network Analysis

- The analysis will maximise the utilisation of the workforce as it will indicate the exact requirements of each individual as well as their contribution towards the RNA;
- The analysis will maintain and increase market share by greatly improving profit, therefore increasing the market share;
- The analysis will maximise the utilisation of forestry equipment and roads as the RNA will create specific roads which should be used for transportation, as well as equipment;
- The analysis will improve the organisation's image as strategic planning planning and economic projections allow for the most current techniques and methods to be used;
- Although there are always various levels of risk and uncertainty involved with RNA, various precautions have been made in order to accommodate and mitigate the risk, therefore controlling uncertainty; and
- The organisation will be content with the results of the RNA, which will meet the strategic goals of the organisation, and greatly improve the economic efficiency of the organisation.

5.3.2 Project Charter

The project will aim to determine what data is required to perform RNA in order to optimise economic timber transportation. The explicit objectives of the project are:

- To clean the existing data into manageable categories;
- To seek advisor's opinion (Engineer, Logistics Manager and Environmentalist);
- To buffer the roads from an environmental perspective;
- To remove depots which are irrelevant to Ntonjaneni. Farm;
- To remove those portions of the road which are too steep; and
- To perform the RNA based on cost and time.

The stakeholders include the Client, Environmental Advisor, Civil Engineer, Logistics Manager, Project Manager and GIS Specialist.

Key dates have been stipulated in order to recognise that RNA is a useful and beneficial tool which can be used to reduce cost and time, based on the existing data of the Ntonjaneni Farm. The analysis for the Ntonjaneni Farm alone will take 5 days, this however will differ if applied to the entire company. The Milestones are illustrated by Figure 5.16.

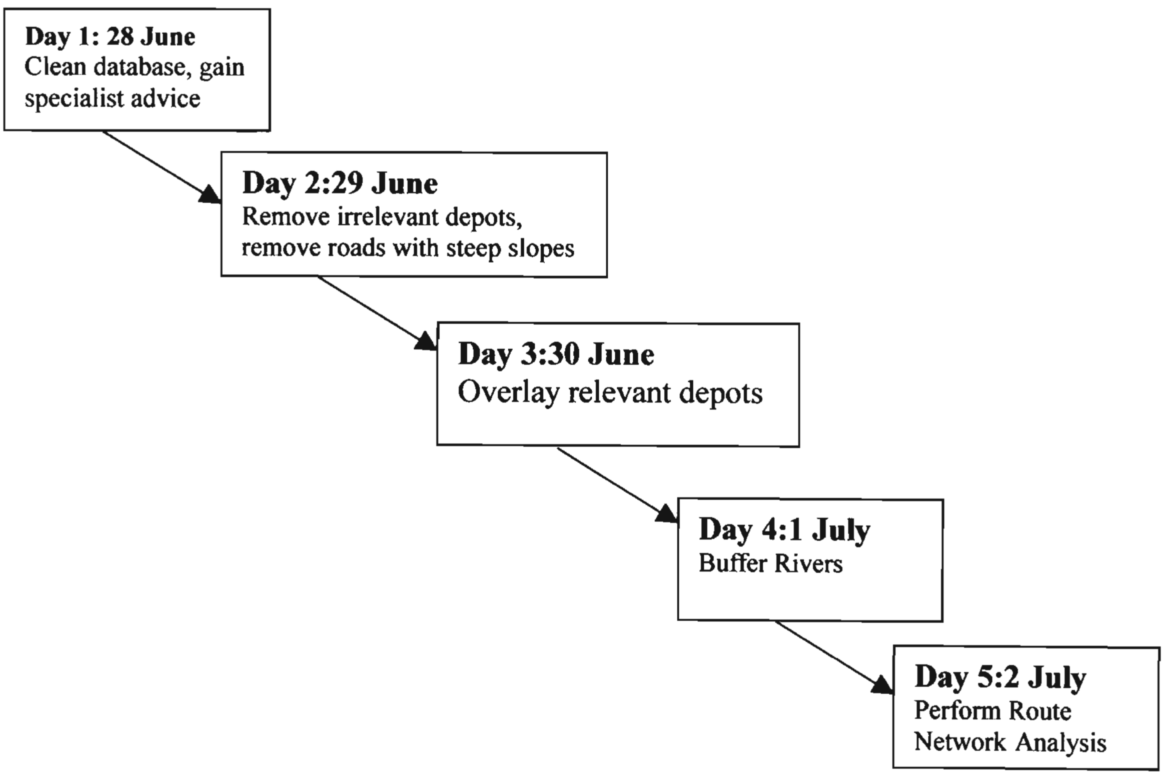

Figure 5.16 Milestones for RNA project.

5.3.3 Project Life Cycle

Table 5.1 illustrates the project life cycle for RNA. The successful completion of the RNA will be determined if each of the phases are completed accurately. Such phases include concept, design, implementation and commission.

Table 5.1 Project Life Cycle.

Concept	Design	Implementation	Commission
Input	**Input**	**Input**	**Input**
• Routing problem within forest farm • Briefed on main objectives and project charter	• Approval to go ahead with the analysis • Design and develop the project	• Approval to implement RNA	• Project commissioning plan, notification of completion of the project
Process	**Process**	**Process**	**Process**
• Gather data • Identify the need for RNA • An estimate of resources, risk, feasibility	• Develop a detailed work schedule, WBS, CPM and budgets • Develop a baseline plan	• Set up contract and communications as well as clear lines of work packages, a detailed schedule, information control	• Start-up and test the product • Has RNA solved the existing Routing system by providing a new network system?
Key Activities	**Key Activities**	**Key Activities**	**Key Activities**
• Stakeholders identified • Cost facilities in abundance for project	• Model the project and to create a suggested final product	• Execute the plan of the project, adhering to rules/conditions previously stipulated	• Finalise the RNA • Transfer product responsibilities • Evaluate Project • Document Results
Hold Points	**Hold Points**	**Hold Points**	**Hold Points**
• None	• Justification of project rejected	• Contract and instructions not being adhered to	• The product incomplete and failed
Output	**Output**	**Output**	**Output**
• Feasibility study • Project Execution Plan • Milestones/Project achievements	• Baseline Plan • Project Design • Project Schedule	• Certificate of completion • Quality control certification	• Closeout Report
Approval	**Approval**	**Approval**	**Approval**
• Approval to go ahead with the project	• The go ahead to implement the project	• Ready to commission	• Project accepted by the client

5.3.4 Project Budget / Estimates

The Budget for the RNA project for the Farm is shown in Table 5.2. It is evident that a total of R280 000 is required for the RNA to be performed, with the organisation acquiring a profit of R 57 000, once the contingency has been included.

Table 5.2 Project Budget / Estimates

WBS	**Description**	**Budget**	**Contingency**	**Total**
1.1 Data Analysis	Clean the data and perform the analysis	R 120 000	R 5 000	R125 000
1.2 Advisors	To make necessary recommendations	R 60 000	R 10 000	R 70 000
Project Management Fee	To oversee the project	R 25 000	R 3 000	R 28 000
Sub-total		**R 205 000**	**R 18 000**	**R 223 000**
Profit	Contingency included	**R 57 000**	**n/a**	**n/a**
Total		**R 262 000**	**R 18 000**	**R 280 000**

5.3.5 Cash Flow

The total amount of money required for the RNA is reflected as Cash Flow in Figure 5.17, which in addition, suggests how the cash should flow during the duration of the project. This can then be compared with the Budget / Estimates, showing that the project was well managed in terms of monetary value, in that a total of R 225 000 was expended, therefore the company actually made a profit of R 57 000 during the RNA.

5.3.6 Work Breakdown Structure

The Work Breakdown Structure (WBS) is illustrated in Figure 5.18 In addition Figure 5.19 illustrates the Gantt Chart which provides an additional planning aid to the WBS.

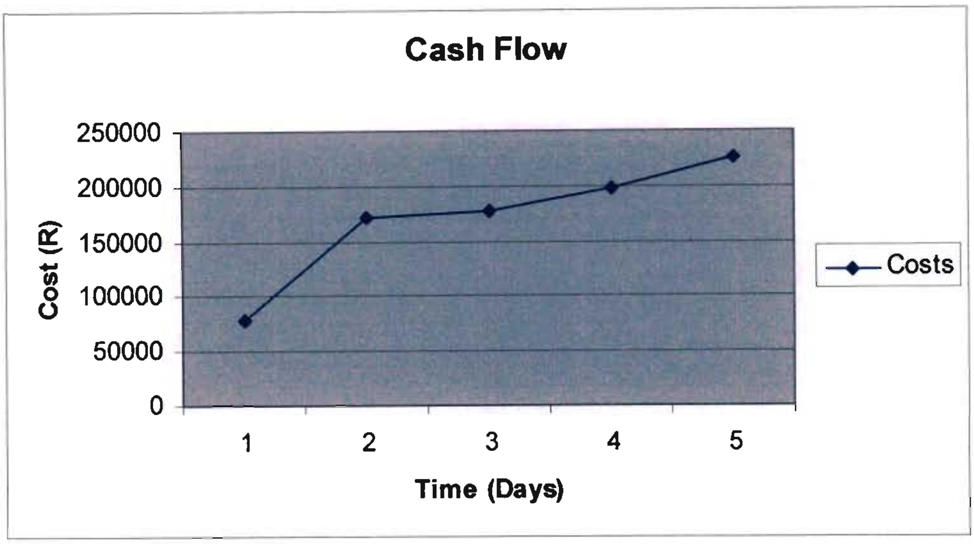

Figure 5.17 Cash Flow for RNA

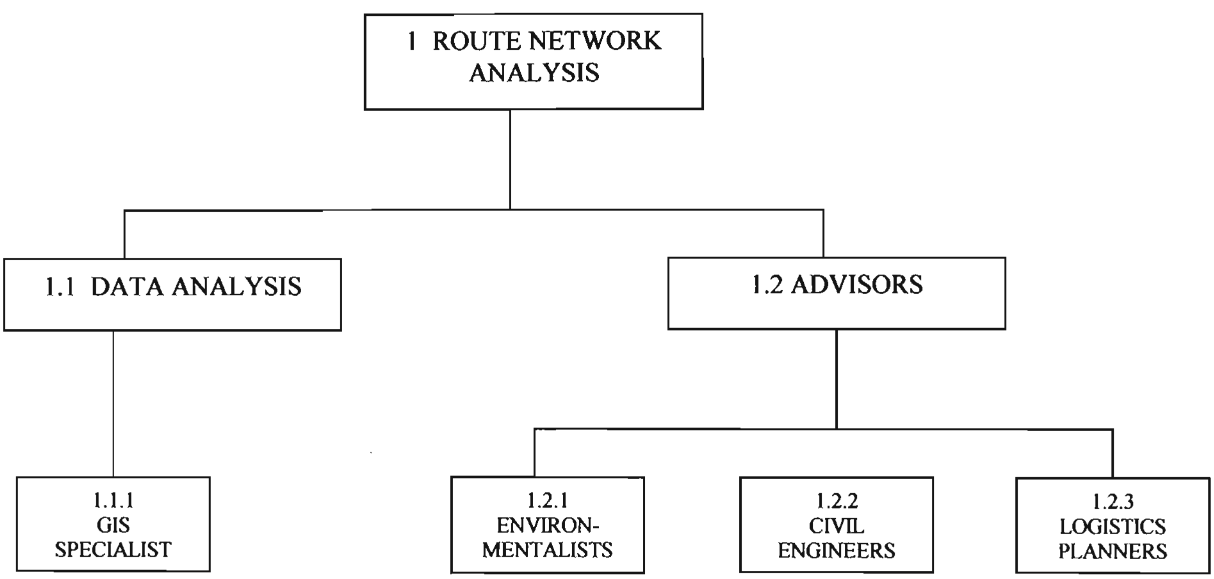

Figure 5.18 Work Breakdown Structure (WBS)

ID	Task Name	Duration	Start
1	Clean the dataset and add specialist advice	1 day	Mon 28/06/04
2	Remove irrelevant depots	0.5 days	Tue 29/06/04
3	Remove roads with steep slopes	0.5 days	Tue 29/06/04
4	Overlay relevant depots	1 day	Wed 30/06/04
5	Buffer rivers	1 day	Thu 01/07/04
6	Perform route network analysis	1 day	Fri 02/07/04

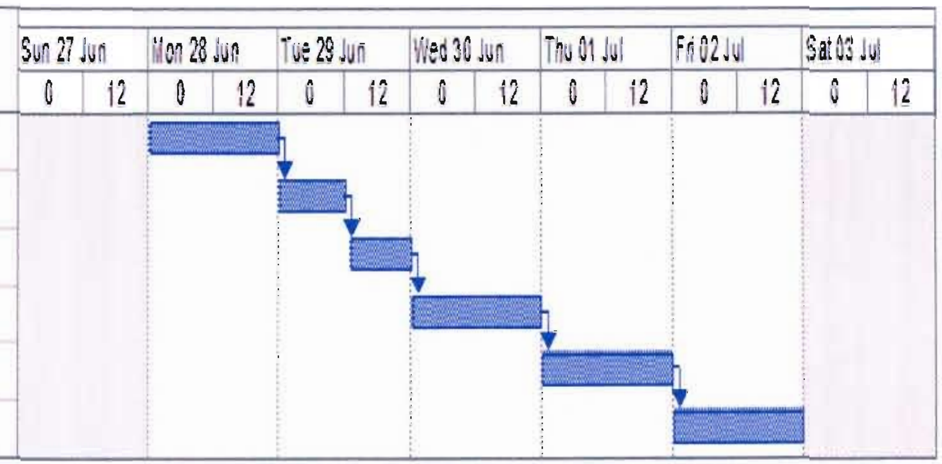

Figure 5.19 Gantt Chart

5.3.7 Critical Path Method

The Critical Path Method (CPM) is illustrated by Figure 5.20 in descriptive words, whilst Figure 5.21 describes the Critical Path using functions of Early Start, Early Finish (Forward Pass), Late Start, Late Finish (Backward Pass) and Float.

There was no float as there is no surplus time within this project's activity scheduling. It is clear that if the project should start late, for some unknown circumstance, the project may still finish within the allocated time of five days.

5.3.8 Resource Planning

The resources for the RNA are reflected in Figure 5.22. The work activities are illustrated against the resources required per day. This allows the employees a clear visual understanding as to how many human resources are needed per day. It is evident that four human resources are required on the first day, the advisors who give specialist advice, as cleaning the database and seeking specialist advice would require more resources than buffering the rivers on the fourth day, which requires a GIS Specialist.

5.3.9 Project Risk Management

The risk which can be anticipated for the RNA is illustrated by Table 5.23. During the data analysis and advisor's stage, there is a risk of employees becoming ill, therefore preventing the project from being completed within the five days as anticipated. To avoid this, one needs to employ 'stand-by' specialists who will be able to replace those originally appointed for the position. Other risks during the data analysis is the likelihood that the data is inaccessible or corrupted, as well as the possibility of the hardware crashing. Therefore, one needs to be prepared for this and implement efficient back-up and hardware systems.

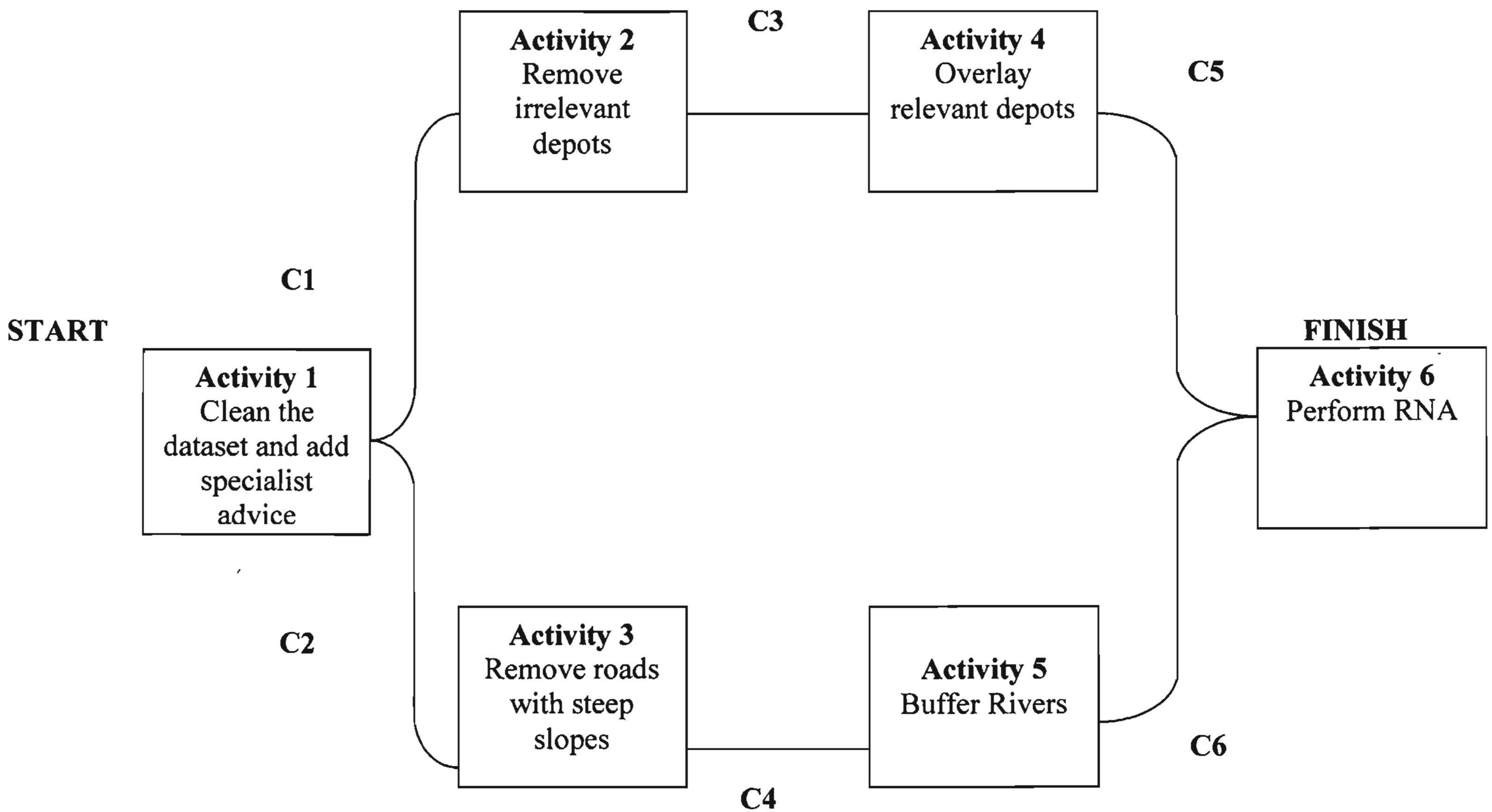

Figure 5.20 Critical Path Network (descriptive)

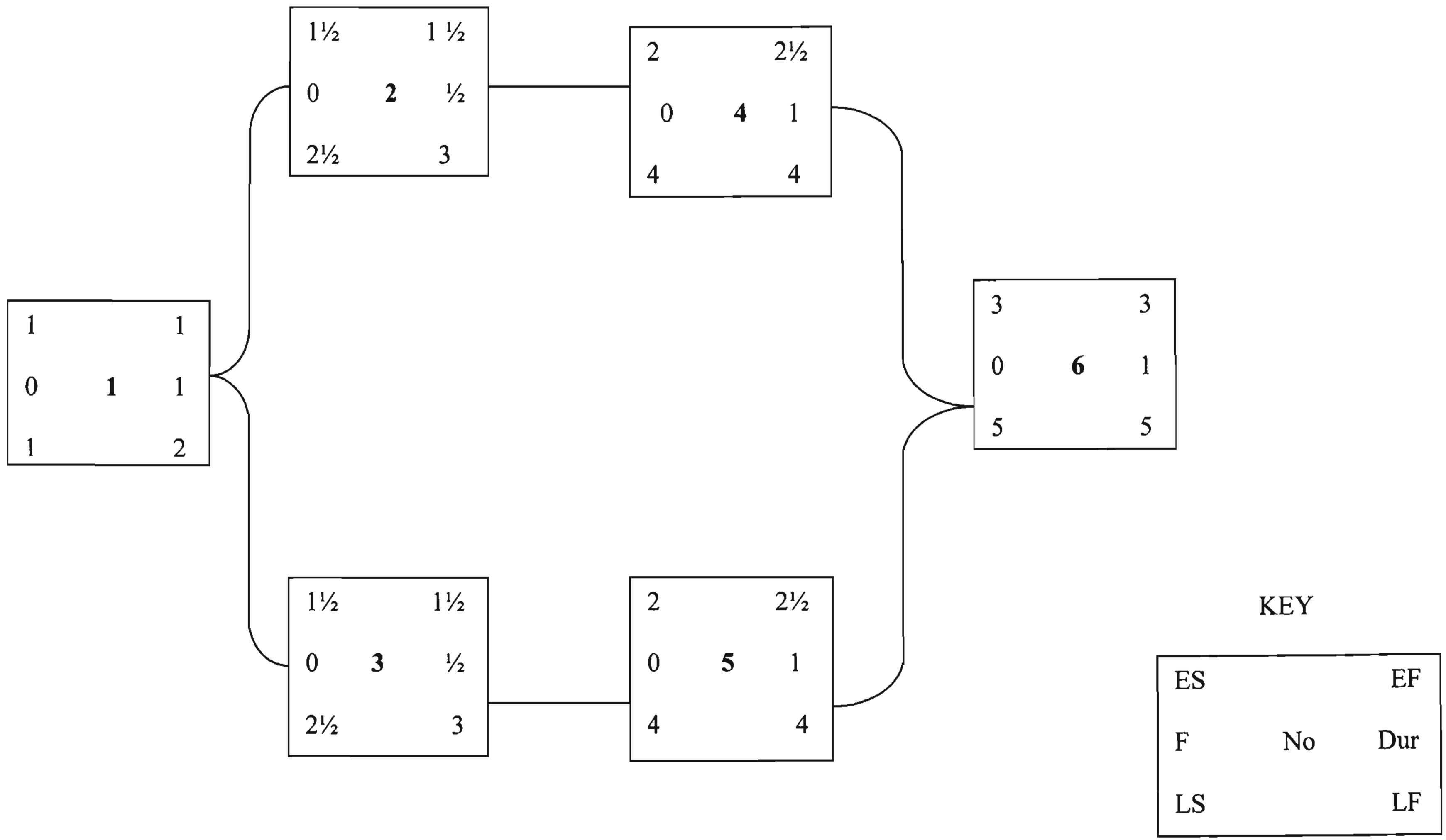

Figure 5.21 Network Diagram

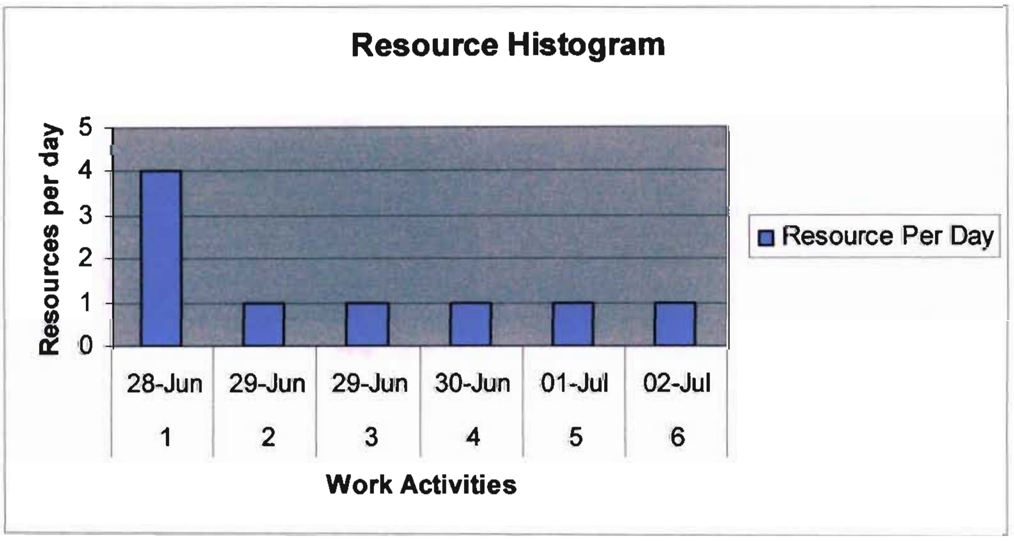

Figure 5.22 Resource Histogram

Table 5.3 Risk Management Plan

WBS	OBJECTIVE	RISK	RESPONSE	MITIGATE
1.1 **Data Analysis**	a) To clean the existing data and to include the advisors information to undertake a Route Network Analysis of the Ntonjeni farm. b) To perform the Route Network Analysis	a) The GIS specialist becoming ill. b) The data being inaccessible or corrupted or an element of the hardware crashing.	a) To employ a 'stand-by' GIS specialist since the project has a short time-frame. b) To have a computer technician available to rectify the situation, if need be.	a) To ensure that an attractive and accepted salary is offered to GIS specialist, making the work more attractive and paying him for his skill; or to have a database of many skilled GIS specialists. c) To back-up data, attain the most modern hardware and software, including virus checks and efficient back-up.
1.2 **Advisors**	To provide useful information with regards to the structural, environmental, logistics and future planning of forestry roads.	a) One of the advisors becoming ill.	a) To employ a 'stand-by' advisor since the project has a short time-frame.	a) To ensure that an attractive and accepted salary is offered to GIS specialist, making the work more attractive and paying him for his skill; or to have a database of many skilled GIS specialists.

5.3.10 Quality Management

Table 5.4 illustrates the quality management plan for RNA, as well as the necessary procedures which need to be undertaken in order for quality standards to be met. Such standards include each phase being inspected by either the client or advisor, to decide whether the phase can be regarded as satisfactory, or whether it needs to be put on hold and re-inspected.

Table 5.4 Quality Management Plan

Activity	Description	Spec	Level of Inspection	Sign Off
1	Clean the dataset and add specialist advice	Client	Hold	
2	Remove irrelevant depots	Advisor	Witness	
3	Remove roads with steep slopes	Advisor	Witness	
4	Overlay relevant depots	Advisor	Witness	
5	Buffer Rivers	Advisor	Witness/ Hold	
6	Perform RNA	Client	Inspection	

5.4 Discussion of results

The RNA performed on the Ntonjaneni Farm has created a less dense transportation system, which has reduced the large amount of road which previously existed on the Ntonjaneni Farm, before the analysis was performed. The roads which now no longer form part of the network should be abandoned and replaced with compartments which once re-planted and harvested, will reap more economic returns.

5.4.1 Shortcomings of the software

ArcView 3.3, with extensions of Network Analyst as well as Spatial and 3D Analyst, has been criticised for not being powerful enough to facilitate transportation models. (Salhotra, undated). This has proven correct, as ArcView 3.3 has not allowed the adequate inclusion of the *Ntonjaneni Acceptable Slope (gradient)* as well as the *Ntonjaneni Rivers.* However, should the data have been more detailed, it is assumed that the RNA could have been performed accurately.

5.4.2 Data which needs to be sourced

The RNA has been performed, with the inclusion of the project management guidelines. Although the RNA has produced the most optimal route, it has not included the environmental considerations of the rivers and varying speed of the roads influenced by a chance of road slope. The data is therefore incomplete and additional data must be sourced for future RNA to be successful and accurate.

The Ntonjaneni Rivers have been buffered according to a 30m suggested environmental recommendation, however this information is not sufficient and more data pertaining to the Ntonjaneni Rivers needs to be collected. This is because some roads are designed to travel alongside the buffered rivers, when in fact they may only cross the buffered rivers. Data relating to the river volume, drainage density and velocity, for example; would provide accurate recommendations from an environmental perspective, with regards to erosion, and the maximum pressure which can be applied to the Ntonjaneni Farm roads.

The data relating to the change of speed of travel due to the influence of gravity needs to be sourced. Such data would assess a more accurate route for transportation of the timber from the plantations to the depot and then to the mill at Richard's Bay.

The data relating to the Ntonjaneni Fell Plan indicates the Area which is covered by timber which applies to each compartment, however there is no indication as to how many tons need to be transported from each compartment. This can be calculated using the stand density and the area of each compartment.

5.4.3 Project Management Plan

The results from the project management plan provide an excellent project outline and a guide as to how a RNA should be performed on the Ntonjaneni Farm. It is clear that the project plan ensures that cost, time and quality are carefully controlled in order to improve the economic status of the project. It is evident that a project of this calibre does require an input from a variety of stakeholders as well as employees, and provides an outline as to how the analysis should be undertaken as well as how to ensure that each member is allowed to deliver their knowledge so as to achieve an effective and competent RNA.

5.5.4 Achieving the objectives of the study

The results confirm that the RNA has achieved and fulfilled the objectives stated at the start of the study:

- ArcView 3.3 with the inclusion of the Route Network Analyst Extension and Spatial Analyst, and the necessary data for Route Network Analysis were sought;
- The best route from the depots to the mill at Richard's Bay was established, as well as the best route from the plantations to the depot;
- A project management plan for the implementation of RNA for Ntonjaneni Farm was established; and
- Additional data was identified in order for the success of future RNA to include all factors affecting a forestry transportation system.

5.6 Summary

The results from the RNA and related project management plan have achieved the objectives of the study, finding the best route from the depots to the mill and from the plantations to the depots. ArcView 3.3 has proved to be an adequate tool for RNA. It is evident that although the routes have been established, they are not entirely accurate in terms of including all the necessary parameters. What the RNA has failed to incorporate are data relating to the environmental condition of the rivers and variance of speed affected by the slope of Ntonjaneni Farm. It is evident that the aim of the dissertation has been achieved by identifying what data is required to perform a successful RNA.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

In order to determine whether the study has been successful, it is imperative to review the aim of the study, which was to determine the type of data required to perform RNA, in order to optimise economic timber transportation. This has been achieved by firstly, identifying the need for applying RNA to commercial forestry transportation in South Africa. Studies performed in India and Malaysia motivated the application, as RNA improved planning as well as greatly improved the economic efficiency of each area. An applicable forestry farm, which was identified as having a transportation problem was Ntonjaneni Farm, near Melmoth on the North Coast of KwaZulu-Natal in Zululand. An appropriate software model for transportation routing was selected which would as a second requirement, analyse the existing data to determine the type of data required in order for RNA over five days to be effectively performed on a five year felling plan, from an environmental and economic perspective.

6.1.1 Data manipulation and analysis

The existing data relating to the Ntonjaneni Farm was analysed and manipulated in order to produce accurate spatial data, as well as the inclusion of the databases relating to the spatial displays. The data required a large amount of correction as well as assessing the error and inaccuracies which are associated with the application of GIS to a RNA.

6.1.2 Route Network Analysis

Using the ArcView 3.3 software, as well as its 3D, Spatial and Network Analyst extensions, vector data were incorporated to provide the best route from the depots to the mill, and from the plantations to the depots, by incorporating environmental buffering guidelines as well as the influence of slope on the network. The results confirm that a considerable amount of data needed to be updated and acquired in order to ensure that RNA be effectively performed in the future. Such data includes data relating to rivers, in terms of their drainage and erosive qualities, as well as data relating to the variation of speed along each road segment. However, the project management plan which was developed to ensure that the cost, quality and time factors ensuring economic optimisation, were emphasised and incorporated with the RNA, have proved successful and should be considered for future projects.

The findings relating to the application of RNA to a current transportation system from an economic perspective were similar to that of Anjaneyulu *et al.*, (undated), when applying RNA to Calicut City, India and Musa & Mohammed's (2002) application of RNA to the Ulumuda forest in Malaysia. Such findings, including this study, emphasises that RNA is an acceptable and modern technique for transportation optimisation.

6.1.3 Minimising the Gap

Hensher & Button (2000) mentioned that it is imperative to try and close the gap between the state-of-the-art theory and the application associated with it. The RNA therefore minimises this gap, and is not a design purely of academic interest, but also a model which can be applied to real-life decision making for forestry companies in the future. In addition, the model provides a graphical illustration of the data as well as providing attribute data which can be used to base imperative decisions upon.

In summary, it is the improvement of technology which optimises economic performance. The technology used for RNA has been optimised and as a result an analysis based on time, cost and quality adds to the effectiveness of the transportation system of Ntonjaneni Farm. Therefore, from an economic perspective the study has greatly improved the economic potential of Ntonjaneni Farm. However there are considerations for the adjustments and acquisition of data.

6.2 Recommendations

It has been proven that RNA is a very powerful tool for solving transportation problems, as well as optimising a forestry company's economic status by improving the cost, time and quality spent on such a process. However, the study had limited success in incorporating various factors relating to a network, such as the environmental aspect of the buffering of rivers as well as the variation of gradient which in turn influences the speed and time travelled on the roads. This has huge implications on the cost of transportation. However, the study was successful in identifying what data is required for future RNA in forestry applications. Once the Ntonjaneni Farm RNA has been performed with the additional data which has been suggested, and proven successful, it can be applied to all forestry farms within the forestry organisation, if all the data is available. This will then be a useful application, in conjunction with project management, to fuel an entirely new route system, as it would be more beneficial to perform RNA based on a new road system, instead of basing the RNA on the existing road system, as performed in this study.

In addition, the analysis may be of greater benefit in the future if research was applied to all spheres of forestry transportation which ensured that costs are minimised. Therefore future recommendations of the study would ensure that in addition to correcting and acquiring the data suggested from the study, research should, according to Anon. 2, (2004) focus on:

1) Load distribution: Ensuring that the exact legal payload capacities and loading parameters are met.
2) Vehicle performance: By incorporating various simulations, accurate distances, trip time, vehicle suitability for realistic costing calculations as well as fuel consumption can be recorded.
3) Estimation of Operating Costs: Technical simulations can convert operational data into accurate fixed and variable cost predictions, for example, ensuring valid, real-time cost inputs.
4) Vehicle Specification Comparison: Transportation planning needs to incorporate the most current and cost-effective means of transportation which is continually being improved for cost optimisation and safety.
5) Vehicle Tracking: The use of both on-board computers, monitoring and recording vehicle trips data and driver behaviour; as well as satellite active tracking for vehicle recovery, are two very new and evolving facets which improve the cost related to forestry transportation.

Additionally, Hensher & Button (2000) suggest that future RNA should focus on detailed server-based dynamic routing which is based on the current network traffic conditions with instructions relating to the network, including GPS (Global Positioning Systems) vehicle-tracking data. In addition, the topography and gradient can be coded using both formal and widely recognised transportation feature identifiers, to allow vehicle routing to be performed without the reliance of maps and directional devices.

Such recommendations for future RNA in forestry applications, can be noted by forestry farm owners and management of how RNA can be applied to particular farms or all farms in the organisation, in order to reduce cost and to produce a road network which is less dense and effective. Such information can be noted by engineers in terms of the planning and design of roads, by applying the most current and accurate information to avoid cost and to keep maintenance to a minimum on a designed route. Even if it is at first a costly exercise, it will in turn provide economic benefit. In addition, policy makers within the forestry industry should take note of the modern and effective methods of RNA and project management and encourage the inclusion of such practices in legislation, planning and decision making.

6.3 Conclusions

The application of RNA and project management to the Ntonjaneni Farm near Melmoth has proved partly successful, by reducing the haphazard array of existing roads, to create a minimalist, less dense transportation system which provides the best route from the depots to the mill, and from the plantations to the depot. However, there have been various shortcomings as the RNA does not successfully include the buffered rivers and variance in slope. The suggestions laid out for future RNA will assist further researchers or commercial employees to seek complete data, particularly relating to rivers and the road slope. Because Ntonjaneni was a representation of most commercial forestry farms in South Africa, many commercial forestry organisations should consider the application of RNA and project management to their farms for greater economic transportation optimisation.

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APPENDIX 1

Table 1 KZN Roads

ROADKEY	ROADNUM	MEASURELENGTH	CLASS	R/T/KM_Eucalyptus.sp	R/T/KM_Pinus sp.	SPEED (k/hr)	TRAVEL TIME(MINS)
1272	D28	1.513	D	6.05	5.75	80	1.89
1276	D133	8.962	D	35.85	34.06	80	11.20
1280	D139	9.271	D	37.08	35.23	80	11.59
1285	D265	1.101	D	4.40	4.18	80	1.38
1295	D447	4.835	D	19.34	18.37	80	6.04
1297	D466	11.437	D	45.75	43.46	80	14.30
1300	D491	8.107	D	32.43	30.81	80	10.13
1302	D512	6.701	D	26.80	25.46	80	8.38
1305	D552	2.068	D	8.27	7.86	80	2.59
1311	D779	1.896	D	7.58	7.20	80	2.37
1315	P2-4	47.301	P	189.20	179.74	80	59.13
1317	P47-3	56.667	P	226.67	215.33	80	70.83
1318	P47-4	46.449	P	185.80	176.51	80	58.06
1319	P47-5	21.136	P	84.54	80.32	80	26.42
1320	P48	70.490	P	281.96	267.86	80	88.11
1321	P50-1	26.315	P	105.26	100.00	80	32.89
1322	P50-2	54.129	P	216.52	205.69	80	67.66
1323	P50-3	33.817	P	135.27	128.50	80	42.27
1324	P52-1	25.655	P	102.62	97.49	80	32.07
1325	P90	28.229	P	112.92	107.27	80	35.29
1326	P106	13.123	P	52.49	49.87	80	16.40
1330	P225	9.994	P	39.98	37.98	80	12.49
1331	P226	21.290	P	85.16	80.90	80	26.61
1332	P227	16.632	P	66.53	63.20	80	20.79
1336	P243	4.729	P	18.92	17.97	80	5.91
1338	P250	24.506	P	98.02	93.12	80	30.63
1340	P260	3.437	P	13.75	13.06	80	4.30
1344	P326	9.574	P	38.30	36.38	80	11.97

Table 2. Ntonjaneni Farm Roads

CLASS	R_KEY	ROUTE_NO	FARM_CODE	OBJECTID	R/T/KM_Eucalyptus sp. and Pinus sp.	SPEED(k/hr)	LENGTH_KM_	TIME_MINS
C	3312100014	0014	331210	162629	1.27	40	1.66	2.07
C	3312102293	2293	331210	72019	1.27	40	2.42	3.02
C	3312100595	0595	331210	69305	1.27	40	5.05	6.31
C	3312100576	0576	331210	69306	1.27	40	0.60	0.75
C	3312100596	0596	331210	69307	1.27	40	1.77	2.21
C	3312100596	0596	331210	69308	1.27	40	1.77	2.21
C	3312100576	0576	331210	69309	1.27	40	0.60	0.75
C	3312100567	0567	331210	69310	1.27	40	1.24	1.55
C	3312100613	0613	331210	69311	1.27	40	0.62	0.78
C	3312100613	0613	331210	69312	1.27	40	0.62	0.78
C	3312100513	0513	331210	69313	1.27	40	0.86	1.08
C	3312100493	0493	331210	69314	1.27	40	2.08	2.60
C	3312100509	0509	331210	69315	1.27	40	0.90	1.13
C	3312100529	0529	331210	69316	1.27	40	2.16	2.70
C	3312100357	0357	331210	69317	1.27	40	0.97	1.21
C	3312100351	0351	331210	69318	1.27	40	1.01	1.26
C	3312100347	0347	331210	69319	1.27	40	0.70	0.87
C	3312100315	0315	331210	69320	1.27	40	1.98	2.48
C	3312100363	0363	331210	69321	1.27	40	1.45	1.81
C	3312100331	0331	331210	69322	1.27	40	4.46	5.58
C	3312100375	0375	331210	69324	1.27	40	1.22	1.52
C	3312100351	0351	331210	69325	1.27	40	1.01	1.26
C	3312100339	0339	331210	69326	1.27	40	1.25	1.56
C	3312100333	0333	331210	69327	1.27	40	2.71	3.39
C	3312100351	0351	331210	69328	1.27	40	1.01	1.26
C	3312100303	0303	331210	69329	1.27	40	1.91	2.39
C	3312100343	0343	331210	69330	1.27	40	0.54	0.68

Table 3. Ntonjaneni Fell Plan

FARM_CODE	COMPT	CLASS	EFF_AREA	OBJECT ID	FELL_DATE
331210	E71	C	42.351	49941	01/01/2004
331210	E72	C	18.958	49945	01/01/2004
331210	E74	C	5.208	49953	01/01/2004
331210	E74	C	5.208	49955	01/01/2004
331210	E63	C	12.713	49965	01/01/2004
331210	E74	C	5.208	49978	01/01/2004
331210	E59	C	14.671	49981	01/01/2004
331210	E61	C	26.808	49983	01/01/2004
331210	E64	C	12.717	49989	01/01/2004
331210	E60	C	18.428	49992	01/01/2004
331210	E68	C	3.486	50021	01/01/2004
331210	E66	C	6.768	50022	01/01/2004
331210	J04	C	35.035	51121	01/01/2004
331210	E65	C	6.506	51165	01/01/2004
331210	E65	C	6.506	51175	01/01/2004
331210	E82	C	1.807	51176	01/01/2004
331210	E65	C	6.506	51264	01/01/2004
331210	E84	C	7.006	51265	01/01/2004
331210	E65	C	6.506	51379	01/01/2004
331210	J10	C	25.302	51398	01/01/2004
331210	J13	C	40.871	51422	01/01/2004
331210	E40	C	5.428	51428	01/01/2004
331210	E40	C	5.428	51446	01/01/2004
331210	E39	C	35.930	51452	01/01/2004
331210	E39	C	35.930	51478	01/01/2004
331210	E39	C	35.930	51487	01/01/2004
331210	J18	C	18.441	51598	01/01/2004
331210	F03	C	9.808	51760	01/01/2004
331210	F04	C	22.264	51821	01/01/2004
331210	F05	C	3.828	51830	01/01/2004

331210	E23	C	5.373	51839	01/01/2004
331210	D30	C	3.747	54110	01/01/2004
331210	B06	C	4.294	74923	01/01/2004
331210	C26	C	18.293	74986	01/01/2004
331210	C26	C	18.293	74993	01/01/2004
331210	K03	C	5.390	77445	01/01/2004
331210	K09A	C	26.374	77514	01/01/2004
331210	K09A	C	26.374	77518	01/01/2004
331210	K16	C	10.916	77557	01/01/2004
331210	K16	C	10.916	77558	01/01/2004
331210	K09A	C	26.374	77559	01/01/2004
331210	K16	C	10.916	77563	01/01/2004
331210	K17C	C	7.356	77574	01/01/2004
331210	K09A	C	26.374	77591	01/01/2004
331210	K09A	C	26.374	77592	01/01/2004
331210	K09A	C	26.374	77603	01/01/2004
331210	K12	C	11.008	77605	01/01/2004
331210	K17C	C	7.356	77608	01/01/2004
331210	K17A	C	12.261	77626	01/01/2004
331210	K15A	C	9.369	77633	01/01/2004
331210	K13	C	9.280	77637	01/01/2004
331210	K15B	C	4.483	77662	01/01/2004
331210	K17A	C	12.261	77671	01/01/2004
331210	K14	C	6.519	77682	01/01/2004
331210	K29A	C	17.677	77688	01/01/2004
331210	K29A	C	17.677	77698	01/01/2004
331210	K24	C	12.762	77699	01/01/2004
331210	K24	C	12.762	77703	01/01/2004
331210	K24	C	12.762	77709	01/01/2004
331210	K24	C	12.762	77711	01/01/2004
331210	K26	C	3.756	77742	01/01/2004
331210	K27	C	6.449	77748	01/01/2004
331210	K26	C	3.756	77751	01/01/2004

331210	K27	C	6.449	77758	01/01/2004
331210	H25	C	27.915	51826	01/05/2004
331210	H21	C	16.226	51848	01/05/2004
331210	H21	C	16.226	51857	01/05/2004
331210	H59B	C	6.069	54076	01/05/2004
331210	H59A	C	18.491	54122	01/05/2004
331210	H61D	C	3.651	54127	01/05/2004
331210	H50A	C	24.634	54152	01/05/2004
331210	H66	C	5.250	54248	01/05/2004
331210	H35	C	17.122	55800	01/05/2004
331210	H45	C	29.721	55808	01/05/2004
331210	H51	C	4.343	56025	01/05/2004
331210	H39A	C	6.953	56470	01/05/2004
331210	J02	C	14.224	50030	01/06/2004
331210	J06	C	13.360	51450	01/06/2004
331210	J23	C	13.413	51611	01/06/2004
331210	J27	C	28.761	51790	01/06/2004
331210	H30	C	45.046	51795	01/06/2004
331210	H32	C	49.148	51810	01/06/2004
331210	H31A	C	14.350	51882	01/06/2004
331210	H20	C	18.546	54004	01/06/2004
331210	H60	C	5.669	54065	01/06/2004
331210	H50B	C	3.121	54140	01/06/2004
331210	H48	C	2.966	55802	01/06/2004
331210	C60	C	18.704	75045	01/06/2004
331210	C61	C	20.746	75013	01/06/2004
331210	B13	C	11.076	75057	01/06/2004
331210	B13	C	11.076	75109	01/06/2004
331210	B13	C	11.076	75424	01/06/2004
331210	J36	C	45.264	51376	01/07/2004
331210	J37	C	13.071	51440	01/07/2004
331210	J37	C	13.071	51451	01/07/2004
331210	J37	C	13.071	51460	01/07/2004

331210	J34	C	7.831	51488	01/07/2004
331210	J47	C	13.069	51491	01/07/2004
331210	J47	C	13.069	51595	01/07/2004
331210	J43	C	9.178	51642	01/07/2004
331210	J49	C	27.977	51667	01/07/2004
331210	J28	C	8.998	51693	01/07/2004
331210	J24	C	14.270	51713	01/07/2004
331210	H22	C	28.763	51831	01/07/2004
331210	D16	C	12.877	52861	01/07/2004
331210	H36	C	7.995	55801	01/07/2004
331210	G11	C	9.969	54989	01/04/2005
331210	E83	C	5.074	51186	01/05/2005
331210	G22	C	28.967	51853	01/05/2005
331210	D35	C	4.702	54137	01/05/2005
331210	H62	C	3.679	54276	01/05/2005
331210	H63	C	7.859	54279	01/05/2005
331210	H65	C	1.718	54300	01/05/2005
331210	E81	C	16.058	50023	01/06/2005
331210	E34	C	4.730	51599	01/06/2005
331210	E34	C	4.730	51668	01/06/2005
331210	E18	C	5.050	51740	01/06/2005
331210	H12	C	41.328	51772	01/06/2005
331210	H13	C	8.985	51841	01/06/2005
331210	E24	C	11.387	51868	01/06/2005
331210	G21	C	6.953	53057	01/06/2005
331210	H16A	C	13.194	54024	01/06/2005
331210	D36	C	6.907	54100	01/06/2005
331210	G16	C	22.660	54105	01/06/2005
331210	D39	C	1.448	54139	01/06/2005
331210	D43	C	29.760	54203	01/06/2005
331210	H08B	C	10.867	54231	01/06/2005
331210	F25	C	4.911	54313	01/06/2005
331210	G14	C	7.426	54390	01/06/2005

331210	D44	C	30.365	55797	01/06/2005
331210	F20	C	10.167	55816	01/06/2005
331210	F20	C	10.167	55830	01/06/2005
331210	D46	C	24.953	56400	01/06/2005
331210	G06A	C	0.869	56430	01/06/2005
331210	D02A	C	8.009	56480	01/06/2005
331210	C03	C	20.349	56482	01/06/2005
331210	C15	C	36.817	74851	01/06/2005
331210	B05A	C	17.815	74915	01/06/2005
331210	C62A	C	29.294	74940	01/06/2005
331210	B08	C	12.063	74989	01/06/2005
331210	C43	C	8.036	75087	01/06/2005
331210	C43	C	8.036	75091	01/06/2005
331210	B10B	C	14.712	75098	01/06/2005
331210	B17	C	10.107	75161	01/06/2005
331210	B10B	C	14.712	75173	01/06/2005
331210	B10B	C	14.712	75458	01/06/2005
331210	B25A	C	7.879	76636	01/06/2005
331210	B26B	C	9.628	76668	01/06/2005
331210	B26B	C	9.628	77438	01/06/2005
331210	E80	C	6.671	50100	01/07/2005
331210	G31	C	15.237	51505	01/07/2005
331210	G31	C	15.237	51563	01/07/2005
331210	J31	C	15.619	51610	01/07/2005
331210	G36	C	3.610	51756	01/07/2005
331210	D45	C	26.767	55825	01/07/2005
331210	D01A	C	29.477	56458	01/07/2005
331210	H02A	C	4.761	56476	01/07/2005
331210	D48	C	28.118	56484	01/07/2005
331210	C06A	C	34.885	73430	01/07/2005
331210	D15A	C	23.419	102854	01/10/2005
331210	C63	C	14.229	74906	01/10/2005
331210	J45	C	10.926	51628	01/05/2006

331210	H29A	C	23.972	51815	01/05/2006
331210	H58B	C	9.507	53986	01/05/2006
331210	H01	C	18.758	56557	01/05/2006
331210	G03B	C	1.950	56791	01/05/2006
331210	C13B	C	5.658	74858	01/05/2006
331210	C44	C	7.433	75123	01/05/2006
331210	B21	C	6.508	76591	01/05/2006
331210	B21	C	6.508	76603	01/05/2006
331210	B21	C	6.508	76616	01/05/2006
331210	B21	C	6.508	76617	01/05/2006
331210	E78	C	13.418	49934	01/06/2006
331210	E79	C	18.446	49939	01/06/2006
331210	E58	C	4.956	49982	01/06/2006
331210	E06	C	2.674	51565	01/06/2006
331210	E06	C	2.674	51640	01/06/2006
331210	J44	C	11.399	51689	01/06/2006
331210	E08	C	1.748	51716	01/06/2006
331210	H15A	C	6.454	51891	01/06/2006
331210	H18	C	26.402	53965	01/06/2006
331210	H15B	C	4.569	53989	01/06/2006
331210	H04B	C	23.979	54275	01/06/2006
331210	H53	C	13.617	54299	01/06/2006
331210	H17	C	30.757	55798	01/06/2006
331210	H47	C	3.470	55824	01/06/2006
331210	G08	C	15.853	56462	01/06/2006
331210	H02B	C	2.498	56468	01/06/2006
331210	C22	C	2.551	74868	01/06/2006
331210	C14	C	21.190	74885	01/06/2006
331210	C24	C	21.453	74886	01/06/2006
331210	C24	C	21.453	74905	01/06/2006
331210	C24	C	21.453	74938	01/06/2006
331210	C14	C	21.190	74954	01/06/2006
331210	B09	C	2.052	75096	01/06/2006

331210	B30	C	9.124	76583	01/06/2006
331210	B30	C	9.124	76589	01/06/2006
331210	G34B	C	5.763	51702	01/07/2006
331210	G34B	C	5.763	51704	01/07/2006
331210	G34B	C	5.763	51723	01/07/2006
331210	G34B	C	5.763	51745	01/07/2006
331210	G27	C	25.590	51746	01/07/2006
331210	G37	C	1.599	51755	01/07/2006
331210	G34A	C	18.464	51758	01/07/2006
331210	G20	C	6.969	51867	01/07/2006
331210	D18	C	1.881	53969	01/07/2006
331210	G17	C	20.090	54005	01/07/2006
331210	G17	C	20.090	54025	01/07/2006
331210	D31	C	1.838	54090	01/07/2006
331210	D34	C	7.041	54167	01/07/2006
331210	H64	C	3.406	55810	01/07/2006
331210	H64	C	3.406	55837	01/07/2006
331210	G06B	C	3.324	56405	01/07/2006
331210	G05	C	35.699	56409	01/07/2006
331210	H03	C	14.828	56437	01/07/2006
331210	C02	C	29.866	56447	01/07/2006
331210	G07	C	8.283	56460	01/07/2006
331210	C07	C	17.236	56481	01/07/2006
331210	C02	C	29.866	56485	01/07/2006
331210	G03A	C	8.404	73288	01/07/2006
331210	C20	C	14.949	74804	01/07/2006
331210	G01	C	30.601	74808	01/07/2006
331210	C20	C	14.949	74818	01/07/2006
331210	C62B	C	9.268	74953	01/07/2006
331210	C62B	C	9.268	75005	01/07/2006
331210	B12	C	1.494	75081	01/07/2006
331210	B11	C	2.610	75110	01/07/2006
331210	B11	C	2.610	75118	01/07/2006

331210	B37	C	4.908	76652	01/07/2006
331210	H73	C	4.418	51774	01/05/2007
331210	H10	C	8.681	52067	01/05/2007
331210	D14	C	20.176	53935	01/05/2007
331210	B04	C	22.448	74887	01/05/2007
331210	G33	C	14.187	51634	01/06/2007
331210	H67	C	7.384	54056	01/06/2007
331210	G23	C	23.901	51789	01/06/2007
331210	E27	C	14.342	51805	01/06/2007
331210	E27	C	14.342	51811	01/06/2007
331210	E27	C	14.342	51825	01/06/2007
331210	E27	C	14.342	51843	01/06/2007
331210	H31B	C	4.458	51860	01/06/2007
331210	D20A	C	11.549	53988	01/06/2007
331210	H61C	C	5.464	53991	01/06/2007
331210	H54	C	13.850	54086	01/06/2007
331210	H06	C	26.317	54088	01/06/2007
331210	H67	C	7.384	54103	01/06/2007
331210	D33	C	13.357	54153	01/06/2007
331210	D41	C	6.447	55799	01/06/2007
331210	G13	C	3.565	55813	01/06/2007
331210	G04C	C	12.893	56443	01/06/2007
331210	G04B	C	19.049	56478	01/06/2007
331210	D01B	C	6.662	74497	01/06/2007
331210	D02B	C	1.775	74740	01/06/2007
331210	C06B	C	11.710	74741	01/06/2007
331210	B01	C	11.203	74793	01/06/2007
331210	B05B	C	2.616	74899	01/06/2007
331210	B10A	C	14.128	75129	01/06/2007
331210	C31	C	1.285	75157	01/06/2007
331210	C41	C	25.063	75552	01/06/2007
331210	H05	C	26.971	54303	01/07/2007
331210	J57	C	4.580	51620	01/07/2007

331210	H58A	C	8.708	53984	01/07/2007
331210	H16B	C	11.250	54013	01/07/2007
331210	D42	C	34.588	54040	01/07/2007
331210	H52	C	4.761	54307	01/07/2007
331210	B02	C	28.903	74801	01/07/2007
331210	C28A	C	18.852	74927	01/07/2007
331210	C28B	C	1.728	74941	01/07/2007
331210	B25C	C	13.642	76587	01/07/2007
331210	B25C	C	13.642	76630	01/07/2007
331210	B25C	C	13.642	76634	01/07/2007
331210	B25B	C	7.745	76639	01/07/2007
331210	B25C	C	13.642	76647	01/07/2007
331210	B25C	C	13.642	76653	01/07/2007
331210	B25B	C	7.745	76655	01/07/2007
331210	K11	C	17.881	77492	01/07/2007
331210	K11	C	17.881	77506	01/07/2007
331210	K11	C	17.881	77529	01/07/2007
331210	C23	C	4.768	74902	01/04/2008
331210	E36	C	11.522	51485	01/05/2008
331210	E37	C	3.034	51650	01/05/2008
331210	E16	C	14.488	51781	01/05/2008
331210	D19	C	16.925	54063	01/05/2008
331210	D20B	C	14.789	53945	01/05/2008
331210	H08A	C	5.903	54147	01/05/2008
331210	F13	C	16.189	54206	01/05/2008
331210	K25	C	9.906	77713	01/05/2008
331210	K25	C	9.906	77717	01/05/2008
331210	K28A	C	17.201	77734	01/05/2008
331210	K28A	C	17.201	77739	01/05/2008
331210	K28B	C	10.092	77752	01/05/2008
331210	E73	C	8.573	49962	01/06/2008
331210	E03	C	5.213	51564	01/06/2008
331210	E10	C	6.773	51586	01/06/2008

331210	E35	C	32.756	51596	01/06/2008
331210	E05	C	3.275	51604	01/06/2008
331210	E03	C	5.213	51608	01/06/2008
331210	E05	C	3.275	51641	01/06/2008
331210	E33	C	6.834	51672	01/06/2008
331210	E33	C	6.834	51674	01/06/2008
331210	E12	C	6.637	51676	01/06/2008
331210	G25	C	31.054	51677	01/06/2008
331210	E11	C	4.326	51690	01/06/2008
331210	G26	C	31.311	51701	01/06/2008
331210	E31	C	16.873	51709	01/06/2008
331210	E31	C	16.873	51718	01/06/2008
331210	E15	C	4.363	51726	01/06/2008
331210	E29	C	2.928	51776	01/06/2008
331210	E29	C	2.928	51780	01/06/2008
331210	E20	C	7.070	51791	01/06/2008
331210	E28	C	5.567	51809	01/06/2008
331210	E28	C	5.567	51813	01/06/2008
331210	E31	C	16.873	51819	01/06/2008
331210	G24A	C	40.211	51840	01/06/2008
331210	E31	C	16.873	51845	01/06/2008
331210	D23	C	5.213	51856	01/06/2008
331210	E22	C	6.412	51862	01/06/2008
331210	G24A	C	40.211	51863	01/06/2008
331210	G24A	C	40.211	51869	01/06/2008
331210	D22	C	13.306	51872	01/06/2008
331210	G24A	C	40.211	51879	01/06/2008
331210	G24A	C	40.211	52074	01/06/2008
331210	D22	C	13.306	53933	01/06/2008
331210	G40	C	7.812	54079	01/06/2008
331210	G40	C	7.812	54214	01/06/2008
331210	D50	C	6.922	56410	01/06/2008
331210	C05A	C	10.161	57609	01/06/2008

331210	C52A	C	19.589	75484	01/06/2008
331210	C72	C	4.655	76605	01/06/2008
331210	C72	C	4.655	76619	01/06/2008
331210	J32	C	9.657	51494	01/07/2008
331210	G29	C	14.563	51631	01/07/2008
331210	G29	C	14.563	51646	01/07/2008
331210	G29	C	14.563	51752	01/07/2008
331210	H11	C	27.497	51823	01/07/2008
331210	D32	C	12.124	53952	01/07/2008
331210	G15C	C	12.492	54221	01/07/2008
331210	G15C	C	12.492	54224	01/07/2008
331210	K04	C	28.396	77472	01/07/2008
331210	K04	C	28.396	77475	01/07/2008
331210	K04	C	28.396	77476	01/07/2008
331210	K04	C	28.396	77477	01/07/2008

Table 4. Ntonjaneni Depots

Number	Description	Locality	Km to Mill	Route Network Number
KA01	ALL WEATHER, APPROX. 2500 TONS	TURN OFF TO DUIKERHOEK	103.1	30
KA02	DRY WEATHER, APPROX. 3000 TONS	IN TREES ABOVE OAKDALE STORE	104.3	29
KA03	ALL WEATHER, APPROX. 2500 TONS	ABOVE OAKDALE STORE LHS OF ROA	104.1	28
KA04	ALL WEATHER, APPROX. 1500 TONS	WOODLAND TURN OFF	105.6	27
KA05	ALL WEATHER, APPROX. 2000 TONS	OLD PINE STOCK PILE	106.0	26
KA06	ALL WEATHER, APPROX. 3000 TONS	SOCCER FIELD	106.6	25
KA07	ALL WEATHER, APPROX. 2500 TONS	LAST ZONE ON WOODLANDS ROAD	107.5	24
KA08	ALL WEATHER, APPROX. 4500 TONS	GARFIED COMPOUND	108.1	23
KA09	DRY WEATHER, APPROX. 1000 TONS	GARF/MCMURRY BOUNDARY	109.6	21
KA10	ALL WEATHER, APPROX. 2000 TONS	GARFIELD FIRE TOWER	109.7	22
KA11	DRY WEATHER, APPROX. 3000 TONS	BROOKLANDS	117.2	21
KA12	ALL WEATHER, APPROX. 2500 TONS	ABOVE SAPPI OFFICE	110.8	20
KA13	ALL WEATHER, APPROX. 3500 TONS	FIRST ON NTONJANENI ROAD	114.0	19
KA14	DRY WEATHER, APPROX. 1000 TONS	RED ROAD FIRST ZONE	115.5	18
KA15	DRY WEATHER, APPROX. 1000 TONS	RED ROAD BOUNDARY MCMURRY	117.0	17
KA16	ALL WEATHER, APPROX. 3000 TONS	KATAZA STORE	113.0	16
KA17	DRY WEATHER, APPROX. 1500 TONS	DINKLEMAN/BELOW KATAZA STORE	114.7	15
KA18	DRY WEATHER, APPROX. 1500 TONS	WALKERS HOUSE	116.5	14
KA19	DRY WEATHER, APPROX. 1500 TONS	WIDE C CLASS ROAD	117.8	13
KA21	DRY WEATHER, APPROX. 1000 TONS	FERNCLIFFE HOUSE	118.9	11
KA22	ALL WEATHER, APPROX. 4000 TONS	RHS FERNCLIFFE/NKANDLA ROAD	119.2	10
KA23	ALL WEATHER, APPROX. 3000 TONS	NKANDLA BRIDGE	122.4	9
KA24	DRY WEATHER, APPROX. 3500 TONS	FIRST ZONE QUQUMENI	125.0	8
KA25	DRY WEATHER, APPROX. 2500 TONS	TOWARDS VIEW POINT	128.5	7
KA26	DRY WEATHER, APPROX. 3000 TONS	VRIENDSCHAP/MINHOOP BOUNDARY	116.5	6
KA27	DRY WEATHER, APPROX. 2500 TONS	VRIENDSCHAPP	118.3	5
KA28	ALL WEATHER, APPROX. 2500 TONS	DIP BELOW MINHOOP HOUSE	117.3	4
KA30	DRY WEATHER, APPROX. 1500 TONS	ESC LINES MINHOOP	120.1	2
KA31	ALL WEATHER, APPROX. 3000 TONS	UITZONDERING	121.2	1
	MONDI MILL	RICHARDSBAY	0.0	1000

Table 5. Best route from Depots to Mill

PATH_ID	ORIGIN	DESTINATION	COST AT ORIGIN	COST AT DESTINATION	TRAVEL COST BETWEEN ORIGIN AND DESTINATION
1	Stop #1	Stop #2	R 0.00	R 2.05	R 2.05
2	Stop #2	Stop #3	R 2.05	R 3.68	R 1.63
3	Stop #3	Stop #4	R 3.68	R 8.87	R 5.19
4	Stop #4	Stop #5	R 8.87	R 9.83	R 0.96
5	Stop #5	Stop #6	R 9.83	R 10.39	R 0.55
6	Stop #6	Stop #7	R 10.39	R 11.30	R 0.92
7	Stop #7	Stop #8	R 11.30	R 16.44	R 5.13
8	Stop #8	Stop #9	R 16.44	R 17.95	R 1.51
10	Stop #9	Stop #11	R 17.95	R 29.76	R 11.81
12	Stop #11	Stop #13	R 29.76	R 47.99	R 18.23
13	Stop #13	Stop #14	R 47.99	R 51.47	R 3.48
14	Stop #14	Stop #15	R 51.47	R 52.92	R 1.45
15	Stop #15	Stop #16	R 52.92	R 59.22	R 6.30
17	Stop #16	Stop #18	R 59.22	R 62.07	R 2.85
18	Stop #18	Stop #19	R 62.07	R 63.66	R 1.59
19	Stop #19	Stop #20	R 63.66	R 70.23	R 6.58
20	Stop #20	Stop #21	R 70.23	R 72.81	R 2.57
21	Stop #21	Stop #22	R 72.81	R 74.85	R 2.05
22	Stop #22	Stop #23	R 74.85	R 81.26	R 6.41
25	Stop #23	Stop #26	R 81.26	R 91.00	R 9.73
27	Stop #26	Stop #28	R 91.00	R 92.74	R 1.74
28	Stop #28	Stop #29	R 92.74	R 96.20	R 3.46
29	Stop #29	Stop #30	R 96.20	R 97.61	R 1.41
30	Stop #30	Stop #31	R 97.61	R 100.22	R 2.61
					TOTAL COST PER ROUND TRIP R100.22

Table 6. Best route from plantations to depots

ORIGIN	DESTINATION	COST AT ORIGIN	COST AT DESTINATION	TRAVEL COST BETWEEN ORIGIN AND DESTINATION
Stop #1	Stop #2	R 0.00	R 0.48	R 0.48
Stop #2	Stop #3	R 0.48	R 1.31	R 0.83
Stop #3	Stop #4	R 1.31	R 2.39	R 1.08
Stop #4	Stop #5	R 2.39	R 2.79	R 0.40
Stop #5	Stop #6	R 2.79	R 3.13	R 0.34
Stop #6	Stop #7	R 3.13	R 3.54	R 0.41
Stop #7	Stop #8	R 3.54	R 4.16	R 0.62
Stop #8	Stop #9	R 4.16	R 5.27	R 1.11
Stop #9	Stop #10	R 5.27	R 6.60	R 1.34
Stop #10	Stop #11	R 6.60	R 8.01	R 1.41
Stop #11	Stop #12	R 8.01	R 8.83	R 0.82
Stop #12	Stop #13	R 8.83	R 9.28	R 0.45
Stop #13	Stop #14	R 9.28	R 10.33	R 1.05
Stop #14	Stop #15	R 10.33	R 11.96	R 1.63
Stop #15	Stop #16	R 11.96	R 12.85	R 0.89
Stop #16	Stop #17	R 12.85	R 13.17	R 0.32
Stop #17	Stop #19	R 13.17	R 13.75	R 0.58
Stop #19	Stop #20	R 13.75	R 14.96	R 1.20
Stop #20	Stop #21	R 14.96	R 15.26	R 0.30
Stop #21	Stop #22	R 15.26	R 16.01	R 0.75
Stop #22	Stop #23	R 16.01	R 17.36	R 1.35
Stop #23	Stop #24	R 17.36	R 17.74	R 0.38
Stop #24	Stop #25	R 17.74	R 18.20	R 0.45
Stop #25	Stop #26	R 18.20	R 18.59	R 0.40
Stop #26	Stop #27	R 18.59	R 19.11	R 0.52
Stop #27	Stop #28	R 19.11	R 26.47	R 7.36
Stop #28	Stop #29	R 26.47	R 26.86	R 0.39
Stop #29	Stop #30	R 26.86	R 26.95	R 0.09

Stop #30	Stop #31	R 26.95	R 27.26	R 0.31
Stop #31	Stop #32	R 27.26	R 27.99	R 0.72
Stop #32	Stop #33	R 27.99	R 28.77	R 0.79
Stop #33	Stop #34	R 28.77	R 29.55	R 0.78
Stop #34	Stop #35	R 29.55	R 30.33	R 0.78
Stop #35	Stop #37	R 30.33	R 31.00	R 0.66
Stop #37	Stop #38	R 31.00	R 31.17	R 0.18
Stop #38	Stop #39	R 31.17	R 33.73	R 2.56
Stop #39	Stop #40	R 33.73	R 34.75	R 1.02
Stop #40	Stop #41	R 34.75	R 35.39	R 0.64
Stop #41	Stop #42	R 35.39	R 37.84	R 2.44
Stop #42	Stop #43	R 37.84	R 39.94	R 2.11
Stop #43	Stop #44	R 39.94	R 40.60	R 0.65
Stop #44	Stop #45	R 40.60	R 41.08	R 0.48
Stop #45	Stop #46	R 41.08	R 43.00	R 1.93
Stop #46	Stop #47	R 43.00	R 43.50	R 0.50
Stop #47	Stop #48	R 43.50	R 44.77	R 1.26
Stop #48	Stop #49	R 44.77	R 45.70	R 0.93
Stop #49	Stop #50	R 45.70	R 46.70	R 1.00
Stop #50	Stop #51	R 46.70	R 47.43	R 0.73
Stop #51	Stop #52	R 47.43	R 49.35	R 1.92
Stop #52	Stop #53	R 49.35	R 50.97	R 1.61
Stop #53	Stop #54	R 50.97	R 52.73	R 1.76
Stop #54	Stop #55	R 52.73	R 52.73	R 0.00
Stop #55	Stop #56	R 52.73	R 53.74	R 1.01
Stop #56	Stop #57	R 53.74	R 56.75	R 3.01
Stop #57	Stop #58	R 56.75	R 58.62	R 1.87
Stop #58	Stop #59	R 58.62	R 59.38	R 0.76
Stop #59	Stop #60	R 59.38	R 59.90	R 0.52
Stop #60	Stop #61	R 59.90	R 60.55	R 0.66
Stop #61	Stop #62	R 60.55	R 62.07	R 1.52
Stop #62	Stop #63	R 62.07	R 67.55	R 5.47
Stop #63	Stop #64	R 67.55	R 71.79	R 4.25

Stop #64	Stop #65	R 71.79	R 76.51	R 4.72
Stop #65	Stop #66	R 76.51	R 76.98	R 0.47
Stop #66	Stop #67	R 76.98	R 77.47	R 0.49
Stop #67	Stop #68	R 77.47	R 77.84	R 0.37
Stop #68	Stop #69	R 77.84	R 78.29	R 0.44
Stop #69	Stop #70	R 78.29	R 79.34	R 1.05
Stop #70	Stop #71	R 79.34	R 80.30	R 0.96
Stop #71	Stop #72	R 80.30	R 81.74	R 1.44
Stop #72	Stop #73	R 81.74	R 82.52	R 0.78
Stop #73	Stop #74	R 82.52	R 84.82	R 2.30
Stop #74	Stop #75	R 84.82	R 88.43	R 3.60
Stop #75	Stop #76	R 88.43	R 91.19	R 2.77
Stop #76	Stop #77	R 91.19	R 92.85	R 1.66
Stop #77	Stop #78	R 92.85	R 95.23	R 2.37
Stop #78	Stop #79	R 95.23	R 95.39	R 0.16
Stop #79	Stop #80	R 95.39	R 97.68	R 2.30
Stop #80	Stop #81	R 97.68	R 99.61	R 1.92
Stop #81	Stop #82	R 99.61	R 100.62	R 1.01
Stop #82	Stop #83	R 100.62	R 100.99	R 0.37
Stop #83	Stop #84	R 100.99	R 102.36	R 1.37
Stop #84	Stop #85	R 102.36	R 102.55	R 0.19
Stop #85	Stop #86	R 102.55	R 103.81	R 1.26
Stop #86	Stop #87	R 103.81	R 110.91	R 7.10
Stop #87	Stop #88	R 110.91	R 111.31	R 0.40
Stop #88	Stop #89	R 111.31	R 113.17	R 1.86
Stop #89	Stop #90	R 113.17	R 115.52	R 2.35
Stop #90	Stop #91	R 115.52	R 116.63	R 1.12
Stop #91	Stop #92	R 116.63	R 118.60	R 1.97
Stop #92	Stop #93	R 118.60	R 119.25	R 0.65
Stop #93	Stop #94	R 119.25	R 119.39	R 0.14
Stop #94	Stop #95	R 119.39	R 121.84	R 2.45
Stop #95	Stop #96	R 121.84	R 122.39	R 0.55
Stop #96	Stop #97	R 122.39	R 123.16	R 0.77

Stop #97	Stop #98	R 123.16	R 126.44	R 3.28
Stop #98	Stop #99	R 126.44	R 127.45	R 1.01
Stop #99	Stop #100	R 127.45	R 129.26	R 1.81
Stop #100	Stop #101	R 129.26	R 130.54	R 1.28
Stop #101	Stop #102	R 130.54	R 130.98	R 0.45
Stop #102	Stop #103	R 130.98	R 131.77	R 0.78
Stop #103	Stop #104	R 131.77	R 133.37	R 1.60
Stop #104	Stop #105	R 133.37	R 133.74	R 0.37
Stop #105	Stop #106	R 133.74	R 135.07	R 1.33
Stop #106	Stop #107	R 135.07	R 137.73	R 2.66
Stop #107	Stop #108	R 137.73	R 138.84	R 1.11
Stop #108	Stop #109	R 138.84	R 139.04	R 0.20
Stop #109	Stop #110	R 139.04	R 139.46	R 0.42
Stop #110	Stop #111	R 139.46	R 139.85	R 0.40
Stop #111	Stop #112	R 139.85	R 140.19	R 0.33
Stop #112	Stop #113	R 140.19	R 141.74	R 1.55
Stop #113	Stop #119	R 141.74	R 147.62	R 5.88
Stop #119	Stop #120	R 147.62	R 149.04	R 1.42
Stop #120	Stop #121	R 149.04	R 152.08	R 3.03
Stop #121	Stop #122	R 152.08	R 152.54	R 0.47
Stop #122	Stop #123	R 152.54	R 152.69	R 0.15
Stop #123	Stop #124	R 152.69	R 152.72	R 0.03
Stop #124	Stop #125	R 152.72	R 153.33	R 0.61
Stop #125	Stop #126	R 153.33	R 154.11	R 0.78
Stop #126	Stop #127	R 154.11	R 155.28	R 1.18
Stop #127	Stop #128	R 155.28	R 155.84	R 0.56
Stop #128	Stop #129	R 155.84	R 158.16	R 2.32
Stop #129	Stop #130	R 158.16	R 158.92	R 0.75
Stop #130	Stop #131	R 158.92	R 159.14	R 0.22
Stop #131	Stop #132	R 159.14	R 159.59	R 0.46
Stop #132	Stop #133	R 159.59	R 159.97	R 0.37
Stop #133	Stop #134	R 159.97	R 160.28	R 0.31
Stop #134	Stop #135	R 160.28	R 160.51	R 0.23

Stop #135	Stop #136	R 160.51	R 160.66	R 0.15
Stop #136	Stop #137	R 160.66	R 161.02	R 0.36
Stop #137	Stop #138	R 161.02	R 161.17	R 0.15
Stop #138	Stop #139	R 161.17	R 161.36	R 0.19
Stop #139	Stop #140	R 161.36	R 161.97	R 0.61
Stop #140	Stop #141	R 161.97	R 162.72	R 0.76
Stop #141	Stop #142	R 162.72	R 163.97	R 1.24
Stop #142	Stop #143	R 163.97	R 174.41	R 10.44
Stop #143	Stop #144	R 174.41	R 175.84	R 1.44
Stop #144	Stop #145	R 175.84	R 177.34	R 1.50
Stop #145	Stop #146	R 177.34	R 188.23	R 10.89
Stop #146	Stop #147	R 188.23	R 188.77	R 0.54
Stop #147	Stop #148	R 188.77	R 188.98	R 0.21
Stop #148	Stop #149	R 188.98	R 189.16	R 0.18
Stop #149	Stop #150	R 189.16	R 189.52	R 0.36
Stop #150	Stop #151	R 189.52	R 189.57	R 0.05
Stop #151	Stop #152	R 189.57	R 190.68	R 1.12
Stop #152	Stop #153	R 190.68	R 191.29	R 0.61
Stop #153	Stop #154	R 191.29	R 192.34	R 1.05
Stop #154	Stop #155	R 192.34	R 197.81	R 5.46
Stop #155	Stop #156	R 197.81	R 198.26	R 0.45
Stop #156	Stop #157	R 198.26	R 198.75	R 0.48
Stop #157	Stop #158	R 198.75	R 199.67	R 0.92
Stop #158	Stop #159	R 199.67	R 207.60	R 7.93
Stop #159	Stop #160	R 207.60	R 207.68	R 0.08
Stop #160	Stop #161	R 207.68	R 214.94	R 7.26
Stop #161	Stop #162	R 214.94	R 215.08	R 0.14
Stop #162	Stop #163	R 215.08	R 215.85	R 0.77
Stop #163	Stop #164	R 215.85	R 216.42	R 0.57
Stop #164	Stop #165	R 216.42	R 218.43	R 2.01
Stop #165	Stop #166	R 218.43	R 218.69	R 0.26
Stop #166	Stop #167	R 218.69	R 218.80	R 0.11
Stop #167	Stop #168	R 218.80	R 219.00	R 0.20

Stop #168	Stop #169	R 219.00	R 221.39	R 2.40
Stop #169	Stop #170	R 221.39	R 221.58	R 0.19
Stop #170	Stop #171	R 221.58	R 221.69	R 0.11
Stop #171	Stop #172	R 221.69	R 222.13	R 0.44
Stop #172	Stop #173	R 222.13	R 222.41	R 0.28
Stop #173	Stop #174	R 222.41	R 222.63	R 0.22
Stop #174	Stop #175	R 222.63	R 224.10	R 1.47
Stop #175	Stop #176	R 224.10	R 226.07	R 1.97
Stop #176	Stop #177	R 226.07	R 226.51	R 0.44
Stop #177	Stop #178	R 226.51	R 227.89	R 1.38
Stop #178	Stop #179	R 227.89	R 228.01	R 0.12
Stop #179	Stop #180	R 228.01	R 228.70	R 0.68
Stop #180	Stop #181	R 228.70	R 230.18	R 1.48
Stop #181	Stop #182	R 230.18	R 231.46	R 1.28
Stop #182	Stop #183	R 231.46	R 231.70	R 0.25
Stop #183	Stop #184	R 231.70	R 236.10	R 4.40
Stop #184	Stop #185	R 236.10	R 236.86	R 0.75
Stop #185	Stop #186	R 236.86	R 237.37	R 0.51
Stop #186	Stop #187	R 237.37	R 238.50	R 1.13
Stop #187	Stop #188	R 238.50	R 240.54	R 2.04
Stop #188	Stop #189	R 240.54	R 240.77	R 0.22
Stop #189	Stop #190	R 240.77	R 241.77	R 1.01
Stop #190	Stop #191	R 241.77	R 242.44	R 0.66
Stop #191	Stop #192	R 242.44	R 243.35	R 0.92
Stop #192	Stop #193	R 243.35	R 244.35	R 1.00
Stop #193	Stop #194	R 244.35	R 245.55	R 1.19
Stop #194	Stop #195	R 245.55	R 246.58	R 1.03
Stop #195	Stop #196	R 246.58	R 248.66	R 2.08
Stop #196	Stop #197	R 248.66	R 250.02	R 1.36
Stop #197	Stop #198	R 250.02	R 250.21	R 0.19
Stop #198	Stop #199	R 250.21	R 250.99	R 0.79
Stop #199	Stop #200	R 250.99	R 251.97	R 0.97
Stop #200	Stop #201	R 251.97	R 256.22	R 4.26

Stop #201	Stop #202	R 256.22	R 256.50	R 0.27
Stop #202	Stop #203	R 256.50	R 257.13	R 0.63
Stop #203	Stop #204	R 257.13	R 257.86	R 0.73
Stop #204	Stop #205	R 257.86	R 258.80	R 0.94
Stop #205	Stop #206	R 258.80	R 260.27	R 1.47
Stop #206	Stop #207	R 260.27	R 261.52	R 1.25
Stop #207	Stop #208	R 261.52	R 263.20	R 1.68
Stop #208	Stop #209	R 263.20	R 264.08	R 0.88
Stop #209	Stop #210	R 264.08	R 283.28	R 19.20
Stop #210	Stop #211	R 283.28	R 283.86	R 0.57
Stop #211	Stop #212	R 283.86	R 285.96	R 2.11
Stop #212	Stop #237	R 285.96	R 293.55	R 7.59
Stop #237	Stop #238	R 293.55	R 294.53	R 0.98
Stop #238	Stop #239	R 294.53	R 295.83	R 1.29
Stop #239	Stop #240	R 295.83	R 297.10	R 1.27
Stop #240	Stop #241	R 297.10	R 298.95	R 1.85
Stop #241	Stop #242	R 298.95	R 299.10	R 0.15
Stop #242	Stop #243	R 299.10	R 300.24	R 1.13
Stop #243	Stop #244	R 300.24	R 301.06	R 0.82
Stop #244	Stop #245	R 301.06	R 301.24	R 0.18
Stop #245	Stop #246	R 301.24	R 301.53	R 0.29
Stop #246	Stop #247	R 301.53	R 302.55	R 1.02
Stop #247	Stop #248	R 302.55	R 303.89	R 1.34
Stop #248	Stop #249	R 303.89	R 304.94	R 1.05
Stop #249	Stop #250	R 304.94	R 305.40	R 0.46
Stop #250	Stop #251	R 305.40	R 306.50	R 1.09
Stop #251	Stop #252	R 306.50	R 307.56	R 1.06
Stop #252	Stop #253	R 307.56	R 309.17	R 1.61
Stop #253	Stop #254	R 309.17	R 310.27	R 1.11
Stop #254	Stop #255	R 310.27	R 315.36	R 5.09
Stop #255	Stop #256	R 315.36	R 316.33	R 0.97
Stop #256	Stop #257	R 316.33	R 316.67	R 0.34
Stop #257	Stop #258	R 316.67	R 317.58	R 0.90

Stop #258	Stop #259	R 317.58	R 318.06	R 0.48
Stop #259	Stop #260	R 318.06	R 320.09	R 2.03
Stop #260	Stop #261	R 320.09	R 321.70	R 1.61
Stop #261	Stop #262	R 321.70	R 321.87	R 0.17
Stop #262	Stop #263	R 321.87	R 322.98	R 1.11
Stop #263	Stop #264	R 322.98	R 323.39	R 0.41
Stop #264	Stop #265	R 323.39	R 323.78	R 0.39
Stop #265	Stop #266	R 323.78	R 324.28	R 0.50
Stop #266	Stop #267	R 324.28	R 324.99	R 0.71
Stop #267	Stop #268	R 324.99	R 326.04	R 1.05
Stop #268	Stop #269	R 326.04	R 327.93	R 1.90
Stop #269	Stop #270	R 327.93	R 329.18	R 1.24
Stop #270	Stop #271	R 329.18	R 329.77	R 0.59
Stop #271	Stop #272	R 329.77	R 331.20	R 1.43
Stop #272	Stop #273	R 331.20	R 332.52	R 1.32
Stop #273	Stop #274	R 332.52	R 335.14	R 2.63
Stop #274	Stop #275	R 335.14	R 339.04	R 3.90
Stop #275	Stop #276	R 339.04	R 340.25	R 1.21
Stop #276	Stop #277	R 340.25	R 340.79	R 0.54
Stop #277	Stop #278	R 340.79	R 341.08	R 0.29
Stop #278	Stop #279	R 341.08	R 341.41	R 0.33
Stop #279	Stop #280	R 341.41	R 343.98	R 2.57
Stop #280	Stop #281	R 343.98	R 346.44	R 2.46
Stop #281	Stop #322	R 346.44	R 354.92	R 8.48
Stop #322	Stop #324	R 354.92	R 383.96	R 29.04
Stop #324	Stop #325	R 383.96	R 386.24	R 2.27
Stop #325	Stop #326	R 386.24	R 386.56	R 0.33
Stop #326	Stop #327	R 386.56	R 394.17	R 7.60
Stop #327	Stop #328	R 394.17	R 404.68	R 10.51
Stop #328	Stop #329	R 404.68	R 405.41	R 0.73
Stop #329	Stop #330	R 405.41	R 407.48	R 2.08
Stop #330	Stop #331	R 407.48	R 408.67	R 1.19
Stop #331	Stop #332	R 408.67	R 409.96	R 1.29

Stop #332	Stop #333	R 409.96	R 435.21	R 25.25
Stop #333	Stop #334	R 435.21	R 437.33	R 2.12
Stop #334	Stop #335	R 437.33	R 438.81	R 1.48
				TOTAL COST PER ROUND TRIP R438.81

APPENDIX 2

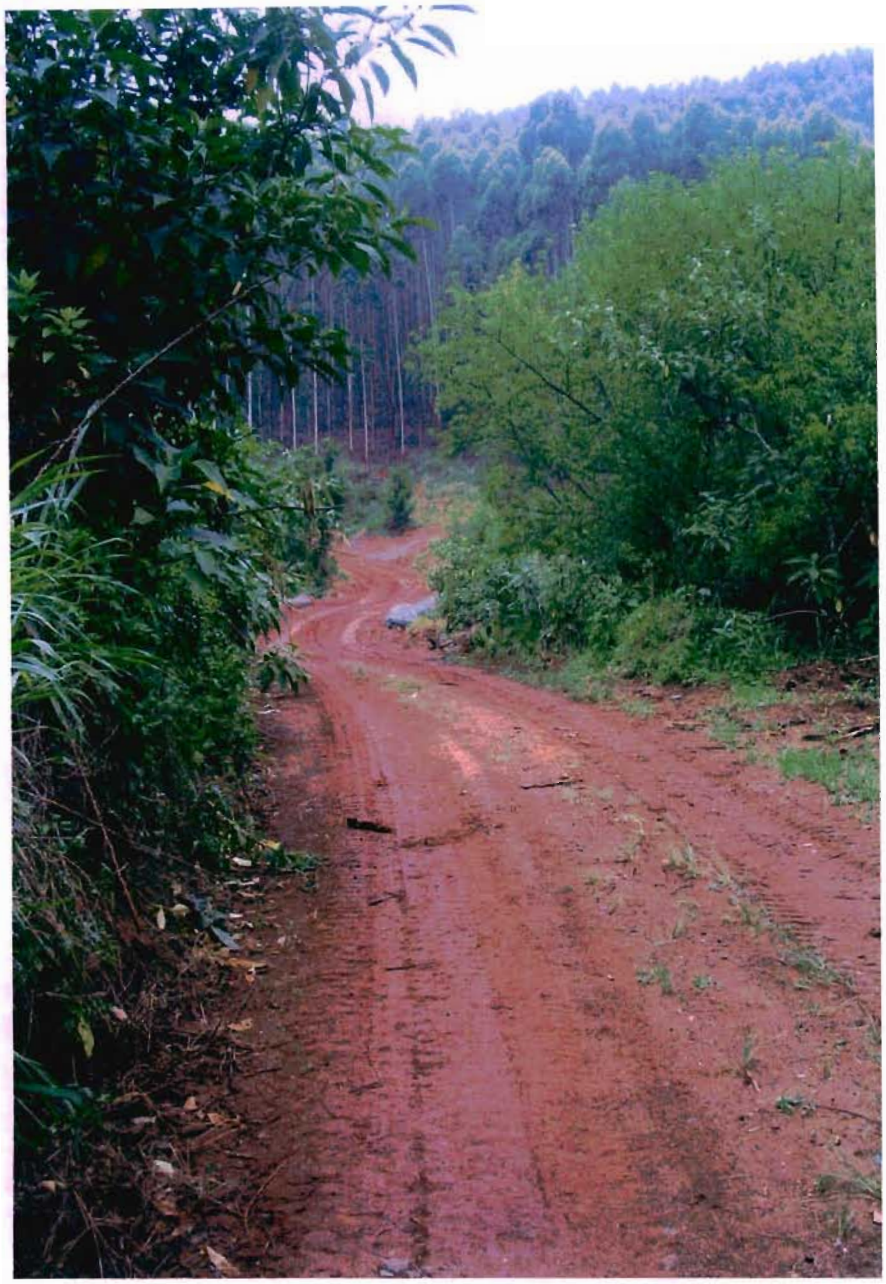

Plate 1. Ntonjaneni Forestry Road providing access to the timber

Plate 2. Forestry road with potential for further damage

Plate 3. Tractor and Trailer, Short-Haul Transportation at a Depot

Plate 4. Tractor and Trailer - Short-Haul Transportation

Plate 5. Rigid and Draw Bar – Long-Haul Transportation