REPORT TO THE WATER RESEARCH COMMISSION

The hydrological implications of afforestation in the North-Eastern Cape

A survey of resources and assessment of the impacts of land-use change

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EXECUTIVE SUMMARY

INTRODUCTION

The Eastern Cape province offers major potential for new forestry development, and forestry has been identified as been one of the most promising economic forces for growth in the province. It is also recognised that forestry has a significant impact on the water resource and that national and regional growth of the industry must be managed with this in mind.

Successive strategic forestry development plans pin-pointed the north-eastern Cape as suitable for forestry and extensive afforestation was initiated by the newly established North East Cape Forests (NECF). The objectives of this development were to establish a primary timber resource approximating one million tons per annum grown on some 100 000 ha of land. A secondary processing plant would be built once the primary source of raw material was guaranteed.

Most of the land earmarked for this development is situated in the Umzimvubu catchment, together with some afforestation in the Bashee catchment. Rainfall varies from about 600 mm to 1 200 mm per annum. To date (1996) some 30 000 hectares of trees have been planted.

The region is considered to be well watered, and water not considered an *a priori* reason for the refusal of afforestation permits. A preliminary survey indicated a dearth of hydrological data. Only one river (the Mooi) had a long and reasonably consistent streamflow record. There was also a very limited rainfall record, and almost no climatic data.

The focus of this report is upon hydrology, and most specifically upon the likely impact which trees may have upon downstream water users, especially with regard to total water yield.

OBJECTIVES

The aims of this study were:

(i) To survey and map environmental resources in the north-eastern Cape forest region;

(ii) To assess the impacts of afforestation and forestry management practice on water yield, water quality, and the conservation of riparian zones;

(iii) To provide guidelines for policy development, together with practical management guidelines to improve water quality and yield, and to ameliorate the impacts of afforestation on the natural environment;

(iv) To provide a wider overview of the impacts of the regional scale land use change through afforestation, and particularly to place this in a socio-economic context.

RESEARCH APPROACH

The use of spatial information and the spatial intelligence of a Geographical Information System (GIS) was fundamental to both the setting up of the information baseline and the subsequent impact modelling exercises. Information incorporated into the GIS included areas of current and immediately planned afforestation, together with information on species, site and rainfall. Use was made, as far as possible, of existing data sets.

On the basis of all available land use and resource information, water use by current and immediately planned afforestation was modelled using the CSIR's forest water use curves, and impacts determined at the level of quaternary, tertiary, secondary and primary catchment. A water quality baseline was also put in place through successive biological monitoring of stream health at 15 stations on the major rivers in the region (the Gatberg, Wildebees, Mooi and Pot).

BASELINE RESOURCE INFORMATION

In addition to existing streamflow records and the spatial distribution of areas afforested and immediately planned for afforestation, an extensive baseline of physical resource information has been assembled. The most important elements include a land cover classification and information on land cover types, the location of wetlands, and the distribution of alien invasives. Additional socio-economic data has been assembled in order to put the potential impacts of afforestation into the regional context.

Prior to current afforestation plans, the principal land-use was extensive livestock grazing of both cattle and sheep, although this has been a very depressed industry. There is also a considerable area of dryland cultivation, and minor areas of irrigated cropland and dispersed forestry on a woodlot scale. Woodlot species are predominantly *Acacia mearnsii*, *Acacia decurrens* and *Eucalyptus* species. There is much evidence of overgrazing in the steep catchments and resultant erosion where thinner soils occur. Land cover data has also been categorised for each of the ten quaternary catchments within which forestry has taken place or is immediately planned.

IMPACTS OF AFFORESTATION ON WATER RESOURCES

Water Quality

A 'biological baseline' has been established at 15 monitoring sites on the major rivers in the district (the Wildebees, Mooi, Pot and Antelopespruit). This methodology entails a survey of the biological health of the river and can easily be repeated either at regular or at event driven intervals. The conclusion from the baseline study is that the rivers are biologically in a good condition.

Water Yield

The CSIR's 'flow reduction curves' were used to estimate impacts of afforestation on the expected virgin yield from 10 quaternary catchments.

The importance of both spatial distribution (across rainfall zones) and of age class distribution in water use was considered. Impacts are primarily dependent on the area afforested, the rainfall class distribution over which that afforestation takes place, and upon the age class distribution of trees within catchments. The concern with age class distribution is a function of the use of peak or maximum impact of afforestation as the chief measure. Where all trees within a catchment mature in the same year then the impact will peak in that year. By distributing the age classes across the length of the rotation the peak impact on the yield from may be reduced by 35%. Depending upon the measures used this could mean that a further 35% of afforestation may be acceptable to the decision making authority. This observation also has implications for the Afforestation Permit System.

In the north-eastern Cape the peak (maximum) impacts of all current and planned afforestation (ie 53 395 ha), on mean annual runoff within the 10 quaternary catchments varies from 2-18%. Worst impacts on low flows range from 5-31%. Mean annual impacts (impacts distributed over the length of the rotation) would be considerably lower than this - with the peak impacts reduced by an estimated 35%.

The maximum total impact of afforestation at the level of the tertiary catchment is 5%, at the secondary catchment about 1%, and <0.5% at the level of the primary catchment. This situation would be reached in 2009 or 2010 and is also a function of the compacted age class distribution. Should forestry age classes be better distributed this maximum impact will be ameliorated. Even given current planting practice the consequences of afforestation at the regional scale do not seem to be of especial significance, which is in line with the original contention that this was a well-watered region which could afford to support a viable forestry industry.

GUIDELINES FOR POLICY DEVELOPMENT AND LAND MANAGEMENT

The major issues in the north-eastern Cape have been identified as maintaining long term run-off and ensuring equitable access to clean water supplies; regional economic development; the conservation of biodiversity; maintaining and improving the agricultural base; addressing the basic needs of the population within the RDP framework; ensuring national forest resource provision; and ensuring a return on investment for commercial forestry.

A number of recommendations are made with regard to policy goals and land management objectives. These include recommendations on regional planning, catchment afforestation planning, the procedure and practice of plantation forestry, the management of wetlands, riparian zones, alien invasive plants, the rehabilitation of degraded land, road construction, monitoring and policy development.

A number of research questions have also been highlighted.

ACKNOWLEDGEMENTS

The Water Research Commission has generously supported this assessment of water resource and land management interactions within the North-Eastern Cape. We must, in addition, thank all members of our Steering Committee and especially Hugo Maaren, Dr Diek van der Zel, Peter Gardiner, Dr George Green and Jan Briers for their valuable contributions to our knowledge and understanding of water resources issues within the North-Eastern Cape Region.

The Department of Water Affairs and Forestry (DWAF) supplied hydrological data from existing weirs and offered inputs with regard to the possible siting of further monitoring stations. Dr Diek van der Zel has displayed a particular interest in the forestry development, and made a number of trips to the region. Our thanks also to the DWAF staff of the Eastern Cape office in Cradock - Amelius Muller, Johnny Beumer, Stephen Mullineaux and Flip de Wet.

The Computing Centre for Water Research (CCWR) has been very helpful in the supply of basic hydrological data.

North-East Cape Forests have assisted in every way through the provision of data and information, facilitation of knowledge exchange, and through logistical support to projects and personnel in the field. In particular we would like to thank Eric Droomer, Grant Botha, Felicity Weir and Hendrik Bauer.

Our thanks also to Eastern Cape Nature Conservation for wetland data, Dr Kate Rowntree for valuable discussions regarding wetlands and riparian zones, Herman le Roux of Land Plan and Associates for collecting data on social issues, Dr Freddie Ellis for information on soils, and Dr Ferdi de Moor for assistance to Brian Fowles in species identification in establishing the limnological baseline.

Lastly we would like to thank our colleagues Dave Scott (streamflow reduction curves and editorial comment); Peter Erasmus (Landsat data analysis); Clare Jones and David McKelly (GIS analysis and map production); Reney Robyntjies (GIS data capture); Brian van Wilgen (editorial comment), Trudy Dor and Heath Thorpe (biological survey); and Arjoon Singh (water quality data management).

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The following abbreviations are used in this report.

ACRU	:	Agricultural Catchment Research Unit
APS	:	Afforestation Permit System
APPC	:	Afforestation Permit Policy Committee
ASPT	:	Average Score per Taxon
BOD	:	Biological Oxygen Demand
BMWP	:	Biological Monitoring Working Party
CAD	:	Computer Aided Design
CCWR	:	Computing Centre for Water Research
DWAF	:	Department of Water Affairs and Forestry
EIA	:	Environmental Impact Assessment
GIS	:	Geographical Information System
ICM	:	Integrated Catchment Management
IDC	:	Industrial Development Corporation
ISCW	:	Institute of Soil, Climate and Water
IEM	:	Integrated Environmental Management
MAP	:	Mean Annual Precipitation
MAR	:	Mean Annual Run-off
NECF	:	North East Cape Forests
NTU	:	Nephelometric Turbidity Units
RDP	:	Reconstruction and Development Programme
SANCO	:	South African National Civics Organisation
SASS2	:	South African Scoring System (Version 2)
SASS4	:	South African Scoring System (Version 4)
SEA	:	Strategic Environmental Assessment
WRSM90	:	Water Resources Simulation Model

1. INTRODUCTION

1.1 BACKGROUND

The study is a review and assessment of the hydrological impacts to be expected as a result of extensive afforestation within the North-Eastern Cape, and particularly in the upper reaches of the Bashee and Umzimvubu river catchments. In addition to assessing the impacts of the current level of forestry activity, the study aims to establish a baseline of natural resource information from which the implications of major land use change can be identified and tracked.

In the second Strategic Forestry Development Plan, van der Zel (1989) estimated the increase in demand for roundwood timber at 2,5% per annum for 30 years. The plan states that the industry has the potential to construct 21 new timber processing plants and create 150 000 new jobs by 2020. To meet this growth in demand would mean a doubling of the current timber production by 2010. This translates into planting 35 000 new hectares of forest land each year. The plan indicated that South Africa's timber plantations could be substantially increased without seriously prejudicing other forms of land use. It pointed out that the region with the greatest potentially afforestable area was the catchments of the Umzimvubu and Bashee Rivers. An estimated 240 000 ha, mostly in the former Transkei, was identified as suitable for forestry development.

Partially as a consequence of this plan it was decided, by a consortium of Mondi Paper, Anglo American and De Beers, to establish a large-scale forestry operation in the North-Eastern Cape. North Eastern Cape Forests (NECF) thus came into being as a division of Mondi Forests. Sixty-six farms were purchased during 1989 and it was the intention to plant 66 000 ha by 1996 (SA Forestry).

The forestry development in the North-Eastern Cape was viewed, at the inception of this study, as the last likely new afforestation development within South Africa of such a scale that impacts might be observed and felt at a regional scale. This development is expected to grow to approximately 100 000 ha in extent. Land-use is being converted currently from extensive grazing, dryland agriculture and some small scale irrigation, to afforestation.

Given that forestry is an almost entirely new practice in the region, there is understandable concern regarding the effects of afforestation on both the yield and quality of water from the catchments being afforested. The main forestry operations generally considered to affect the hydrology beyond the act of planting trees, are: land allocations to forestry (position in the landscape), site preparation, species choice, riparian zone management, silvicultural practices, and other management operations such road making and fire breaks. Impacts at the regional scale of conversion of large areas of farmed grassland to silviculture have not been studied before in South Africa. It must also be recognized that not all changes are likely to be detrimental.

It is recognised that any form of land use change is likely to have an impact on the catchment undergoing change in terms of its role and condition as a water source. Forestry has long been viewed in South Africa as an important user of water - with afforestation impacting negatively on catchment water yield. Land use change must, however, always be viewed in context and with the understanding that one is (a) talking about change from one state to another, and (b) change to forestry may preclude change to some other more, or less, favourable state. This document is an attempt to put the experiences of the North-Eastern Cape into this context, and to draw upon these experiences in the quest for rational decision making and optimal forest management.

1.2 BRIEF

The brief established at the inaugural meeting of the Steering Committee, held on 30 March 1993, was to set the baseline for the tracking of any hydrological change which might result as a consequence of increasing afforestation and associated operations within the region known as the North-Eastern Cape. The focus of this report is upon hydrology, and most specifically upon the likely impact which trees may have upon downstream water users, especially with regard to water yield and quality.

1.2.1 Objectives

The objective of this project (as established by the steering committee) has been to establish and capture the baseline information necessary to deal with hydrological and environmental issues that may arise out of current and planned afforestation in the region. More specifically, the aims of the study were:

(i) To survey and map environmental resources in the North-Eastern Cape forest region; 'Environmental resources' were taken to mean those features directly related to land management and hydrology. Typically these included land cover, water resources (rivers and dams), wetlands, rainfall and plantation area.

(ii) To assess the expected impacts of afforestation and forestry management practice on water yield, water quality, and the conservation of riparian zones;

(iii) To provide guidelines for policy development, together with practical management guidelines to improve water quality and yield, and to ameliorate the impacts of afforestation on the natural environment;

In addition to these primary aims the Project Steering Committee requested that the research team should take a broader socio-economic view of forestry development in the North-Eastern Cape. We have therefore included the following additional aim:

(iv) To provide a wider overview of the impacts of the regional scale land use change through afforestation, and particularly to place this in a social context.

The anticipated benefits of research in this area included the creation of a baseline[1] of information for the monitoring of changes to catchment hydrology resulting from afforestation, and assessments on the impacts of both land management practices (in the short term) and afforestation (in the longer term) on water quality. The project is aimed at providing practical information for policy makers, such as the Department of Water Affairs and Forestry, as well as for forest managers on options for optimizing both water yield and quality from the forestry estate.

1.2.2 Study Area

The North-Eastern Cape region lies in the Eastern Cape Province of South Africa. It forms a shelf between two escarpments: to the east and south-east which roughly forms the western border of the former Transkei, and the other to the west and north-west which is the southern most extension of the Drakensberg, and borders on Lesotho. The nearest major centres are Umtata to the south and Queenstown to the west. The closest port is East London to which the main district towns of Elliot, Ugie and Maclear are joined by a rail link which ends in Maclear.

The research programme has focused on the magisterial districts of Maclear and Elliot. The Umzimvubu River is included, from the watershed to the confluence of the **Tsitsa and Tina Rivers** (see Figure 1.1). This incorporates the catchments of the Wildebees, Mooi and Pot rivers close to the settlements of Maclear and Ugie. Nine quaternary catchments are immediately affected by current forestry planning and development; T11B, D and E; and T34A, B, C, D, F and G.

[1] Baseline is used here to reflect an expression of the current situation at a particular point in time. It does not imply an ideal situation nor a minimum standard. The baseline date was taken as 1989 - the year in which significant afforestation commenced.

1.3 PRODUCT SUMMARY

The following products are a direct outcome of this study:

- ❐ A spatial database of all relevant available information as a baseline for monitoring of the impact of land-use change on water resources. This includes spatial data associated with land cover, forestry, rainfall, streamflow and water quality. These data are stored in a format suitable for use in ArcView 2.0, a GIS desktop query system;
- ❐ The establishment of a benchmark of biological indicators of water quality, and a network of in-stream water quality monitoring stations;
- ❐ An assessment of the likely effects of afforestation on streamflow;
- ❐ Policy and management recommendations with regard to both forestry and land management within the region; and
- ❐ Recommendations for future research.

1.4 COMPLEMENTARY RESEARCH

A number of complementary research projects, aimed at understanding the region's natural resources, have been initiated by NECF, universities and others since 1990. These are briefly described below.

1.4.1 University of Natal

The Department of Agricultural Engineering of the University of Natal, in collaboration with NECF and the WRC, is undertaking research into soil moisture movement in the Weatherly catchment near Ugie. This site has become the new field laboratory for soil water processes for the Department of Agricultural Engineering.

Two weirs have been designed by the University researchers, and are shortly to be constructed in the Weatherly catchment. Numerous soil water monitoring sites have also been constructed within the catchments above the two weirs. A climate monitoring station has been established. At some stage the catchments above the weirs will be afforested by NECF and the impacts of the afforestation on runoff and soil water movement will be monitored and analysed (see section 1.4.5)

1.4.2 University of Pretoria

Pieter Bester of the University of Pretoria has undertaken an extensive survey of the natural vegetation of the Maclear district as part of an MSc study. This project was also supported by Eastern Cape Nature Conservation. Field work has been completed and most of the information has been entered into a database. Data is still with the Department of Botany, University of Pretoria.

This work has revealed that the plant diversity is very high (over 1500 species) with many Drakensberg alpine and sub-alpine rare and endemic species present (P Bester pers. comm.). These rare and endemic species occur mainly at altitudes above 1500 m and include mostly herbs and orchids. The wetlands are not particularly rich in species, and the entire study area has been badly disturbed by grazing. Most of the afforestation has to date been below 1500m, which is outside the zone of greatest endemism.

1.4.3 University of Stellenbosch

Large-scale afforestation with exotic species is focused primarily on the montane grasslands of South Africa. This will result in the loss of wildlife from the planted areas. The unplanted areas on most forestry estates will allow for the survival of some wildlife, provided this remaining grassland is correctly managed. Indeed the protection offered to these areas could be advantageous to some species. Habitat fragmentation will however inevitably mean a loss of other, and particularly larger wildlife.

Research by Adrian Armstrong of the Department of Nature Conservation, Forestry Faculty at the University of Stellenbosch, has focused on evaluation of afforestable montane grasslands for wildlife conservation in the North-Eastern Cape. Landscape features along a gradient of land types (defined by combinations of classes of geology, altitude and rainfall) were used to predict conservation value. High-altitude land types and low-altitude *Protea* savanna were found to be most valuable for conserving endemic species. Low-altitude land types had high conservation values for species richness. One third of the threatened rare bird species occurring in South Africa are present in the Maclear district. In addition, small mammal populations were sampled in six potentially afforestable land types. Most species were widespread in the afforestable landscape. The threatened, white-tailed mouse *Mystromys albicaudatus* was largely confined to crests and ridges (Armstrong and van Hensbergen 1996).

Armstrong and van Hensbergen (in press) recommend that land should be reserved to ensure the long-term survival of the wildlife within the potential afforestation area. Areas of each of five identified land types should be set aside for the protection of all the montane-endemic grasshopper, butterfly and bird species recorded.

1.4.4 Rhodes University

Research by the Department of Geography at Rhodes University has included a hydro-geomorphic survey of the wetland areas of the Ugie-Maclear districts with an assessment of the potential impacts of afforestation by North East Cape Forests. Wetlands were also mapped for Eastern Cape Nature Conservation (Rowntree 1992). This research team also reviewed the effects of riparian vegetation on channel form and the hydro-geomorphic controls on vegetation. Rhodes University hosted a visit by Malcolm Newson (Newcastle University) to the North-Eastern Cape to consider riparian and wetland function and the possible impacts of land use change.

1.4.5 Institute of Soil, Climate and Water

The Agricultural Research Council's Institute of Soil, Climate and Water (ISCW) together with Department of Agricultural Engineering of the University of Natal are examining the influence of site preparation on runoff in the Weatherly catchment near Ugie.

ISCW are also processing the weather data being recorded by NECF's four automatic weather stations. These automatic weather stations are located near the offices on Funeray, Wildebees, Glen Cullen and Elands Heights estates (see Figure 3.1).

1.4.6 Institute for Commercial Forestry Research

The Institute for Commercial Forestry Research (ICFR) has engaged in a number of site and species related trials. These include research trials into the genetic improvement of both eucalypts and pines, regeneration (tillage), nutrition, weed management, and site-species matching.

1.4.7 Eastern Cape Nature Conservation

Vlok and Briers (1992) of the Eastern Cape Nature Conservation Department conducted a rapid survey of the grasslands in the study area during a four day visit in February 1992. This field visit concentrated on the geophyte families *Amaryllidaceae*, *Iridaceae* and *Orchidaceae* as indicators of specialized habitats. Findings of the field survey were supplemented by a literature review on the floristics of the area.

1.4.8 North East Cape Forests

NECF have developed significant in-house research capacity, directed at both silvicultural and environmental issues. Typical silvicultural problems have been difficulties in establishing trees on old agricultural lands, and the j-rooting and subsequent wind-throw experienced by certain classes of nursery raised trees. NECF assist in the running of research projects and have expressed an interest in developing the capacity to continue limnological monitoring along the lines established in this project.

1.5 REPORT LAYOUT

This report is divided into 8 sections of which this chapter is the first.

Chapter 2 describes our research approach.

Chapter 3 describes the baseline information as captured in a GIS for subsequent analysis, and what data is now available for assessments of the future impacts of land use change. Baseline information covers the physical characteristics, together with some social factors, which are likely to be impacted as a result of afforestation.

Chapter 4 gets down to the actual impacts of afforestation. In Section 4.1 the establishment of a limnological baseline is described and the biological health of the major rivers determined. In section 4.2 the impacts of current and expected afforestation on the water yield from 10 quaternary catchments is modelled and reviewed at local and regional scale.

Chapter 5 considers land management issues and options and offers guidelines for management and research, together with certain suggestions for policy development.

Chapter 6 provides discussion of major issues raised in Chapters 4 and 5, including the importance of certain forest management strategies, and the benefits of a strategic environmental assessment (SEA) wherever a major development involving land use change is contemplated.

Chapter 7 summarises the most important conclusions and discussion.

Recommendations for future research are listed and discussed in Chapter 8.

References are listed in Chapter 9.

The report closes with an appendix indicating what data has been captured, what other data has been accessed and where it resides. A discussion on the custodianship, storage and maintenance of the data sets created through this project is included in this appendix.

2. RESEARCH APPROACH

This research into the impacts of afforestation in the North-Eastern Cape has focused on water resource issues. Forestry practice in South Africa has long been recognized as having a negative impact on the total water resource - but also that it may be an effective user of water. There is recent recognition in South Africa of the water supply needs of both downstream communities and of the environment. This has increased the pressure on forestry as an upstream water user. At the same time the need to distribute the resource more equitably, and to optimise benefits at local, regional and national level encourage a more wide-ranging and strategic view of the value and use of the water resource. These issues have impacted upon our research approach.

A three step process was followed:

Description

The survey and mapping of environmental resources was aimed at providing a baseline of information on the resource at the time of change - to serve as inputs into the modelling of the impacts of change, and from which the degree of change can be measured. Parameters include information on vegetation, land use patterns, climate, water, wetlands, agricultural lands, invasion by alien plant species, and areas designated for afforestation.

Diagnosis and prediction

This component, requiring an assessment of the impacts of afforestation and forestry management practice on water yield, water quality, and riparian conservation, demanded a knowledge of planned and possible future afforestation, along with information on species, site and rainfall.

Prescription

A formulated framework to guide future action. This comprises the setting of goals and objectives, compliance requirements, institutional arrangements, and procedures or management guidelines.

With the objectives of setting up a baseline against which hydrological and environmental changes can be determined and evaluated, this study was approached with the goal of putting in place a functional and accessible information data base and a series of repeatable procedures for the determination of past, present and future impacts.

It has also become increasingly clear that the issues concerning afforestation development in the North-Eastern Cape go well beyond the biophysical suitability of the area, that more wide ranging and strategic considerations are required in planning new afforestation both in this region and throughout South Africa, and that environmental, economic and social issues are paramount. We have therefore attempted to introduce these factors into our research approach by identifying and reviewing the relevant issues, and by paying close attention to the arguments and debate stimulated by the forestry development. This has been achieved through workshop sessions, field days, and in-depth visits to the study site stretching back almost to the initiation of afforestation in the North-Eastern Cape (Forster 1991, Scott 1992).

2.1 USING GIS

Particular emphasis has been placed on the use of GIS technology in providing the spatial component to the study. The chief benefits of this approach have been the establishment of a body of baseline data which can be made available to any relevant role player (see Appendix 1 - on managing the database), and applications in the modelling of land use change in new and innovative ways.

2.2 USE OF EXISTING DATA

Throughout the project every effort has been made to maximise on the availability of existing data. Critical to this has been access to the rainfall database through the Computing Centre for Water Research, the use of orthophoto mapping for an assessment of alien invasives, quaternary catchment data from the Water Research Commission's WRSM90 database and the DWAF/CSIR 'Handy Manual', an existing database on wetlands provided by Eastern Cape Nature Conservation, the National Digital Elevation Model, and digital plantation information extracted from NECF's Microstation (CAD system) and converted into ArcInfo GIS format.

2.3 LAND USE MAPPING

The project has been dependent in a number of ways on land cover data interpreted from satellite imagery purchased by the project. Land cover patterns prevalent at the time of afforestation by NECF were established by analysing and ground truthing a March 1989 Landsat Thematic Mapper image. The data were not field sampled to produce a statistical measure of accuracy but the interpretation was verified in the field to improve the classification (see Section 3. 7). This data is compatible with the current national land cover initiative being undertaken by the CSIR in partnership with the Department of Agriculture and the Agricultural Research Council (Institute for Soils, Climate and Water).

2.4 HYDROLOGICAL MODELLING (WATER USE ESTIMATES)

A review of the existing hydrological network together with an analysis and discussion of the available rainfall and streamflow data for all records in the Ugie/Maclear districts was conducted by Scott (1992) for the Water Research Commission. This study used Scott's research as a starting point.

The lack of suitably located stream gauging stations precluded the direct measurement of forestry impacts on the water resource. A number of predictive modelling approaches were available to the project team including an application of the van der Zel / Nanni forest water use curves (Nanni 1970, van der Zel 1995), the use of the Pitman model (Pitman 1973, Pitman and Kakebeeke 1991), ACRU catchment modelling (Schulze 1995), and the CSIR flow reduction curves as developed by Smith and Scott (1992) and Scott and Smith (in prep). The Pitman model was calibrated for the Mooi River from streamflow records for the Water Affairs weir at Maclear (the best record available for the district), but estimates of forestry impacts were abandoned when it proved impossible to preserve the variability in flow from year to year - probably due to the highly variable rainfall and the accuracy of rainfall estimates from the poor raingauging network. See also section 4.2.

Given the extensive area planned for afforestation, its location across ten quaternary catchments, and the availability of a spatial information data base on ArcInfo GIS, an application of the CSIR flow reduction curves was finally adopted. This has had the advantage of allowing full benefit to be made of the spatial data sets, and has encouraged some innovative ways of looking at the impacts of forestry - notably the importance of age class distribution in influencing water yield, and how factors such as rainfall affect the impact of the distribution of the forest resource across the catchment.

2.5 DETERMINATION OF WATER QUALITY

The objectives in monitoring water quality in the North-Eastern Cape were to establish a baseline so as to determine the short and long term impacts of forestry management practices. Short term impacts include road construction, site preparation, tree felling, the application of pesticides, herbicides and fertilizers, and the longer term impacts of land use change such as possible acidification. The reductions in water yield can also lead to a deterioration in quality through reduced dilution effect and loss of habitat.

Alternative approaches to the determination of water quality, and the setting up of a baseline from which change could be monitored, included the establishment of a sophisticated chemical sampling and monitoring network, and the far less demanding limnological approach as described by Chutter (1992, 1994). The project team, in consultation with the project steering committee, opted for the limnological approach given the integrative nature of the biological indicators to impacts over time and to variation in the flow regime. The use of this 'biological assessment' approach has allowed the establishment of baseline data on the quality of those key North-Eastern Cape rivers most affected by afforestation, and against which degrade or improvements can be monitored. One of the chief criticisms of this approach is that while change may be detected there is little or no indication given of the nature or cause of such change. Benefits are that the method is relatively cheap, quick, and repeatable (local staff could be trained to do the monitoring) - although fluctuations in rainfall and riverflow can confound results (see Section 4.1).

2.6 SOCIO-ECONOMIC ISSUES

Throughout the course of the study it has become apparent that there are many social issues relating to land use change which also require attention. Whilst not many of these issues have been identified as relating directly to the regional hydrology some of the major urban and agricultural concerns have been collated by means of a series of telephone and personal interviews with agricultural organizations, local authorities, and other affected parties. This task was contracted to Herman le Roux of LandPlan in Aliwal North.

This assessment achieves a perspective of the impacts of land use change primarily from the point of view of established interests and 'white' structures such as churches, schools and cooperatives. Community inputs and opinions were not canvassed with any depth. NECF have, however, commissioned a full social assessment through the firm of Potgieter and Nel. The difficult task is to determine who really derives the benefits, or suffers the consequences of the change in land use.

2.7 GUIDELINES FOR MANAGEMENT AND POLICY

A wide ranging discussion has been developed in Chapters 5 and 6 of this report as an outcome both of research results, and of the many meetings, workshops and field-trips conducted around issues arising from the North-Eastern Cape forestry development. These opinions and resulting recommendations are a distillation of our understanding of issues and the expected hydrological impacts. This is, however, a working document and to prescribe management from some of the opinions and hypotheses developed may be presumptuous. We hope, at least, to stimulate a vigorous debate around many aspects of forest hydrology.

3. BASELINE RESOURCE INFORMATION

3.1 PHYSICAL DESCRIPTION OF THE STUDY AREA

3.1.1 Climate

Climate

The climate of the study area is warm temperate and is typical of the high elevation summer rainfall areas of eastern South Africa. Summers are warm with regular thunderstorms bringing most of the high annual rainfall, while winters are cold and dry with frequent frosts and occasional snowfalls.

The mean annual precipitation varies between 600 mm to 1200 mm and is strongly influenced by the topography (see Table 3.1). Mean monthly precipitation is greater than 50 mm between October and March while it is less than 25 mm in June and July.

Table 3.1 Median monthly rainfall (mm) for four rainfall gauging stations in the North-Eastern Cape region. Rainfall distribution and the siting of rainfall stations are shown in Figure 3.1 *(Source: Computing Centre for Water Research).*

Station	Jan	Feb	Mar	Apr	May	Jun	Jun	Aug	Sep	Oct	Nov	Dec	Annual
Elliot	102.1	108.2	90.5	43.2	19.1	8.9	7.2	9.0	27.0	53.0	78.2	86.0	701.1
Ugie	114.1	137.2	95.7	50.6	13.3	12.0	11.4	19.8	25.3	69.3	87.5	111.4	938.9
Maclear	116.6	112.8	105.9	36.2	11.7	4.3	3.5	8.2	24.2	48.4	77.5	111.6	767.0
Elands Heights	160.4	137.9	121.3	32.1	14.7	4.2	4.9	7.3	31.7	59.4	92.4	133.4	1011.9

Mean maximum temperature peaks at 25° C between January and February (Table 3.2) while minimum temperatures are reached between June and July (Table 3.3) at Maclear (1300m).

Table 3.2 Monthly maximum temperature (° C) for five stations in the North-Eastern Cape. *(Source: Computing Centre for Water Research).*

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Elliot	25.3	25.0	23.3	21.6	19.1	15.8	16.3	18.0	19.6	20.8	22.7	24.7
Ugie	25.1	24.9	23.9	22.4	20.3	17.5	17.8	19.4	20.5	21.3	22.6	24.9
Maclear	25.1	24.3	23.8	22.9	20.7	17.7	18.6	19.7	21.5	21.0	23.1	24.1
Sheeprun	26.7	25.8	25.3	21.8	20.0	17.4	18.3	20.1	22.3	23.2	23.9	26.1
Rhodes	26.2	24.8	23.3	20.7	17.6	13.7	14.9	16.0	21.0	21.3	23.1	25.5

Table 3.3 Monthly minimum temperature (° C) for five stations in the North-Eastern Cape. *(Source: Computing Centre for Water Research).*

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Elliot	12.7	12.5	10.8	7.4	4.3	2.0	1.1	2.9	5.4	7.5	9.3	11.4
Ugie	13.5	13.3	11.7	7.8	3.9	0.3	-0.2	2.8	6.1	8.2	10.4	12.4
Maclear	13.8	13.7	12.2	10.0	7.0	3.7	4.2	6.0	7.8	9.3	11.3	12.8
Sheeprun	14.3	13.6	12.7	8.4	4.4	0.6	0.7	2.9	6.9	9.6	11.1	13.1
Rhodes	9.8	9.4	6.4	3.0	0.9	0.5	0.3	0.8	2.2	4.0	6.5	8.5

Table 3.4 Monthly mean evaporation (mm), measured by the American Class-A pan, for three stations in the North-Eastern Cape. *(Source: Computing Centre for Water Research).*

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Elliot	182.2	152.2	141.1	119.3	125.2	104.7	129.6	151.9	157.4	159.5	168.9	203.1	1795.1
Ugie	149.0	112.6	119.2	99.4	99.8	74.4	126.0	126.0	140.2	146.3	142.8	169.2	1504.9
Sheeprun	165.3	132.4	123.9	88.0	70.5	55.6	76.8	108.7	128.3	148.7	159.3	179.1	1436.6

3.1.2 Climate and Streamflow Monitoring Networks

Raingauge Network

There are daily rainfall records for 33 raingauges in the broad vicinity of the catchments being afforested. Most of these raingauges belong to the South African Weather Bureau, the others belong to the Department of Agriculture or are privately owned. Twelve gauges have long records (> 30 years). An additional 14 stations have records longer than 15 years. All the data can be obtained from the Computing Centre for Water Research (CCWR).

Many records are not complete, but reliable records are available for at least 16 of the gauges. NECF have managed to obtain a number of additions to the regional rainfall records from surrounding farmers. The longest additional record dates back to 1964. This information has been sent to CCWR for inclusion into the national database.

It is apparent that most of the rain gauging stations (Table 3.5) are located outside the afforested and potentially afforestable areas, while the upper catchment areas are also poorly represented. This is of particular concern because of the steep orographic gradients that can be expected due to the mountainous nature of the region.

It is also apparent from Table 3.5 that the annual variation in rainfall is high, with maximum recorded values generally at least 50% higher and lower than mean rainfall, despite the fact that most records are very short.

Table 3.5 Rainfall gauging stations in the North-Eastern Cape region showing annual rainfall (mm) and length of record at each station. *(Source: Computing Centre for Water Research).* Rainfall distribution and the siting of stations are shown in Figure 3.1.

Station Name	Station Number	Length of record (years)	Mean rainfall (mm)	Median rainfall (mm)	Standard Deviation of mean rainfall	Range (mm)
Sassun	150444	21	546	532	142.7	327 - 954
Paxton WC	150466	31	760.9	711.7	179.2	336 - 1148
Granard	150511	8	559	549.5	120.5	387 - 781
Barkly Pass	150581	23	722.8	721.9	124	476 - 1049
Glen Hope	150595	41	771.2	746.6	162.9	499 - 1180
Elliot	150620	90	728.2	701.1	161.7	384 - 1159
Lisburn	150635	42	576.6	564.1	120.6	366 - 950
Taynuilt	150779	22	679.9	641.0	174.3	341 - 963

Station Name	Station Number	Length of record (years)	Mean rainfall (mm)	Median rainfall (mm)	Standard Deviation of mean rainfall	Range (mm)
Greyling AC	150863	20	585.8	565.5	130.8	383 - 852
Xuka Drift	151019	15	685.2	738.6	246	120 - 1125
Ronan	151080	19	751.4	766.3	147.9	543 - 1203
Gubenxa	151231	16	755.8	664.7	304.8	501 - 1784
The Home	151290	14	667.4	664.9	168.9	359 - 1022+
Ugie	151463	7	937.8	938.9	158.9	762 - 1199
Maclear (Mag.)	151604	99	754.0	762.0	179.0	370 - 1151
Maclear (Mun.)	151604b	23	802.3	772.4	149.5	497 - 1108
Hopefield	151623	41	637.3	621.5	149.7	330 - 964
Langeni	151839	38	1197.6	1153.6	215.2	765 - 1779
Kelvin Grove	177441	40	648.5	663.4	146.3	321 - 877
Giddy	177442	36	683.6	669.5	145.4	454 - 976
Clontarf	177622	14	676.9	657.6	142.4	487 - 975
Rhodes	177828	20	696.7	691.6	124.6	487 - 921
Malpas	177885	42	685.7	687.0	140.4	412 - 984
Cransmoor	178320	11	1062.0	1070.4	200.3	729 - 1335
Kilmeny	178321	16	1026.0	1022.5	188.3	747 - 1318
Antelope Park	178349	17	978.1	955.6	159.5	665 - 1379
Elands Heights	178378	19	977.7	1011.9	197	587 - 1388
New Lynndale	178564	13	878.9	905.2	164	439 - 1095
Bloegomhof	178585	36	685.6	681.0	173.2	283 - 1046
Delvillebos	178615	32	840.1	822.0	134.6	560 - 1228
Sheeprun	178689	12	756.1	788.7	202.3	527 - 997
Stockenstrom	178689w	25	811.5	815.5	166.7	419 - 1151
Kromhoek	178807	24	718.8	714.8	137.1	495 - 1006

Temperature Monitoring
There are only two daily temperature monitoring stations in the area of interest, at Sheeprun and at Ugie. The Sheeprun station has measured daily maximum and minimum temperature for about 20 years, starting in 1963 and ending 1983. The station at Ugie has records which started in 1982 and is still being monitored (see Tables 3.2 and 3.3).

Evaporation Monitoring
Daily evaporation (as measured by the American Class-A pan) is currently being monitored at Elliot, Ugie and Sheeprun.

Automatic Weather Stations
NECF has installed four automatic weather stations between June and December 1994, for the principal purpose of monitoring fire danger on their estates. The automatic weather stations are located in the vicinity of the forester's offices on the Funeray (1 490 m), Wildebees (1 320 m), Glen Cullen (1 320 m) and Elands Heights (1 760 m) estates.

At present the following are recorded on a hourly basis: dry and wet bulb temperature, sunshine hours, wind speed and direction (average hourly rates plus gusts), maximum and minimum temperature and rainfall. The Agricultural Research Council's Institute of Soils, Climate and Water (ISCW) download data monthly directly from the field via telephone lines and processes this on behalf of NECF.

Until the advent of the NECF automatic weather stations, there was a dearth of climate monitoring activity in region. Rainfall and evaporation measurements are especially important in the higher reaches of the catchments, which are important sources of runoff for the major catchment areas.

3.1.3 Streamflow Monitoring

The hydrological coverage of the key areas earmarked for afforestation is poor. Although it has been recommended (Scott 1992) that the weir T3H009-A01 on the Mooi River at Maclear and weir T3H011-A01 on the Wildebees river at Ugie be improved this is not a priority of DWAF (see Figure 3.2). Data from the weir on the Mooi River is of adequate resolution to meet the regional water supply information needs of the Department of Water Affairs and Forestry. Accuracy is however inadequate for the quantification of impacts of land use change through forestry within the catchment. This highlights the need for project specific monitoring sites should hard evidence of impacts be demanded.

Selection of additional stream gauging sites
Following a field visit to the North-Eastern Cape region with DWAF officials early in 1994, members of DWAF'S Eastern Cape regional Hydro team completed a site survey of suitable gauging sites along the Wildebees, Mooi, Pot and Gat rivers. Potentially good sites were identified, particularly on the Pot and the Wildebees, which would be useful in assessing flow from the afforested areas (see Figure 3.2).

3.1.4 Topography

The region forms a shelf between two escarpments: one to the east and south-east which roughly forms the western border of the former Transkei, and the second to the west and north-west which is the southern-most extension of the Drakensberg.

The elevation of the area to be afforested ranges from ± 1 300 m to 1 950 m. The terrain is fairly variable, ranging from steep craggy Drakensberg escarpment slopes and foothills in the crest to gently undulating slopes of the plateau (at about 1400m) to the south and east.

The highest points are Scobell's Kop (2 730m) and Tina Head (2 824m) to the south and north of Naude's Nek Pass respectively. These are situated along a prominent basalt capped ridge of the Drakensberg. This ridge forms the watershed between the Orange River catchment and the eastwards flowing rivers, and gradually decreases to 2 400m in altitude to its end near Indwe. Long narrow sandstone capped spurs with fairly even crest lines extend to the south-east. These ridges separate the gorges of the Wildebees, Mooi and Pot rivers.

3.1.5 Geology and Soils

De Decker (1981) describes the geology as follows: The region is characterized by a series of near horizontal sedimentary layers of the Karroo Sequence. Particular features include the *Molteno Formation*, consisting of coarse, pebbly, felspathic sandstone, mudstone and shale. This is followed by the *Elliot Formation* of red and purple mudstones predominating over medium-grained feldspathic sandstone. Above this the aeolian *Clarens Formation* which forms the impressive cliffs of features such as the Prentjiesberg. This formation consists of very pale-orange to cream coloured, well sorted, massive, fine to very fine grained feldspathic sandstone with minor mudstone intercalations. At the highest altitudes the extensive flows of basaltic lava that form the *Drakensberg Formation* are found. In the underlying sedimentary rocks widespread sills and dykes of dolerite are present.

Some alluvial and colluvial (debris) deposits are found near the river courses occupying the valley floors. These constitute the bulk of the Quartenary deposits present. Structurally the area shows little change since the deposition of the sediments. The regional dip of the strata is 2° to 7° and is towards the west and north-west. This tilting probably resulted from the loading of the crust by the enormous amount of basalts poured out in Jurassic times (de Decker 1981).

Soils

Mudstone, shale or sandstone belonging to the subgroup Tarkastad of the Beaufort Group of the Karoo Sequence form the dominant parent material of the currently afforested area. In some places, dolerite intrusions occur.

The *Molteno Formation* consisting of mudstone, shale and sandstone lies generally to the south of the main road (R56) in the area, while brownish-red and grey mudstone and sandstone of the Elliot formation lies to the north. Fine-grained sandstone of the Clarens formation occurs in the higher mountainous areas, younger alluvium and colluvium occur alongside rivers or on some middle and lower slopes respectively. Due to the layering effect of the sediments, water permeability should be affected in the layers below the soil profile.

Dr Freddie Ellis (pers. comm.) describes the soils in the area where most afforestation has taken place as dominantly deep (>1000 mm to any restriction) red-yellow apedal, freely drained soils belonging to the Kranskop, Magwa (closer to the high-lying Drakensberg) and Hutton, Clovelly and Oakleaf soil forms (MacVicar *et al.* 1977). The clay content is as high as 25 - 40 %. Subsoils are generally higher in clay content than topsoils. In general the soils have a low pH and base status, and fertilisation is recommended for plantings on virgin land. Some of the old agricultural lands have been limed and fertilised. In some of the areas, especially those where grey mudstone forms the parent material, soils with a duplex morphology (i.e. a permeable topsoil lying on a less permeable subsoil) dominate. The mudstone soil forms include Sterkspruit, Estcourt, Klapmuts and Kroonstad a have shallow rooting depths (<600 mm).

North East Cape Forests has a comprehensive data base of soils for all its farms earmarked for afforestation. Data points are on a grid of 150 m. The mudstone soils are particularly erosive, and are avoided both for this reason and because of the shallow rooting depth.

The relatively good depth of soils reported appears to conflict with the experience that many of the soils are shallow and unsuited to forestry. (Soils of < 600 mm depth are not considered for planting). This is a consequence of the fact that the survey reported is for sites already selected as suitable for forestry. The extensive areas of shallow soil have therefore already been excluded.

3.1.6 Water Repellent Soils

The June 1994 fire in the North-Eastern Cape afforded the opportunity to test for water repellency in soils at a number of sites. Water repellent soils resist wetting by water, a behaviour which is caused by a coating on the soil particles of hydrophobic substances of organic origin (Scott and van Wyk 1990, Scott 1994). Intense fires, the result of high fuel loads, cause water repellency to be burned off the surface soil but intensify it in lower soil layers. Some soils are more susceptible to repellency than others. Very serious erosion problems have been experienced after fire in pine plantations both at Cathedral Peak in the Northern Drakensberg, and at Jonkershoek in the Western Cape (Scott 1994). There is a risk on susceptible soils, especially on steep slopes, for heavy soil loss to follow fire because of increased overland flow occurring during heavy rain.

From our 1994 observations significant repellency was observed within established stands of Black Wattle (*Acacia mearnsii*) burnt by the fire. Repellency within the young stands of pines proved to be less obvious. In the absence of more data these observations nevertheless stand as a precautionary warning - and particularly against afforestation on naturally erosive sites.

These risks must be considered in the light of the fact that fires are an inevitable feature of the South African forestry landscape. From national plantation statistics the fire return period within plantations is 200 years (van Wilgen and Scholes 1997). This means that 0.5 % of all South African plantations burns each year. If the North-Eastern Cape realizes a plantation area of 100 000 ha, then 500 ha can be expected to burn every year, or 8 500 ha every rotation.

3.1.7 Land cover prior to afforestation

The land cover patterns prevalent at the time of afforestation by NECF were established by analysing and ground truthing a March 1989 Landsat Thematic Mapper (TM) image. The Landsat TM data has a resolution of 30 m x 30 m and covers an area of approximately 120 km by 120 km. The data were not field sampled to produce a statistical measure of accuracy but the interpretation was verified in the field to improve the classification. The Ugie and Maclear districts, the plantations in the former Transkei north of Umtata, and the confluence of the Tsitsa and Umzimvubu rivers are included.

The following classes were mapped and results are listed in Table 3.6; grasslands, indigenous bush, thicket, agriculture, woodlots, settlements, bare rock, water bodies, cloud obscured and shadow. The high degree of relief variation in the region has resulted in a high percentage of terrain shadow (6,97%).

Agriculture has been categorized into commercial and non-commercial, while bare rock has been separated from low grassland and degraded areas. The low grass cover and degraded category includes both those areas of naturally occurring low ground cover (ie on steeper slopes) and those that are actually degraded. It was not possible to separate the numerous small vleis in the Maclear district from the closed canopy bush/thicket and agricultural categories, so unfortunately these remain mixed in with these categories. Areas of alien vegetation infestation (i.e. wattles and poplars) are included within the closed-canopy bush/thicket category.

Table 3.6 Land cover classification for North-Eastern Cape region.

Description	Area (Hectares)	Area (%)
Agriculture (non-commercial)	157898,8	5,83
Agriculture (commercial)	53099,5	1,96
Grassland (low) and degraded land	305357,3	11,27
Grassland (high and good)	1509949,5	55,72
Closed canopy bush and thicket (including exotics)	174583,5	6,44
Plantations and woodlots	77658,7	2,87
Indigenous forests	83273,0	3,07
Open water surfaces	93475,5	3,45
Urban and rural settlement	21859,3	0,81
Bare rock (exposed strata)	30282,4	1,12
Terrain shadow and unclassified	188917,9	6,97
Totals:	**2 709 746,4**	**100,00**

Mondi Forests have also established an Environmental Conservation Data designed to hold information on all non-afforested land within their forest estates. This is also available for the North-Eastern Cape.

Prior to current afforestation plans, the principal land-use has been extensive livestock grazing of both cattle and sheep. There is also a considerable area of dryland cultivation, and minor areas of irrigated cropland and dispersed forestry on a woodlot scale. Woodlot species are predominantly *Acacia mearnsii* , *Acacia decurrens* and *Eucalyptus* species. There is much evidence of overgrazing in the steep catchments and resultant erosion where thinner soils occur.

Table 3.7 Total land cover (1989) for quaternary catchments within the Bashee Catchment. Areas are hectares. Only those quaternary catchments for which afforestation has been planned are included. (Derived from Landsat TM imagery 1989)

Description	T11B	T11D	T11E
Agriculture (non-commercial)	68.6	1424.8	733.8
Agriculture (commercial)	3953.2	1582.6	830.2
Grassland(low) and degraded land	5357.0	3062.8	1844.5
Grassland (high and good)	28646.1	24192.9	15867.8
Closed canopy bush and thicket	505.1	949.1	773.1
Plantations and woodlots	573.8	350.7	1405.8
Indigenous forests	353.6	680.2	365.1
Open water surfaces	0.2	42.2	11.7
Urban and rural settlement	-	-	-
Bare rock (exposed strata)	332.1	222.3	15.4
Terrain shadow and unclassified	1688.8	1753.1	1441.9
Totals:	**41478.5**	**34260.7**	**23289.3**

Table 3.8 Land cover (1989) before afforestation for land allocated as forestry compartments within those quaternary catchments in the Bashee Catchment. Areas are expressed in hectares. (Data is a sub-set of table 3.7).

Description	T11B	T11D	T11E
Agriculture(non-commercial)	-	-	-
Agriculture (commercial)	273.8	411.3	122.0
Grassland (low) and degraded land	176.3	177.2	170.9
Grassland (high and good)	1236.0	1610.5	2288.5
Closed canopy bush and thicket	16.1	21.1	44.6
Plantations and woodlots	20.9	41.2	71.0
Indigenous forests	4.2	4.5	6.2
Open water surfaces	-	0.6	-
Urban and rural settlement	-	-	-
Bare rock (exposed strata)	-	8.5	5.4
Terrain shadow and unclassified	3.8	7.6	41.2
Totals:	**1731.1**	**2282.5**	**2749.8**

Table 3.9 Total land cover (1989) for quaternary catchments within the Umzimvubu Catchment. Areas are hectares. Only those quaternary catchments for which afforestation has been planned are included. (Derived from Landsat TM imagery 1989)

Description	T34E	T35A	T35B	T35C	T35D	T35F	T35G
Agriculture (non-commercial)	-	1154.6	-	-	643.9	-	758.6
Agriculture (commercial)	275.5	231.2	2484.3	1017.1	2424.8	2712.2	7448.3
Grassland (low) and degraded land	2632.6	6337.5	4591.3	3043.3	4566.7	2970.7	6584.7
Grassland (high and good)	20852.3	34235.8	27939.8	23074.8	24413.7	26654.9	38964.0
Closed canopy bush and thicket	454.8	734.6	955.9	632.7	627.7	334.2	835.0
Plantations and woodlots	38.9	78.5	77.8	291.3	283.4	467.0	496.3
Indigenous forests	154.9	283.2	496.9	359.9	207.9	311.3	306.5
Open water surfaces	-	-	14.9	-	45.4	18.9	107.8
Urban and rural settlement	-	-	-	30.4	204.3	103.2	-
Bare rock (exposed strata)	288.7	915.3	302.2	365.4	736.3	145.9	979.9
Terrain shadow and unclassified	2121.6	3543.9	3002.4	1803.7	624.6	2153.4	973.8
Totals:	**26819.3**	**47514.6**	**39865.5**	**30618.6**	**34778.7**	**35871.7**	**57454.9**

Table 3.10 Land cover (1989) before afforestation for land allocated as forestry compartments within those quaternary catchments in the Umzimvubu Catchment. Areas are expressed in hectares. (Data is a sub-set of Table 3.9).

Description	T34E	T35A	T35B	T35C	T35D	T35F	T35G
Agriculture (non-commercial)	-	-	-	-	-	-	-
Agriculture (commercial)	-	164.7	438.1	819.3	49.0	1621.1	939.8
Grassland (low) and degraded land	-	583.2	276.6	723.6	147.8	973.8	703.4
Grassland (high and good)	3.2	5707.6	2283.2	7078.6	1992.3	11716.3	6461.2
Closed canopy bush and thicket	0.9	271.8	70.5	132.9	67.8	246.2	186.9
Plantations and woodlots	-	30.0	54.0	168.4	-	351.8	76.6
Indigenous forests	-	46.9	26.7	55.5	9.9	154.7	74.2
Open water surfaces	-	-	3.5	-	-	14.5	3.6
Urban and rural settlement	-	-	-	-	6.1	-	-
Bare rock (exposed strata)	-	135.7	10.3	124.0	21.6	53.0	110.7
Terrain shadow and unclassified (1)	-	347.0	152.7	124.8	73.3	804.9	270.2
Totals:	**4.1**	**7286.9**	**3315.6**	**9227.1**	**2367.8**	**15936.3**	**8876.6**

3.1.8 Land cover types

(i) Forestry

We were successful in transferring some spatial information from the NECF CAD system (Microstation) to our GIS (Arc/Info). Plantation and compartment boundaries, as well as roads were transferred but, because of system incompatibilities, attribute information such as compartment numbers, species and planting dates had to be added manually. This was a time consuming exercise but was vital to the hydrological analyses. Table 3.11 lists planted areas by the 10 quaternary catchments where afforestation has taken place. NECF have recently decided to convert all their data from Microstation to Arc/Info. While too late to be of benefit to the project this will be of great value in keeping the database up to date, and in any future analyses.

Table 3.11 Current[1] (1997) area (hectares) under NECF plantation trees by Quaternary Catchments. *(Source: NECF)*

Species	T11B	T11D	T11E	T34E	T35A	T35B	T35C	T35D	T35F	T35G
Pinus	1 044.4	1 751.4	1 641.6	96.5	4 236.7	1 774.9	4 718.8	1 360.3	7 257.5	5 063.8
Eucalyptus	2.2	10.9	-	-	-	-			618.5	34.8
Total Area	**41 479**	**34 261**	**23 289**	**26 819**	**47 515**	**39 866**	**30 619**	**3 4779**	**35 872**	**57 455**

(ii) Agriculture

The North-Eastern Cape is an isolated agricultural district, traditionally dependent on rangeland stock farming together with some winter pastures, on limited cropping (maize and potatoes) and on dairy activity. Often viewed as improverished there are however some very successful enterprises. That the area is not as rich as its great natural beauty would seem to indicate is a consequence of distance from markets, shallow and erodible soils, and an extreme and variable climate. Land prices have therefore been low and many farmers have welcomed the intervention of forestry.

[1] Current area based on areas already afforested together with immediately planned planting (1997) for which permits have already been allocated and plans approved.

There is a paucity of reliable agricultural statistics in the district. The agricultural extension officer at Elliot was unable to provide any statistics on stock numbers, the number of farmers or other production figures. What data there may be is apparently scattered in a number of reports and would have to be extracted and analysed in order to be of value. Data gathered by the Directorate of Agricultural Statistics is not seen as reliable because very few farmers reply or give correct data.

The analysis of a Landsat TM digital image showed that prior to the start of NECF's forestry development in 1989, the 10 currently afforested quaternary catchments (see Section 3.1.7) comprised 6.1 % commercial farmland (mostly used in dryland cropping), 11.0 % degraded grasslands, whilst 'healthy' grasslands made up 71.2 % of the cover (see Tables 3.7 - 3.10).

Crop farming

Dryland maize and potatoes are important cash crops. Almost all crop farming has traditionally been under dryland conditions, with irrigation only taking place on a very limited scale. The recent advent of ESKOM power in the region has however increased the area of land under irrigation, with the primary crop being potatoes.

Facing the lack of agricultural production statistics some inferences have been gleaned from the production experience of Maclear Maize Milling (November 1995). Maclear Maize Milling process approximately 85 % of the maize and potatoes produced in the area. The level of production, of both maize and potatoes, does not seem to have been affected by the forestry development. One possible reason offered is that North-Eastern Cape forests bought farms from marginal to weak farmers who in the main had debt problems. The sale of their farms was seen as a way out by many farmers. It is also argued that farmers are now hesitant to plant cash crops on land close to the towns because of the problem with theft from the growing townships but again this does not seem to have affected production.

Tonnages in 1995 were; White Maize : 11 700 tons; Yellow Maize : 3 200 tons. This was about half that of 1994 due to the drought but the quality was much higher due to the drier conditions. From the tonnage produced it can be inferred that this is not a major maize production area at the best of times.

Stock farming

The North-Eastern Cape is primarily a sheep and cattle farming area. The number of sheep increased during the 1980's as a consequence of good wool prices and low beef prices. Lower wool and meat prices have since depressed stock farming in the region. Increases in stock theft and in losses due to predators (jackal and caracal) are also given as contributory problems although there is little substantive evidence to this effect.

(iii) Natural vegetation

The study area is predominantly covered by grasslands with *Protea* savanna occurring on the rocky slopes of the Clarens formation. Patches of afromontane forests occur in the sheltered kloofs. Geophytes are abundant (Vlok and Briers 1992).

Two predominant grassland types are recognised by Low and Rebelo (1996) within the study area. These are; Moist Upland Grassland (# 42) which is synonymous with Acocks' (1988) Highland Sourveld (# 44a) and Dohne Sourveld (# 44b), and South-eastern Mountain Grassland (# 44), which is synonymous with Acocks' Themeda-Festuca Alpine Veld (# 58) and Stormsberg Plateau Sweetveld (# 59).

Moist Upland Grassland originally occupied 440 125 km^2. Of this approximately 60% is transformed and 2.5 % is conserved (Low and Rebolo 1996). These grasslands occur at attitudes of 600m to 1400m and are most common in the Drakensberg foothills of the Eastern Cape and KwaZulu-Natal. They occur on shallow, rocky and leached soils derived from the Karoo Sequence sediments and dolerite intrusions.

The vegetation forms a dense, sour grassland with *Themida triandra* (Rooigras), *Heteropogon contortus* (Speargrass), *Tristachya leucothrix*, *Eragrositis curvula* and *Elionurus muticus*, *Hyparrhenia hirta* (Common Thatchgrass) and *Sporobolus pyramidalis* (Catstail Dropseed) as some of the dominant species.

Overgrazing encourages the invasion of unpalatable *Elionurus muticus* (Wire Grass) and herbaceous weeds such as *Senecio retrorsus* and *Helichrysum argyrophyllum*. In areas protected from fire, forest pioneer species, such as *Rapanea melanophloes,* and fynbos species such as *Cliffortia* species, *Erica* species and *Metalasia muricata* appear. The Coleford and Himeville Nature Reserves in KwaZulu-Natal are the major conserved areas of this grassland, while it is heavily overgrazed in the former Transkei.

South-Eastern Mountain Grassland is found in the upper parts of the district towards Elands Heights. Acocks' synonyms include Themeda-Festuca Alpine Veld (# 58) and Stormsberg Plateau Sweetveld (# 59). This grassland occupies 226 757 km^2, of which approximately 32 % is transformed but only 0.33 % conserved (Low and Rebelo 1996).

The volcanic soils in this high rainfall region are covered by short dense grassland dominated by *Themeda triandra* (Rooigrass), *Festuca costa*, *Festuca scabra* and *Elionurus muticus* (Wire Grass). *Leucosidea sericea* (Ouhout) is found in kloofs and on sheltered slopes and patches of grassy fynbos also occur. This is important stock land owing to suitable winter grazing. However selective grazing can convert it to sourveld or result in an invasion by fynbos elements. It is poorly conserved. The project has relied on land cover as interpreted from satellite imagery. This should be supplemented by the, as yet incomplete, mapping section undertaken by the University of Pretoria (Section 1.4.2).

(iv) Invasive exotic vegetation

All the major rivers are infested with invasive exotic woody species, principally black and silver wattle (*Acacia meamsii* and *Acacia dealbata*), grey poplar (*Populus canescens*) and to a lesser extent weeping willow (*Salix babylonica*) and *Robinia pseudoacacia*. There is a heavy silt covering on the stream and river bottoms indicating considerable erosion in the catchments, and a high load of plant material (BOD) in the streams from the weed infestation. While chemically the streams may be of good quality, they are certainly not pristine. Where alien vegetation is found outside of riverine habitats it is generally associated with woodlots occurring close to abandoned homesteads. As some of these homesteads occur in the upper catchments these unmanaged woodlots present a constant source for downstream invasion.

A limited amount of alien vegetation invasion mapping was undertaken as it was not possible, using the Landsat TM imagery, to separate invasive vegetation from the closed canopy bush/thicket and agricultural categories (see Section 3.1.7). This was done for quaternary catchments; T35A, T35B, T35C, T35D, T35F and T35G were mapped from pre-1989 1: 10 000 orthophotos (supplied by NECF) while invasive vegetation in the river valleys was mapped in the field using a combination of 1: 10 000 and 1: 50 000 topographical maps (see Appendix 1).

It is difficult to say with great certainty what the extent of alien vegetation was prior NECF forestry development as at the time of this study a substantial amount of invasive vegetation had been cleared by NECF, with most of this activity has been concentrated along the Pot and Mooi Rivers. Also many *Acacia mearnsii* stands were cleared to make way for the pine plantations.

3.1.9 Wetlands

Background

One of the most defining characteristics of the midland areas of the North-Eastern Cape is the predominance of wetlands within the landscape. This is quite unique in South Africa. Wetlands in the North-Eastern Cape comprise riparian zone wetlands, consisting of small ox bow lakes and pans, and high altitude bogs. The importance of these wetlands lies in their contribution to the diversity of the mountain grassland, providing different habitats for local fauna and flora. In addition, they may have important hydrological functions, such as slower release of stored water, sediment trapping, and flood peak attenuation.

Riparian zone wetlands.
These predominate in the region as a consequence of the geology of the area. Hard caps of Beaufort Sandstone of the Karoo Supergroup have impeded downward erosion of local streams. This has caused local valley bottoms to be flat, resulting in meandering stream beds. Over time, these meanders have left behind ox bow and pan remnants of the original stream bed. This type of terrain is quite common for similar occurrences of geology throughout the Drakensberg mountain range, but particularly so within the North-Eastern Cape region (see Figure 3.3).

The flatness of the landscape has allowed the deposition of fine sediment and clays in the valley bottoms, which combine with the underlying sandstones to form relatively impermeable layers under some riparian zone wetlands. In places soils with high contents of organic matter have developed from the reeds and grasses that grow there. These soils are highly porous and can be more than 2 metres deep.

Wetland function
A wetland will retain water in a catchment over and above that associated with the underlying and surrounding soils. Wetlands do this in two ways, on the surface as impeded drainage and in highly porous soils. There are two primary hydrological effects of this water storage. One is that there are increased opportunities for evaporation of the water on site. The second is that the stored water is released to the catchment drainage system and manifests itself in increased flow of water during the low flow periods. Wetlands may therefore be viewed as sinks or sources, depending on perspective (see also Chapter 5).

The importance of wetlands in terms of control over the hydrological characteristics of the region cannot easily be quantified and may often be site specific. That wetlands play a role cannot be doubted and any change in function must be critically assessed. That there has been some change in wetland function in the North-Eastern Cape is quite obvious. In some cases stream beds have eroded vertically, causing a sharply defined trench and exposing the clay soils of the surrounding wetland. Changes in the hydrological function of the wetland have been caused by this deepening of the channel - drainage in the channel is now more rapid and the wetlands have drained. The evidence for this drainage is the change of vegetation in the wetlands from sedges and reeds to one more dominated by grasses in common with the surrounding grasslands.

Analysis of small research catchments in KwaZulu-Natal catchments in Schulze (1979) show an annual peak flow delayed by two months in the catchment containing a wetland. During low-flow conditions in the dry months, the catchment containing the wetland produces more than twice the runoff than its comparable non-wetland catchment. There is also a reduction in the monthly coefficient of variability in the wetland dominated catchment. Net yield from the wetland catchment can however be expected to be lower because of the increase in evaporation opportunities. The function of streamflow regulation, and the importance of low flows, may therefore be weighed against maximizing total water yield.

Channelling as a result of disturbance
The channelling of flow through the wetland, at deeper levels, will drain the wetland and negate the delaying effect on streamflow. Drainage channels have been cut through a number of the wetlands in the North-Eastern Cape whilst in others existing channels have become deeply incised - a probable result of local land management over the past 100 years (grazing, crop farming). Incised channels now act as drainage channels, reversing the function of the wetlands which are now likely to drain rapidly and will no longer behave as wetlands. Channels may even serve as drainage ditches. Observation at Franklin Vlei, just north-east of Kokstad, in KwaZulu-Natal is that reduction of thick wetland vegetation around the original channel has lead to energy of streamflow concentrated increasingly within a narrowly defined channel, leading to bed erosion and straightening of channels (Chapman pers. obs.). Both the construction of drainage ditches and processes of this nature have led to very deep channelling through many North-Eastern Cape wetlands. Rehabilitation of these channels may revive the function of the wetlands and lead to flood retention and release of water in low-flow periods.

3.1.10 North-Eastern Cape as a tourism resource

The North-Eastern Cape is an area of great natural beauty, and obvious tourism potential. Infrastructure and tourism accommodation are, however, very poorly developed and local hotels need to be brought up to standard. NECF has a number of sites well suited to tourism development. An improved road link to KwaZulu-Natal would be a priority in any strategy to encourage tourism.

3.2 SOCIO-ECONOMIC DESCRIPTION OF STUDY AREA

This socio-economic description offers only a snapshot of some of the issues the North-Eastern Cape. This section is a response to an added request from the Steering Committee to the project team to review the impacts of forestry not only in the hydrological, but also in the social, context. In recognition of the need for a detailed study this was commissioned independently by North East Cape Forests (Potgieter and Nel 1996).

3.2.1 Demographics

The towns of Maclear, Ugie and Elliot have all experienced significant growth in population since 1990, with this increase confined entirely to the black community (Table 3 .12).

Table 3.12 Population data for three towns in the North-Eastern Cape *(Source: Landplan and Associates).*

Population	Maclear	Ugie	Elliot
Total	15 180	15 105	21 150
Black	14 000	14 000	20 000
'Coloured'	580	305	250
White	600	800	900

Maclear

Nine thousand people have moved to Maclear since 1990. Of these only 500 have come from nearby farms, with the remaining 8 500 reflecting influx from the former Transkei. It would seem that this influx was stimulated by the hope that land would be available for settlement and not by job opportunities. NECF has been having difficulty in recruiting labour locally and finds it necessary to recruit staff from the Herschel district and from Lesotho.

One impact has been in the use of the town commonage, traditionally available to local farmers, at a fee, for grazing. Township stock owners have been using the commonage without paying rent, and income has dropped from R 50 000 to R 12 000 per annum. It is expected that soon no income at all will be generated from this source.

Ugie

Ugie's black population has also grown very rapidly although the local council and South African National Civics Organisation (SANCO) now has a policy prohibiting settlement from the Transkei unless family members are already resident in Ugie. The growth of the town is reflected in figures compiled by Ninham Shand in 1993 in an application for water provision. While this study projected a population of 11 000 people in 1998, the population already reached approximately 16 000 in 1995. The situation in Elliot is similar although growth statistics are not available.

3.3.2 Community Issues

(i) Impact on community life of commercial farmers

The impact of forestry on the established commercial agricultural sector in the district is reflected in large drops in membership of farmer organizations. This is partially, but not entirely, due to the purchasing of farms for afforestation. We were unable to gain a clear picture on the levels of occupancy of farms from which to draw a baseline reflecting the influence which wide scale afforestation might have.

Membership of the Dutch Reformed Church in both Maclear and Ugie has declined drastically in recent years. This is a reflection of a decline in the number of local white farmers and the closure of the Dutch Reformed orphanage in Ugie. The NECF employees who have moved into the district often belong to a different social and cultural milieu.

(ii) Water requirements

Urban and Industrial Water Supply
Both Ugie and Maclear are growing very rapidly (see Section 3.2.1) and recognize the need for water augmentation schemes, while Elliot appears to be adequately supplied for the present. None of these towns have expressed major concerns with regard to the security of supply as a result of forestry development. Elliot has no plantations in the catchments tapped by the town, while in Maclear the experience has been one of a positive improvement in water quality, with less siltation of the dam and few chemicals required in achieving quality standards (Landplan & Associates 1995).

Water supply to both Ugie and Maclear has been below average in recent years, but any possible impacts of afforestation cannot be separated from the drought prevailing through the early 1990's.

Maclear is looking at various water augmentation options, notably:

(I) Construction of an additional dam below the existing dam site;
(ii) Pumping directly from the river below the township

Ugie has applied to DWAF through Ninham Shand for funding for water supply development. Planning projects includes R 200 000 for a new dam. Population growth has been so rapid that the town population now exceeds the 11 000 prediction for 1998, and these plans might already require revision.

Rural Water Supply
In the rural areas most water requirements are met from surface water resources (dams and streams). There is no record of the number of boreholes and windpumps. Very few windpumps are visible in the region, while those boreholes in operation are almost exclusively for domestic use. Stock rely on dams and streams.

The local impacts of forestry on water resources are of great concern to farmers in the district, but these have yet to be felt or demonstrated.

(iii) Energy

ESKOM is actively engaged in an electrification programme which will at least meet the needs of the local towns. NECF has been providing wattle, made available through the company's riparian zone clearing operations, for firewood.

(iv) Job creation

No records exist as to the number of workers employed in the district before NECF arrived. NECF currently employs about 450 workers directly, and a further 250 jobs are filled through contracted services. There is a considerable flow of money into the area as a result of NECF's operations, with current annual expenditure by NECF in the order of R 25 m (this is estimated to increase to R 45 m when harvesting begins).

Plantation forestry is a major employer. But it is the secondary industries which provide the greatest job benefits. It is estimated that up to 3000 jobs would be created should the afforestation development result in the establishment of a pulp mill (pers. comm. Eric Droomer 1996). Should this happen it will have a major impact, with added buying power affecting the use of resources and especially water resources.

Provincial Government sees the Ugie - Maclear areas as a priority for the provision of infrastructure necessary to support the developments arising from the forestry project. The new District Council will provide the channel for Government funds to come into the area. More jobs will then be created in the provision of services.

(v) Land ownership and land use

One of the problems accompanying the movement of farm labourers to the towns of Elliot, Ugie and Maclear, has resulted from their accompanying stock. The utilization of commonages by this stock, without any form of compensation, has led to a reduced income for the municipalities (Landplan & Associates).

(vi) Security

Some farmers feel threatened and say that NECF plantations serve as a refuge for criminals but this does not accord with the recorded statistics. There is no correlation between either stock theft or housebreaking and the vicinity of plantations. Most incidents of housebreaking are recorded within the towns. The trends for both Elliot and Ugie, do indicate some increase in the levels of housebreaking and stock theft, but these need to be read alongside the data reflecting rapid population increase. For example the incidence of housebreakings has risen 68% (from 99 to 166) in Elliot between 1990 and 1994, but stock theft has remained static, perhaps reflecting the reduction in stock numbers rather than a lack of increase in crime.

Stock theft provides common cause for complaint from established farmers. Interviews with SAPS District Commissioners and the local police commanders tend, however, to negate the validity of such complaints. While no statistics are readily available it would appear that most incidences of stock theft occur along the former Transkei border or close to urban settlements. In the latter case these are often confined to the loss of single sheep.

3.3.3 Infrastructure

(i) Commercial

The North-Eastern Cape has been economically depressed for many years and desperately needs economic development. Given that the area abuts the former Transkei the degree of support which can offer this vast rural hinterland should not be underestimated. However, at present there is a danger that the rapid influx of people will swamp the available infrastructure.

Development by established interests within the towns of Ugie, Elliot and Maclear is considered to be stagnant, although it is recognised that there is growth within the black townships. A number of businesses were registered with the Drakensberg District Council (Barkley East) in October 1995 (Table 3.13).

Table 3.13 Numbers of businesses registered in three towns in the North-Eastern Cape in October 1995.

	Elliot	**Ugie**	**Maclear**
Hotel	1	2	1
Restaurant/Eating places	4	3	9
Garages	3	3	6
Engineering Works	1	-	1
Builders	-	6	2
Shops	83	24	68
Doctors	2	-	1
(Actual)	(3)	(1)	(1)
Driving School	-	-	1
Farm Store	6	2	2
Butchery	4	2	3

NECF have expressed a policy of using local services whenever possible, yet in 1995 vehicles were still being maintained in Barkley East due to lack of local reliable services.

Hopes for future business development are centred upon the construction in the district of a pulp mill, or other secondary processing plant. There are fears that, should this fail or be constructed elsewhere, or not at all, there will be an opportunity cost to the area of 3 000 jobs. The establishment of a secondary processing plant is dependent on a viable forest plantation industry, with the estimates offered by NECF suggesting a timber source of at least 100 000 hectares. The Drakensberg RSC submitted an application for RDP funding to support the future development of pulp mill in the district (pers. comm. Henk Steyn 1995). NECF has not yet made its intention clear with regard to the secondary processing but the nature of development will depend upon the outcome of the drive to secure sufficient land under timber to provide the requisite primary resource.

(ii) Health

The provision of health services in the region is clearly inadequate. Administrative difficulties in the Eastern Cape Health Service, and a lack of funding, have deprived the region of services generally available elsewhere. NECF have indicated a willingness to address these services, if only for company employees. If NECF were to introduce an efficient service it is expected that there would be a heavy demand on such a service from people outside the company.

(iii) Education

There are in the order of 50 schools in the Maclear, Ugie and Elliot district. Statistics for these schools are tabulated in Table 3.14.

Table 3.14 Schools and pupil numbers in 1995 in the Maclear and Elliot Magisterial Districts (Landplan and associates).

Type	Number	Pupils
Farm Schools	36	2 402
Historically Black		
Pre-primary	1	?
Primary	5	7 258
Secondary (High)	3	2302
Historically White		
Primary	3	Approx 600
Secondary (High)	2	217

NECF's arrival in the North-Eastern Cape coincided with the most important social, political and economic changes seen in South Africa in this century. It is therefore highly unlikely that many of the changes observed within the above schools are due to the commencement of forestry operations. Additional new primary schools are planned for both Elliot and Maclear, to serve the growing black communities. It is also clear that either many children never graduate to high school, or there has been enormous population growth as reflected by numbers in the lower grades (Table 3.14).

The historically white schools are now fully integrated. Maclear recorded a drop in pupil numbers at the time NECF arrived in the district (225 to <200) but gained children from both Transkei High in Umtata and Ugie High, on the closure of these schools. The total number of pupils is now 286.

Ugie also saw the closure of the MT Smit Children's Home (state-run orphanage with 270 children and 50 staff) in 1980 and subsequently the High School. Many of the farm schools now find themselves on NECF property but have continued to function. We have been unable to gather any information on the closure of farm schools.

The historically white schools have felt disadvantaged by the arrival of NECF through the loss of white pupils. Few children of NECF employees are attending school in the district, perhaps as a consequence of employer subsidy schemes allowing children to attend school elsewhere in the country. But it is suggested that the changes experienced in the region are more a product of the times than a result of increased afforestation.

(iv) Communications

Roads

Although remote the district is reasonably well serviced by roads. A high standard paved road (R56) links Elliot, Ugie and Maclear to the national road (N6) and Queenstown (see Figure 1.1). There are also good road links to Engcobo and East London and to the N2 at Umtata. The shortest route to KwaZulu-Natal, through Mount Fletcher and Matatiele needs to be upgraded. Attention to the local road network is hampered by a shortage of funds. The road to Mount Fletcher apparently should have been paved by now but the allocated funds have apparently been diverted elsewhere.

Road construction is a major part of any forestry development programme and NECF has engaged in an extensive road construction programme to provide access to all their plantations. This work makes use of outside contactors.

Rail

The district is currently linked to the national rail network, and notably the port of East London, through a branch line from Sterkstroom to Maclear. This railway still operates but does not offer a regular service at present. It has been kept open in the expectation of new demand for the transport of wood and wood products. Continued rail links are therefore dependent on the success of the NECF operation (see Figure 1.1).

Air

The closest commercially operating airport is at Umtata, about one hour's drive from Maclear. There are daily flights from Johannesburg, Durban and Cape Town (via East London) but links with the rest of the country are poor or non-existent. Elliot has a very long runway but this airstrip sees private use only.

4. IMPACTS OF AFFORESTATION ON WATER RESOURCES

4.1 WATER QUALITY

4.1.1 Objectives

The objective of this study has been to design and initiate a water quality monitoring network and sampling strategy which would provide baseline limnological information. This baseline information would be used for future assessment of water quality changes resulting from the changed land use in the catchment. Our approach relied on the use of biological indicators of water quality, rather than on the use of water quality samples per se.

4.1.2 Monitoring Network

The monitoring network was designed to spread a limited number of sampling points to cover as much of the study area as possible without compromising the usefulness of the collected data. It was also necessary to cover the areas most likely to experience the greatest changes in water quality as a result of afforestation in sufficient detail and to have control stations on sections of the rivers which would reflect water quality conditions minimally influenced by forestry.

The network design was determined in the field in August 1993 with the assistance of the resident NECF environmental officer and took into account accessibility of the site and the suitability in terms of the aquatic invertebrate habitat availability.

The major rivers in the area were represented by:

- a low altitude, meandering river with low flow - the Gatberg;
- a high altitude, fast flowing, rocky river - the Pot; and
- three intermediate rivers whose catchments have either seen, or will see, the most dense afforestation - the Wildebees, KuNtombizininzi and Mooi rivers.

The Wildebees river (Quaternary catchment T35F) was selected for intense investigation because of its location in relation to the afforestation programme and its range of suitable and easily accessible monitoring sites. Five sampling stations were established along the river from close to its headwaters to the town of Ugie. Four sampling stations were established on the Klein Mooi and Mooi rivers and two stations were established on the slow flowing Gatberg river. A single station was established on the KuNtombizininzi close to its confluence with the Wildebees river. Although this river had very little flow, the catchment was already very densely afforested and was very clearly defined. This was considered by the team to be an ideal site at which to record water quantity data. The Pot river and its tributaries were not included in the initial sampling network as it drained mountainous areas of lower suitability for planting and was considered to be less likely to suffer severe water quality impacts as a result of its fast flowing nature. Table 4.1 and Figure 4.1 give detailed localities of the sampling stations.

Table 4.1: Locality of the water quality monitoring sites established in the North-Eastern Cape.

Station Number	Locality	Grid Reference		Altitude
1	Klein Mooi River at Elsburg	31°05'23"S	28°09'37"E	1360m
2	Mooi River at Oakhurst	31°04'39"S	28°09'25"E	1340m
3	Mooi River at Hutton	31°04'44"S	28°18'04"E	1300m
4	Mooi River at Riverside	31°04'33"S	28°15'35"E	1270m
5	Kuntombizininzi River at Moffieskloof	31°09'30"S	28°19'39"E	1280m
6a	Wildebees River at Glenelg	31°13'18"S	28°02'47"E	1400m
6b	Wildebees River at Maloja	31°14'56"S	28°01'15"E	1420m
7	Wildebees River at Morven	31°11'56"S	28°04'45"E	1360m
8	Wildebees River at Camadra	31°11'23'"S	28°06'08"E	1340m
9	Wildebees River at NECF Nursery	31°11'00"S	28°09'33"E	1320m
10	Wildebees River at Lanark	31°10'04"S	28°12'16"E	1300m
11	Gatberg River at Bridge	31°15'10"S	28°03'20"E	1350m
12	Gatberg River at Chantry	31°14'20"S	28°07'05"E	1390m
13	Pot River at Fairview	30°56'55 "S	28°14'07"E	1320m
14	Hawer River at Falstaff Glen	30°51'41"S	28°12'16"E	1680m
15a	Rush River at Cransmoor	30°50'31"S	28°12'16"E	1750m
15b	Antelope Park River at Antelope Park	30°49'05"S	28°12'24"E	1770m

Each of the 12 sampling stations were sampled three times during August, September and October of 1993. Low flow conditions were sampled during August while during September and October substantial rainfall in the area enabled a broader range of baseline conditions to be recorded.

In addition to repeat sampling of the 12 stations first sampled in 1993, a further four stations, on the Pot, Hawer, Rush and Antelope Park Rivers were sampled in 1994. A total of 16 sampling stations were thus sampled twice during 1994. Sampling was done during the low flow months of July and August.

4.1.3 Methodology

The method used in the water quality assessment study was the rapid biological assessment method, or the South African Scoring System (SASS) method, which is based on the bottom-dwelling invertebrates of streams and rivers (Chutter 1992). A list of families in an assessment sample is scored from a standard table of scores for each invertebrate family. The scores are then summed to give a total sample score, number of taxa and the average score per taxon for each sample. The scores allotted to each family are related to the response of the families to water quality, families most sensitive to pollution being scored 15 and those most tolerant scored 1.

The SASS methodology is still evolving. As more field information has become available countrywide it has become apparent that certain families previously thought of as intolerant of poor quality water are in fact tolerant and vica versa. This has resulted in changes in the quality values assigned to those families. The original SASS version 2 scores have therefore been adjusted according in the SASS version 4 scoring (see Table 4.2). The scores tabulated are therefore directly comparable with more recent studies elsewhere in the country.

It was intended that the Biotic Index scores, based on the invertebrate communities, would provide an indication of the baseline water quality as reflected by the invertebrate communities in the rivers at the sampling point during 1994/5. Water samples were collected at each of the stations during each visit for the determination of six physical/chemical parameters, turbidity, conductivity, dissolved oxygen, suspended solids, pH and temperature. Some of the parameters were determined on the river banks with portable instruments, while the others were fixed and transported back to the laboratory for analysis.

Strong arguments favouring the biological approach to water quality assessment and monitoring are that the river life is well-known to be sensitive to changes in water quality, and that it represents a continuous monitoring system which integrates water quality over time. Despite these properties biological monitoring has not been extensively practised in water quality monitoring in South Africa. There is an erroneous expectation that biological monitoring should be capable of identifying the nature of chemical changes, in order to be useful to compliance monitoring. An approach was adopted which addressed the water quality issue in terms of the Department of Water Affairs and Forestry's policy of managing the water quality according to the intended uses. In the case of the rivers of the North-Eastern Cape the main identified user is the environment, and the concern for the environment was focused not on the chemical quality as such but on the effects the chemical and physical attributes of the water may have on the plants and animals. As McIntyre (1984) stated, knowledge of the distribution of chemicals may indicate actual or potential trouble spots, but the detection of a biological signal may help to focus later chemical studies, and in the context of the environment in general, the ultimate evaluation of contamination must be made in biological terms. Hence when selecting the approach to the limnological study a new cost-effective method, the South African Scoring System (SASS), for rapid biological assessment of stream and river water quality by means of the macro invertebrate community in South Africa was considered to be relevant for the baseline water quality determinations. This method is being developed by Chutter (1994) on a Water Research Commission contract.

In order to complement the biological assessment, those affordable chemical and physical parameters most closely associated with the biology were also monitored, and an assessment of the habitats, in stream habitat, channel morphology, and bank and riparian vegetation, was undertaken. Additional ecological information on the benthic macro-invertebrates has also been collected for the study area in a separate, more detailed, baseline study conducted by Dr Ferdi de Moor of the Albany Museum, for NECF (de Moor and Barber-James 1994).

One of the topics discussed at length at the three Rapid Biological Assessment Forums held during the development of the SASS scoring method was habitat assessment. The forum recognised that there were several reasons for habitat assessment. It was argued that the factor of overwhelming influence in the SASS score achieved was the nature and diversity of habitats available to sample at the sampling point. The diversity of available habitats itself often incorporated information on the conservation status of the river. Chutter (1994) had drawn up a score sheet in which the diversity of sampled habitats accounted for 60 % of the habitat evaluation score, the remaining 40 % being concerned with the size of the ecosystem as stream order, the proximity of dams, evidence of unnatural levels of terrestrial erosion and the extent of alien vegetation on the stream banks. The system collapsed over the difficulties of agreeing upon the order of streams, besides which all scores seemed to work out to be at the upper end of the possible range (1 to 100).

At the forum meetings it was agreed that researchers should score the habitats when measuring SASS scores for a number of reasons. The supporting role of habitat assessment in biosurveys include that it:

- assists in the selection of appropriate sampling sites;
- provides basic information for and improves the interpretation of biosurvey results;
- is used to identify obvious constraints on the attainable potential of a specific site;
- is used to establish confidence limits for a relation between biological health and habitat quality for specific regions.

Furthermore, it is important to monitor habitat quality over the long-term to detect possible trends indicating habitat degradation, such as would result from bad land-use practices.

In the North-Eastern Cape limnological study, the aims of which were to collect baseline data to enable future assessments of the impacts of site preparation and afforestation on water quality, sampling sites were selected on the basis of suitability in terms of habitat availability and comparability to overcome the problem of comparing results between stations. In the event of attempting to normalize SASS results to eliminate differences due to habitat diversity, habitat scores were collected during 1993 and 1994 using two different habitat assessment methods. This will enable results collected in the North-Eastern Cape to be compared with results from other areas of South Africa. These assessments will also provide baseline information about the conservation status of the rivers as it is an assessment of the physical habitat degradation.

4.1.4 Results

The results of the chemical parameters recorded were obtained, except in the case of dissolved oxygen, by one-off in stream sampling using portable instrumentation. Dissolved oxygen was measured in the laboratory using the Winkler Method. This was done in support of the baseline biological sampling presented in Table 4.3.

During September 1993 there was no flow at station 5 on the Kuntombizininzi river and no sampling was possible. During that month there was also very low flow at stations 1, 4, 5, 8, 9, 11 and 12 although sampling was still possible. During the week of sampling substantial rain fell over the area resulting in high flows at the remaining stations. The results of the SASS total scores, Average Score per Taxon (ASPT) are presented in Table 4.2.

The chemical and physical parameter values for the most part, are well within the minimum to medium values recommended by Kempster *et al.* (1980) for the protection of aquatic life in South African rivers and dams. Turbidity levels increased considerably at most stations after rain events, but were particularly high at the low lying Gatberg river stations, 11 and 12, during October 1993 and July 1994.

Water temperatures were considerably lower during the 1994 monitoring cycle at nearly all the stations. During sampling in 1994 extensive areas of mountain were covered with snow. It was centimetres deep at stations 15a and 15b where water temperatures were 6° C for July, and 7° C and 4° C for August and September respectively. Sampling during these cold, winter months provided baseline data under extreme conditions which were not experienced during the previous year or during the time of the study conducted by Dr Ferdi de Moor. Suspended solids exceeded the recommended maximum at station 2 in October 1993 after a heavy downpour. There was also a large quantity of algae in the water at this point. Suspended solids also increased after rain and levels exceeded the maximum recommended value at station 11 in October 1993, and approached the maximum at station 12. This is to be expected at these stations on the slow flowing, meandering Gatberg river. Conductivity measurements were all low to medium compared to the recommended levels. The oxygen saturation was relatively high at all stations considering that problems arise when saturation drops below 40 % at 15° C. Oxygen values below this minimum are likely to cause adverse effects on the aquatic biota. Sensitive fish and insect larvae which are endemic to or adapted to aerobic, warm water habitats may be prevented from completing their life cycles.

The SASS results are more or less self explanatory: the *higher* the total score the *better* the water quality. SASS total scores consistently above 80, and Average Score Per Taxon (ASPT) scores consistently above 5, are considered to indicate unpolluted, clean water (Chutter, pers. comm.). Scores below this indicate contamination, with the greater the deviation the greater the level of contamination. A low ASPT indicates large numbers of pollution tolerant invertebrate families. The number of taxa present in the sample is high in the range 25-30; intermediate 15-25; and low at <15.

The SASS scores for the two lowland stations on the Gatberg river (11 and 12), and for station 5 on the Kuntombizininzi reflected the poorest quality water. The Klein Mooi River at Elsburg also indicated a poor quality water but only during 1993. There was a vast improvement in 1994 which could have been related to the improved water quality as a result of increased flows during that year. The river was barely flowing during the 1993 sampling period.

There is considerable variability in SASS scores, but this is not an unexpected outcome. Armitage *et al.* (1983), for example, undertook an appraisal of the performance of a similar methodology known as the British Monitoring Working Party (BMWP) system. In a study across 268 sites in Britain there was considerable variability in achievable score and ASPT within the different groups of unpolluted sites. As found in the North-Eastern Cape, Armitage *et al.* (1983) also found that, in general, scores were highest in the middle to top of the range of environmental features (mainly upland rivers), and lowest in groups at the bottom of the range (lowland areas).

4.1.5 Conclusion

The SASS method is applicable to the North-Eastern Cape water quality study site since the range of factors that could change significantly as a result of the afforestation programme constitute some of the parameters of primary significance in determining macro-invertebrate micro- distributional patterns. This is reinforced by the fact that overall the SASS and ASPT scores have not deviated from the water quality which would be expected from the geographical circumstances of the sampling sites.

The physicochemical status and water quality as indicated by the benthic invertebrate communities present in the streams of the North East Cape, during the 1993 / 1994 monitoring was in all instances good. Very clean, unpolluted water was indicated in the higher reaches of the rivers. Some of the slower-flowing, lower reaches of rivers, where sediments would settle out showed heavy siltation.

To date the largest observed variations occurred following substantial rainfall in the catchment indicating the sensitivity of the index to ecological change. The increased turbidity after heavy rainfall, caused by secondary input of silt into the system from road cuttings and farming activities, and the increased flow resulted in changes in the community structure which was reflected in the SASS index.

Table 4.2: South African Scoring System (SASS2 and SASS4) and average scores per taxa (ASPT) from sampling points in the North-Eastern Cape for 1993/94. See Table 4.1 for localities of stations. SASS scores above 80, and ASPT scores above 5 indicate clean unpolluted water. Lower scores indicate degrees of degradation.

Station Number	Date of sampling	Number Taxa	SASS2	ASPT2	SASS4	ASPT4
	August 1993	18	92	5.1	103	5.7
	September 1993	15	62	4.1	68	4.5
1	October 1993	16	77	4.8	85	5.3
	July 1994	25	133	5.3	150	6.0
	August 1994	23	128	5.6	144	6.3

Station Number	Date of sampling	Number Taxa	SASS2	ASPT2	SASS4	ASPT4
2	August 1993	22	99	4.5	111	5.0
	September 1993	25	130	5,.2	147	5.9
	October 1993	25	137	5.5	155	6.2
	July 1994	22	129	5.9	146	6.6
	August 1994	21	111	5.3	125	5.9
3	August 1993	26	150	5.8	170	6.5
	September 1993	27	150	5.6	170	6.3
	October 1993	25	129	5.2	146	5.8
	July 1994	25	127	5.1	143	5.7
	August 1994	24	142	5.9	161	6.7
4	August 1993	21	123	5.9	139	6.6
	September 1993	23	130	5.7	147	6.4
	October 1993	29	167	5.8	190	6.5
	July 1994	21	129	6.1	146	6.9
	August 1994	21	130	6.2	147	7.0
5	August 1993	18	81	4.5	90	5.0
	October 1993	15	73	4.9	81	5.4
	July 1994	14	71	5.1	79	5.6
	August 1994	14	83	5.9	92	6.6
6b	August 1993	-	-	-	-	-
	September 1993	27	174	6.4	198	7.3
	October 1993	20	127	6.4	143	7.2
	July 1994	20	127	6.4	143	7.2
	August 19 94	21	135	6.4	153	7.3
6a	August 1993	26	149	5.7	169	6.5
	October 1993	23	134	5.8	151	6.6
	July 1994	22	122	5.6	138	6.3
	August 1994	21	120	5.7	135	6.4

Station Number	Date of sampling	Number Taxa	SASS2	ASPT2	SASS4	ASPT4
7	August 1993	24	121	5.0	136	5.7
	September 1993	28	138	4.9	156	5.6
	October 1993	17	90	5.3	101	5.9
	July 1994	22	119	5.4	134	6.1
	August 1994	25	142	5.7	161	6.4
8	August 1993	26	136	5.2	154	5.9
	September 1993	21	100	4.8	112	5.3
	October 1993	18	98	5.4	110	6.1
	July 1994	27	135	5.0	153	5.6
	August 1994	24	135	5.6	153	6.4
9	August 1993	25	127	5.1	143	5.7
	September 1993	19	100	5.3	112	5.9
	October 1993	24	127	5.3	143	6.0
	July 1994	24	137	5.7	155	6.5
	August 1994	28	168	6.0	191	6.8
10	August 1993	19	93	4.9	104	5.5
	September 1993	27	139	5.2	157	5.8
	October 1993	22	112	5.1	126	5.7
	July 1994	25	143	5.7	162	6.5
	August 1994	27	151	6.0	171	6.3
11	August 1993	14	63	4.5	69	5.0
	September 1993	16	74	4.6	82	5.1
	October 1993	16	71	4.4	79	4.9
	July 1994	15	72	4.8	80	5.3
	August 1994	17	75	4.4	83	4.9
12	August 1993	16	87	5.4	97	6.1
	September 1993	24	130	5.4	147	6.1
	October 1993	18	78	4.3	87	4.8
	July 1994	19	102	5.4	114	6.0
	August 1994	21	101	4.8	113	5.4
13	July 1994	21	121	-	21	5,8
	August 1994	19	125	-	19	6,6
14	July 1994	25	138	-	25	5,5
	August 1994	23	128	-	23	5,6
15A	July 1994	26	145	-	26	5,8
	August 1994	25	147	-	25	5,9
15B	August 1994	24	146	-	24	6,1

Table 4.3: Water chemistry data recorded for North-Eastern Cape rivers during August, September & October 1993 and July & August 1994. See Table 4.1 for localities of stations.

Station Number	Date	Turbidity (NTU *)	Spot Temperature (°C)	pH	Suspended Solids (mg/l)	Conductivity (mS/m)	Dissolved oxygen (%)
1	August 1993	1.5	10	7.0	3	6.2	108
	September 1993	0.7	15	6.4	6	9.7	96
	October 1993	21	18	6.5	26	3.5	106
	July 1994	20	6	6.3	17	6.4	106
	August 1994	2	9	6.3	2	4.4	113
2	August 1993	0.7	10	6.9	3	6.1	100
	September 1993	0.8	13	6.6	4	7.4	86
	October 1993	73	18	6.3	134	3.9	93
	July '94	13	6	6.3	5.7	5.4	92
	Aug	1	9	6.5	2	4.8	103
3	August 1993	1.3	15	6.9	2	6.5	115
	September 1993	1.0	19	7.1	2	7.9	111
	October 1993	4.6	18	6.5	10	4.3	99
	July '94	4	9	6.5	3	4.9	104
	August 1994	1	12	6.3	10	5.4	123
4	August 1993	1.0	13	6.9	1	7.0	113
	September 1993	1.1	16	7.0	6	8.4	88
	October 1993	6.8	17	6.7	9	4.5	99
	July '94	22	9	6.3	27.1	5.2	91
	August 1994	2	12	6.5	4	5.6	123
5	August 1993	2.5	11	7.0	7	6.1	105
	September 1993	-	-	-	-	-	-
	October 1993	13	19	6.5	23	2.3	104
	July '94	7.5	8	6.7	8	6.7	110
	August 1994	3	15	6.5	10	3.2	122

Station Number	Date	Turbidity (NTU ˙)	Spot Temperature (°C)	pH	Suspended Solids (mg/l)	Conductivity (m³/m)	Dissolved oxygen (%)
	August 1993	0.8	16	6.9	1	7.6	123
6a	Sept	-	-	-	-	-	-
	October 1993	7.6	19	6.7	6	4.5	98
	July '94	15	9	6.3	20	5.2	89
	August 1994	1	14	6.6	4	5.8	123
6b	August 1993	-	-	-	-	-	-
	September 1993	4.5	13	7.0	4	5.1	96
	October 1993	12	20	6.7	15	3.0	104
	July 1994	6	9	6.4	16	5.5	93
	August 1994	2.5	14	6.6	4	4.3	117
7	August 1993	1.5	16	7.0	4	7.9	114
	September 1993	1.5	21	7.1	6	9.7	103
	October 1993	12	16	6.8	15	4.5	109
	July 1994	10	7	6.6	9	6.0	93
	August 1994	3	13	6.3	6.7	6.3	111
8	August 1993	2.7	13	7.0	5	7.6	99
	September 1993	1.9	15	6.8	4	9.7	63
	October 1993	15	16	6.7	15	4.4	10
	July 1994	12	9	6.6	12	5.9	92
	August 1994	4	14	6.6	5	6.1	119
9	August 1993	1.7	12	7.0	2	7.4	127
	September 1993	1.5	19	8.4	3	7.3	118
	October 1993	1.2	16	6.7	14	4.6	106
	July 1994	14	9	6.6	2.7	5.8	95
	August 1994	4.5	14	6.5	10	5.7	118

Station Number	Date	Turbidity (NTU *)	Spot Temperature (°C)	pH	Suspended Solids (mg/ℓ)	Conductivity (m^s/m)	Dissolved oxygen (%)
10	August 1993	2.0	14	7.1	5	7.9	139
	September 1993	3.5	17	7.9	7	8.5	93
	October 1993	16	15	6.7	17	4.4	86
	July 1994	15	10	6.6	7.1	5.8	98
	August 1994	5	12	6.4	15	5.7	96
11	August 1993	14	11	7.0	18	6.6	106
	September 1993	12	15	7.0	19	8.2	88
	October 1993	62	17	6.3	103	4.4	86
	July 1994	36	8	6.0	24	7.9	80
	August 1994	11	11	6.2	13	6.6	82
12	August 1993	9.2	12	6.9	13	4.9	110
	September 1994	2.9	16	7.1	12	12.5	76
	October 1994	42	16	5.9	70	4.7	75
	July 1994	55	7	6.3	41	6.0	88
	August 1994	5	10	6.3	9	7.3	113
13	July 1994	10	8	6.8	9	6.4	108
	August 1994	1.5	9	6.7	3	7.7	130
14	July 1994	18	8	6.7	7	5.7	94
	August 1994	4	10	6.9	4	5.7	115
15a	July 1994	12	6	7.1	4.3	1.0	104
	August 1994	8	7	6.9	18	9.3	123
15b	July 1994						
	August 1994	1.5	4	6.9	10	6.6	109

* NTU = Nephelometric Turbidity Units. NTU is a unit of turbidity based on the phenomenon of scattering.

4.2 WATER YIELD

4.2.1 Scope of Study

This section describes the predicted impact of afforestation on the water resources of the North-Eastern Cape and how the expected reduction in streamflow due to afforestation is estimated. The modelling philosophy and approach are explained. The results from the modelling studies are described and discussed, along with a number of case studies illustrating possible changes to the way plantations could be managed in South Africa in future.

Finally, the section is concluded with a discussion and a list of possible mitigatory measures that could mitigate the negative impacts of afforestation.

4.2.2 Methods of Estimating Streamflow Reduction

The flow reduction models developed by the CSIR (Smith and Scott 1992, Scott and Le Maitre 1993) were used in this study to estimate the reduction in streamflow following afforestation. These are empirical models that predict reduction in streamflow as a function of tree/plantation age and water availability, a function of both rainfall and runoff regimes. They are widely applicable and robust and used routinely by the Department of Water Affairs and Forestry (DWAF) in estimating impacts of planned forestry developments. The curves or models are based on observed total and low flow reductions following afforestation in gauged experimental catchments in various forestry regions in South Africa.

It must be remembered however that we are working with **models** derived from catchments elsewhere in South Africa, that nature is infinitely variable, and that there is no substitute for hard experimental data. While there is no need to doubt the size and nature of the impacts estimated through this study it would add great value if this output could be further calibrated against streamflow data from North-Eastern Cape rivers. This would require an improved monitoring network. Alternatively, or preferably, additional hydrological process measurements, such as the measurement of forest evaporation using Bowen Ratio technology (Black 1971) could be used in confirming water use estimates from hydrological models.

The pine model

The models considered appropriate to the North-eastern Cape are those derived from results of the afforestation experiments with *Pinus patula* at Cathedral Peak in KwaZulu-Natal and *Pinus radiata* in the Western Cape - the pine models for the so-called "sub-optimal growth zones". Given similarities in tree species and climate, these models are expected to be appropriate to the North-East Cape region. The models are shown in Figure 4.2. Two modifications to the original curves for sub-optimal growth zones were made:

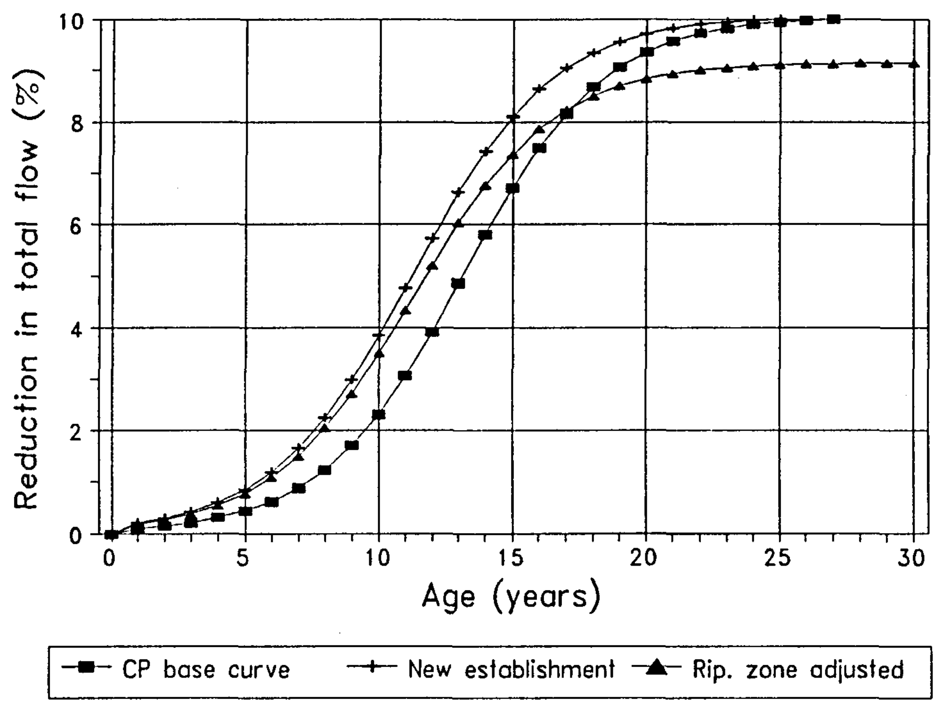

Figure 4.2: The *Pinus patula* streamflow reduction model for total flow from Cathedral Peak (CP), adjusted for a suite of new establishment practices and non-riparian planting.

1. Curves were advanced by 1.5 years, without changing the shape, to account for the more rapid establishment and early growth expected following site preparation, fertilising at establishment, and genetically improved trees. Early growth is expected to be faster than observed for the pit planted trees upon which the original model (Cathedral Peak) was based. This is expected to lead to a concomitant earlier reduction in streamflow.

2. As a rule of thumb, riparian zones consist of about 10 % of a catchment. The original models were derived from experiments where the trees were planted through the riparian zones, but in the North-eastern Cape a generous width of riparian zone is left unplanted. The flow reduction models were adjusted down proportionately to account for the riparian zones not being planted. The basis of this adjustment is given in Table 4.4, in which, based on the experimental results of Scott and Lesch (1995), the greater impact attributed to trees in riparian zones has been estimated at about double that of similar vegetation elsewhere in the catchment.

Table 4.4 Curve adjustment factor for upslope plantings and their derivation for cases where no riparian land is planted. The estimated flow reduction curve is adjusted by multiplying by the factor given below.

Proportional area of catchment	Relative quantity of water produced in each area	Percentage of total water yield	Curve Adjustment factor
Total 10	11	100.00	
Riparian zone 1	2	18.18	
Non-riparian zone 9	9	81.82	0.909

The Eucalypt model

Scott and Smith (in prep.) hypothesized that a similar pair of flow reduction curves would exist for eucalypts growing under sub-optimal conditions as does for pines. Scott and Smith have little observational data from which to formulate the exact nature of such curves. But, from a theoretical point of view they chose to increase the observed time taken for eucalypts (under optimal growth conditions) to reach a set flow reduction. This increase was defined by a value equal to the observed ratio between the times taken by pines under optimal as opposed to sub-optimal conditions to result in an equivalent flow reduction.

In this way Scott and Smith (1996) synthesized curves for eucalypts growing under sub-optimal conditions. This may over-estimate the effect of eucalypts under such sub-optimal conditions as eucalypts appear to be more demanding than pines in terms of site requirements. These are speculative curves, but they do lie between the measured bounds of fast-growing eucalypts and slow-growing pines, and Scott and Smith 1996 feel the curves are justified by their potential usefulness as an interim tool. We used these curves in this study on the same basis. The area in the North-Eastern Cape is, in any event, only 3 % of the total present afforested area, and no further eucalypt plantings are planned. Any errors resulting from the application of this model will therefore have little impact on final output.

Data inputs to the model

A GIS was used to derive inputs for the model by overlaying maps of afforested area, tree genera and species, afforested compartment age and rainfall for each quaternary catchment. The plantation area and age data were provided by NECF. Gridded mean annual rainfall data developed by Dent *et al.* (1987) were extracted from the national data base managed by the Computing Centre for Water Research.

Individual data records were therefore defined by the plantation area, age of trees, type of trees (pines or eucalypts) and the rainfall zone in which that afforestation occurred (50 mm intervals). Fifty millimetre rainfall zone intervals were chosen because of the quantity of data records produced by the GIS classification. If the interval was smaller, the data set size increases disproportionately to the gain in accuracy. At a larger rainfall zone interval, the modelling resolution becomes coarse.

Estimating MAR in the afforested area

The streamflow reduction curves were originally developed for a catchment at Cathedral Peak that was completely afforested. In the application of these curves to catchments which are only partially afforested, streamflow reductions must therefore be calculated *pro rata* per catchment area afforested. The reductions in streamflow from the afforested area are then subtracted from the virgin streamflow from the whole catchment, the values of which were obtained from Midgley *et al.* (1994).

We applied the streamflow reduction curves by dividing the afforested area firstly into compartments (which have uniform age) and then further subdivided these compartments into 50 mm rainfall zones. For each of these sub-areas a value of streamflow reduction was then estimated on an annual basis. This technique requires a prior estimate of mean annual runoff for each of the sub-areas, this was estimated by using an equation developed by Schulze (1979) for the KwaZulu-Natal Drakensberg. We used this equation because it performs well in the high rainfall areas of the Drakensberg and is superior in this respect to similar curves reported in Midgley *et al.* (1994), which tend to underestimate runoff for rainfall depths greater than 1 200 mm. The Schulze (1979) equation is:

$$MAR = 10^{-5.4476}\ MAP^{2.6255}$$

where MAR is the mean annual runoff and MAP is mean annual precipitation, both in mm.

4.2.3 Modelling Results

Estimates of streamflow reduction in each quaternary catchment were obtained by adding all simulated streamflow reductions due to afforestation, for each sub-area and for each year within which growth would take place. It was assumed that when a sub-area reached its rotation age (18 years - this was the initial value and is used in this study, it has however now been decreased to 16 years), that sub-area would be felled and replanted in the next year.

This procedure resulted in a string of estimated streamflow reduction values projected into the future. In general we used a period greater than the rotation age so that we could observe the effects of staggered planting dates on the hydrology of a catchment.

Appendix 2 provides a listing of the estimated annual streamflow reductions, over a full rotation after initial afforestation, for each of the quaternary catchments.

Total flow reduction due to afforestation
From the simulations we noted that streamflow reductions reach a peak value. Peak total flow reductions that result from afforestation are presented in Table 4.5 for each of the affected quaternary catchments, based on current afforestation activities and those under consideration by NECF. The year in which the projected peak flow reduction would occur is also given and is based on actual planting dates within these catchments.

At current afforestation levels, only quaternary catchment T35F would have a peak water utilisation by forests of more than 10 % of mean annual runoff. In all other catchments, the impacts of afforestation would maximise at approximately 6 % or less of mean annual runoff. The rate of water use by a plantation is also not constant, but varies over time depending on the age of the plantation. As trees grow, their biomass increases, as does the water demand. Afforestation of new plantations in South Africa is often rapid, occurring within a few years, and this has an influence on the way afforestation affects streamflow reduction. This time related impact of planting patterns is described and analysed in section 4.2.4.

A cumulative impact of present and planned afforestation on each of the three tertiary catchments, as well as the impact on the secondary and primary catchments, was calculated by adding the quantities of forest streamflow reduction for each of the quaternary catchments nested within the parent tertiary catchment (Table 4.6).

The impact of total afforestation which may take place in the future was also assessed using projections of potential afforestation in the region (data courtesy NECF- Table 4.6). The results are also given in Table 4.6. The projected future afforestation is quite substantial in areal extent and affects the reduction in runoff accordingly (see Tables 4.5 and 4.7 for afforestation area). Should all of this afforestation take place then the maximum effect should be observed. Catchments T34E and T35B show the biggest impact, with streamflow reduction by afforestation in each of the catchments rising from 0.2 to 18.5 and 2.7 to 11.0 million m^3/y respectively. Under this scenario, three catchments have streamflow reduction of greater than 10 %, with T34E and T35F having substantial (18.5 and 18.2 million m^3/y respectively) reductions.

At the tertiary catchment level, impacts of afforestation remain low in all catchments, with only T35 showing a maximum impact approaching 6 % of total streamflow once all potential land has been afforested. T11 and T34 are affected by at most between 1 % and 2 %. Secondary catchments T1 and T3 may experience a maximum impact of 0.5 % and 2.3 % respectively., and the primary catchment (T) an impact of 0.9 % of MAR. All of these impacts are estimated on conditions before any effort has been made to normalize plantation ages.

Table 4.5: Total flow reductions of the mean annual runoff of 10 quaternary catchments affected by afforestation in the North-Eastern Cape, based on current and intended future afforestation operations. Mean annual runoff values are from Midgley *et al.* (1994). For the location of the quaternary catchments, see Figure 4.8.

			Current afforestation scenario (1997)				Future afforestation scenario			
Quaternary catchment	Area (km^2)	Virgin MAR (million m^3/yr)	Area afforested (ha)	Maximum annual total flow reduction (million m^3/yr)	% MAR	Year of peak flow reduction	Area afforested (ha)	Maximum annual total flow reduction (m. m^3/yr)	% MAR	Year of peak flow reduction
T11B	415	45.9	1 047.6	0.96	2.1	2009	1 047.6	0.96	2.1	2009
T11D	343	58.6	1 762.3	1.69	2.9	2009	1 762.3	1.69	2.9	2009
T11E	233	51.8	1 641.6	1.79	3.5	2009	1 641.6	1.79	3.5	2009
T34E	268	55.4	96.5	0.13	0.2	2014	6 996.5	10.25	18.5	2015
T35A	475	109.8	4 236.7	5.76	5.2	2010	7 117.7	10.03	9.1	2010
T35B	396	92.3	1 774.9	2.47	2.7	2009	7 895.9	10.15	11.0	2015
T35C	306	88.6	4 920.0	5.39	6.1	2009	7 001.0	7.96	9.0	2009
T35D	348	65.2	1 418.4	1.75	2.7	2009	3 338.4	3.65	5.6	2009
T35F	359	72.0	7 876.0	8.93	12.4	2009	11 496.0	13.07	18.2	2009
T35G	575	85.6	5 098.5	4.83	5.6	2009	5 098.5	4.83	5.6	2009

Table 4.6: Total flow reductions of the mean annual runoff of the tertiary , secondary and primary catchments affected by afforestation in the North-Eastern Cape study area, based on current and intended future afforestation operations. Mean annual runoff values and catchment areas are from Midgley *et al.* (1994).

			Current afforestation scenario (1997)				Future afforestation scenario			
Tertiary catchment	Area (km^2)	Virgin MAR (million m^3/yr)	Area afforested (ha)	Total flow reduction (million m^3/yr)	% MAR	Year of peak flow reduction	Area afforested (ha)	Total flow reduction (million m^3/yr)	% MAR	Year of peak flow reduction
T11*	2 489	375.0	4 461.5	4.42	1.2	2009	375.0	4.42	1.2	2009
T34**	3 197	537.7	96.5	0.13	0.02	2015	6 996.5	10.25	1.9	2015
T35***	4 929	696.0	25 324.5	28.88	3.0	2009	41 947.5	53.52	5.5	2010
Secondary catchment										
T1	6 053	805.6	4 461.5	4.42	0.5	2009	375.0	4.42	0.5	2009
T3	19 852	2 832.9	25 421.0	29.01	1.0	2010	48 944.0	63.77	2.3	2010
Primary catchment										
T	46 704	7 397.1	29 882.5	33.43	0.5	2010	49 319.0	68.19	0.9	2010

* at confluence of Xuka River with Bashee River

** at confluence of Tina River with Tsitsa River

*** at confluence of Tsitsa with Mzimvubu River (excluding the Tina River)

Table 4.7: Reductions of the low flow from the 10 quaternary catchments affected by afforestation in the North-Eastern Cape, based on current and intended future afforestation operations. Virgin low flow runoff values are based on statistical analysis of Midgley *et al.* (1994) simulations.

			Current afforestation scenario				Future afforestation scenario			
Quaternary catchment	Area (km^2)	Virgin low flow (million m^3/yr)	Area afforested (ha)	Max. annual low flow reduction (million m^3/yr)	% Low flow [1]	Year of peak flow reduction	Area afforested (ha)	Max. annual low flow reduction (million m^3/yr)	% Low flow	Year of peak flow reduction
T11B	415	0.42	1 047.6	0.033	7.9	2009	1 047.6	0.033	7.9	2009
T11D	343	0.44	1 762.3	0.057	13.0	2009	1 762.3	0.057	13.0	2009
T11E	233	0.36	1 641.6	0.045	12.5	2009	1 641.6	0.045	12.5	2009
T34E	268	0.80	96.5	0.001	1.0	2014	6 996.5	0.067	8.4	2015
T35A	475	1.70	4 236.7	0.052	3.1	2010	7 117.7	0.085	5.0	2010
T35B	396	1.42	1 774.9	0.024	1.7	2009	7 895.9	0.087	6.1	2015
T35C	306	1.28	4 920.0	0.070	5.5	2009	7 001.0	0.094	7.3	2009
T35D	348	1.11	1 418.4	0.040	3.7	2009	3 338.4	0.080	7.2	2009
T35F	359	1.19	7 876.0	0.269	22.6	2009	11 496.0	0.367	30.8	2009
T35G	575	1.60	5 098.5	0.203	12.7	2009	5 098.5	0.203	12.7	2009

[1] For a discussion on discrepancies in the low flow model see section 4.2.6

Reduction of low flows by afforestation
Low flows are defined here as the lowest flow record quartile, which is equal to the 25 percentile non-exceedable level (flows not exceeding the specified level more than 25 % of the time). The low flow quartiles have been determined by statistical analysis of Midgley *et al.* (1994) simulations. These are given for each of the quaternary catchments in Table 4.7, along with estimates of the low flow reductions due to afforestation.

The low flow reductions in each of the afforested catchments, as a proportion of virgin low flows, are mostly greater than the proportion of total reductions to virgin MAR. This implies that forests use proportionately more water during dry conditions than during moist conditions. It may be noticed when comparing Tables 4.5 and 4.7 that the relative increase in low flow reduction to that of total flow reduction is not similar in all cases. This is because some catchments are drier than others, and that the frequency distribution of streamflow is therefore also different.

There are exceptions, however. These are quaternary catchments T35A, T35B and T35C. The reasons for these exceptions are not known, but are thought to be a result of differing runoff frequency distributions of each of the different catchments.

4.2.4 The impacts of age class distribution on catchment hydrology

During the modelling process we noted that predicted streamflow reduction varies over time, with plantation age as the primary driver of this variation. When a large part of the catchment is afforested very rapidly, in this case over a few years, plantations will to reach maturity within the same interval to that over which planting took place. Similarly, streamflow reduction, which starts at small quantities for very young trees, increases with age to reach a peak at or near attainment of maturity of the plantation (defined by potential for harvesting).

If the plantings were to be conducted over a much longer period, for example one that might span the full length of a desired rotation, rates of streamflow reduction would be minimized. Given an even age class distribution (normalised plantation), the total impact of the plantation would be distributed over the entire rotation and would be approximately equivalent each year.

The hydrological impact of actual age-class distribution in the different catchments of the North-Eastern Cape imparts a "wave" form to the patterns of streamflow reduction within each catchment (see Figure 4.3). Note that these curves were derived under the assumption of mean annual rainfall - and not actual rainfall which could either exacerbate or smooth the variability. Peak rates of streamflow reduction occur when the greater part of a plantation reaches maturity simultaneously. Similarly, the lowest rate of streamflow reduction by plantations in a catchment occurs when the greater part of the plantations have recently been cut or replanted. Figure 4.3 shows that the level of streamflow reduction by the plantations can be highly variable over the length of the rotation.

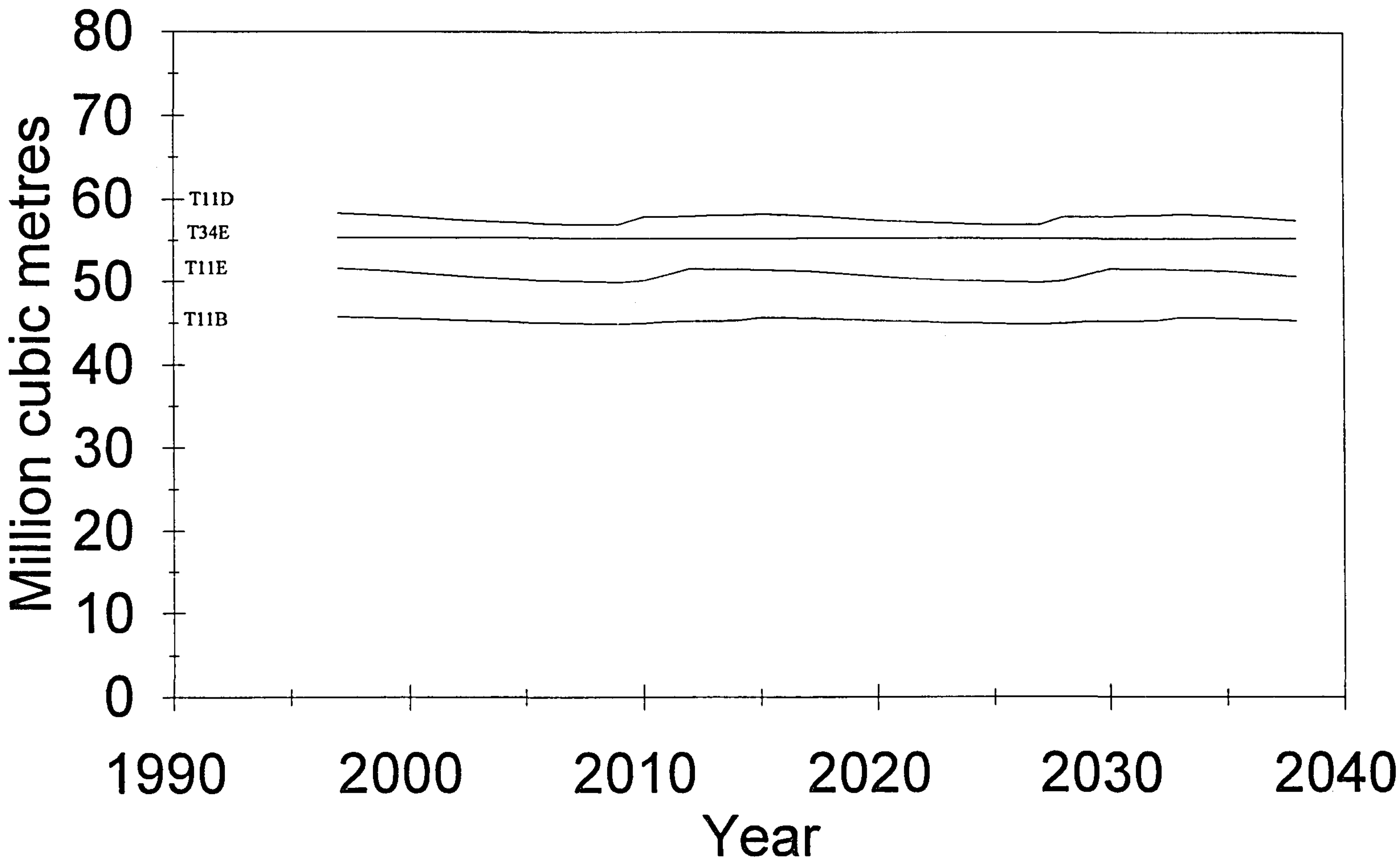

Fig 4.3 Streamflow reductions projected for certain quaternary catchments, showing the impacts of afforestation in the North Eastern Cape. Note that these curves have been generated for the impact of forestry under conditions of mean annual rainfall

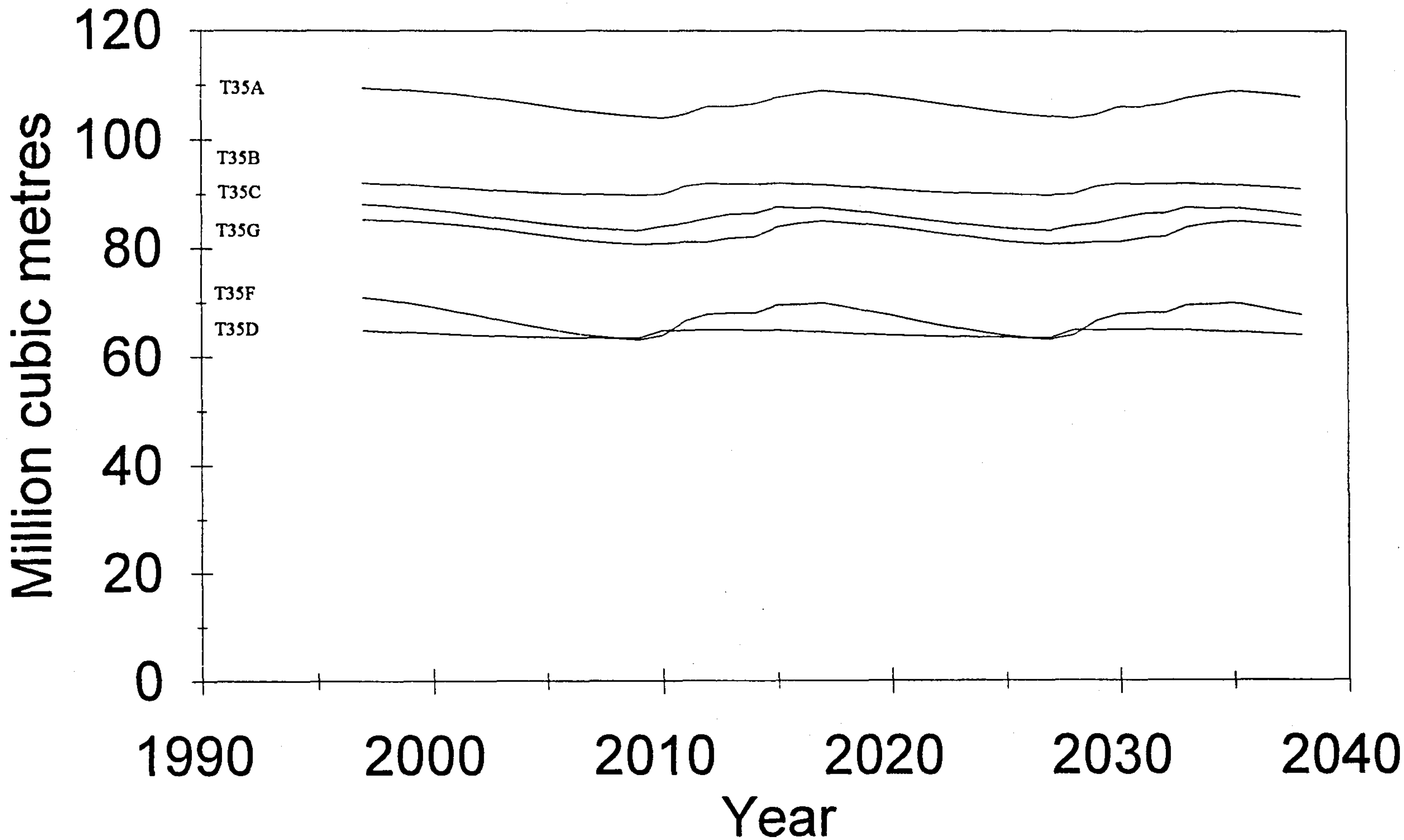

Fig 4.3 Continued.

In the quaternary catchments planted by NECF, streamflow reduction in each catchment has a sharply defined peak because the majority of plantings in each catchment have taken place in a relatively small portion of the time available for planting. Plantings which are spread equally across a whole rotation period are not likely to show the difference in streamflow reductions from year to year as is the case with the current planting patterns in NECF.

To show how plantings have been grouped together in the North-Eastern Cape, a series of graphs relate percentage of total planted area with age-class for each quaternary catchment. Included are a set of three graphs for each tertiary catchment which combines the planting patterns of all nested or internal quaternary catchments (Figure 4.4). In each case, it is clear that the majority of afforestation takes place within a small proportion of the time that could possibly be used for planting, namely the whole duration of a rotation.

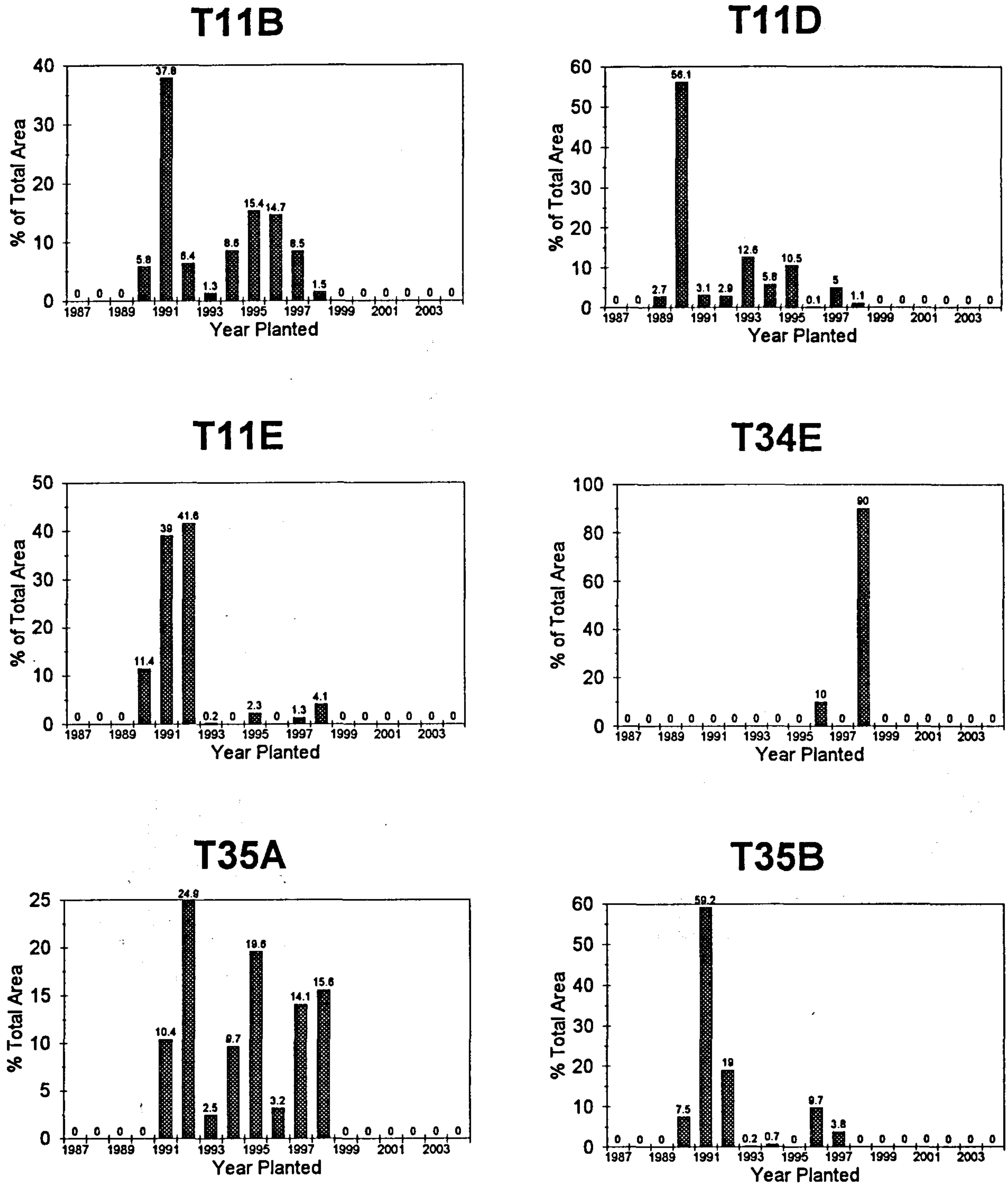

Figure 4.4 The percentage of total afforested area in each quaternary catchment planted in any one year. In some catchments more than 80 % is planted within three years or less, which will lead to proportionally high streamflow reductions in some future years.

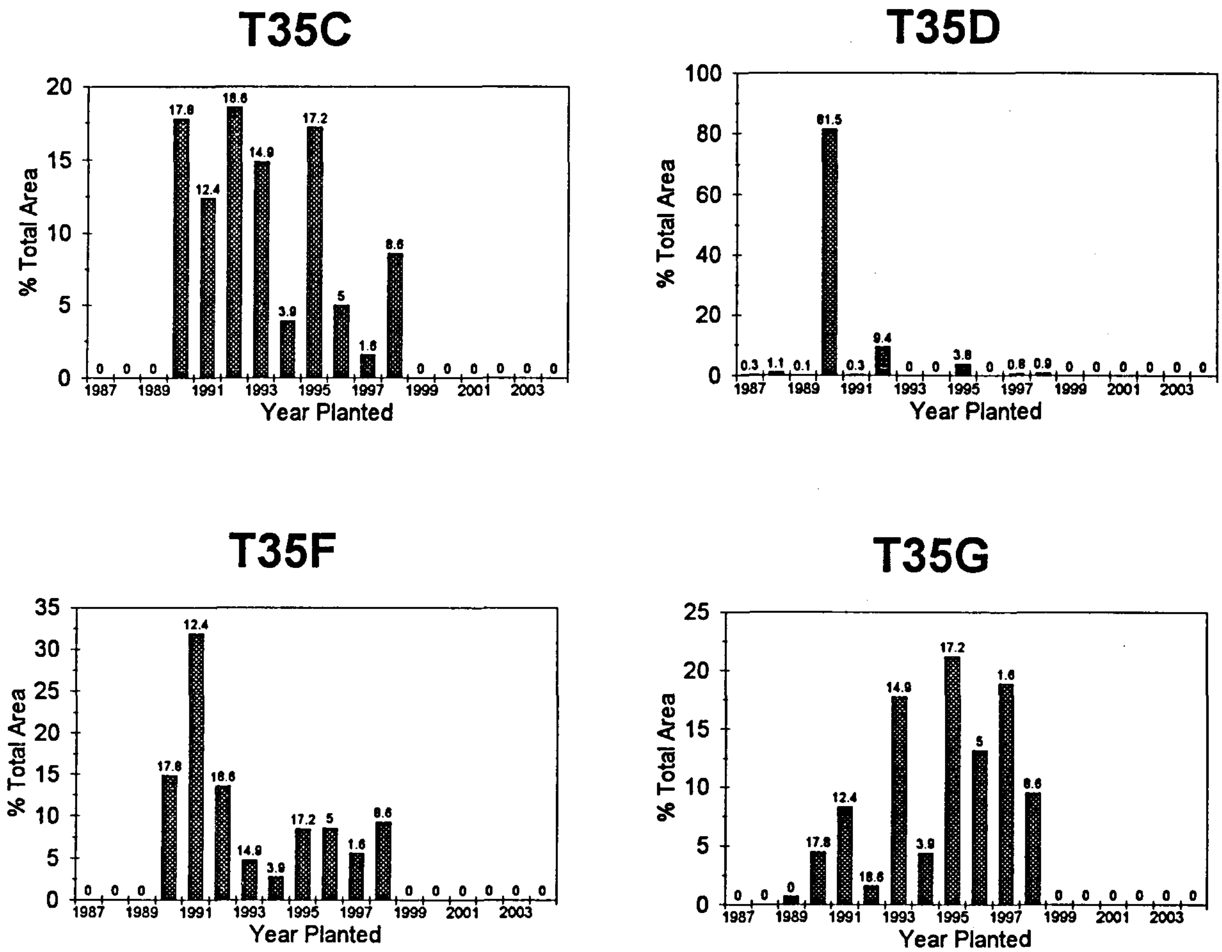

Figure 4.4 (Continued)

4.2.5 The importance of plantation age - a scenario

We hypothesised that a plantation with a normal age class distribution (equal area planted each year) substantially reduces the peak rates of streamflow reduction in comparison to that caused by total afforestation conducted over a short period.

To show that streamflow reduction can be reduced by changing the age class distribution of afforestation in a catchment, we used quaternary catchment T35F as a test case. This catchment was selected because the reduction in streamflow due to current afforestation is likely to peak at more than 10 % (see Table 4.5). A data set was created that had the following attributes:

- The same fraction of area afforested in each rainfall zone as that occurring in the field at present;
- The afforestation age in each rainfall zone is further equally divided into 18 components representing the full length of the rotation period length.

By allocating the same fraction of total afforestation to each rainfall zone as occurs in the field, the analysis could maintain the spatial pattern attributes of current afforestation. Thus the new data set differed only in plantation age distribution.

Figure 4.5 illustrates the results of this scenario analysis. Peak rates of streamflow reduction in an age-normalised catchment are only 65 % of the peak rates likely to be obtained from the present planting patterns. This would reduce maximum streamflow reduction in T35F from 12.4 % of MAR to 8 % MAR. It is also true however that this more moderate rate of water use is now sustained for each year over the whole rotation. The highs and lows of water demand have therefore been spread over the length of the rotation. Conversely, changing the period of afforestation from an age normalised catchment to one of short duration will increase the impact on runoff reduction by 56 %. Note however such afforestation over a short period can also result in a streamflow reduction considerably lower in certain years than that resulting from a normalised plantation.

The rising limb of the graph in Figure 4.5 for an age-normalised catchment immediately shows that rates of streamflow reduction increase more slowly than in the situation of the current rate of afforestation. The rising limb then reaches a plateau which represents the start of felling within the plantation. This result unequivocally shows the decrease in peak streamflow reduction of an age normalised plantation.

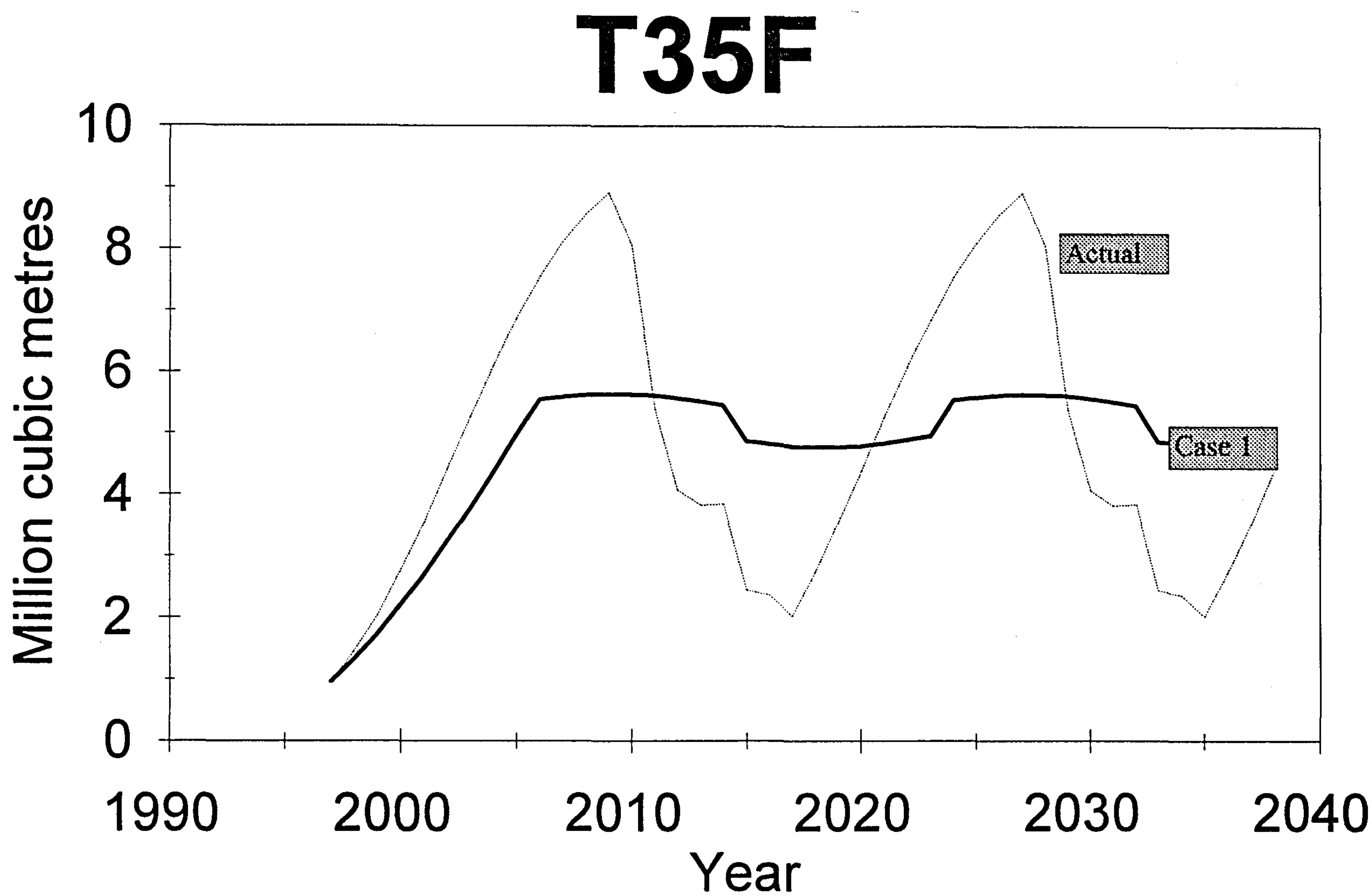

Fig 4.5 A comparison between stream flow reductions of current afforestation in catchment T35F and a simulated age-normalised catchment (Case1).

The age-state is an important consideration when undertaking risk analyses of the hydrological impacts of afforestation. For example, droughts may occur at any given time and are unrelated to the planting cycle. Thus the hydrological impact of age-un-normalised afforestation may be greater or less than might be understood from use of average plantation age in a hydrological analysis.

4.2.6 Discussion: assessing streamflow reduction by afforestation

The choice of hydrological models

In this study we have not used models such as WRSM90 (Pitman and Kakebeeke 1993) or ACRU (Schulze 1995). There are several reasons for this, some of which are given below, while others become apparent later in the section.

The Pitman model (WRSM90) was initially used to simulate the hydrological response of the Mooi River catchment, and calibrated on the weir at Maclear (T3H009). This proved to be a somewhat difficult exercise because of the paucity of rainfall data within the catchment. The only raingauge of consequence in the catchment is also at Maclear and has rainfall records dating from 1896.

An adequate simulation of MAR was obtained but the variation in flow from year to year of the Mooi River could not be preserved in the simulated results. A feature of these simulations, which included years of both high and low flows, was that modelled runoff was conservative about the mean value. So, although the long term mean annual runoff could be modelled with some accuracy, years of high and low flows could not.

The reason for these difficulties is the likely result of the mountainous country present in the headwaters leading to highly variable rainfall in the catchment, and the paucity of raingauges in the area. This deficiency leads to poor rainfall data inputs to the model. Other raingauges nearby did not have sufficient record to parallel the runoff observations for any suitable substitution to be made.

A presentation of these results to the Steering Committee on the project was concluded by an agreement to use models developed by the CSIR for the analysis of the hydrological impacts of afforestation in the North-eastern Cape region.

The CSIR flow reduction models are robust, widely accepted, and widely used in south Africa. There is however always scope for refinement and improvement both in terms of the model and its implementation. The synthesis of impact in this study has been based on a simple projection of mean annual precipitation, and therefore does not take into account the variability which will be induced by variations in rainfall. There is, for example always the possibility of a period of extreme drought coinciding with the period when a catchment is most densely afforested. The model is sensitive to annual changes in rainfall but an annual rainfall synthesis was not used in predicting future impacts.

The impact of forestry on low flows has become the immediate concern of water managers given recent emphasis on rural water supply. South African predictive models, inclusive of the CSIR's flow reduction model, are not well equipped to deal with this need. Low flow estimates are therefore necessarily less certain than estimates of MAR and these analyses would bear repeating once this model has seen further refinement during 1997.

Streamflow reduction by afforestation
The hydrological impact of afforestation in the North Eastern Cape differs according to where that afforestation takes place (moist or somewhat drier catchments), the frequency distribution of runoff in each catchment, the duration over which planting took place and, of course, the total area of afforestation that has taken place.

These impacts are illustrated in Figures 4.6 to 4.9. In general, they show that the predicted hydrological impacts of current afforestation in the region is not great in most catchments. Quaternary catchment T35F, on the basis of current plantings is most affected however, where streamflow reduction reaches more than 12 % of MAR in the case of current plantings. Streamflow reduction reaches 18 % and more of MAR in the case of future afforestation plans by NECF being implemented. Quaternary catchment T34E is targeted heavily for future expansion of afforestation.

The impact of afforestation on MAR at tertiary catchment level is minimal. Reduction of total flow is less than 6 %, even when including potential future afforestation.

The impacts of afforestation on low flows are expectedly more severe. Low flow reduction reaches 31 % (see Table 4.7) in the case of T35F under a scenario of potential future plantings in this catchment. The drier T11 catchments are also more severely affected, relative to the quantity of afforestation in these catchments and in comparison with the more moist T35 and T34 catchments to the north.

A discrepancy in the low flow model results has been observed. Whereas it is expected that the impact of afforestation on low flows will be relatively greater than that on total flows - this relationship does not always exist in the results presented here.

Within the "Future afforestation" scenario, catchments T34E, T35A, T35B and T35C show percentages of reductions of low flows less than those percentage reductions of total flows (Table 4.5). We believe this to be a result of the way in which the impacts of afforestation on low flows were modelled.

Reductions in total flows were modelled on the basis of a series of curves, different curves being selected according to the quantity of estimated runoff for each sub-compartment. For the estimates of low flows however, only one curve was available. The result is that reductions in low flows are likely to be under-estimated in some catchments, and over estimated in others. This problem is the basis of ongoing research.

In all catchments there are opportunities for reducing the impact of afforestation on runoff. Previous studies on the hydrological effects of afforestation in South Africa have tended to give plantation age as a single average age, which reflects the long-term condition of status of the plantations within a catchment. In reality, plantations in a catchment do not have a uniform age structure and this fact has certain important implications for the hydrological impacts of forestry. This fact has been emphasized by our study of streamflow reduction in the North-eastern Cape.

For example, one implication is that the severity of streamflow reduction may often be underestimated. This underestimation may not be of great importance when the proportion of total catchment area covered by plantation is small. If the proportion is large, however, the underestimation may have severe consequences. Hydrological statistics may be incorrectly calculated and the effects of streamflow reduction can accumulate through a series of nested catchments, possibly increasing the negative impacts of afforestation. The case study, however, makes the argument for significant gains in peak streamflow reduction in an age normalised catchment.

Afforestation in the North Eastern Cape has been relatively highly concentrated over a few years. The impact of this afforestation could be substantially reduced by striving towards an age normalised plantation. It could also have implications for the acceptability of increasing the total area of plantation and these implications should be borne in mind when considering forestry in the holistic sense of environment.

5. GUIDELINES FOR POLICY DEVELOPMENT AND LAND MANAGEMENT

5.1 INTRODUCTION

The objective of this component of the project was defined as 'To provide guidelines for policy development, together with practical management guidelines to improve water quality and yield, and to ameliorate the impacts of afforestation on the natural environment'.

This objective contains two elements: (i) Guidelines for policy development, and (ii) practical management guidelines. Both need to be aimed at optimizing hydrological resource use and minimizing environmental impact.

The intention of this chapter is not to prescribe, but to build upon South African forest hydrology experience together with the functional and hydrological knowledge assembled with regard to the North East Cape Forests in formulating policy, management and operational strategies for the future of both this, and perhaps all, forestry developments within South Africa.

This chapter has been written from a forestry perspective, with consideration of the opportunities and constraints upon the forestry industry. It has not been possible to consider all of the other potential, and perhaps even preferable, land uses in each instance. The need for a strategic environmental assessment, or SEA, before embarking upon an extensive forestry venture, is however discussed in section 5.5.3 and again in section 6.9.

It has not been the intention of the authors to show bias or favour towards the forestry industry over and above other land uses. We have simply approached the question of land use from the angle of the forestry sector. Ideas propounded are not intended to suggest that 'this is how things must be done', but rather to create a fertile filed for debate.

There are a number of steps in the development of policy for a land management operation of this nature:

- Goals and objectives must be clearly defined;
- Rules, regulations and compliance requirements need to be established;
- Institutional arrangements must be clarified and put in place, particularly with regard to the controls on development; and
- Guidelines are required for procedure and practice.

These steps are addressed in the following sections.

5.2 POLICY GOALS AND LAND MANAGEMENT OBJECTIVES

The major issues in the North-Eastern Cape have been identified as maintaining long term run-off and ensuring equitable access to clean water supplies; regional economic development; the conservation of biodiversity; maintaining and improving the agricultural base; addressing the basic needs of the population within the RDP framework; ensuring national forest resource provision; and ensuring a return on investment for commercial forestry.

These issues are reflected in the primary goals of different role players, expressed in a very abbreviated form, below:

North East Cape Forests, Mondi and the IDC (the forestry developers) all seek an increase in the forestry base aimed at a sustainable forest industry sufficient to support local beneficiation. Ultimately the investors require a return on that investment.

Agricultural unions / farmers: That agriculture should develop on an economic and sustainable basis. Present and future water supplies must not be endangered by forestry development. Many private landowners see forestry as an opportunity to expand or even change their agricultural base, and would like to grow trees.

Eastern Cape Nature Conservation: Conservation of biodiversity, conservation and sustainable use of natural resources.

Water Affairs Branch of DWAF: Water for dams. Maintaining sustainablity of low flows. Fairness in the allocation and distribution of water. Ensure that river flow meets the needs of downstream users.

Forestry Branch of DWAF: To sustainably grow the national forest resource base.

Local Government: Regional economic development.

Farm workers and communities: Land, water and jobs.

Advocacy groups: Sustainable development; development within a sustainable environment, improved standard of living.

It is only in considering all of these and the needs of other land and resource users - at both the strategic and local level - that the most acceptable land use policy can be established.

Land management objectives will inevitably differ in line with the sectoral interests and responsibilities of each of South Africa's various land management agencies, and particularly where a new agency, such as forestry, moves into a new region. There is, however, always some common ground. In the North-Eastern Cape there are a number of clear areas of commonality, including recognition of the value of the area as a natural resource and the need to conserve this, the need for economic development, and the importance of the water resource.

North East Cape Forests has impacted upon the *status quo* through the establishment of an industry which is demanding of land (or, at least, land use change) and of water. But the industry also offers an opportunity for regional upliftment. To achieve this North East Cape Forests must establish a viable operation, and to be viable this must be large enough to sustain a secondary processing industry. This requires a forestry operation of the order of 100 000 hectares. It is important to note that the sentiment within the Water Affairs Branch of DWAF, at the time of the project commencement, was that forestry development within the North-Eastern Cape would only be acceptable provided it was large enough to sustain a secondary processing industry. It was also important that forestry development would not jeopadize critical low flows. In other words the water allocation to an extensive forestry development was foreseen, but water used by trees would only be justifiable if there was value addition benefitting the region.

North East Cape Forests recognizes that the timber required to sustain the planned operation must occupy a significant land area - but at the same time the company acknowledges the conservation priorities. The hydrological consequences of forest development are very clear, along with the need to manage in such a way as to minimize demand and impacts whilst maximizing benefits.

Ownership of the land, and of the timber resource, are not of particular consequence to NECF except in that supply must be guaranteed and land management responsibilities have to be delineated clearly.

Summary and recommendation

- **NECF requires a significant threshold volume of timber for economic viability and the establishment of a secondary processing plant. The economic development of the region is dependent upon this. Land ownership is not important but supply must be guaranteed.**
- **Consider the needs of all land and resource users at both strategic and local level, in the establishment of an acceptable land use policy.**

5.3 RULES, REGULATIONS AND RESPONSIBILITIES

The forest industry is at present constrained by a range of rules and regulations aimed at conserving the landscape and protecting the downstream water user. The primary rationale for these restraints is water conservation. In addition to the compliance legislation in place the forest industry has also imposed a number of self-regulatory instruments. Economic instruments play the final role. It is worth looking at each of these limitations on forestry.

Compliance: Rules and Regulations
The most important legislation restricting afforestation resides in the Forest Act of 1984 (Act 122 of 1984), the Water Act (Act 54 of 1956), the Conservation of Agricultural Resources Act (Act 43 of 1983), the Environment Conservation Act (Act 73 of 1989) and the Mountain Catchment Areas Act (Act 63 of 1970). The afforestation permit system, and the more recent requirement for an environmental impact assessment in the event of any extensive new development, or where there are objections, are the critical new elements within this legislation.

Self-regulatory instruments
Despite the seeming plethora of controlling or compliance instruments the industry has added a number of self-imposed regulatory measures. The industry has developed a set of 'Guidelines for environmental conservation management in commercial forests in South Africa' (Forestry Industry Environmental Committee 1995) and all of the major producers (Sappi, Mondi and Safcol) have either developed, or are in the process of developing, company environmental policy statements. Typically forest managers are obliged to, for example, apply the 'Bosch model' (Bosch 1993) when planning afforestation in the vicinity of riparian zones. Estates are also subject to stringent company auditing procedures. External, or foreign, audits are also becoming commonplace as foreign buyers look to the acceptability of buying South African timber products.

Economic instruments
True economics is starting to play its rightful role in South Africa in determining land use practices, with the phasing out of agricultural subsidies, and of protective trade tariffs. Natural resource accounting is also encouraging a more holistic look at the true costs and benefits of different land use types (United Nations 1993, Hassan 1996). In the current climate the economic benefits of forestry are generally favourable to the industry, particularly where the means of beneficiation are in place. A critical view of crop agriculture, particularly in terms of water use, is also likely to ease pressure on the industry.

The rules and regulations currently in place, and with which NECF is obliged to comply, have evolved to protect certain users and may not necessarily take into account changes of circumstance. Given the new maxim of 'an equitable sharing of resources' old rules and regulations should not be invoked in order to sustain entrenched interests, to the detriment of new interests which may be far more efficient in utilizing that resource. For resources to be shared equitably one must start with a clean slate and not with one or other party backed up by a history of legislation. Achieving an equitable sharing of the water resource in this way will, however, take time and will result in some hardships, where accustomed 'rights', established over time, have to be re-negotiated (see also Versfeld 1996).

The introduction of forestry to the North-Eastern Cape offers an illustration of the above. Riparian owners have become accustomed to 'normal flow' rights based upon irrigation needs, in terms of the Water Act of 1956. It would appear that some new agricultural development upstream may be allowed to impact on supply (the upstream owner also having riparian rights) but that forestry, which uses water in a different way, may not. Such forestry may be riparian, or well away from the stream. Clearly forestry is a new user with impacts which were not foreseen when riparian rights were first established. Yet does forestry not have a legitimate claim to an equitable share of the water resource, even if it is a latecomer, or one whose influence has only lately been established? Forestry cannot be accommodated equitably while old, and in today's terms inequitable, allocations remain on the statute books. At the same time existing users must be reasonably accommodated.

Recommendation

An equitable sharing of water resources requires a review of entrenched rights, and a negotiated redistribution. The revision to the water law must review the situation with regard to riparian allocations, so as to allow for upslope water use by forestry - whilst best accommodating existing users.

5.4 INSTITUTIONAL ARRANGEMENTS

Government has a long established and accepted responsibility towards the management of the national water resource, applied to the forestry industry primarily through the Department of Water Affairs and Forestry and notably through the Afforestation Permit System.

Afforestation in the North-Eastern Cape was encouraged through the publication of national forestry planning documents outlining strategic thinking. Clearly the government should take responsibility for strategic decisions, and for the establishment of development and management guidelines. But once a strategic decision has been taken then it is required that government should stand by and support that decision if business confidence is to be maintained. Where decisions are seen to have been wrong then corrective steps are quite in order, but compensation may be required unless the risks were clearly articulated at the outset.

Should forestry development be seen as strategically acceptable, within the North-Eastern Cape or elsewhere, then it is suggested that responsibility for that development should, as far as possible, devolve upon the timber growers. Environmental constraints, as determined by impacts, do need to be determined for region, district or catchment. But once this has been done a forestry company with an acceptable development strategy could be 'accredited' to afforest, either on purchased land or through joint ventures, with a minimum of institutional interference. Such accreditation would be dependent upon responsible development within set principles. Failure to abide by these principles (to do things properly) would result in the loss of accreditation and expose the company to the full weight of bureaucratic planning and control. In this way much of the responsibility for detailed planning and management can be removed from the hands of government, whilst private growers will be under a constant tension to ensure that things are properly done.

Recommendations

The government must take responsibility for strategic decisions.
Responsibility for the nature of the development should devolve upon the timber growers through a system of accreditation.

5.5 GUIDELINES FOR POLICY

5.5.1 Regional Planning

Strategic decisions encouraging or discouraging afforestation must take national, regional and local needs into account. The North-Eastern Cape has water as a major resource and it is apparent that there is sufficient water to support forestry on a significant scale at a regional level. Afforestation policy could however still be influenced by both national and local needs. This has been demonstrated by the proposal for an interbasin transfer scheme whereby water would be taken from the Umzimvubu catchment to supply Gauteng Industria, although this now seems unlikely to come seriously into play before 2020 or 2025. Certainly it does not seem reasonable to penalise the economy of an entire region on the off-chance that the transfer of that region's water to some other region might at some stage be affordable.

While there would seem to be sufficient water at a regional level it remains important that:

(i) A ceiling be placed on the maximum desirable level of afforestation within catchments down to the level of the quatemary, and perhaps even normal flow, catchment. This may need to be determined for each individual catchment.

(ii) Sole rights to this afforestation should not be placed in the hands of one individual or company, but any major investor should have reasonable guarantees that strategic plans will be supported through to implementation.

(iii) Local level impacts must be taken into account, with the outcome reflecting a reasonable and equitable sharing of the water resource.

(iv) Responsibility for wise afforestation can be demanded of the forestry company. The forestry developer should consider all afforestation schemes, of any scale, in the context of regional and local impacts on hydrology and should be party to an accommodation of needs according to the principle of equitability.

Recommendations

- **Levels of acceptable water use need to be determined for each catchment (from 'normal flow' or quaternary to primary catchment scale);**
- **Local level (farm scale) impacts must be taken into account - but should not be allowed to dominate;**
- **There should be a reasonable and equitable sharing of the water resource;**
- **Strategic decisions by national or regional planners should be accompanied by reasonable guarantees of support in implementation;**
- **Communities and individuals should have opportunity to share in any forestry development;**
- **All forestry development should be considered in the context of regional and local impacts on hydrology, with needs accommodated according to the principle of equitability.**

5.5.2 Integrated catchment management

Burton (1995) has usefully defined integrated catchment management as follows: "Integrated river basin management implies that informed decision makers take into account all uses and resources of the basin, following an ecosystemic approach. The overall goal is to ensure that human collectivities will benefit forever from the basin through the development of harmonious relationships between its users and between man and the river." The concept of integrated catchment management (ICM) has taken root internationally and catchment management, 'where agency and land owner representatives must combine across disciplines to tackle the natural resource problems that now face them', offers a comprehensive solution. Problems need to be faced and managed on a catchment basis, with community participation vital at all levels. South Africa is moving towards the implementation of integrated catchment management and it can be expected that in the process procedures for the resolution of many of the conflicts between users will be developed. At this stage ICM is a vision towards which South African catchment managers strive - and the principles of the process certainly play an important role.

Recommendations

Forestry development in the North-Eastern Cape must be viewed in the context of the entire catchment, and managed accordingly (see also 5.5.3).

5.5.3 Strategic Environmental Assessment (SEA)

South African and international experience shows that a change is occurring to the accepted practice of Environmental Impact Assessment (EIA). New techniques are being used to address environmental issues earlier in planning and policy making processes. The new approach is called Strategic Environmental Assessment, or SEA. Strategic Environmental Assessment has been described as "a process of anticipating and addressing the potential environmental consequences of proposed initiatives at higher levels of decision-making. It aims at integrating environmental considerations into the earliest phase of policy, plan or programme development, on a par with economic and social considerations" (Sadler, 1995). SEA is not a laid down procedure and the process itself is defined by the issues. It is argued that rigid procedural approaches will not succeed where regions or sectors of policy development are to be addressed. This is because of the complex nature of decision making and the need for SEA to provide information at different stages of planning and policy making. (Wiseman 1996).

The need for a form of SEA for the forestry industry has been identified as a result of frustrations that exist with the application of project-specific EIAs to afforestation permits. All forestry developments now have to be advertised or in the event of reasonable objection, each application is then subject to an EIA. This may result in a great many EIAs being required within a single river catchment or watershed. This slows down decision-making and limits the potential for community based forestry activities. Project-specific EIAs are unable to address the cumulative effects of afforestation or its effect on competing long term water demands within a catchment.

The need for new approach has arisen from dissatisfaction with the scope of project-specific EIAs and an awareness that environmental issues must be included in development planning at various scales. These issues have been recognised internationally and are not unique to South Africa. Whilst the Integrated Environmental Management procedure has become accepted good practice, SEA techniques have the potential to better integrate the principles of IEM with planning processes.

The rationale for SEA can therefore be summarised as:

- To streamline EIAs by ensuring that environmental issues are addressed adequately at the policy or planning stage;

- To improve the assessment of cumulative environmental impacts from secondary and downstream development; and

- To focus on sustainable development by appropriate policies and guidelines.

SEA is a process: It is issues driven and participative. Sustainable development is promoted by addressing the effect of the environment on development, rather than on the effect of development on the environment, which is the focus of EIA (Wiseman 1996).

Historically strategic decisions with regard to the suitability of new land for forestry have been made by Government Departmental National Forestry Planning. These decisions have been based on the physical suitability of the land for forestry - unclouded by any other consideration, or whether forestry was necessarily the best form of land use. Today such planning decisions should be seen only as an input to a Strategic Environmental Assessment.

Recommendations

- All new forestry development should be based upon a strategic assessment which considers all aspects and viable alternatives for land use
- In the North-Eastern Cape a Strategic Environmental Assessment (SEA) approach should be adopted with the objectives of assessing the suitability of forestry as a land use, and of developing a protocol with which to screen afforestation applications within a catchment. This would reduce the number of project-specific EIAs needed and improve the regional coordination of afforestation.

5.5.4 Catchment Afforestation Planning

Consideration of impacts on catchment hydrology provides a major driver in afforestation planning. Questions include:

(i) How much of the catchment should be afforested?
(ii) Which is more desirable hydrologically - a consolidated or fragmented pattern of forestry? and
(iii) Where in the catchment should trees be planted?

From the data available in the North-Eastern Cape it is not possible to answer any of these questions unequivocally. Clearly the percentage of any catchment which should be allocated to afforestation will depend upon the downstream demand. At the same time it is important that any decision be taken at all levels of scale, for example the decision to plant up a small catchment fully may be acceptable at the level of that small catchment but unacceptable at the level of the larger catchment. Alternatively it may be acceptable within the larger catchment, but quite unacceptable at the level of the small catchment. All levels of scale must be considered at all times.

The question of a consolidated *vs* fragmented pattern of forestry is related to the above consideration. Much of the land within the North-Eastern Cape, even in the high potential areas is either unsuitable for afforestation (eg. through slope or poor soil depth) or excluded as riparian zone, wetland, heritage site or through some other conservation objective or legal restriction. In consequence it is rare that any management unit (considered here to be the farm unit upon which afforestation decisions are currently based) is afforested to more than 60 %.

Beyond this the zones of suitability for forestry are relatively narrow and dispersed, with the result that all major forestry development is scattered across the two primary catchments (Bashee and Umzimvubu) and many quaternary catchments. This fragmentation of afforestation across water catchment areas entails certain management costs, but may also serve to spread the risk of fire, hail damage or other natural disaster. It is unlikely that there will be benefits in terms of total water yield at the level of the primary catchment but there are certain to be advantages at the local level where no one stream has to bear the full extent of the impact.

Where in the catchment should one plant? It would no doubt be optimal for all river water to be used once it had already served the full course of the river and entered the sea. Forests planted in the headwater areas can therefore be seen as most detrimental to the life of any river system as they deprive it of water right at source. In the North-Eastern Cape the headwater zones of the major river systems are primarily steep and inhospitable to forestry. Afforestation is therefore concentrated in the gentle mid-reaches of most catchments, thus allowing natural streamflow generation in the headwater zones. This is an accidental consequence of terrain, but one which could happily have been guided by a policy to avoid planting up the headwater areas of all major catchments.

Any relative benefits with regard to afforestation impacts on total water yield, of protecting catchment headwater areas, tends to be a function of the higher rainfall enjoyed by these areas, rather than the fact that first flow is generated on these sites. Certainly water use and flow routing models offer no other weighting to upstream sites other than those of rainfall, climate and soil. These can, however, indeed be important.

Recommendations

- **Limiting the total area under trees of any management unit has hydrological benefits - but planning and research are necessary to ensure that this benefit is commensurate with the area, and consequent timber volume, lost.**
- **The clearing and maintenance of riparian zones is hydrologically beneficial.**
- **Forests are 'primary' water users. The further down a catchment a forestry development is situated the less impact it has upon that system. Planning should take this into account.**
- **A fragmented distribution of forest may have both hydrological and ecological benefits, but also disadvantages. Zoning practice will depend upon relative impacts, but weighted by management considerations. Research is required on forest distribution.**

5.5.5 Farms as Decision Units

In afforestation planning, and certainly in the process of permit application, farm boundaries are used in determining the management unit. Unfortunately it is very rare for the farm boundary to follow that of the catchment. If planning is to consider the impacts of forestry on hydrology at the level of the catchment then impacts also need to be considered at this level. Clearly, in the case of the small grower the farm is often the logical unit upon which both permit applications and management will be exercised, although this should always be within a catchment context. For the larger grower these boundaries are often illogical, and where permit applications are for adjoining properties it is apparent that the total extent of afforestation should be considered rather than that of each individual property. There is a strong case for the use of the quaternary catchment in screening for hydrological impact.

Recommendations

- **The farm boundary is often an unsuitable decision unit. Decision making at the catchment scale is preferred. The North-Eastern Cape the quaternary catchment would seem to be a generally appropriate scale for screening for hydrological impact. But all scales should be considered, and studies at a scale smaller than the quaternary may be required in some instances.**

5.5.6 Protecting the Hydrological Resource

Afforestation has long been restricted from the immediate vicinity of streams, rivers, 'sponges' and wetlands, with a buffer of at least 20 metres usually prescribed. In effect the legislation has aimed at protecting areas of land with free water. Sponges and wetlands have traditionally been viewed as water *source* areas, when in fact they can play no special role in streamflow *generation*, but should rather be viewed as water *regulation* areas. See also section 3.1.9.

It is now prevalent in forestry circles to argue that modern or 'new generation' forestry, which is far more environmentally sensitive and takes account of the need to avoid hydrologically sensitive areas, has relatively little impact upon the hydrology of the catchment. We have summed this up as a hypothesis which needs to be tested:

"A carefully planned and well managed forest estate - with broad but flexibly designed riparian zones, protected wetlands, and wide buffer strips around all hydrologically sensitive areas - has relatively little impact on the water yield of a catchment".

Headwater areas are not yet viewed as 'hydrologically sensitive' in this hypothesis. In effect the protective measures outlined within this hypothesis have already been packaged as management policy by progressive forestry companies, although application is still a question of degree. Research reported by Scott and Lesch (1995) indicates that trees within riparian zones will use far more water (twice as much) than trees away from streams. That does not mean that trees away from streams use nothing at all!

In considering this hypothesis, however, it does become apparent that all catchment research into the hydrological influences of forestry has been done within catchments planted according to an older paradigm - that is catchments either totally afforested, or planted as close to riparian zones as legally permissible (20 m), and with riparian zones maintained in a state of total protection (ie. without fire and often, in consequence, experiencing dense bush invasion). Whilst researchers have attempted to factor out these influences, it can be argued that it is really quite unfair to compare the hydrological impacts of maximum afforestation of the past with the far more conservative practices implemented by responsible forestry companies today. It is this argument that finds its expression in the stated hypothesis.

From the above arguments, and in order to develop an afforestation policy which optimizes the water yield from a catchment whilst still producing economically viable volumes of timber, three aspects of catchment hydrology need to be considered. In the first instance: Where is streamflow generated? Should wetlands be viewed as sources or sinks, and what is their role in streamflow regulation? And finally, what constitutes a riparian zone? The intensive study of catchment hydrological processes initiated in the Wetherley Catchment (see also section 1.4.5), and particularly the evaporation studies using the Bowen ratio technique, should assist in providing the answers.

The North-Eastern Cape is a mountainous region and the slopes drain rapidly. Ground water and surface water drainage are closely linked and it is not useful to see surface and Ground water components as separate entities. Any sub-surface saturation is likely to be fairly small cells (limited and shallow Ground water compartments). Trees will have an impact on Ground water by reducing available water, but measures of streamflow will still give a picture of the total water yield. There is no separate Ground water store which has been left unaccounted for when considering forestry impacts (Scott 1996, pers. comm.).

In effect, trees will almost always use additional water if that water is available to them. This usually goes hand in hand with some increase in production. In the catchment trees growing in the areas of highest rainfall, areas of deepest soil accessible to roots, seepage areas or wetlands, and riparian zones can therefore be expected to be most demanding of the water resource, and it is for these areas that careful planning can be most effective in minimizing impacts and optimizing supply.

Recommendations

- The hypothesis that *"A carefully planned and well managed forest estate - with broad riparian zones, protected wetlands, and wide buffer strips around all hydrologically sensitive areas - has relatively little impact on the water yield of a catchment"*, needs to be scientifically tested.
- Three aspects of catchment hydrology need research. In the first instance: Where is streamflow generated? Should wetlands be viewed as sources or sinks, and what is their role in streamflow regulation? And finally, what constitutes a riparian zone?
- In the catchment trees growing in the areas of highest rainfall, areas of deepest soil accessible to roots, seepage areas or wetlands, and riparian zones can therefore be expected to be most demanding of the water resource, and it is for these areas that careful planning can be most effective in minimizing impacts and optimizing supply.

5.6 GUIDELINES FOR PROCEDURE AND PRACTICE

5.6.1 Zoning for Forestry

In the North-Eastern Cape, despite the extreme drive to maximize afforested areas in the first years of the project, unusually strict criteria were used to define that area which constitutes a riparian zone (defined in the Forest Act as the zone adjacent to a perennial stream). In consequence many gullies, depressions which may carry water from time to time, and even dongas, were excluded from afforestation. This led to many scattered and unmanageable patches of trees - with the attendant problems of access and, more seriously, management of the intervening grassland.

It has been suggested that the fragmentation, or spreading, of forestry across the broader landscape is hydrologically sensible, as both impacts and risks can be spread across a range of catchments. It is also apparent that, on the micro scale, fragmentation (many small blocks) has serious managerial, and ecological, land management implications.

North East Cape Forests have developed the concept of zoning for forestry - arguing that the land management benefits can outweigh any hydrologically negative implications. If zoning is to become an accepted policy then these arguments need to be explored, particularly as many of the principles of hydrologically sound land management practice are countermanded in the implementation of zoned forestry.

The practice of forestry zoning involves the deliberate consolidation of afforested land through the planting of some areas which would otherwise be excluded, either by existing policy or by law - usually for reasons of hydrology. As a *quid pro quo* alternative land is left vacant, or unplanted, even though such land might otherwise legally be afforested, in order to compensate for the additional impacts on the hydrology which the zoned afforested area might have.

The concept of zoning is very attractive from a management perspective. Fingers of land (for example weak riparian zones) which break up the forestry block, which must be crossed by access roads, which present a fire hazard and are very hard to manage, can be planned for planting. So too there may be wetland areas which may no longer have any useful purpose to serve as a consequence of surrounding afforestation.

With zoning the creation of a logical and efficient forestry management unit is counterbalanced by the allowance of a logical and manageable ecological unit of meaningful dimensions. Given that the necessary justification is hydrological this balancing area must be seen to yield at least as much, or more, water than the additional area allocated to forestry through zoning. Herein lies the rub. If well managed and hydrologically sensitive afforestation is so effective in minimizing impacts, then what is the hydrological cost associated with zoning? Assuming that this can be calculated, then it should not be difficult to estimate the conservation area required as 'compensation', recognizing that far larger areas of land may have to be kept open in order to 'compensate' adequately. This is because such areas may have a far lower hydrological value.

Recommendations

- **From a forestry and land management perspective the potential value of forestry zoning is clear. It is important however that the planning scale remain small, and that zoned forestry areas do not concentrate forestry in such a way as to dominate the hydrology of a catchment. It would probably usually be preferable for the compensation area to lie within the same catchment.**
- **In the application of zoning full recognition must also be given to arguments whereby good management through the avoidance of hydrologically sensitive areas is used to downplay the impacts of forestry. This will ensure that adequate 'compensation' is offered - with both forestry and the environment coming out as winners.**

5.6.2 Forestry and wetland management

The role which wetlands play in the hydrology of catchments has been discussed in Section 3.1.9. The importance of wetlands within the landscape of the North-Eastern Cape has also been made clear.

Agricultural activity has had a major impact on the functioning of many of these wetlands - most obviously through the construction of drainage ditches. Many of the natural drainage channels have also become deeply incised. This is most probably as a result of direct, although perhaps inadvertent, agricultural intervention resulting in the creation of a notch, which migrates backwards up into the catchment, getting deeper along the way, with the process exacerbated by faster flows. Deep drainage channels will alter the functional nature of the wetland (section 3.1.6). Forestry can be expected to impact primarily on the smaller wetlands, particularly where these are surrounded by plantation, through a reduction and perhaps even complete drying up of water supply.

The policy which forestry should adopt towards these wetlands must be defined by their function. Wetlands may be seen to serve as sources, as sinks, as regulators of flow, and as filters vital to water quality. This will depend on geology, size and position in the landscape.

A small wetland (eg. < 1 ha) on a slope or in a depression probably owes its existence to an impermeable barrier down slope which impedes drainage. While this wetland might hold water and release it slowly to Ground water its function is likely to be one primarily of sink. That it is not a source is clear in that its existence is threatened by the presence of surrounding forest up slope. Unless an important slow release function can be demonstrated there seems to be little hydrological purpose in protecting such a wetland sink. There may, of course, be ecological reasons.

Alternatively a large wetland (eg. 10 - 100 ha) such as the Gatberg Vlei is likely to serve as a sink, as a filter, and could also be construed as a source through its function in regulating flow. The benefits of filter and flow regulator are likely to outweigh the costs as a sink.

These wetlands also have an important function to fulfil with regard to the containment of impact of any disturbance which might be attributed to forestry upstream (site preparation, roads, clearfelling) and as such should be maintained in, or rehabilitated to, optimum condition. If, however, forestry is expected to have a major impact on the water yield feeding through such a wetland, then the functional value of such a wetland will diminish in importance and management may be adapted accordingly.

Recommendations

- **Every effort should be made to re-establish the natural function of large wetlands important in the filtration and regulation of streamflow - particularly through the closure of artificial drainage channels, the rehabilitation of unnaturally incised channels, with attention given to the causes of such incision.**
- **Should forestry surrounding a smaller wetland (eg. < 1 ha) result in a loss of its functional effect, or a reduction in the need for such a wetland, then these areas could be considered for afforestation, depending upon their ecological value.**

5.6.3 Riparian zone management

The North-Eastern Cape Forest region is an environment incised by major rivers fed by high mountains above the forestry zone. But the region also has its fair share of rivers and streams emanating from within the forestry zone, along with dry or non-perennial gullies and dongas.

Any area which may serve as a source area from which trees can extract preferential water, either as a result of seepage due to its position in the landscape, or as a result of its proximity to the stream, or groundwater table, should be viewed as hydrologically sensitive.

The decision to avoid afforestation close to large and clearly perennial streams is an easy one, and suitable guidelines for decision making with regard to riparian zone exclusion widths are offered by the Bosch Model (Bosch 1993). The situation is far more complex in the case of moist depressions and ephemeral streams, with value judgements often necessary. In terms of modern and responsible forestry, decision support guidelines are required here too - even though such sites may legally be afforested.

Dongas are opportunistic pathways which serve no hydrological function other than to transmit water downhill as fast as possible. This is rarely a desirable characteristic and the planting of trees adjacent to and within such features for the purpose of site rehabilitation and improved infiltration, should be encouraged rather than avoided. Where erosion is too severe for containment through planting of pine species, then alternative species and methods of management should be considered.

Recommendations

- **Any area which may serve as a source area from which trees can extract preferential water, either as a result of seepage due to its position in the landscape, or as a result of its proximity to the stream (seepage out of the stream), or groundwater table, should be viewed as hydrologically sensitive.**
- **The 'Bosch' model is useful in planning for the protection of riparian zones. This model should now be reviewed in terms of the field experience gained in the implementation of the model.**
- **Decision support guidelines are required in terms of the afforestation planning of non-perennial water bodies, even where such sites may be legally afforested.**
- **Dongas should be planted rather than avoided. Alternative species and management strategies should also be considered for erosion control.**

5.6.4 Invasive species

There are two components to the problem of invasion. Firstly the problems, costs, and management issues relating to invasive species already present in the landscape. Secondly there is the risk of invasion of the surrounding countryside attributable to the introduction of forestry. Primary issues arising are the apportionment of responsibility for such invasions and the implementation of preventative and curative practices.

Landowners may, in terms of current legislation be pressed to clear invasive plants in terms of the Conservation of Agricultural Resources Act (Act 43 of 1983), Regulations Part II 'Control of weeds and Invader Plants'. Yet it seems rare that these regulations are enforced. The new Water Act, currently under revision, is expected to take a far stronger line on the management of land for the control of invasive species.

Invasion from trees already in the area
Although large scale forestry is a relative newcomer to the region invasives have long had a major impact on much of the landscape within the North-Eastern Cape (Section 3.1.8.3). The worst of this invasion, but not all, is concentrated within riparian zones, for example areas excluded from commercial forestry by virtue of their hydrological importance. The major invasive species within the region are the Australian species Black Wattle (*Acacia mearnsii*) and the Silver Wattle (*Acacia dealbata*).

All woody invasive species are assumed to consume more water than the grassland they might replace. Riparian invaders have added implications for bank stability. It has been the clear and active policy of North East Cape Forests to systematically remove and control invasive species on properties under its control. This is well grounded on at least two counts. In the first place, forestry in riparian zones is seen as particularly costly in terms of water use (Scott & Lesch 1995) and there is little reason to believe that *Acacia mearnsii* is a conservative forest species (Smith *et al.* 1992). In the second instance invasive canopies are unmanaged and are seldom harvested, although there is some utilization of trees for firewood. This means the continual presence of a mature stand of trees with all the attendant water use implications.

The hydrological value of the clearing of alien invasives within the North-Eastern Cape region has not been quantified given our lack of knowledge of actual water use by the major species. There can however be no doubt that both regional ecology and hydrology have benefitted from the clearing activity, with added water now reaching downstream users. While it is unlikely that North East Cape Forests will ever receive any credit in terms of a water allocation in return for the effort expended, it is important that this should be quantified and added into the regional resource economic equation. This could be taken further and a calculation of the potential impact to water resources made of the implications of **failure** to act against invasive species. In other words, what would the cost to water resources have been had there been no intervention, and had invasive species been allowed to continue to spread unhindered as in the past, and as is happening on many non-forestry properties?

It is therefore important that all landowners engaged in the clearing of riparian zones keep careful cost accounting of all clearing operations. This can then be weighed against real and putative water estimates of savings to the water resource.

Black Wattle (*Acacia mearnsii*) is a valuable timber species in KwaZulu-Natal and this has kept the brakes on biological control research, although the species is now recognised as South Africa's worst invader species and is the focus of an eradication programme costing R 100 m per year. Silver Wattle (*Acacia dealbata*) is a major invader of the region yet the species has little commercial value, although it can be utilized as a pulping timber. A wise investment may be to channel funds in the direction of the eradication of this species.

Recommendations

- **NECF should assess the *hydrological value* of its clearing of alien invasives both in terms of direct impacts and the hydrological costs of failure to act. This needs to be recognised by the regulatory authorities.**
- **The costs of black wattle invasion need to be argued in support of biological control programmes.**
- **Biological control of Silver wattle should be researched and implemented without delay, provided the social costs are not too high.**
- **The management of land for the control of invasives should be strongly legislated for the new water act.**

Invasion resulting from forestry

Afforestation immediately introduces a new source of potentially invasive species, often into remote natural areas. This risk becomes far greater where, as in the North-Eastern Cape, forestry has encompassed a wide area. Fragmented forestry may have benefits through the spreading the water resource impacts - but the risk of invasion increases due to the widespread source. Forestry activity will become even more widespread as small farmer and community forestry become integrated into the development.

Any invasive trees spreading from plantations can be considered to have a wasteful negative impact on the hydrology, wasteful in that the trees will use water without any useful product in return. Such invasions are usually evaluated, in terms of hydrological impacts, as equivalent to plantation forestry (Chapman *et al.* 1995). But even this estimate may be conservative as invasive species do not respect any limitations on riparian zones or other hydrologically sensitive areas. Nor are there regular clearfellings to reduce the biomass loading. Le Maitre *et al.* (1995) estimate, for the Western Cape mountains, that metropolitan Cape Town will be deprived of between 30% and 60% of its assured water supply if invasion of the surrounding mountain catchment continues unchecked.

That policy should ensure the containment of all invasive trees from plantations goes without saying. The real policy issues lie in the setting of responsibility, and the limits of that responsibility, with a difficulty being the apportionment of blame. This becomes all the more complicated in the case of independent small grower forestry, and where small growers buy into a major scheme.

Recommendations

- **Avoid and actively discourage (legislate against!) the planting of invasive species such as *Acacia mearnsii* - both in forestry and woodlot situations.**
- **Ensure the containment of invasives from forestry areas**
- **Educate and encourage landowners to take responsibility for the spread of alien invasives.**
- **Establish and enforce the legal liability for the spread of exotic invasives from forest, woodlot and farmstead.**
- **Investigate biocontrol agents as a means of limiting seed spread from pine plantations.**

5.6.5 Management of unplanted land

On all forestry estates considerable areas of land are left unplanted. These include areas of poor soil, steep slopes, roads and verges, riparian zones, and wetlands. In the North-Eastern Cape such areas account for an average 40% of each forestry estate.

North East Cape Forests also owns a number of undeveloped farms, many of which are no longer considered suitable for forestry and will not be planted. Natural veld, throughout the North-Eastern Cape region, has historically been subjected to regular burning, either on an annual or biennial cycle. This remains the standard practice on all grazing land in the district.

In order to maintain the grassland, which has evolved as a stable vegetation type under a regular fire regime, it is necessary that North East Cape Forests regularly burn all those areas which have not been converted to trees. This can be a risky and complex procedure particularly in situations where the forest estate is dissected by a number of riparian zones, and is one of the arguments favouring the implementation of a zoning policy which would result in some consolidation.

Failure to maintain the grassland by means of regular burning has a number of implications. The grasses will senesce, fire hazard will increase, and a slow influx of woody plant species can be expected, particularly within the riparian zones. Although the hydrological implications of such a change have not been accounted for, the expected increase in biomass could impact negatively on water supply (Bosch & Hewlett 1982). But it is the ecological implications which are of most immediate importance.

It is the stated policy of North East Cape Forests that all unplanted areas of the forestry estate will be burnt. But in the case of many riparian zones and other small conservation areas it already appears that this is proving difficult to implement in practice. Given that the implementation of this policy has more immediate ecological consequences, as opposed to hydrological, an ecologically suitable solution must be found for the dilemma.

Neighbouring farmers have also expressed growing tension with regard to the burning of their own lands for grazing. The risk of fire spreading to plantations is ever present and greatly increases the landowners responsibility. Any error could result in damages which could drive the farmer off his land. A speculative consequence of this tension is that stock farming could become untenable in some areas, that burning regimes alter or desist completely, and that large scale vegetation change results. Land management policy must therefore not only drive behaviour on the forest estate but must encourage ecologically and hydrologically acceptable practices on neighbouring lands.

Given the added importance of ecological management, responsibilities should be clarified and systems put in place to ensure that all natural grassveld can be regularly maintained through fire both on and off the forest estates.

Recommendations

- **Areas of unplanted grassland, both on and off the forest estate, must be managed by fire wherever appropriate.**
- **Consolidation under a zoning policy may be essential in order to achieve a practical fire management policy and maintenance programme.**
- **Land management policy must not only drive behaviour on the forest estate but must encourage ecologically and hydrologically acceptable practices on neighbouring lands.**
- **Given the importance of ecological management, responsibilities should be clarified and systems put in place to ensure that all natural grassveld can be regularly maintained through fire both on and off the forest estates.**

5.6.6 Rehabilitation of degraded land

Severely degraded lands lose the hydrological functions of infiltration, water storage and slow release to streams. Rainfall is channelled by rills and gullies to dongas, and out of the catchment and thus serves as a liability rather than an asset. Forestry is often seen as a way of restoring that hydrological functionality, despite the recognized water requirements of trees.

Very little of the North-East Cape region currently targeted for forestry classifies as severely degraded. Although overgrazing and poor grass cover is a common feature, with the probable result of increased siltation of streams, catchment function is generally intact. It is nevertheless probable that severely degraded lands within the region will see some afforestation, particularly as community initiatives are incorporated into the development.

What role can forests really play on degraded lands?
There is no South African hydrological data demonstrating the impacts of catchment degradation on hydrological function, nor any scientific evidence to prove the potential role of forestry in re-establishing the *status quo*. This is an important gap in the national research base which requires urgent attention.

Using local and international experience it is however possible to express our understanding of commercial forestry on severely degraded land.

- In the first instance it is unlikely that commercial forestry will actually *rehabilitate* such landscapes. What trees will do is to halt the degradation process and the further loss of soil, both directly (through improving infiltration) and indirectly (through reduction in grazing pressure). This should lead to some recovery of catchment hydrological function, although clearly there will be a cost associated with the water used by the growing trees.

- The scenario is therefore one of severely degraded land now productively occupied by trees, with some recovery of hydrological function and a better regulated flow but, most probably, with less total runoff. The underlying surface will be little changed, at least in the short to medium term, but perhaps this is not of concern as the land, while not rehabilitated, has returned from waste to production.

- Species selection is essential to this process, with pines favoured over eucalypts for soil protection properties.

- The revegetation of deep dongas, riparian zones and even wetlands may often be a requisite if further degradation is to be halted. Commercial forest species, whilst suitable in some instances, may prove destructive in others. These 'conservation' areas will require special attention, and prospects for mixed species forestry and special introductions of soil binding grasses and shrubs should be considered.

Recommendations

- **Revegetation, with forest trees or other species must be considered as a remedy where land is degraded. These 'conservation' areas require special attention, and prospects for mixed species forestry and special introductions of soil binding grasses and shrubs should be considered.**
- **Forestry will not necessarily totally rehabilitate degraded land - but afforestation can still be a productive land use, by for example, being used in restoring a degree of hydrological function. Species selection is very important, with pines better suited for this than eucalypts.**
- **The role which trees can play in rehabilitating degraded land is not understood. Research is required - particularly into the hydrological implications.**

5.6.7 Road construction

In the North-Eastern Cape a very intensive network of new roads has been constructed to access new areas of activity. This includes 1 100 km of forestry roads, approximately 20 % (220 km) of which are main roads, gravelled with a 5 m driving surface. The balance of the network (880 km) comprises 4 m wide graded tracks. Mondi Forests including NECF are currently designing a detailed data base of all their forestry estate roads. This includes information on slope, gradient, cutting depths and soil types.

Roads are the one indelible and permanent scar on the landscape resulting from forestry activity. In forestry practice 90 % of all sedimentation off forest lands is attributed to forest roads. Roads have other, but relatively minor impacts on the catchment hydrology, primarily through the routing of runoff.

Recommendations

In the light of the permanence of roads, and the costs to water quality, every effort should be given to:

(i) Minimizing the network
(ii) Providing very regular drainage, where possible into natural filters
(iii) Revegetation of verges and embankments
(iv) Grassing of roadways
(v) The need for road planning in afforestation permits

5.6.8 Species selection

North East Cape Forests have taken the policy decision to plant only softwoods with the current species mix dominated by *Pinus patula (61.0 %), P. greggii (16.6 %),* and *P. elliottii (13.0 %).* Over one thousand hectares of eucalypts were established on commencement of the North East Cape Forests project but these have either already been removed (with 926 ha still standing), or will not be replanted on the next rotation.

The policy to plant only softwoods is critical in that any secondary processing will be limited exclusively to softwood species, and this will determine the nature of all future afforestation by both North East Cape Forests and by local small growers and communities.

Hydrologically the choice of species, or at least of genus, is also very important in terms of water use, erosion (either as a cause or a solution), and the risk of invasion.

Species and Water Use

In South Africa where trees are fast growing (most notably the eucalypts) and grown on a very short rotation (the eucalypts) or somewhat longer rotation (the pines), the eucalypts are perceived as the most voracious water users. Evidence from catchment research (van Lill *et al.* 1980, Dye 1996) does show that eucalypts are very quick (eg. two years) to have an influence on the water resource, whilst pines may take several years (5 - 10) to have an equivalent impact. Research on water use by individual *E. grandis* trees of different age classes goes so far as to suggest that water use may maximize between ages 3 and 6 years, and decline as the trees mature, along with a decline in leaf area (Olbrich 1994).

But modelling this water consumption over a series of rotations, where eucalypts might be felled every 10 years and pines every 20 years, shows that there may be little difference in total water use by these two genera. This could mean that pines, over the long term, are not necessarily more conservative of water than eucalypts. As a counter to this North East Cape Forests are growing pines on a relatively short rotation (16 -17 years) and this could bring some of the benefits of both worlds. A better knowledge of evapotranspiration trends for different management scenarios is needed in order to substantiate this hypothesis.

Where specie's water use could also differ is where trees are planted on very deep soils. Eucalypts have an exceptional capacity to exploit deep soil profiles (Dye 1996) and on these sites may have the edge over pines in terms of total water use. Pines would therefore be preferable trees to plant. On shallow sites both eucalypts and pines are equally efficient at exploiting the available soil volume.

Recommendations

▸ **Pines planted on a short rotation offers the most favourable forestry practice in terms of catchment hydrology**

Species selection and erosion

There is too little hard evidence on the comparative roles which different commercial timber species might play in **destabilizing** previously well vegetated landscapes (eg. through afforestation of grassland) or in **stabilizing** badly degraded lands. Pines are generally seen as offering a more stable option than eucalypts due to longer rotations, less aggressive competition with the natural vegetation, and often a dense litter mat.

Recommendations

▸ **Pines are preferred to eucalypts. Special species may be required in situations requiring rehabilitation.**

Species and invasion

With regard to invasiveness, pine species may well pose more of a risk than most of the eucalypts. *Pinus patula*, a favoured species in the region, has a very light, winged seed which can be wind dispersed over many kilometres (Bainbridge 1976). This particular species has shown itself capable of spreading widely in the Southern Drakensberg and in particular between 120 m and 2 500 m altitude. (Bainbridge *loc. cit.*). The invasiveness of *P. greggii* has not been ascertained, but the species is very similar to *P. patula* and has seed with similar characteristics.

The advantage of pines over eucalypts is that they are relatively easy to clear from an area unless the terrain is very steep and rugged. Clearly defined responsibilities for all invasives emanating from forestry lands, careful monitoring of the catchment areas, and strict preventative measures, such as planting new 'bio-tech' lines that produce no cones, and control procedures are essential in managing the risk (see also section 5.5.4).

Recommendations

- **The invasiveness of *Pinus greggii* must be assessed.**
- **Strict preventative and control procedures are necessary in managing the risk. This may include a *cordon sanitaire.***
- **Plant as far as possible only species which do not have recognised invasive characteristics.**
- **Trees which fail to produce cones are being developed through bio-technology. This research should be encouraged and suitable material sought out for use, particularly in sensitive areas.**

5.6.9 Silviculture

Forest management

Thinning and pruning of trees can be expected to offer some small returns in terms of water yield, but tree canopies are fast to respond through additional growth and any gains are not only hard to quantify but also short-lived (Versfeld and Bosch1982).

Age class distribution

The results of this study have demonstrated very clearly that any forestry development should aim towards the establishment of a 'normal forest' within any catchment - and particularly where forestry is a dominant land cover within that catchment.

A 'normal forest' is defined as a forest with a normal distribution of age classes, ie. with an equivalent area under trees within each age class between planting and clearfelling. The hydrological argument favouring a normal forest distribution is that a plantation will use most water at maturity, and least after clearfelling. If a catchment is fully planted within the same season then the water demand of all the trees will maximize simultaneously. In a normal plantation the water demand is spread over the full rotation. This has been demonstrated in section 4.2.6. If the extent of afforestation is limited by the maximum permissible impact upon the catchment, sub-catchment, or even parcel of land, then planning on the basis of a normalised forest could mean the planting of up to 56 % more land than would be acceptable were the planting all of a single age class (Chapman, this study). The normalizing of any forest unit will also reduce impacts on erosion, and will maximize the benefits of the forest as a flood control measure.

The principles of normalizing are probably most important at the level of the quaternary catchment and smaller, simply because single plantings at a larger scale are rarely practicable. At the level of the primary catchment development is likely to be more random of nature and the impacts therefore likely to evened out. But even at this scale the principles will apply.

In the North-Eastern Cape, as in any new development, large areas of plantation were established at the same time and are therefore even-aged. This has been an artifact both of the commercial need for rapid development, but also of the restriction within the Afforestation Permit System (APS) that all approved afforestation must be implemented within three years of the issue of the permit. This provision was introduced to pre-empt land speculation with forestry but has had unintended consequence. The grower is therefore obliged to establish what will in effect be a single aged stand - although this has negative impacts on the sustained yield of the water resource.

Recommendations

- **In rectifying the situation of large single aged stands in the North-Eastern Cape it is recommended that management should strive, through staggered clearfelling towards the creation of a normal forest distribution within each quaternary catchment, and that age class distribution should be a consideration at all levels of catchment planning where supply might be critical to downstream users.**
- **The Afforestation Permit System should also see revision to allow planning for the establishment of plantation over the full rotation of the species.**

Rotation length

Rotation length refers to the standing time of trees from planting to clearfelling. Rotation length is a function of the intended end use of the product - for saw-timber at 25 - 35 years or pulp at perhaps 15 - 20 years. In the North-Eastern Cape the chosen and expected clearfelling age is 16 and 18 years. This is therefore a relatively short rotation. Although the connotations with regard to timber extraction, use of roads and resultant erosion are negative there are real potential benefits in terms of water yield. Short rotation forestry is therefore to be encouraged - provided the necessary erosion control measures are in place.

Recommendation

- **Short rotation forestry with pine species will deliver more water. Hydrological and timber yield outputs should be optimised.**

5.6.10 Site preparation

Site preparation has as its objectives the improvement of survival and growth of young trees through the suppression of weeds, and also improved access to available water. This is achieved either by increasing the permeability of the soil for root penetration or by improving the availability of moisture in the soil through decreasing competition, reducing runoff, and increasing infiltration.

In the North-Eastern Cape the most prevalent site preparation method has been deep contour ripping, with simple pit planting on the steeper slopes. Deep contour ripping is aimed at maximizing both root colonisation and the availability of rainwater to trees. This can be expected to reduce water available to the streams, although a visible impact on the hydrology is only likely where overland flow was previously a feature. Overland flow is not common on high rainfall grasslands of reasonable quality and would have been limited to poor and degraded sites.

Deep ripping to a depth of 1 metre, together with ridging, has been practised on some 20 000 hectares of land in preparation for afforestation. All ripping and ridging has been strictly on the contour. Concerns regarding this site preparation practice related both to the possible impacts on water quality through increased erosion and to the expected negative hydrological impacts. At the catchment scale no negative impacts on water quality have been detected although this could be a consequence of other positive benefits arising from afforestation (eg. withdrawal of cattle) counteracting negative impacts from ripping. In practice the riplines are well contoured, were found to regrass very quickly, and may even have improved water quality through encouraging infiltration and limiting overland flow, especially on poor and degraded sites.

The hydrological impacts of intensive site preparation have not been quantified. Where infiltration has been improved the increases in soil moisture will be available to both the natural grasses and the trees. Even though tree growth and survival may be better it is unlikely that these small trees will be using significantly more water even if growing significantly faster. But faster early growth of the plantation could result in trees maturing, and start using measurable volumes, more quickly. There is a growing body of evidence suggesting a positive correlation between volume increment and water use (Le Maitre and Versfeld *in press*, Dye 1996). If silvicultural improvements are attained then this will affect the hydrology, but the increase in water use is compensated for by improved timber yield - possibly at a greater level of efficiency.

Observations in the forestry regions of KwaZulu-Natal show that the significant growth benefits sometimes attained through intensive site preparation in the early stages of the growth cycle are generally not sustained. Intensive site preparation therefore offers a "once off" benefit of rapid growth in the first stages of the first rotation. Trees on less prepared sites will usually catch up quite quickly in terms of growth rate although they will not gain the additional volume initially accumulated by these trees on well prepared sites. Hydrologically the fast early growth observed on fully prepared sites may be a result of decreased competition, improved infiltration and channelling of water to the root system, or improved access to available moisture through increased root access to the available soil volume.

In the North-Eastern Cape the observed natural recovery of grass on the rip lines was very rapid and there was very little evidence of direct overland flow. Any improved growth can therefore most probably be ascribed to improvements in the permeability of the soil profile. In practice (Droomer 1996, pers. comm.) no production benefits can be ascribed to deep ripping and it is unlikely that this practice will be continued.

Should there be significant improvements to growth through intensive site preparation then the expected impact on the water resource would need to be catered for in the hydrological model accounting. In the CSIR flow reduction model this would be introduced through a shortening of the rotation and/or through an increase in the site quality (eg. from sub-optimal to optimal). Should there be positive impacts resulting from site preparation then these will automatically be assimilated into water use calculations.

On some sites elsewhere in the country first rotation benefits of intensive site preparation have been reported, but these do not seem to be repeated in the second rotation and this phenomenon is therefore of no importance in long term water use accounting.

On badly degraded sites, where overland flow is a recognised feature of the hydrological cycle, the influence of site preparation in improving infiltration and channelling water to the tree roots is likely to be far more important - both to survival and growth and to water yield from the catchment, with a slightly reduced but better regulated flow of a higher quality expected. Badly degraded sites are not a feature in the catchments under study but this may become an important factor should forestry development take place in certain parts of former Transkei.

Recommendations

- **Site preparation (deep ripping) in the North-Eastern Cape should be planned on silvicultural, and not hydrological considerations.**
- **The impacts and benefits of deep ripping as a site preparation practice on degraded lands requires research and evaluation.**

5.6.11 Afforestation and the conservation of biodiversity

Afforestation of natural grasslands with monospecific stands of trees reduces biodiversity by replacing the species-rich flora and their associated faunal communities. While afforestation can even favour certain species, the negative impacts are usually associated with the rare and endemic species that are important from a conservation perspective (Allen *et al.* 1996; Armstrong and & Hensbergen in press). Certain principles should be taken into account when afforestation is planned so as to minimise the impacts on biodiversity. These include:

(I) The avoidance of certain areas that have high rankings in terms of conservation value (see, for example, Armstrong & van Hensbergen in press);

(ii) Adherence to the principles of island biogeography (for example grouping afforestation and leaving larger areas unplanted, and leaving corridors between unplanted areas);

(iii) Ensuring that an adequate inventory of biodiversity is carried out to support any ranking exercise; and

(iv) Adopting management practices that will minimise the impacts of afforestation on biodiversity (for example regular burning of unplanted areas).

Recommendation

- **Take account of key principles aimed at minimising the impact of land use change on diversification**

5.6.12 Monitoring

Streamflow

No arrangements have yet been made with regard to responsibilities for monitoring the impacts of forestry on streamflow within the North-Eastern Cape. Indeed no agricultural land user carries this responsibility anywhere in South Africa. The Department of Water Affairs and Forestry, through its Eastern Cape Regional office, has indicated that the macro hydrological monitoring network in place is sufficient for its purposes (See Figure 3.2). This will indicate how much water is available but will not provide any scientific measure of upstream impacts of forestry.

Hydrological models, from which estimates can be made of the expected impacts of afforestation, provide an alternative approach. These include the *ACRU* model (Schulze 1995), considered most accurate at the scale of farm or small catchment, and the CSIR flow reduction models (Smith & Scott 1992, Scott % Smith 1996) - best applied at the level of the quaternary catchment. But all models require a degree of verification and the closer this can be to the site of application the better.

North East Cape Forests has been encouraged, but not compelled, to monitor streams in the district with the intention of assessing afforestation impacts. The difficulties in this process are as follows:

(a) If the catchments are small then the layout and results will be of an experimental nature. North East Cape Forests may not see any responsibility for, or benefit, from hydrological research - in the past considered to be a national concern.

(b) Larger catchments require large weirs. Given the fragmented nature of the afforestation development, and the limited area afforested within any single large catchment, the scientific pairing of afforested catchment and unplanted control in the expectation of seeing (or **not** seeing) any significant impact may prove difficult. Costs are also very high and the issue is held by the developers to be one of national responsibility. Nevertheless it may be strictly to NECF's advantage to provide the monitoring stations by means of which the impact (or lack of impact) of its activities can be observed.

Recommendations

- **The DWAF network of monitoring stations appears adequate for regional needs at the present time.**
- **NECF should consider at least one monitoring station (the Mooi river is suggested) in order to demonstrate the impact (or lack thereof) of forestry activities at this scale.**
- **A multiple catchment experiment to study the hydrological impacts of 'new generation' forestry would be very valuable. Should research catchments be established then any process or other research should endeavour to be within these catchments. Initial siting and layout of any research catchment should take this into consideration.**
- **The responsibility of all South African forestry (and other) land users with regard to the monitoring of hydrological impacts must be considered - especially in the light of declining national inputs into hydrological research and the increasing demands of downstream users.**

Climate

Hydrological modelling is very dependent on good climate data, and particularly on patterns of rainfall. Climate monitoring becomes especially critical in the absence of a stream gauging network if estimates of afforestation impacts are to be made.

One question constantly arising is whether forestry does indeed have a climate feedback loop, and particularly with rainfall. While this is highly improbable within the Southern African context, given the extent of our commercial forests and the fact that most rainfall seems to be generated over the Indian Ocean, the question persists and encourages the maintenance of an accurate climate record.

More pertinent perhaps is the question of data. Clearly any in-house network will provide data which is the property of NECF. Clearly too, this data can serve the national interest and the holders of such data are urged to ensure that it is entered into the national network.

Recommendations

- **A long term record on a range of sites should be established. Rainfall is the most important variable.**
- **Data should be housed with the Computing Centre for Water Research and made available to national researchers.**

Water Quality

The primary water quality issues faced by afforestation programmes are those of sedimentation resulting from site preparation, road construction, harvesting, acidification where catchments are planted to pines, and contamination as a consequence either of the application of fertilizers or use of herbicides or pesticides.

A biological water quality monitoring baseline has been established in the North-Eastern Cape using the SASS2 and SASS4 techniques on 14 monitoring stations. If repeated at suitable intervals this will provide an indicator of any significant degrade or improvement in the aquatic environment, but will not necessarily identify the cause or source.

The forestry industry has an interest in demonstrating overall benefits of afforestation on the environment as it affects water quality, which biological monitoring is certainly in a position to do, but should also be able to detect both short and long term negative impacts. The methodology is less suited to the assessment of short term impacts, and this limitation should be recognized.

Recommendations

- **The network should be expanded before any major new areas are afforested.**
- **Monitoring should be event driven.**
- **All SASS limnological records data should be entered into the national data base currently being established by DWAF.**

Monitoring within degraded catchments
Too little is known about the hydrology of degraded catchments, and consequently also about how afforestation may impact on such catchments. It is hypothesized that streamflow will show better regulation (although total flow may be reduced) and that water quality (sedimentation) should improved.

Recommendations

- ▸ **The intensive monitoring of the hydrological impacts of afforestation on degraded land through an experimental catchment approach is unreservedly recommended, perhaps as a coordinated venture between the forest industry and the South African hydrological research community.**

5.7 LESSONS FOR NATIONAL POLICY

An ecologically and hydrologically sound framework is required to guide future action. This study has, to some extent been overtaken by events, with the preparation of a new Green Paper on forestry policy (DWAF 1995), with a White Paper in the making, and with the advances in the revision of the Water Act of 1956. On the other hand it could not have been more timeous, and there is little doubt that the North-Eastern Cape has provided a test bed for much of the new thinking being developed within these major policy papers. The approaches which are developing within the region will continue to serve this purpose.

Managing for hydrological efficiency
Hydrological efficiency can be achieved through management consideration of the following aspects:

Site selection, avoidance of riparian zones and hydrologically sensitive areas, species selection, appropriate site preparation, clearing and control of invasives and spread, plantation management, silviculture, rotation, and natural veld management.

The most important new aspect raised by this study is the question of cumulative planting and how impacts can be reduced, or at least spread over the duration of te rotation, through the normalization of age classes. The afforestation permit system will require revision in order to facilitate forestry development over longer time frames.

Environmental planning and control is easier to achieve through large company structures than through small growers. Aggregated planning for the multitude of small growers expected to enter the market may devolve as a state responsibility.

Who gets the benefit?

Many of the management guidelines above reflect on the nature of water use by forestry and how, despite the need to optimize production, steps can be taken to optimize afforestation, growth and water use. The incentives, however, are directly linked to the benefits incurred by the forest manager. It has been suggested , for example, that the clearing of riparian zones incurs significant cost and offers large benefits, but that these are enjoyed downstream.

With stringent allocations of water restricting the expansion of the industry, and with the advent of tradable water rights, computations of the exact volume of water consumed by forestry must be taken into account. So too must the savings accrued through careful management and conservation forestry, with suitable allowances made.

Monitoring

A review is required of information needs and of national water monitoring policy at the scale of land use impact. In terms of forestry impacts the following issues should receive priority attention in policy development: water yield and especially low flows; the function of vleis, wetlands, and rivers; water quality.

Exercising hydrological control

An integrated approach is required and must be encouraged. A number of policy tools are now available: SEA (Strategic Environmental Assessment), ICM (Integrated Catchment Management), IEM (Integrated Environmental Management, and finally EIA (Environmental Impact Assessment).

Recommendations

- **Policy must create opportunity and support investment in forestry, within context of national economy, but not to the detriment of other sectors including the environment.**
- **Water demands by forestry must be more accurately computed (further research is required).**
- **Positive incentives (for example for the clearing of riparian zones), should be introduced.**
- **An integrated approach to planning and management is required and must be encouraged and facilitated at all levels. At the highest level any forestry development should start with a Strategic Environmental Assessment.**

6. DISCUSSION

This project to survey resources and assess the impacts of land use change in the North-Eastern Cape, with particular reference to the hydrological implications of afforestation, was commissioned in 1993. The North-Eastern Cape had been identified as biophysically suited to afforestation in Strategic Forestry Development Plans of 1982 and 1989 (Directorate of National Forestry Planning 1989), and by implication encouraged as a strategically suitable land use. By 1991 North East Cape Forests had been established, large tracts of land purchased, and afforestation begun. Two issues arise:

Attempts to establish a true baseline have been confounded by the fact that development was already well under way at the start of the study. This has meant that much of the emphasis has in fact been on the nature of the forestry operation, on direct observation of impacts, and on consideration of issues arising out of land use change and the concomitant development concerns. The study has however also made use of 1989 Landsat imagery in order to establish a true pre-afforestation land cover baseline.

Afforestation in the North-Eastern Cape constitutes a very large investment (R 500 m to R 1 bn *before processing) and is running ahead of the observational process thereby requiring* that research be fast-tracked. There are two sides to this. Progress with afforestation cannot be held to be dependent on research results but, at the same time, the forestry programme has been able to provide, and continues to do so, a test bed for forestry development thinking.

The North-Eastern Cape development has also straddled the time of major political change in South Africa. In addition to the complete political turn-around and about face in social priorities, attitudes with regard to the environment and the sharing of natural resources are also maturing. Water, and particularly water for communities, has taken on a new ecological and social significance resulting in ministerially directed changes to the implementation of legislation, with tighter controls on forestry growth, and the feeling by the industry that the 'goalposts have been shifted'. At the same time the need for economic growth has become ever more pressing. Forestry development in the North-Eastern Cape may therefore be seen as the victim of changing circumstance. But, inadvertently and perhaps unconsciously, it has also served as an important source of guidance and inspiration in the redrafting of the Forest Act of 1972, and the Water Act of 1956 - both activities which are still in progress. The pivotal position occupied by North East Cape Forests, and by this research project in analysing the process and its implications, has therefore been a very important one.

6.1 WHO OWNS THE WATER?

The Eastern Cape, and particularly the North-Eastern Cape, is a relatively water rich part of South Africa. As such it has been singled out as well suited to forestry development - both because trees will grow well and because the impact of forestry on the water resource is less likely to be felt. But this wealth has also resulted in the conceptualizing of ambitious inter-basin transfer schemes - pertinent being the idea of damming the Umzimvubu and feeding this water to Gauteng via the Lesotho Highlands Scheme. This remains a conceptual plan, and Department of Water Affairs and Forestry officials have indicated that it is unlikely to see serious consideration before 2020 or 2025. Nevertheless one must question whether development in the Eastern Cape should in any way be curtailed in the event of a putative future scheme to export the water to another part of the country. 2025 is, after all, only a second rotation away in forestry terms. From the results of this study it would seem, however, that forestry will have a minimal impact at the level of the primary catchment.

What is most important is that these issues should be understood and debated, and that there should be no hidden agendas. This is one purpose of the Strategic Environmental Assessment Approach proposed for the region (cf section 6.9) is to ensure a participative public debate on potentially crucial issues.

6.2 HYDROLOGICAL IMPACTS OF FORESTRY

6.2.1 Water yield

Water has always been assumed to be the major issue determining the acceptability of forestry or otherwise. With decision making regarding the allocation of land for forestry historically driven by the economic needs of industrial and irrigation development, hydrological impacts have been the primary focus of this study.

The North-Eastern Cape is well watered - and this abundance was recognised in the initial strategic planning recommending the area for forestry. Demands upon the resource are relatively few, and local agricultural needs have further diminished as land has converted to trees. The scale at which hydrological need and demand is considered becomes critical. In South Africa decisions with regard to the planting of trees have been weighed according the Afforestation Permit System (APS) as introduced in 1984. This was a decision system based upon the needs of the primary catchment which allowed for fixed but limited maximum reductions to catchment yield, depending on the perceived importance of the catchment to downstream users (primarily urban, industrial and irrigation). In 'category 1' catchments no further forestry development was permitted, whilst in category 2 and 3 catchments total flow reductions of 5 - 10% of pre-1972 levels were deemed acceptable. The disadvantages of this system were its inflexibility, and particularly its inability to consider the needs of immediate neighbours and downstream users. Decision making was at the macro scale. The advantage of the system was the level of certainty it provided. With the revisions instituted by the minister of the Department of Water Affairs and Forestry, Professor Kader Asmal in January 1995, the situation has changed radically. New regulations require that any new forestry development be advertised and neighbouring land owners advised, and in the event of reasonable objections being lodged, that an Environmental Impact Assessment (EIA) should be completed for each individual land title for which forestry was planned. Now the neighbour and the downstream user are considered - but the cumulative effects within a catchment are no longer part of the decision making equation. From macro scale decision making South Africa had moved directly to micro scale decisions without an apparent strategy to consider cumulative or whole catchment impacts. The certainty imposed by fixed limits was also abandoned.

It was in this context that we considered the use of water by forest trees at the scale of the quaternary, tertiary, secondary and primary catchments - although not at the farm scale which provides the current level of decision making. It is very apparent (Section 4.2) that water use at the scale of the quaternary catchment can be significant, with a peak impacts of 10 %, and even 18 % for planned afforestation in two catchments should age class distribution not see normalization. Whether this is important will depend on the number and demands of downstream users, and also whether these are likely to increase. There has been little or no irrigation demand on most of these catchments but even where demands are significant questions of optimal use of resources and an equitable sharing of these resources arise (Versfeld 1996).

At the scale of the tertiary catchment the peak impact of current forestry reduces to 3 % of Mean Annual Runoff, and to 5 % should all potential land be planted. At the secondary catchment level the impact would not in fact be measurable (estimated at 1 %), and even less so if one were considering only the flow of the primary Umzimvubu catchment. 50 000 ha or even 100 000 ha of forestry is simply not significant at this scale. At the farm or neighbourhood scale, however, forestry can really matter. One should also not negate the possible importance of the impact at the large catchment scale just because it cannot be measured at a level of significance. All impacts are cumulative, forestry may grow by several hundred percent, and even a small impact *could* be critical.

Water use demands can also change, and this change may be brought about by the very forestry development initially constrained because of the need to protect the resource. These issues have not been considered in this analysis, but the towns of Ugie, Maclear and Elliot have all grown four-fold in recent years. The establishment of a successful timber growing industry must perforce be followed by secondary processing and, particularly should this be a pulp mill, the demands on water will grow.

6.3 MANAGING FORESTS FOR WATER

6.3.1 Conservative or 'new generation' afforestation

Concerns for the water resource have led to a slow evolution of conservative forestry management practices in South Africa. The most visible and important of these has been legislation to protect stream zones, 'sponges' and wetlands. The forestry industry has taken up the challenge and a 'new' style of forestry has developed. This is very evident in the North-Eastern Cape where 40 - 50 % of land holdings often goes unplanted, although critics might argue that this has largely been forced upon the forestry industry by the inhospitable terrain. But stringent internal environmental audit procedures have evolved. International environmental standards for forestry have also contributed. The benefits to both the environment and to the hydrology are significant - riparian zones are generally far wider than legislated, buffers are generous, indigenous forest patches and areas of interest are protected, steep slopes are avoided and a relatively open forest environment has been established. Hydrological benefits are at present determined by recognising the extent of unplanted land and offering a special weighting to the protection of riparian zones. But this has been a subtractive approach - based upon the argument that research catchments were managed under 'old style' forestry and that 'new style' forestry will have fewer impacts because of the hydrological value of now protected riparian zones and source areas (although no special value is, as yet, given to upslope source areas). In fact very little is known about the importance, in terms of both water generation, of the selective protection of parts of the catchment - and the overall differences between 'new style' and 'old style' forestry could do with some conclusive measurement.

The industry does now argue that 'new generation' forestry is both hydrologically and biologically 'sound' and has very little impact on the environment because it avoids the most sensitive areas. That it has less impact than 'old generation' forestry is a certainty - but how much less is something to be determined.

6.3.2 Normalizing forest stands

One of the axioms of classical forest management is the importance of establishing a 'normal' forest, ie. a forest plantation comprising an even distribution of age classes. This arose from the obvious benefits of annually distributed demands on silviculture and harvesting, and the benefits of a distributed income. This study in the North-Eastern Cape has also made clear the benefits of distributed water use.

In any 'first time' development the primary need is to maximise the afforested area as quickly as possible for maximum early return. Concerns with regard to normalization come later. The Afforestation Permit System has also inadvertently forced short-term maximum afforestation of permitted areas by setting a very tight time limit (3 years) before the expiry of the permit although an extension to this limit may be granted. The consequences are large even aged stands maturing simultaneously, with an unnecessary peak demand on the water resources of the system as trees reach maturity. There are a number of implications. Water yield from a catchment will be far more variable under even aged stands over the rotation than they would be if stands were normalized. If the maximum afforested area is to be determined by the maximum water demand estimated for the stand then clearly an even aged stand would have to be far smaller than a normalized stand if water use is to be at an acceptable level - given the peak demand in the critical year when the stand reaches maturity. Normalizing the catchment 'spreads the load', reduces the peak demand, and could allow for an increase in the permissible afforested area. Simulations on quaternary catchment T35F indicate that an additional 50 % afforestation under a normalised regime would have the same peak impact (see also section 4.2).

Other models for forestry development (for example the ACRU model) consider an idealised stand - or a stand with some arbitrary mean age. Clearly age distribution is an issue which must be given careful consideration when determining the acceptability of planned afforestation areas - and the management regime may in some instances become a necessary part of permit conditions. In practice the larger the scale of a forestry operation, or conglomerate of operations, the more likely that a relatively normal forest will evolve (for example when considering the entire Umzimvubu catchment). The smaller the scale the more care management may need to take in order to mitigate hydrological impact.

It is now being recognised that the Afforestation Permit System should not penalize properly planning forestry and should also take into account the implications of imposing a three year validity threshold. This restriction was designed to limit land speculation but, as can be seen, can have serious inadvertent implications. Flexibility needs to be introduced into the permit lifespan - to account for the possible need to distribute hydrological demand.

6.3.3 Modelling forest water use

This study has adopted the CSIR flow reduction approach (Smith and Scott 1992; Scott and Le Maitre 1993) to modelling the hydrological impact of the North-Eastern Cape forest development. The primary strength of the approach has been through the consideration of the actual distribution of the trees across the landscape, and how this changes with time. This has allowed insights into these aspects of management.

The modelling approaches available to South African forest hydrologists and environmental impact assessors include the use of the Nanni / van der Zel curves, the CSIR flow reduction curves, and the ACRU model. In an EIA the conservative approach would be to run more than one of these models for the site and then to work on the basis of the worst scenario output.

In practice the use of any one single model leads to a constricted outlook on the nature of the forestry process. So, for example, a very complex process model may lose sight of the importance of real time spatial and age class distribution issues. On the other hand it must be accepted that the use of broad empirical curves cannot satisfactorily handle the variability introduced by site, site quality, site preparation and management practice.

6.4 LAND COVER CHANGE

From the GIS land and forestry cover data for the 10 quaternary catchments in the North-Eastern Cape the total area currently afforested is 29872 ha. The total compartment area intersected with the land cover is 53778 ha. This means that 55 % of the estate area is actually planted giving credence to NECF claims that 40 - 50 % of most farms goes unplanted.

Of the 53 778 ha of 'intersected' land, 9 % comprised commercial farmland in 1989, degraded grasslands 7.3 % and 'healthy' grasslands 75 %. Most of the 'commercial farmland' was used in dryland cropping. Land cover breakdown by quaternary catchment is presented in tables 3.8 and 3.9. These figures indicate some of the wealth of information now available on the GIS database.

6.5 CONSERVATION MANAGEMENT

Some 40 - 50 % of the surface area of most farms purchased by NECF for forestry will not be afforested (see also tables 3.8, 3.10 & 3.11). Much of this is riparian zone, but unplanted areas include steep slopes, shallow soils, rocky sites, and areas of special conservation value in addition there are a number of large holdings, particularly in the upper catchments of the Mooi and the Pot rivers, which are not planned for afforestation (for example the 'Mooi River Head Farms). The hydrological benefits of retaining this land unplanted will depend strictly upon its management. Will the land be grazed and, if so, then will this be conservative? Will alien invasives be controlled, and even cleared off the lands? And will the grassland areas between belts of plantation, and particularly the riparian zones, be maintained regularly through fire?

6.6 WATER QUALITY

A limnological monitoring baseline has been put in place with the objective of determining the current condition of the rivers flowing through the North-Eastern Cape forestry focus area, and providing a base from which changes can be monitored. Degradation of the river systems is likely to be a result of, *inter alia,* erosion and siltation, leaching of fertilizers, uptake and transmission of herbicides and/or pesticides, riverbank invasion by alien trees and consequent shading and bank erosion, and acidification. Forestry was expected to present major risks to erosion through site preparation, road construction, and harvesting operations, and perhaps to acidification through the change in land use from agricultural crops and grazing to pine species. In practice site preparation could not be observed to contribute to erosion and, although the same cannot be said of roads, these are expected to stabilise. Roads are recognised as the primary source of erosion from forest plantations worldwide and NECF will do well to take care in minimizing road area and investing in design, stabilization and maintenance. (Roads are also found to be primary sites for invasion throughout the North-Eastern Cape forestry region). Harvesting could have negative impacts but this is infrequent (every 16 - 18 years), and plantations designed for water conservation have resulted in wide buffer strips which will probably serve as effective filters. Such catchment forests are designed to comprise stands of mixed ages the impact of harvesting will also be reduced. The role of wetlands as filters is also a significant feature.

The baseline survey has found a rich biological flora, indicative of relative stream health. It is interesting that in 1993 unsourced rumours were rife that the chemical programme exercised by North East Cape Forests had 'killed off' the rivers. Certainly the biological data refutes this.

The limnological baseline is not especially sensitive and has the failing of indicating only trends and not the reasons for such trends. But it does offer a firm starting point, integrates impacts over time, is easily repeatable, and could be managed as an in-house monitoring process by NECF. Prospects for water quality as a consequence of forestry development are in fact mixed: the removal of alien riverine vegetation should be very positive in the long term (with perhaps some short term increases in bank erosion until grass re-establishes); the withdrawal of large areas from grazing should undoubtedly have positive benefits. But trees will reduce flow - resulting in some higher chemical concentrations in the remaining runoff.

6.7 THE GAUGING OF STREAMFLOW

It had been initially hoped that this project would be able to pinpoint suitable gauging sites useful to the determination of impacts of afforestation, and that the Department of Water Affairs and Forestry would then take on the responsibility of installing a gauging network.

The questions of responsibility for such a network were quick to arise. The Department of Water Affairs and Forestry considers the downstream network adequate for regional decision making and has also its hands full managing the regional and national hydrological network NECF did not feel responsible, and nor is it either by law or by precedent. NECF is willing to maintain a monitoring network but this requires both the construction of weirs and the establishment of a data management system - for which national support would be necessary. A 1995 estimate for the cost of construction of weirs is R 10 000 per running metre of weir. Weirs built only to monitor the low flow situation could be smaller, and concomitantly cheaper than structures suited to both low flow and flood monitoring.

In addition to the cost and maintenance factor, and while five sites suitable for the construction of weirs have been identified (Figure 3.2), the intensity of forestry within individual catchments is such that it remains a moot point whether the impacts will be measurable. The only reasonable option would seem to be the installation of *research* weirs on *research* catchments which could then be managed and monitored by NECF in collaboration with a hydrological research institution. Questions of costs, responsibilities, and long term support for the programme still arise. Until such demands are legislated it will probably be necessary to rely upon the current (declining) research network and upon the output of hydrological models.

6.8 SMALL GROWER FORESTRY AND HYDROLOGY

The content of this report has been dominated by the problems and issues arising from large scale development by a single landholder, in this case NECF. There are however a number of small growers in the region, and potential for many more. A large number of permits had in fact been issued to farmers, but very few of these have been taken up and most will by now have expired. Future small grower activity is expected not only within the commercial agricultural sector but also on community owned lands. NECF have a target of some 60 000 hectares of company owned land supplemented by timber supplies from 40 000 hectares of private and community owned land.

This is going to raise many different and new hydrological issues. Cumulative impacts on water supplies will arise. So too will the question of responsibility for environmental impacts, and conservation management practices.

6.9 REGIONAL ECONOMIC DEVELOPMENT AND STRATEGIC ENVIRONMENTAL ASSESSMENT

These issues have already been debated in section 5.5.3. The forestry industry is confident in its position as a valuable and efficient user of natural resources, including water. But there are many issues to add to the decision making process. Hydrology is only one of these - and perhaps for the region not the most important. Upstream development is increasingly governed by downstream demand. It is important to note that this demand within the Umzimvubu and other major Eastern Cape catchments has only recently seen any serious quantification (eg. Amatole Basin System Analysis and Eastern Cape Situational Analysis, in progress - Ninham

Shand Consulting Engineers). But the determination of the number and size of communities, and of community needs, is now the first target of a DWAF-supported programme in terms of the White Paper on Water Supply and Sanitation. Upstream planning and downstream needs will be critical inputs in any strategic environmental assessment.

Most encouraging has been the recognition of the need for strategic decision making and an evaluation of the most appropriate land use in terms of opportunities afforded by the landscape. Through this process water, the environment, people, and regional economic development can all take their rightful place.

7. CONCLUSIONS

The North-Eastern Cape is one of the last new areas in South Africa likely to see forestry development. To date 30 000 ha of trees (almost all pine) have been planted by North East Cape Forests. Another 30 000 ha of forestry is planned on company estates, supported by perhaps 40 000 ha of small commercial and community forestry. Processing, or beneficiation, of this primary resource is also almost certain to take place within the region, although plans for such processing have not yet been released. A development of this scale is resulting in a major change to the land use and economic patterns of the region.

The objectives of this project (section 1.2.1) were to survey and map environmental resources in the North-Eastern Cape forest region; to assess the impacts of afforestation and forestry management practice on water yield, water quality, and the conservation of riparian zones; to provide guidelines for policy development, together with practical management guidelines to improve water quality and yield, and to ameliorate the impacts of afforestation on the natural environment; and finally to provide a wider overview of the impacts of the regional scale land use change through afforestation, and particularly to place this in a socio-economic context.

The approach taken in achieving these objectives has been to invest not only in the establishment of a GIS data base in support of land cover assessments and modelling exercises, but also in trying to understand the critical hydrological issues and how these could be used to advance both our modelling approach and our thinking as regards forest hydrology in South Africa. The North-Eastern Cape has provided a very exciting outdoor laboratory at a critical time when both the Forest Act and the Water Act are undergoing revision.

7.1 USING GIS

An important series of land cover and land use coverages has been captured within a GIS database. Data on land cover was derived from 1989 satellite imagery so that a true baseline of pre-afforestation land use is available for all future comparisons. From this the amount of irrigated and other ploughed land has been determined, as has the area of grassland converted or likely to be converted to forestry. The lack of irrigation demand is striking, as is the almost complete lack of artificial water bodies (dams). Yet local resistance to forestry has been strong, with arguments based on conservation value and on water requirements. The capture of baseline data within a decision support GIS allows a clearer picture of actual land use change, provides for a powerful modelling tool, and makes strategic thinking at both the local and region level a feasible reality.

7.2 WATER USE BY FOREST TREES

In this study we have determined the impact of existing and planned future forestry within ten quaternary catchments in the North-Eastern Cape. The GIS has allowed for a distributed modelling approach which could consider the importance of both spatial distribution (across rainfall zones) and the importance of age class distribution in water use. Impacts are primarily dependent on the area afforested, the rainfall class distribution over which that afforestation takes place, and upon the age class distribution of trees within catchments. The concern with age class distribution is a function of the use of peak or maximum impact of afforestation as the chief measure. Should all trees within a catchment mature in the same year then the impact will peak in that year. By distributing the age classes across the length of the rotation the peak impact on the yield may be reduced by 56 %. Depending upon the measures used this could mean that a further 56 % of afforestation may be acceptable to the decision making authority. This observation also has implications for the Afforestation Permit System, which, by imposing a three year expiry date, encourages the planting up of approved areas within a very short space of time - effectively creating a single age class situation.

In the North-Eastern Cape the peak (maximum) impacts, of all current and planned afforestation (ie. some 60 000 ha) within the 10 quaternary catchments, varies from 2 - 18 % of MAR. The total impact of afforestation at the level of the tertiary catchment is 5 %of MAR, at the secondary catchment about 1 %, and <0.5 % at the level of the primary catchment. Consequences at the regional scale do not therefore seem to be of especial significance, which is in line with the original contention that this was a well-watered region which could afford to support a viable forestry industry.

7.3 IMPACTS OF FORESTRY ON WATER QUALITY

A 'biological baseline' has been established at 15 monitoring sites on the major rivers in the district (the Wildebees, Mooi, Pot and Antelopespruit). This methodology entails a survey of the biological health of the river and can easily be repeated either at regular or at event driven intervals. The conclusion from the baseline study (which admittedly took place in the middle of major afforestation activity) is that the rivers are particularly sound.

7.4 FORESTRY AND STRATEGIC DEVELOPMENT

Forestry was identified in the 1980's as a strategic national resource and this had a powerful influence on decision making. In today's global economy our strategic resource is capital, foreign exchange and a positive balance of payments. This has led to a shift in thinking from forestry as a land use to optimal resource use. The forestry industry views itself as a strong contender in the optimal use of resources (land and water). What has become clear from this study and from the experience of NECF and all forestry developers in South Africa today, is that a strategic approach to decision making is required. Water is likely to be a major issue in most situations.

A strong argument for the adoption of a Strategic Environmental Assessment approach both for the North-Eastern Cape and for other possible forestry growth areas, is made in this report.

8. RECOMMENDATIONS FOR RESEARCH

A detailed database has now been put in place from which land use change, and particularly the impacts of such change on water yield and quality, can be followed and assessed into the future. This study has noted both the richness of the region as a water resource and the limitations on hydrological data for its rivers. Future research should be directed at optimising the use of the natural resources of land and water.

North East Cape Forests (NECF) is engaged in the largest new forestry development in South Africa, and has endeavoured to meet the considerations demanded by the new community and environmental ethics which now pertain. This 'new forestry' offers a number of research and development opportunities. Areas for research therefore reflect the need for monitoring and evaluation, the value of catchment research pertaining to forestry in a new physical and social environment, and the opportunities offered by large scale development.

The following research questions are highlighted:

8.1 HYDROLOGICAL MONITORING (CATCHMENT RESEARCH)

Experimental catchments would be of great value both to NECF and to the wider forestry and hydrological communities. Suggested elements for research using this approach include:

- The impact on catchment hydrology of carefully planned and managed plantations ('new generation forestry' - see sections 5.5.6 and 6.3.1). Determine the significance of the hydrological benefits in catchments where full consideration is given to plantation design and conservation measures.

- Is forestry an option in the rehabilitation of degraded catchments? Catchments which have been heavily trampled, overgrazed, eroded or otherwise damaged so as to lose infiltrability to the point where the hydrological cycle is changed from that of infiltration, storage and release to overland flow and flash flooding, require rehabilitation in order to re-establish hydrological function. Research is required to determine the impacts of afforestation on the hydrology of degraded catchments in terms of water yield, sustainability of yield, and water quality.

  This issue becomes particularly pertinent as areas of former homeland are considered for afforestation, and as community forestry becomes more prevalent.

- Site preparation appears to have had little impact within relatively undisturbed catchments in the North-Eastern Cape, both in terms of improved growth and changed hydrology. But once catchments have been disturbed to the point of losing their 'hydrological functionality' this situation may prove very different. It is likely also that the current forestry development will be a pre-cursor to extensive new forestry within former Transkei where degraded lands are a common feature. Research is therefore required to determine how site preparation (deep ripping) can impact upon the hydrology of degraded catchments.

  It would be important in this research to use realistic controls - where control catchments continue under old management regimes, and are not part of the accompanying conservation landscape.

- Research should assess the hydrological implications of withdrawing catchments from agricultural production (cropland and grazing) and managing these as conservation catchments.

8.2 WATER QUALITY MONITORING

- Confirm the effective value of biological monitoring in detecting forestry impacts.

- Develop an easy, reproducible method for assessment of sediment loads in streams.

- In the North-Eastern Cape the existing limnological monitoring network should be expanded into new areas *before* any new forestry expansion takes place. Monitoring of the existing network should ideally be repeated annually, but alternatively monitoring should be event driven - to include major perturbations such as fire and clearfelling.

8.3 HYDROLOGICAL MODELLING

- Evaluate the applicability, accuracy and ease of use of the available hydrological models (eg. CSIR and ACRU). If the outputs are satisfactory to both the forestry industry and the downstream water user - then perhaps there is no need for any specific monitoring of impacts at the catchment scale. This will need to be tested.

- Model output (this study) needs to be checked and calibrated against real data - if and when more accurate streamflow monitoring should be implemented. Bowen ratio evaporation output from the Wetherley catchment should also be checked against model outputs.

- The low flow modelling exercise needs to be improved as a matter of urgency to ensure applicability when used over a range of different conditions. The CSIR model should be re-run against this revised low flow model and the text in this document updated.

- Hydrological modelling should be used in making site specific recommendations. While not an area of new research there is definite scope for the implementation of modelling results in improved planning practices.

- These recommendations do not attempt to provide an exhaustive list of useful process research. But a research approach to development within North East Cape Forests is encouraged and should also be directed at species water use, water use efficiency, evapotranspiration, streamflow generation, soil water impacts and plantation water use issues. Research initiated within the Wetherley catchments should be encouraged and supported.

8.4 WETLANDS

- Determine the hydrological role of wetlands in the North-Eastern Cape. Assess the role of Eastern Cape wetlands as sources and/or as sinks of water.

- To what extent will the rehabilitation of wetlands modify the hydrological behaviour of the catchments? An economic assessment is required to determine how ecologically and economically cost effective the rehabilitation of degraded wetlands is likely to be.

- Determine the importance of wetlands to the survival of endemic flora and flora.

8.5 RIPARIAN ZONES

- Determine how effective the application of the 'Bosch' model (or other means of planning for forestry in relation to riparian zones) has proved to be. This model should be evaluated in terms of practical improvements, in the light of practical field experience.

- Determine the water demand of riparian black wattle *(Acacia mearnsii)* and assess the impact of black wattle invasion on catchment water yield.

- Assess the extent of the benefits which the programme for the clearing of black wattle, executed by NECF, has had in terms of protecting and augmenting the downstream water resource.

- Methods of clearing riparian zones, most suited to the region, need to be researched (eg. ringbarking of *A. mearnsii*).

8.6 INVASIVE SPECIES

- Determine the extent of threat by invasive species, and particularly as a consequence of the introduction of large scale commercial forestry, to the catchments of the North-Eastern Cape.

- Determine the invasiveness of *Pinus greggii*

- Determine the benefits resulting from the clearing of invasive species, particularly in riparian zones (see also section 8.5).

- Research into the biocontrol of problem invasive species should be encouraged - one particular example being the control of silver wattle *(A. dealbata).*

8.7 NATURAL VELD MANAGEMENT

- How will NECF continue to manage natural veld (ie.those parts of its plantation area not converted to trees)? Determine the importance, both ecologically and hydrologically, of maintaining these grassland areas in a 'pre-afforestation' condition.

8.8 FOREST MANAGEMENT

- **Normalizing plantations - hydrological impacts and implications**
  The potential for either reducing the peak impact of afforestation on water yield, or alternatively for increasing afforested area without reducing peak estimated impact on yield (using either MAR or low flow as a measure) by normalizing age classes within catchments, has been highlighted in this study. But this has only been looked at in any detail for one quaternary catchment (T35F) in this study, and this analysis should be

extended. This concept also needs further exploration. So, for example, normalized stands will reduce the peak impact experienced over a short time span - by establishing a lower (but more substantial) level of impact over the length of the rotation. This may have critical implications to risk management.

- **Rotation length**
  Assess the hydrological benefits of managing trees on a short rotation, and determine how best these benefits could be optimised.

- **Water repellency**
  Major fires, such as those of 1994, are certain to recur. What are the risks where land use has converted to forestry, and can these be avoided? Areas of potential water repellency need to be identified, and either avoided or mitigation measures put in place.

8.9 REGIONAL SOCIO-ECONOMIC DEVELOPMENT (ECONOMICS OF RESOURCE USE)

- The value of forestry development should be compared with other existing and potential land uses in order to assess the comparative benefits of resource use (especially land and water) to district, province and country. The process of Strategic Environmental Assessment (SEA), with a protocol for the introduction of new forestry development to a district of region, needs to be advanced. The North-Eastern Cape provides an excellent opportunity for the research and application of this approach.

- There is a need for more site specific information and for additional research into the role of the forestry industry as a job creator. Assessments to date have only considered the potential role of forestry in creating jobs. A resource economic study should also be embarked upon to assess other land uses (eg. maize farming, grazing) in terms of their contribution to job creation.

- The social impacts of large scale afforestation, in areas where this is a new form of land use, need far more attention. In the past all emphasis has been limited to the physical impacts. Any new forestry development should be accompanied by an in-depth social assessment.

- Determine the impacts of forestry development within the North-Eastern Cape upon the eco-tourism potential of the region.

8.10 ZONING

- Any existing attempts to implement forestry zoning should be reviewed and assessed. The existing status of zoning practice (legal and practical) should see immediate review with results publicised in a position paper.

- The introduction of zoning for forestry introduces the prospect of planting of certain wetlands, riparian zones, or other areas which would normally have been excluded from forestry for hydrological reasons. Compromise strategies will have to be determined in terms of trade-offs and benefit. Research is required to determine how best to optimize forestry zone design to maximize water production and management benefit.

8.11 TAKING THIS PROJECT FORWARD

A number of very general, and some specific, research recommendations have been made with regard to an evaluation of past and future forestry development in the North-Eastern Cape. These suggestions have been limited to the impacts of tree production, and have not considered the possible consequences of secondary growth. In addition to these recommendations some immediate and practical steps are also suggested:

- In the first instance an extremely valuable database has established the *status quo* in terms of natural resource use and hydrology. This level of information should be kept in place, and updated on a regular basis.

- The hydrological impacts of afforestation have been determined from an accurate spatial representation of current and some projected forestry development, and the application of the robust CSIR water use model. More specific applications of this model are suggested in order to refine the level of planning of future afforestation within the region, notably with regard to the management of a mixed rotation length within any one quaternary catchment. The CSIR low flow model, must however see immediate refinement and should be reapplied to the data sets used in this study.

- The state and the forestry industry, informed by forest hydrology research organizations, should meet to establish a mutually acceptable policy with regard to hydrological monitoring. Issues include both the need to determine the impacts of afforestation upon local and regional hydrology, and the allocation of responsibilities.

- It is recommended that the extensive section provided within this report on 'guidelines for policy development and management' should be abridged and published as a separate report within the forestry media - either as one, or as a series of papers - in order to ensure widespread circulation. Should the issues raised spark the anticipated debate then this could be used as the focus of a workshop on "forestry practice today".

Finally, future research programmes of this nature must maximise emphasis on the integration of issues and concerns in optimising the use of natural resources of land and water to the benefit of people.

9. REFERENCES

Acocks, JPH (1988). Veld types of South Africa. Memoirs of the Botanical Survey of South Africa 57: 1 -146.

Anon (1995). Standard methods for the examination of water and waste water, 19th Edition. American Public Health Association American Water Works Association Water Environment Federation.

Allen, DG, Harrison, JA, Navarro, RA, van Wilgen, BW and Thompson, MW (in press). The impact of commercial afforestation on bird populations in Mpumalanga province, South Africa - insights from bird atlas data. *Biological Conservation.*

Armitage, PD, Moss D, Wright, JF and Furse, MT (1983). The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. *Water Research* 17, No. 3: 333-347.

Armstrong, AJ and Van Hensbergen, HJ (1996). Small mammals in afforestable montane grasslands of the NE Cape, South Africa. *South African Journal of Wildlife Research.* 26:11-18.

Armstrong, AJ and Van Hensbergen, HJ (in press). Selection of nature reserves in afforestable montane grasslands of the NE Cape, South Africa. *Biological Conservation.*

Bainbridge, W (1976). Memorandum: *Pinus patula* becoming a problem plant in the Drakensberg catchment area. Department of Forestry unpublished memorandum, Pietermaritzburg.

Begg, G (1986). The Wetlands of Natal (Part 1): An Overview of their Extent, Role and Present Status. Natal Town and Regional Planning Commission Report, 68.

Black, TA (1971). Psychometric apparatus for Bowen ratio determination over forests. *Boundary Layer Meteorology* 2: 246 - 254

Bosch, JM (1979). Treatments effects on annual and dry period streamflow at Cathedral Peak. *South African Forestry Journal* 108: 29-38.

Bosch, JM (1993). Guidelines for the delineation and management of riparian zones. Forestek CSIR Report to the Department of Water Affairs and Forestry, March 1993.

Bosch, JM, Berliner, D and Le Maitre, DC (1993). Guidelines for the delineation and management of riparian zones. Report FOR-DEA 675, Department of Water Affairs and Forestry, Pretoria.

Bosch, JM and Hewlett, JD (1982). A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. *Journal of Hydrology* 55: 3-23.

Burton, J (1995). A framework for integrated river basin management. In: International *Specialised Conference: River Basin Management for Sustainable Development - conference* Proceedings. Kruger National Park, South Africa.

Chapman, RA, Scott, DF and Le Maitre, DC (1995). Hydrological impacts of aliens in fynbos catchments. In: C Boucher and C Marais (eds) Managing Fynbos Catchments for Water. FRD Programme Report Series No. 24, Foundation for Research Development, Pretoria.

Chutter, FM (1992). The rapid biological monitoring of water quality and stream status. Paper presented at the 1992 Conference on Aquatic ecosystems. Cape Town, South Africa.

Chutter, FM (1994). The rapid biological assessment of stream and river water quality by means of the macroinvertebrate community in South Africa. In: Uys, MC (compiler), Classification of rivers and environmental health indicators. Proceedings of a joint SA-Australian workshop. February 7-14, Cape Town South Africa. Water Research Commission Report No. TT 63/94.

DeBano, LF (1966). Formation of non-wettable soils involves heat transfer mechanism. USDA Forestry Service, Research Note PSW-132, Pacific Southwestern Forest and Range Experiment Station, Berkeley, California.

DeBano, LF (1981). Water repellent soils: a state-of-the-art. USDA Forest Service, General Technical Report PSW-46. Pacific Southwest Forest and Range Experiment Station, Berkeley, California, USA.

De Decker, RH (1981). Geology of the Kokstad Area. Geological Survey. Department of Mineral and Energy Affairs. Pretoria.

De Moor, FC and Barber-James, HM (1994). A survey of the freshwater invertebrates of the North East Cape rivers. Internal report. Department of freshwater invertebrates, Albany Museum, Grahamstown.

Dent, MC, Lynch, SD and Schulze, RE (1987). Mapping mean annual and other rainfall statistics over Southern Africa. WRC Report 109/1/89. Water Research Commission, Pretoria.

Directorate of National Forestry Planning (1989). Strategic Forestry Development Plan for South Africa. Department of Environment Affairs, South Africa.

Dye, PJ (1996). Climate, forest and streamflow relationships in South African afforested catchments. *Commonwealth Forestry Review* 75: 31-38.

Department of Water Affairs & Forestry (1995). Towards a Policy for Sustainable Forest Management in South Africa: a Discussion Paper. DWAF, Pretoria.

Forest Industry Environmental Committee (1995). 'Guidelines for the environmental conservation management in commercial forest in South Africa'.

Forster, SF (1991). Report-back from a field trip to North-Eastern Cape Afforestation Development (2 - 5 October 1991). Department of Water Affairs and Forestry Internal Report DF//C - Forest - Policy.

Foundation for Research Development (1990). Characteristics and dynamics of the riparian zones of Kruger National Park rivers: A research approach. Skukuza Workshop.

Hassan, R (in prep). Environmental accounting for sustainable management of forest resources in SA: an input-output framework. Environmentek, CSIR.

Kempster, PL, Hattingh, WAJ and Van Vliet, HR (1980). Summarized water quality criteria. Department of Water Affairs, Forestry and Environmental Conservation, Hydrological Research Unit, Pretoria. Technical Report No. TR 108.

Le Maitre, DC and Versfeld, DB (in press). Forest growth and evaporation. *Journal of Hydrology.*

Le Maitre, DC, Van Wilgen, BW, Chapman, RA and McKelly, DH (1996). Invasive plants and water resources in the Western Cape Province, South Africa: Modelling the consequences of a lack of management. *Journal of Applied Ecology* 33: 61-172.

Low, AB and Rebelo, AG (1996). Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism. Pretoria.

MacVicar, CN, Loxton, RF, Lambrechts, JJN, Le Roux, J, De Villiers, JM, Verster, E, Merryweather, FR, Van Rooyen, TH and Von M. Harmse, HJ (1977). Soil Classification - A Binomial System for South Africa. Department of Agricultural Technical Services. Pretoria.

McIntyre, AD (1984). What happened to biological effects monitoring? *Editorial. Mar. Poll. Bull.,* 18(11): 391-392.

McNeill, L, Brandao, A, Zucchini, W and Joubert, A (1994). Interpolation of the daily rainfall model. University of Cape Town, WRC Report No 305/1/94.

Midgley, DC, Pitman, WV and Middleton, BJ (1994). Surface water resources of South Africa 1990: Volume V Drainage Regions M, N, P, Q, R, S, T: Appendices. Water Research Commission Report 298/5.1/94, Water Research Commission, Pretoria.

Nänni, UW (1970). Trees, water and perspective. *South African Forestry Journal* 75: 9-17.

Nänni UW (1970). The effect of afforestation on streamflow at Cathedral Peak. *South African Forestry Journal* 74: 6-12 (CP2-CP4).

Olbrich, BW (1994). Transpiration from *Eucalyptus grandis* measured using the heat pulse velocity technique. PhD thesis. University of Natal, Durban.

Pitman, WV (1973). A mathematical model for generating monthly river flows from meteorological data in South Africa. Report No 2/73, Hydrological Research Unit, University of the Witwatersrand, Johannesburg.

Pitman, WV and Kakebeeke, JP (1991). WRSM90 User's Guide. Stewart Scott Inc., Johannesburg.

Potgieter, JF and Nel, H (1996). Economic and developmental impact study of the North East Cape Forests Project (NECF). University of Port Elizabeth, Port Elizabeth.

Roux, DJ, Van Vliet HR and Van Veelen, M (1993). Towards integrated water quality monitoring: Assessment of ecosystem health. *Water SA* 19 (2): 275-280.

Rowntree, K (undated). Riparian vegetation and its relationship to channel morphology: Implications for South African river systems. Department of Geography, Rhodes University, Grahamstown.

Rowntree, KM (1992). A hydro-geomorphic survey of wetland areas in the North Eastern Cape forests area. Draft report to Cape Nature Conservation.

Sadler B (1995). Towards the improved effectiveness of environmental assessment. Executive Summary of Interim Report prepared for IAIA'95. Durban, South Africa.

SA Forestry (1989). Mondi begins planting in NE Cape: 66000 ha November/December 1989 pp 27-28.

Schulze, RE (1979). Hydrology and Water Resources of the Drakensberg. Natal Town and Regional Planning Reports, No. 42, Natal Town and Regional Planning.

Schulze, RE (1995). Hydrology and Agrohydrology: A Text to Accompany the ACRU 3.00 Agrohydrological Modelling System. Water Research Commission, Pretoria, Report TT69/65.

Scott, DF (1992). Hydrological impacts of afforestation in the North-Eastern Cape. Unpublished contract report, FOR-C 83, to the Water Research Commission. CSIR Division of Forest Science and Technology, Pretoria.

Scott, DF (1994). The hydrological effects of fire in south African catchments. Unpublished PhD thesis, University of Natal, Pietermatrizburg.

Scott, DF and Le Maitre, DC (1993). A procedure for calculating the percentage reductions in annual and low flows for use in the allocation of permits for afforestation. Unpublished contract report, FOR-DEA 664, to the Department of Water Affairs and Forestry. CSIR Division of Forest Science and Technology, Pretoria.

Scott, DF and Lesch, W (1995). The water yield gains obtained from clearfelling riparian zone vegetation. Proc. 7th National Hydrology Symposium, Grahamstown, Sept, 1995.

Scott, DF and Van Wyk, DB (1990). The effects of wildfire on soil wettability and hydrological behaviour of an afforested catchment. *Journal of Hydrology* 121: 239-256.

Smith, RE, Moses, G and Versfeld, DB (1992). Verification of the heat pulse velocity technique for *Acacia mearnsii. South African Forestry Journal* 163:1-4.

Smith, RE and Scott, DF (1992). The effects of afforestation on low flows in various regions of South Africa. *Water S.A.* 18(3): 185-194.

Smith, RE and Scott, DF, (1992). Simple Empirical Models to Predict reductions in Annual and Low flows resulting from Afforestation. Unpublished contract report, FOR-DEA 465, to the Department of Water Affairs and Forestry. CSIR Division of Forest Science and Technology, Pretoria.

Scott, DF and Smith, RE (in prep). Preliminary Empirical Models to Predict reductions in Annual and Low flows resulting from Afforestation.

United Nations (1993). Integrated environmental and economic accounting: Studies in methods. Handbook of National Accounting Series F, No. 61. New York: UN.

Van der Zel, DW (1989). Strategic Forestry Development Plan for South Africa. Directorate of National Forestry Planning, Department of Environment Affairs. Pretoria.

Van der Zel, DW (1995). Accomplishments and dynamics of the South African afforestation permit system. *South African Forestry Journal* 172: 49-58.

Van Wilgen, BW and Scholes, RJ (1997). The vegetation and fire ecology of sub equatorial Africa. In: van Wilgen BW, Andreae MO, Goldammer JG and Lindesay JA (eds) Fire in southern Africa Savannas: Ecological and atmospheric perspectives. Wits University Press.

Van Wyk, DB (1987). Some effects of afforestation on streamflow in the Western Cape Province, South Africa. *Water S.A.* 13: 31-36.

Van Lill, WS, Kruger, FJ and Van Wyk, DB (1980). The effects of afforestation with *Eucalyptus grandis* Hill ex Maiden and *Pinus patula* Sclecht. et Cham. on streamflow from experimental catchments at Mokobulaan, Transvaal. *Journal of Hydrology* 48: 107-118.

Versfeld, DB (1996). Forestry and water resources - policy development for equitable solutions. *South African Forestry Journal* 176: 55-59.

Versfeld, DB and Bosch, JM (1982). The options for catchments - how to make the right decisions: another view. Foris, Faculty of Forestry, University of Stellenbosch Communication No. 98.

Vlok, J and Briers, J (1992). Investigation of possible afforestation impacts on the flora of the Elliott-Ugie-Maclear Districts. Unnumbered Internal Report: Eastern Cape Nature Conservation. Port Elizabeth.

Wicht, CL (1967). Forest hydrology research in the South African Republic. In: Sopper WE and Lull HW. *Forest Hydrology.* Pergamon Press, Oxford. pp. 75-84.

Wiseman, K (1996). Strategic Environmental Assessment (SEA) - *A Primer.* CSIR Report ENV/S-RR 96001. Division of Water, Environment and Forestry Technology CSIR. Stellenbosch.

Appendix 1

North-Eastern Cape Database.

- Description of the data
- Storage and availability of data
- Maintenance of the data

1. DESCRIPTION OF THE DATA

The following data sets are stored in the GIS lab of environmentek, Stellenbosch on a Sun Unix workstation. The database has been captured on a geographical information system (Arc/Info)

Table 1 Salient features of the spatial database compiled during the duration of the project

Data layer	Description	Custodian	Storage	Availability
Land cover	Classes derived from 30 * 30 m resolution Landsat TM satellite imagery	WRC	Environmentek CSIR to be transferred to DWAF	free on request (handling fee)
Plantation compartments & boundaries	1: 10 000	NE Cape Forests	Environmentek CSIR, NECF	at discretion of NECF
Plantation data	Attribute data including species and age	NECF	Environmentek CSIR, NECF	at discretion of NECF
Plantation roads	1:10 000	NE Cape Forests	Environmentek, CSIR, NECF	at discretion of NECF
Farm boundaries	1: 50 000	NE Cape Forests	Environmentek, CSIR, NECF	at discretion of NECF
Alien coverage	1:10 000/ 1:50 000	WRC	Environmentek, CSIR to be transferred to DWAF	free on request (handling fee)
Rivers, quaternary catchments	1:250 000	DWAF	DWAF	at request from DWAF
Contours (derived from National DEM)	200 * 200m	Environmentek, CSIR	Environmentek, CSIR	free on request (handling fee)
Infrastructure	1:50 000	WRC	Environmentek, CSIR	free on request (handling fee)
Rainfall (derived from CCWR data)	1.6 km * 1.6 km	CCWR	Environmentek, CSIR, CCWR	free on request from CCWR
Rainfall stations, weirs	point data	CCWR	Environmentek, CSIR, CCWR	free on request from CCWR
Biological monitoring network	point data	WRC	Environmentek, CSIR	free on request (handling fee)
Biological data	non-spatial attributes & field sheets	WRC	Environmentek, CSIR - transferred to the National data base for all SASS data	free on request (handling fee)
Streamflow runoff scenarios	1:50 000	WRC	Environmentek, CSIR	free on request (handling fee)
Wetlands	1:50 000	Eastern Cape Nature Conservation	Environmentek, CSIR, Eastern Cape Nature Conservation	free on request (handling fee)

2. AVAILABILITY OF DATA

Data including GIS data captured during this project will be made available to all users approved by the Water Research Commission. It is probable that the Department of Water Affairs will be asked to act as custodians of the data. All the spatial data is available in Arc Info exchange format. The NE Cape Forest data will only be available in this format in 1997. If users want to obtain the data from the CSIR, the data will be supplied free of charge, although a small handling is charged to cover the costs of data transfer onto acceptable mediums such as stiffy disks or tapes. Permission to use the data must also be obtained by the owners.

3. MAINTENANCE OF DATA BASE

The data listed in the Table above reflects the baseline situation during the initial establishment of the NE Cape development. This data has been collected at a particular point in time. For it to remain relevant as a data source, it will need to be continuously updated. Either the WRC must take responsibility for this process or they need to sub-contract some other agency to do this on their behalf. Advantages of maintaining this database include:

- Access to reliable and comprehensive information to support policy and management decisions
- Greater efficiency in the use of information. Much information once collected is inaccessible or in danger of being lost.

Appendix 2

Estimated annual streamflow reductions, over a full rotation after initial afforestation, for each of the quaternary catchments.

North Eastern Cape afforestation impacts - normal flow

Quaternary catchment T11B
Total area afforested = 1047.6 ha

Total water use (42 yrs) = 21.7890 E6 cubic m
Rotation length = 18.0 years

Frequency distribution area afforested - by age class

0	1	2	3	4	5	6	7	8	9
179.	157.	87.	13.	65.	385.	59.	0.	0.	0.

Year	Reduction (million cubic metres/yr)
1997	0.08
1998	0.13
1999	0.19
2000	0.27
2001	0.36
2002	0.45
2003	0.55
2004	0.65
2005	0.74
2006	0.82
2007	0.88
2008	0.93
2009	0.96
2010	0.92
2011	0.59
2012	0.53
2013	0.53
2014	0.45
2015	0.17
2016	0.14
2017	0.19
2018	0.27
2019	0.36
2020	0.45
2021	0.55
2022	0.65
2023	0.74
2024	0.82
2025	0.88
2026	0.93
2027	0.96
2028	0.92
2029	0.59
2030	0.53
2031	0.53

North Eastern Cape afforestation impacts - normal flow

Quaternary catchment T11D
Total area afforested = 1762.3 ha

Total water use (42 yrs) = 39.7346 E6 cubic m
Rotation length = 18.0 years

Frequency distribution area afforested - by age class

0	1	2	3	4	5	6	7	8	9
4.	186.	103.	223.	52.	54.	987.	47.	0.	0.

Year	Reduction (million cubic metres/yr)
1997	0.28
1998	0.41
1999	0.56
2000	0.74
2001	0.92
2002	1.09
2003	1.24
2004	1.38
2005	1.49
2006	1.58
2007	1.65
2008	1.69
2009	1.67
2010	0.71
2011	0.69
2012	0.67
2013	0.51
2014	0.48
2015	0.39
2016	0.42
2017	0.56
2018	0.74
2019	0.92
2020	1.09
2021	1.24
2022	1.38
2023	1.49
2024	1.58
2025	1.64
2026	1.69
2027	1.67
2028	0.71
2029	0.69
2030	0.67
2031	0.51

North Eastern Cape afforestation impacts - normal flow

Quaternary catchment T11E
Total area afforested = 1641.6 ha

Total water use (42 yrs) = 39.8455 E6 cubic m
Rotation length = 18.0 years

Frequency distribution area afforested - by age class

0	1	2	3	4	5	6	7	8	9
0.	42.	0.	3.	682.	638.	187.	0.	0.	0.

Year	Reduction (million cubic metres/yr)
1997	0.21
1998	0.32
1999	0.47
2000	0.65
2001	0.86
2002	1.06
2003	1.25
2004	1.41
2005	1.54
2006	1.63
2007	1.70
2008	1.75
2009	1.79
2010	1.63
2011	0.96
2012	0.20
2013	0.23
2014	0.28
2015	0.31
2016	0.40
2017	0.47
2018	0.65
2019	0.85
2020	1.06
2021	1.25
2022	1.41
2023	1.54
2024	1.63
2025	1.70
2026	1.75
2027	1.79
2028	1.63
2029	0.96
2030	0.20
2031	0.23

North Eastern Cape afforestation impacts - normal flow

Quaternary catchment T34E
Total area afforested = 96.5 ha

Total water use (42 yrs) = 2.4937 E6 cubic m
Rotation length = 18.0 years

Frequency distribution area afforested - by age class

0	1	2	3	4	5	6	7	8	9
14.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Year	Reduction (million cubic metres/yr)
1997	0.00
1998	0.00
1999	0.00
2000	0.01
2001	0.01
2002	0.01
2003	0.02
2004	0.03
2005	0.04
2006	0.05
2007	0.07
2008	0.08
2009	0.10
2010	0.11
2011	0.11
2012	0.12
2013	0.12
2014	0.13
2015	0.11
2016	0.11
2017	0.00
2018	0.01
2019	0.01
2020	0.01
2021	0.02
2022	0.03
2023	0.04
2024	0.05
2025	0.07
2026	0.08
2027	0.10
2028	0.11
2029	0.11
2030	0.12
2031	0.12

North Eastern Cape afforestation impacts - normal flow

Quaternary catchment T35A
Total area afforested = 4236.7 ha

Total water use (42 yrs) = 123.9239 E6 cubic m
Rotation length = 18.0 years

Frequency distribution area afforested - by age class

0	1	2	3	4	5	6	7	8	9
138.	829.	409.	108.	1056.	439.	0.	0.	0.	0.

Year	Reduction (million cubic metres/yr)
1997	0.28
1998	0.45
1999	0.70
2000	1.01
2001	1.42
2002	1.91
2003	2.47
2004	3.07
2005	3.67
2006	4.24
2007	4.75
2008	5.18
2009	5.51
2010	5.76
2011	5.20
2012	3.76
2013	3.72
2014	3.26
2015	2.07
2016	1.40
2017	0.69
2018	1.01
2019	1.42
2020	1.91
2021	2.47
2022	3.06
2023	3.67
2024	4.24
2025	4.75
2026	5.18
2027	5.51
2028	5.76
2029	5.20
2030	3.76
2031	3.72

North Eastern Cape afforestation impacts - normal flow

Quaternary catchment T35B
Total area afforested = 1774.9 ha

Total water use (42 yrs) = 53.2982 E6 cubic m
Rotation length = 18.0 years

Frequency distribution area afforested - by age class

0	1	2	3	4	5	6	7	8	9
174.	0.	13.	3.	336.	1049.	133.	0.	0.	0.

Year	Reduction (million cubic metres/yr)
1997	0.28
1998	0.42
1999	0.61
2000	0.84
2001	1.11
2002	1.39
2003	1.65
2004	1.88
2005	2.07
2006	2.22
2007	2.33
2008	2.41
2009	2.47
2010	2.35
2011	0.86
2012	0.40
2013	0.45
2014	0.50
2015	0.37
2016	0.42
2017	0.61
2018	0.84
2019	1.11
2020	1.38
2021	1.65
2022	1.88
2023	2.07
2024	2.22
2025	2.33
2026	2.41
2027	2.47
2028	2.35
2029	0.86
2030	0.40
2031	0.45

North Eastern Cape afforestation impacts - normal flow

Quaternary catchment T35C
Total area afforested = 4920.0 ha

Total water use (42 yrs) = 121.4320 E6 cubic m
Rotation length = 18.0 years

Frequency distribution area afforested - by age class

0	1	2	3	4	5	6	7	8	9
248.	843.	190.	733.	915.	608.	875.	0.	0.	0.

Year	Reduction (million cubic metres/yr)
1997	0.52
1998	0.78
1999	1.12
2000	1.54
2001	2.02
2002	2.55
2003	3.10
2004	3.64
2005	4.13
2006	4.56
2007	4.92
2008	5.19
2009	5.39
2010	4.51
2011	4.01
2012	3.05
2013	2.26
2014	2.16
2015	1.08
2016	1.24
2017	1.12
2018	1.53
2019	2.02
2020	2.55
2021	3.10
2022	3.63
2023	4.13
2024	4.56
2025	4.91
2026	5.19
2027	5.39
2028	4.51
2029	4.01
2030	3.05
2031	2.26

North Eastern Cape afforestation impacts - normal flow

Quaternary catchment T35D
Total area afforested = 1418.4 ha

Total water use (42 yrs) = 40.2413 E6 cubic m
Rotation length = 18.0 years

Frequency distribution area afforested - by age class

0	1	2	3	4	5	6	7	8	9
10.	54.	0.	0.	133.	5.	1148.	1.	16.	5.

Year	Reduction (million cubic metres/yr)
1997	0.36
1998	0.51
1999	0.69
2000	0.88
2001	1.08
2002	1.26
2003	1.41
2004	1.53
2005	1.60
2006	1.67
2007	1.71
2008	1.73
2009	1.75
2010	0.32
2011	0.34
2012	0.22
2013	0.28
2014	0.37
2015	0.39
2016	0.52
2017	0.68
2018	0.88
2019	1.08
2020	1.26
2021	1.41
2022	1.52
2023	1.60
2024	1.67
2025	1.71
2026	1.73
2027	1.75
2028	0.32
2029	0.34
2030	0.22
2031	0.28

North Eastern Cape afforestation impacts - normal flow

Quaternary catchment T35F
Total area afforested = 7876.0 ha

Total water use (42 yrs) = 203.5384 E6 cubic m
Rotation length = 18.0 years

Frequency distribution area afforested - by age class

0	1	2	3	4	5	6	7	8	9
687.	667.	224.	376.	1071.	2510.	1168.	0.	0.	0.

Year	Reduction (million cubic metres/yr)
1997	0.97
1998	1.44
1999	2.03
2000	2.74
2001	3.55
2002	4.41
2003	5.27
2004	6.10
2005	6.87
2006	7.55
2007	8.12
2008	8.58
2009	8.93
2010	8.07
2011	5.40
2012	4.08
2013	3.84
2014	3.86
2015	2.46
2016	2.37
2017	2.03
2018	2.74
2019	3.54
2020	4.40
2021	5.27
2022	6.10
2023	6.86
2024	7.55
2025	8.12
2026	8.58
2027	8.93
2028	8.07
2029	5.40
2030	4.08
2031	3.84

North Eastern Cape afforestation impacts - normal flow

Quaternary catchment T35G
Total area afforested = 5098.5 ha

Total water use (42 yrs) = 111.8650 E6 cubic m
Rotation length = 18.0 years

Frequency distribution area afforested - by age class

0	1	2	3	4	5	6	7	8	9
680.	1080.	225.	904.	79.	422.	231.	35.	0.	0.

Year	Reduction (million cubic metres/yr)
1997	0.26
1998	0.41
1999	0.62
2000	0.89
2001	1.24
2002	1.66
2003	2.16
2004	2.71
2005	3.27
2006	3.79
2007	4.24
2008	4.60
2009	4.83
2010	4.73
2011	4.41
2012	4.43
2013	3.64
2014	3.48
2015	1.75
2016	0.97
2017	0.61
2018	0.88
2019	1.23
2020	1.66
2021	2.16
2022	2.71
2023	3.26
2024	3.79
2025	4.24
2026	4.60
2027	4.83
2028	4.73
2029	4.41
2030	4.43
2031	3.64