CONSERVATION OF FARMLAND IN KWAZULU-NATAL

Agricultural Production Guidelines for KwaZulu-Natal

CONSERVATION OF FARMLAND

IN

KWAZULU-NATAL

Compiled by
the KwaZulu-Natal Department of Agriculture
on behalf of the
Co-ordinated Extension Committee of KwaZulu-Natal

This document will be revised and
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God will not seek thy race, nor will He ask thy birth;
Alone will He demand of thee –
"What hast thou done with the land I gave thee?"

(Ancient Persian proverb)

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PLEASE READ THIS

Before deciding to implement any technology,
consider carefully:

(i) its effect on profitability, and

(ii) its effect on the environment, especially the conservation of soil, vegetation and water.

SPECIAL THANKS

to

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for sponsoring the cover
of this document

Conservation of Farmland in KwaZulu-Natal

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ADDITIONAL LEAFLETS AVAILABLE ON REQUEST:

Conservation of Farmland in KwaZulu-Natal

PREFACE

W B Russell
KwaZulu-Natal Department of Agriculture

This series of leaflets forms an integral part of those Agricultural Production Guidelines for Natal already published, and those still to come. Conservation of the resources should not be separated from the other production processes in this way, but including them in each and every publication would have added greatly to the cost of producing these guidelines.

Motivation for a document of this nature is covered in leaflet number 1.5 : The Cost of Farmland Degradation. That accelerated erosion and farmland degradation is still occurring in KwaZulu-Natal today, after many years of dedicated extension work by many, is an indisputable fact. Many landusers are all too aware of the causes of degradation, but they are possibly not fully aware of the consequences of their actions in causing that degradation. It is the sincere hope of all the authors of this publication that their efforts in compiling it will lead rapidly to a better land care ethic throughout the Province and, indeed, throughout the Republic of South Africa as a whole.

The KwaZulu-Natal Department of Agriculture provides a Soil Conservation Service, free of charge, to all users of agricultural land. This document should be seen as an adjunct to that service, and an assistance in a DIY manner when the thinly-spread staff cannot provide immediate help.

Conservation of Farmland in KwaZulu-Natal

FARMERS' RESPONSIBILITIES IN TERMS OF ACT 43/1983

W B Russell
KwaZulu-Natal Department of Agriculture

SUMMARY

This document describes the effects of farmland degradation on the environment, the land user's legal responsibility in terms of the Conservation of Agricultural Resources Act (No. 43/1983) in general, and his moral obligations towards the land he manages in particular. It also sets out the procedures to which he will be subjected when his farming practices are in conflict with the requirements of Act 43/1983, and describes the role of Conservation Committees.

Various awards that are made in recognition of good conservation farming in the KwaZulu-Natal Region are also described.

THE EFFECTS OF FARMLAND DEGRADATION ON THE ENVIRONMENT

Many people question the need for State intervention in farming practices, claiming that a person should be able to do what he wishes with his own investment. The situation is not as simple as that, and for three main reasons:

* The plants that produce food, fibre and timber require moisture that is stored in the soil for their growth. In general, the deeper the soil, the more water it can store for plant use. Soil erosion therefore directly reduces the capacity of land to produce food, fibre and timber. Continued soil erosion can lead, and has led, to the production potential of land being radically reduced, and in some instances to zero. When it is borne in mind that soil lost cannot be regained (*i.e.* soil, to all intents and purposes is a non-renewable resource), it becomes clear that the best possible soil erosion control measures are essential for the continued welfare of mankind.
* Ideally, rain falling on a soil surface should penetrate it with minimal runoff and percolate through the profile, where some of it is stored for use in plant growth. The remainder drains deeper into the groundwater and finds its way to springs, wetlands and rivers. In this scenario, conditions are best for veld and crop production, and for clean and perennial water in streams and rivers. Factors which increase runoff (*e.g.* reduction of vegetative cover, poor veld management and bad conservation practices), and which decrease water intake by the soil not only cause accelerated soil erosion, with the consequences described above, but also have a detrimental effect on perennial flow in streams and rivers, and cause increased flood peaks as well as downstream sediment deposition. Excessive sediment in runoff, for example, causes damage to the pumps and piping of irrigators, and to coastal marine life habitats; it reduces the life of storage reservoirs and results in an increased expense in purifying water for urban use. This has an impact on the welfare of all people downstream.
* Weeds are a serious threat to the environment, especially in a climate generally as mild as that of KwaZulu-Natal. They rapidly colonise large areas because of their robust competitiveness, and their massive seed dispersal systems. A land user who, through neglect, allows his farm to become overgrown with weeds, is guilty of assisting in the widespread distribution of alien vegetation which is of use to no one, and is a threat to veld, vlei, cropland and indigenous forest alike. Degradation of the agricultural resources therefore can have an extremely negative effect on the lifestyle of the community as a whole, and it is for that reason that the State must control it.

PREVENTING FARMLAND DEGRADATION

The objects of Act 43/1983 are to provide for the conservation of the natural agricultural resources of the Republic by:

* the maintenance of the production potential of soil,
* the combating and prevention of soil erosion,

* the protection of the water sources,
* the protection of the natural vegetation, and
* the combating of weeds and invader plants.

The following aspects are covered by the Act and the regulations promulgated under it:

* **Cultivated land**
  General considerations
  In the first instance, no one may cultivate virgin land, or land that has not been cultivated during the preceding ten years, without a permit. This allows staff from the local agricultural extension office to determine the potential of the land, and to incorporate conditions of a soil conservation nature into the permit to cultivate it, if granted. It also serves to protect the natural vegetation growing on non-arable land from destruction. Further, and in respect of all cultivated land, no one may allow active erosion to occur on any cultivated land. The land user is advised to use as many of the following precautions and/or practices as will be necessary to reduce soil loss (by both water and wind) to a level which is considered acceptable by the Executive Officer appointed to administer Act 43/1983:

  * Suitable soil conservation works, *i.e.* waterways, contour banks and/or windbreaks.
  * Cultivation methods that will reduce the risk of excessive soil loss, *e.g.* conservation tillage.
  * Rotation of crops in a manner which will reduce soil erosion, *e.g.* inclusion of a grass ley with cash crops, or strip cropping and strip harvesting.
  * Leaving crop residue on the land surface in order to protect the soil from the erosive action of wind or water, or both.
  * Avoidance of cultivation during periods of high erosion hazard.
  * Establishment of a suitable perennial grazing crop, or permanent withdrawal of the land from annual cropping, if this is the only suitable alternative.

  Prevention of waterlogging and salinization of irrigated land
  In order to prevent these conditions occurring, land users are required to:

  * Seal all leaking irrigation furrows and storage dams where this is a cause of the problem.
  * Schedule their irrigation cycles properly.
  * Desist from using water that has too high a salt concentration.
  * Construct suitable surface and/or subsurface drainage works where necessary.
  * Use soil ameliorants where necessary.

* **Timber land**
  The Cedara Agricultural Development Institute (CADI), in collaboration with the forestry industry, has drawn up a set of guidelines for soil and water conservation in timber land. These guidelines form part of the conditions under which a permit is granted when new land is brought into timber production. They should also be followed when replanting of timber land takes place. In respect of all applications for permits under Act 43/1983, the land user is referred to his local Department of Agriculture Extension Office. The Soil Conservation Officer or the Extension Officer will assist him in his application, will carry out the necessary investigation, and will assist in the procurement of the permit. Land users should note that in the specific instance of the need to establish timber, procurement of a tree planting permit in terms of the Forest Act does not automatically exempt them from the need, under Act 43/1983, for a permit to break up virgin land.

* **Conservation of wetlands**
  As of 19 June 1984, no one may drain and/or cultivate any wetland, or do so within ten metres of the flood area of the wetland, without a permit. In respect of the Forest Act (No 122 of 1984), the distance from the wetlands to the point at which timber may be planted will be increased, in the judgement of the inspecting Forestry Extension Officer, to at least fifty metres, depending upon local terrain and the importance of the wetland to the environment downstream. In those cases where cultivation was taking place within the prescribed zones prior to the promulgation of the Act, no permit will be necessary to continue the practice as long as none of the agricultural resources are at risk. It is unlikely that a permit will be granted to drain a wetland which is permanently saturated during normal rainfall seasons.

* **Conservation of natural veld**
  Every user of natural veld is obliged to carry out as many of the following practices as are necessary in order to ensure the conservation of the veld:

  * Rotational grazing and resting according to the physiological requirements of the vegetation.
  * Maintenance of a balance of different types of grazing animals, so that any one natural constituent type of vegetation will not, through specific grazing practices, become threatened.
  * Restriction of the number of animals kept on the veld to a number determined as being the maximum for the particular veld type.
  * The land user may not burn any of his veld, or graze veld that has been burnt, unless he is in possession of a permit to do so. Fire is recognised as a management tool in KwaZulu-Natal, and permission to burn has been granted

by declaration in Government Gazette No. 14058 dated 26th June 1992, but under certain conditions. KwaZulu-Natal has been divided into six different veld burning control zones. With the exception of the Dry Thornveld, each zone has its own set of prescribed dates during which burning may take place, dependent upon antecedent rainfall and management practices.

* Veld burning in the Dry Thornveld is considered on merit each time a land user wishes to burn.
* No grazing is allowed until the sward has attained a minimum height of 100 mm after the burn.

The whole question of burning is more fully dealt with in Guideline No 1.4 entitled `Regulations Controlling the Burning of Veld and Crop Residue in KwaZulu-Natal' in this series.

* **Invader plants and weeds**

  In terms of Act 43/1983, certain plants are declared invader plants, and others, weeds. Invader plants must be effectively controlled if they occur in such numbers on a farm that they constitute a threat to the production potential of the land. Weeds are recognised in two different categories. One category of weeds may not be present on farms at all in areas that are specified in the Act, either Republic-wide or in certain stated Provinces, while the other category includes plants that must be kept under control on all farm units in areas that are similarly specified in the Act. No declared weeds may occur in urban areas under any circumstances. It is an offence to disperse, or promote the dispersal, of any declared weed material (including seed) in any manner, be it by sale, exchange, advertisement, etc., anywhere in the Republic of South Africa.

  The list of invader plants and weeds appear in the Government Gazette No. 9238 dated 25 May 1984. A summarized version of the lists is attached as Appendix 1 to this leaflet.

ADVISORY SERVICES FOR THE CONSERVATION OF AGRICULTURAL RESOURCES IN KWAZULU-NATAL

Both the Soil Conservation and the Agricultural Extension Services of the Department of Agriculture provide a free conservation advisory service to users of agricultural land in KwaZulu-Natal in order to assist them with the best management practices for the natural resources on their farms. The Experiment Station of the S.A. Sugar Association (SASEX) provides a similar service for registered sugarcane planters, although there is a charge attached.

The Advisory Services cover the following:

* **Cultivated Land**

  Cultivated land in general: A Runoff Control Plan (called a Landuse Plan by SASEX) for protecting the land from erosion by rainfall runoff will be drawn up. This comprises the identification of suitable discharge areas (very often in the form of artificial or pre-constructed waterways), the siting of suitable infield roads, and the layout of contour banks in order to divert excess runoff from the lands in a controlled and non-erosive manner. The plan is presented on a map of the land unit at a suitable scale. A follow-up service provides the dimensions of the structures, and the marking of them on the land. It is then up to the land user to ensure that the structures are built. Due to staff shortages and the pressure of work, it is becoming increasingly difficult to supply the complete survey service, but the marking of waterways, at least, will be carried out by Departmental staff, and the farmer will be taught to survey his own contour banks.

  Irrigated land: Where waterlogging and/or salinization of irrigated land is causing a reduction in yield, the local Soil Conservation Officer will carry out a thorough investigation, will supply detailed plans and specifications for drainage, and will mark the position of proposed drainage lines on the ground.

  Timber land: The Directorate of Forestry of the Department of Water Affairs and Forestry provides a free extension service to plantation owners. This includes matters of a resource conservation nature. Soil Conservation and Extension Officers of the Department of Agriculture will also, on request, assist in the layout of plantation roads, and give general advice on the correct tillage practices to follow and on other resource conservation matters.

* **Wetlands**

  While the best techniques for wetland management are not yet fully understood, both Departmental and KwaZulu-Natal Parks Board officials are in a position to advise on basic principles at this stage. The land user should consult his local Extension Officer in this regard.

* **Natural Veld**

  Both Extension and Soil Conservation staff of the Department of Agriculture will assist the land user, at not cost, in compiling a fencing plan for his natural veld. They will make suggestions regarding the most economical methods of stockwatering, and will draw up a veld management plan, indicating the numbers and type of stock which the specific veld types can carry. Implementation of rotational grazing systems will be part of the recommendations.

* **Invader plants and weeds**

  Advice on combating these plants can be obtained from the local Extension Officer.

FINANCIAL AID IN PREVENTING FARMLAND DEGRADATION

In terms of Act 43/1983, subsidies and loans at low interest rates are available in respect of:

* Soil conservation works such as internal camps and erosion control fencing, stockwatering facilities, runoff control structures, subsurface drainage and gulley stabilization structures.
* Repairs to flood-damaged soil conservation works in areas proclaimed under a Flood Relief Scheme.
* Herbicides for the control of specified noxious weeds: at the moment chemicals are only supplied for the control of Jointed cactus and Nassella tussock grass.

PROCEDURES INVOLVED WHEN DEGRADATION TAKES PLACE

Act 43/1983 requires that users of agricultural land conserve their resources in the manner spelled out in the foregoing sections. Inspectors from the Directorate of Resource Conservation of the Department of Agriculture carry out inspections in a random manner throughout their given area, in this instance the province of KwaZulu-Natal. Wherever they come across cases which are in conflict with the aims of Act 43/1983, they will visit the land user, and will point out the cause for concern. If it is apparent that the malpractice was in direct contravention of a regulation, and was done through gross negligence, or if the land user will not co-operate to correct the malpractice, a charge may be laid against him immediately. Otherwise, the solution to the problem will be explained to the land user, who will then be given a specified period of time in which to correct the malpractice, *i.e.* issued with a Direction. Should the land user have not complied with the requirements of the Direction within the specified time, a submission for a charge to be laid against the transgressor will be made with the Public Prosecutor.

Penalties which can be incurred on conviction range from a fine not exceeding R500, or three months in prison (or both), to one not exceeding R10 000, or four years in prison (or both), depending upon the nature of the contravention.

THE ROLE OF CONSERVATION COMMITTEES

Conservation Committees, comprising *bona fide* farmers from the area concerned, are established in most magisterial districts throughout KwaZulu-Natal, in order to:

* promote, by means of persuasion, the conservation of the natural agricultural resources in the area under their jurisdiction, and
* advise the Minister of Agriculture on any matter concerning the application of Act 43/1983, or on any of its financial assistance schemes.

Committee members are nominated by the local farmers' associations and appointed by the Minister of Agriculture. Their *modus operandi* is by way of meetings and inspection visits to farms, and the holding of farmer information days. They co-opt suitably experienced and knowledgeable persons, such as Conservation and Extension officers, to assist them in their duties.

AWARDS IN AGRICULTURAL RESOURCE CONSERVATION

* The local conservation committees organise farming competitions on a regular basis, with conservation of the resources as the main theme. Land users in the district are urged to enter their farms in these competitions. Choosing a winner means that suitably qualified judges must carry out a comprehensive inventory of the farm and farming operations. The actual awards are but one aspect of the competitions. Judges' comments are offered to all entrants, and in this way farm competitions become an ideal method of promoting sound conservation practices.
* KwaZulu-Natal is divided into four regions for administrative purposes, and the Ian Sclater Trophy is competed for each year, in a different region, on a roster system. The trophy is awarded on an inter-district basis, when the winners of the various district competitions in the region are judged.
* The Mercury Trophy is an annual award, presented to the Conservation Committee which made the greatest effort towards the conservation of the agricultural resources in the preceding year. The award is handed to the Chairman of the winning committee at the annual KwaZulu-Natal Agricultural Union Congress.
* The Themeda Award is made to a farmer in respect of an economically sound farming system which, on a whole-farm basis, meets a certain high standard of conservation. It is awarded by the KwaZulu-Natal Conservation Advisory Board and the ceremony takes place at the annual Congress of the KwaZulu-Natal Agricultural Union. The minimum standards by which a farm is judged, and which serve to indicate the criteria to which a conservation-minded farmer should aspire, are given in Appendix 2 to this Guideline.

REFERENCES

Notice No. 883, Government Gazette, No. 8673, 27th April 1983.

Notice No. R1048, Government Gazette, No. 9238, 25th May 1984.

APPENDIX I

List of Declared Invader Plants and Weeds of Legal Significance on Farmland in KwaZulu-Natal

* **Weeds that may not exist on farmland:**

Dagga	Rock hakea	Silky hakea
Sweet hakea	White tussock	Nassella tussock

* **Weeds that must be controlled if growing on farmland in KwaZulu-Natal:**

Australian albizia	Camel thorn	Mauritius thorn
Queen of the night	Yellow cestrum	Ink berry
Chilean cestrum	Triffid weed	Moon cactus
Lantana	Jointed cactus	Clover broom rape
Barbados gooseberry	American bramble	Red sesbania
Satans bush	Bugtree	Bitter apple

All the prickly pear (Opuntia) species

* **Invader plants, the spread of which must be controlled in KwaZulu-Natal:**

Rooikrans	Sweet thorn	Australian blackwood
Silver wattle	Golden wattle	Black wattle
Red-heart thorn	Port Jackson willow	Threehook thorn
Umbrella thorn	Cork tree	Wild currant
Rough-leaved raisin	Australian myrtle	Red-spike thorn
Cluster pine	Camphor bush	Silver terminalia

APPENDIX 2

The Themeda Award

OBJECTIVE

To give recognition to a farmer who has achieved a high and sustained conservation standard, while implementing sound management practices on the farming unit as a whole.

THE AWARD

* The minimum standard is measured against a set of criteria based upon accepted conservation practices.
* Recipients of the award have the right to use the emblem on, for example, farm signboards and letterheads.
* Should the standard of a recipient's farm deteriorate below the norm, the KwaZulu-Natal Regional Conservation Committee will require him to refrain from using the logo, in any form, until the standard has improved.
* It is made to a person or company for a specific farm unit.
* The award comprises a plaque showing the logo and is inscribed with the name of the issuing body, the name of the recipient and the date of issue.
* The award is made by the KwaZulu-Natal Conservation Advisory Board.

NOMINATION PROCEDURES

* Conservation Committees are invited to nominate local farmers who they feel are worthy of consideration. This nomination normally takes place in the latter half of the year.
* A regional selection committee, comprising the members of the various KwaZulu-Natal Conservation Committees and Regional Officers, together with any specialist considered necessary, visits the farm and evaluates its standard against the set of standards set out below.
  - The findings of the selection committee are discussed and accepted or rejected at the bi-annual meeting of the KwaZulu-Natal Regional Conservation Committee which is held in February or March each year.
  - The award is made at the congress of the KwaZulu-Natal Agricultural Union each year.

CRITERIA AND MINIMUM STANDARDS FOR EVALUATION

To qualify for the award the farm must satisfy certain minimum standards in respect of each component of the farm.

Veld

* Veld types must be separated.
* The official grazing capacity of the veld may not be exceeded in a period of twelve consecutive months.
* A grazing system must be applied which allows the following:

Locality	Grazing period (days)	Rest period (days)
Highland Sourveld	7 to 10	30 to 40
Tall Grassveld	10 to 14	45 to 55
Sweetveld	14 to 20	60 to 70

or

If a 4-camp system, or less, is applied, then one-quarter of the veld must be rested each year. Greater leniency may be applied to veld requirements when the area of veld is limited to less than 20% of the total area of the farm

or

Where veld plays such a minor role in the fodder flow programme that a camping system is not warranted, the condition of the veld must prevent greater soil loss than would occur from well-managed veld.

* Veld must be burnt, and utilized, in accordance with the KwaZulu-Natal Veld Burning Control Measures.
* All camps must have permanent stockwatering facilities which do not promote erosion.

Animal performance

Because of the logistical problems of carrying out a veld condition assessment on each farm judged, animal performance is used to assess whether the stocking rate matches the actual grazing capacity of the veld.
A minimum of the following must be achieved:

* Reproduction rates:

Calving	80%
Lambing	100%(woolled sheep)
	120% (dual-purpose sheep)
	120% (mutton sheep)
	140% (goats)

* Average weaning mass of 190 kg for cattle.
* Wool production (12 months):

Woolled sheep	5 kg
Dual-purpose sheep	4.5 kg

Cultivated land

* There must be a properly designed, implemented, and maintained runoff control plan for all cultivated land, including properly placed access roads.

Wetlands

* Must be in a well-conserved state.
* Must be clear of all weeds and invader plants.

Farm roads
These must be correctly sited, regularly maintained, and properly drained so that they do not cause damage.

Economics
The farming unit must be an economically viable enterprise.

Noxious weeds
None of the following may be present on the farm:

Dagga	Rock hakea	Silky hakea
Sweet hakea	White tussock	Nassella tussock

All other declared weeds and invader plants must be under control (*i.e.* not spreading).

Eroded areas
These must be fenced off, with erosion control structures where necessary in order to curb active erosion.

Timber

* Spill-over roads should be on the contour and/or on crests, with diagonal roads only where steepness necessitates.
* Plantation slash should preferably be stacked on the contour or scattered as a blanket.
* Land preparation must be in accordance with the officially recognised `Soil and Water Conservation Norms for the Timber Industry in KwaZulu-Natal'.
* Firebelts must be strategically placed, and fully protected against soil loss.
* The timber that is planted near the edge of watercourses, springs, vleis, and indigenous bush must be no closer than that specified on the planting permit for the farm.
* Harvesting methods must not increase the risk of erosion.

Irrigation practices
Application of water should be based upon soil characteristics and a satisfactory scheduling procedure.

REFERENCES

Notice No. 883, Government Gazette, No. 8673, 27th April 1983.

Notice No. R1048, Government Gazette, No. 9238, 25th May 1984.

Conservation of Farmland in KwaZulu-Natal

FINANCIAL AND TECHNICAL ASSISTANCE FOR THE PLANNED UTILIZATION OF THE AGRICULTURAL RESOURCES

R G Mattison
KwaZulu-Natal Department of Agriculture

INTRODUCTION

The Conservation of Agricultural Resources Act (Act No. 43 of 1983) provides for control over the utilization of the natural agricultural resources of the Republic of South Africa, in order to promote the conservation of the soil, the water sources and the vegetation, as well as for the combating of weeds and invader plants. It also provides for financial assistance to users of agricultural land in order to assist them in carrying out the requirements of the Act by means of the institution of a number of financial assistance schemes, described below. These Schemes are administered by the Department of Agriculture through the Soil Conservation Officer attached to the local governmental Agricultural Extension Office. There are also other assistance schemes for the supply of water for both stockwatering and irrigation, which are provided for by the Water Act (No. 54 of 1956). These are also described. ***In every case, a written approval must be obtained before any works under any of the Schemes may be commenced.*** Failure to do so will result in rejection of the claim for financial assistance.

THE SOIL CONSERVATION SCHEME

Financial and technical assistance under this Scheme is only available to those land users who do not overstock their veld, and who erect the necessary structures in the positions recommended by a Departmental planning officer, and in accordance with the specifications issued. In initiating the farm planning process, the land user makes formal application to participate in the Soil Conservation Scheme, supplies a certified copy of the title deeds pertaining to the farm unit and indicates the boundaries of the farm on a standard aerial photograph obtainable at the local Agricultural Extension Office. While the user of the land (manager, lessee, *etc.*) may apply to enter the farm in the Scheme, subsidies are only paid to the registered owner of the farm, unless the latter has signed a cession in favour of someone else. A photo-based farm map is produced to a suitable scale free of charge by the Department of Agriculture. A farm plan is drawn up on this map by the Soil Conservation Officer in consultation with the land user, although the latter is quite at liberty to draw up his own plan, and if it meets Departmental requirements it will be accepted. The main factors influencing this plan are the farmer's choice of enterprise (*e.g.* beef, mutton, grain production, *etc.*), topography of the farm, soils, aspects, climate, etc., and the measures needed to combat farmland degradation which occurs when agricultural activities take place. The objectives of the plan are to make provision for the placing of soil conservation works that will facilitate conservation farming. Careful consideration is given to the placing of camp fencing, stockwatering facilities, erosion control measures, to the layout of roads and the control of runoff water, to herd management requirements, and to cropping practices, all of which will control soil loss if correctly planned, designed and constructed. The various aspects are dealt with in greater detail below.

* **Fencing**
  Camp fencing involves the exclusion of eroded areas and cultivated land camps from grazing areas, and the separation of different veld types and areas of differing production potential into veld grazing camps of a manageable size. Camp sizes are based on the grazing capacity of the veld, the herd size and composition, and the number of herds required for the animal enterprise(s). Sufficient veld camps (to a maximum of six per herd) are planned to ensure that the veld will acquire sufficient physiological rests during the growing season, through rotating of the herds, so that the sward will not degenerate either in basal cover, species composition, or both. Boundary fencing is not subsidizable.
* **Stockwatering**
  The provision of permanent watering facilities is planned and designed to ensure that the optimal use of the veld in each camp is achieved. Different options are considered from an economic point of

view. The watering points can take any form, from a catchment storage dam to a complicated pipeline reticulation system. Soil Conservation Officers will carry out the survey and design, and will provide specifications free of charge.

* **Runoff Control Planning on Cultivated Lands**
  Assistance with the survey and design of adequate surface drainage systems for the safe disposal of excess rainfall will be given. These include stormwater drains, waterways, contour bank systems and access roads. Whole catchments can be planned and, when topography is such that farm boundaries have to be crossed by structures, the protection works are planned so that they accommodate all properties involved.
* **Subsurface Drainage of Irrigated Land**
  Where waterlogging and/or salinization of the soil is causing crop yield reductions, remedial plans for the lowering of the water table and/or the leaching out of harmful salts through the installation of subsurface drains will be drawn up to assist in the solution to the problem. Note that cost-sharing in this instance does not apply to lands under dryland cultivation.
* **Gulley Stabilization**
  Active erosion in gulleys can be controlled by the construction of such structures as concrete weirs, gabion structures, chutes and earthen diversion embankments. Assistance in the form of designs and cost-sharing on such work is also available.

PARTIAL FARM PLANNING

While the ideal would be for a land user to carry out a conservation plan to cover all aspects of possible environmental degradation in one action, this need not necessarily be the *modus operandi*. Provision is also made in the Scheme for partial planning of the farm. The land user might, for instance, only require assistance for the fencing of veld to begin with, without wishing to give immediate attention to the remainder of his farming enterprises. Such a partial farm plan would then only deal with the physical requirements of veld management, but in all its aspects. This would mean that the plan drawn up would include the provision for sufficient permanent stockwatering facilities in each grazing camp if such is not already available.

SPECIFICATIONS OF SOIL CONSERVATION WORKS

Inasmuch as public funds are used to provide cost-sharing for the construction of these works, minimum standards of construction are laid down and must be adhered to if the works are to be recommended for subsidy. So, for instance, in the case of fencing, a minimum of a five-strand fence is required (four strands in bushveld areas), with treated straining/corner posts bearing the SABS mark, with standards no more than 20 metres apart and with a minimum of four droppers in between. In the case of stockwatering facilities, for instance, catchment storage dams are designed for a twenty-five year frequency storm flood, polyethylene piping must bear the SABS mark, and brick reservoirs must have a certain minimum amount of reinforcing.

SUBSIDIES (COST-SHARING)

Tariffs are fixed for the cost-sharing of various categories of works based on an average cost for the country as a whole, and they vary between:

- 25% for veld utilization works such as camp fencing, reservoirs, pipelines, troughs, and storage dams (either concrete or earthen work) for stockwatering purposes,
- 33% for subsurface drainage of irrigated land in order to combat waterlogging and salinization,
- 70% for construction of erosion control structures such as fences to protect eroded areas, stormwater drains, waterways and contour banks on cultivated lands, and for gulley control structures. In this specific group of works, when the subsidy paid out passes the R 5 000 mark on the farm as a whole, a sliding scale comes into operation, increasing the amount of subsidy payable beyond 70%.

  After deciding which improvements are to be built within the following year, the land user requests official consent to commence construction. As soon as funds are available, specifications will be drawn up and issued with the necessary consent. When construction of an individual work or group of works is complete, an inspection is carried out. If all the specified requirements have been carried out, the subsidy payment follows. No interim payments on partially completed works will be considered.

LOANS FOR SOIL CONSERVATION WORKS

Money for the construction of these works can be borrowed from the Directorate of Financial Assistance of the Department of Agriculture. The full cost of the work may be borrowed and repaid over a specified period not exceeding 20 years. This redemption period is set by officials of the Directorate and is dependent on the size of the loan. The interest rate is currently 8% per annum. The capital amount borrowed is reduced by the subsidy payable on those works for which a loan was obtained. A mortgage bond is registered against the title deeds of the farm as security, at State cost, and payments may be requested as the work progresses. Existing bondholders should be convinced that the purpose of the loan will enhance the value of the property. Should the registration of this bond be unacceptable to them, no assistance can be offered. However, they are at liberty to submit clauses to satisfy their requirements to the State and if these are acceptable the registration will be concluded.

THE QUID PRO QUO

Strong emphasis is placed on the conservation of veld, and NO SUBSIDY payments are made if the livestock numbers on veld exceed the prescribed limits for that farm unit. In fact, while the State provides for the sharing of costs on the construction of approved soil conservation works, it is expected of the applicant that he will, in turn, carry out conservation measures between the structures. Having received a subsidy on stock fencing and watering points, for example, he is obliged to practise correct rotational grazing and resting, as prescribed in the farm plan. He is also required to maintain works which have been subsidized, or pay back the amount of subsidy granted on the non-maintained work.

For further information the reader is advised to contact his local Agricultural Extension Office.

THE FLOOD RELIEF SCHEME

The object of this Scheme is to assist financially in the repair of flood damage to soil conservation works that were previously subsidized, so that production potential is maintained and excessive soil loss prevented. The Scheme is applicable in areas which have suffered such damage by flooding that a Ministerial declaration has been issued declaring a state of disaster in specified magisterial districts.

The following structures are included for cost-sharing under the Scheme: waterways, storm water drains, contour banks, fences (including boundary fences), storage dams, erosion control structures, pipelines and troughs for stockwatering purposes, and any facilities which were previously approved for drought relief, e.g. a stall-feeding facility.

Applications for aid must be submitted to the local Agricultural Extension Office within 6 months of the date of the declaration by the Minister of Agriculture, and the Scheme ceases to operate 30 months after the declaration. No cost-sharing whatsoever will be made after this deadline date.

Damage is assessed and specifications for the repair thereof are issued to the applicants by the Soil Conservation Officers of the Department of Agriculture. Tariffs are set which aim to represent 75% of the cost for all works, irrespective of whether the works are for erosion control, stockwatering or drainage.

THE BUSH CONTROL SCHEME

The object of this Scheme is to promote the control of certain invader plants in the extensive grazing areas of the country, with a view to maintaining the production potential of the land being invaded by the plants. This Scheme is not administered country-wide, as is the case with the Soil Conservation Scheme, but will be instituted in a defined area only after submission by Organised Agriculture, and after it has been proven that the land users in the area cannot carry out the necessary eradication without state assistance. It is allied to the Soil Conservation Scheme in that those persons obtaining assistance for the eradication of the invaders must complete an approved camp fencing plan, and implement a grazing management strategy which will assist in combating the invaders by providing a good grass cover. Where the scheme is implemented, applicants are advised of the method to be adopted for eradication, and paid a subsidy on successful results.

No assistance of this nature is presently available in KwaZulu-Natal.

THE WEED CONTROL SCHEME

The object of this Scheme is to promote the combating of certain weeds with a view to maintaining the production potential of the land. This Scheme becomes applicable upon a declaration by the Minister, in which the locality is defined and the type of weed involved is specified. Cost-sharing under this Scheme in KwaZulu-Natal is only available for the eradication of the following *Opuntia* species:

aurantiaca	-	Jointed cactus
dillenii	-	Pipestem prickly pear
exaltata	-	Long spine cactus
ficus-indica	-	Mission prickly pear (excluding all spineless cultivars)
imbricata	-	Imbricate cactus
lindheimeri	-	Round-leaved prickly pear
rosea	-	Rosea cactus
spinulifera	-	Saucepan cactus
stricta	-	Sour prickly pear
vulgaris	-	English prickly pear

The approved weedkillers, MSMA and Fenoprop, are supplied to applicants free on rail at Fort Beaufort at a subsidized price. Application forms may be obtained from, and must be submitted to, the Chief Resource Conservation Inspector, at P.O. Box 345, Pietermaritzburg, 3200 (phone 0331-453515), who will advise on the procedures to be followed. He will also make regular checks on progress with the eradication and advise on any problems encountered.

FINANCIAL & TECHNICAL ASSISTANCE FOR IRRIGATION DEVELOPMENT

* **Individual private irrigation schemes**
  The Regional Engineer, Directorate of Irrigation, of the Department of Agriculture at Cedara advises on the technical aspects of irrigation schemes. He is also responsible for the administration of the financial assistance schemes incorporated in the Water Act of 1956 (as amended). These cover assistance for both the necessary irrigation equipment for approved irrigation schemes, and for costs charged by approved consulting engineers who are employed for the design

of the scheme. Both are limited to $33^1/_3$% of the actual costs, with a maximum subsidy of R 7 500 per project, in each case. "Necessary irrigation equipment" covers such items as dams, canals, pumps and piping, *etc*. Farmers wanting a subsidy must have the irrigation scheme designed privately by competent persons, or by consulting engineers. The Regional Engineer is available to evaluate such designs at a nominal fee, *viz*:

(i)	Schemes to be erected under the Departmental subsidy scheme	R 100
(ii)	Schemes to be erected under a loan scheme	R 40
(iii)	Schemes designed by consulting engineers	No charge
(iv)	Evaluation of a design by any competent designer	R 100
(v)	Although the Department requires only one design, the applicant may submit two, simultaneously. The charge is then	R 140
(vi)	Site inspection visits by Departmental staff	R 40 per visit

The Regional Engineer checks schemes in good faith and accepts absolutely no liability whatsoever for any oversights or failures which might occur.

* **Irrigation Boards**
  The Regional Engineer assists farming communities with the establishment of Irrigation Boards. The need for an Irrigation Board usually arises when farmers' irrigation needs are no longer being met because of increasing upstream usage or the alleged unfair abstraction of water. At the request of the irrigators the Regional Engineer investigates their needs in order to determine if the formation of an Irrigation Board would benefit them. Factors such as total area under irrigation, potential expansion of the areas under irrigation, availability of water, number of irrigators and crops produced, are analyzed before a decision is made. An Irrigation District is controlled by a committee consisting of irrigators voted onto the Board, with Departmental officials acting as advisors.

An Irrigation Board

* is autonomous, i.e. controls the administration of the Board
* may negotiate loans for development of communal storage facilities, canal systems, pipe layouts, etc.
* is responsible for collecting levies/rates from irrigators
* is responsible for the fair distribution (control) of available water to all irrigators within the Board area
* is responsible for the orderly control and development of the irrigation scheme.

WATER RIGHTS AND PERMITS

Land owners have an intrinsic right to use their fair share of the normal flow of water from a stream or river which runs through their property. It should be noted that the term 'fair share' in a non-controlled water area is usually based on a proportional share of the low flow as determined by the officers of the Directorate of Water Affairs of the Department of Water Affairs and Forestry. The amount of water to which a landowner has an intrinsic right is normally just sufficient for household and stockwatering purposes, and sometimes for a little irrigation as well. On the other hand, and in terms of Section 9B of the Water Act (Act 54 of 1956 as amended), a permit is required by any farmer who impounds more than 250 000 m^3 on one registered property, or diverts more that 110 *l*/sec of surplus water from a public stream. This means that the total quantity of water stored in all the dams on one registered property may not exceed 250 000 m^3, and abstraction may not exceed 110 *l*/sec without a permit. Application for such a permit must be submitted to the Director, Directorate of Water Affairs, P.O. Box 1018, Durban, 4000. This restriction ensures that no individual may threaten the rights of other riparian owners by storing excessive amounts of water, to the detriment of other users downstream. Section 9C of the Act controls the safety aspects of dams. A permit is required for any dam/structure which impounds 50 000 m^3 (or more) of water and which has a wall height of 5 m or more. This permit is available from the Dam Safety Office, Department of Water Affairs, P/Bag X313, Pretoria, 0001. Before undertaking the construction of any storage dams the land user should also determine whether his dam falls within a Government Water Control Area, in which case the impoundment of water is restricted, and in some cases prohibited. Maps showing these areas are available at Extension Offices.

* It should be borne in mind at all times that the subject of Water Rights in general is an involved and complicated one, that very few cases are identical and that there are many exceptions.

FINANCIAL ASSISTANCE FOR THE DEVELOPMENT OF BOREHOLES FOR STOCKWATERING PURPOSES

The drilling of boreholes is expensive and very risky, because of the high percentage of dry holes that are drilled. Fixing the point at which to drill for water should only be done by those qualified in the geo-sciences. The Director, Directorate of Water Affairs, (Box 1018, Durban, 4000; Tel. 031-3061367) has contact with most of the consultants in the groundwater field and could advise on experienced firms or individuals. Reliable drilling contractors are also best chosen on the recommendation of satisfied fellow farmers or by contacting the Borehole Water Association (B.W.A.), at P.O. Box 62397, Marshalltown, 2107.

The following checklist is proposed by the B.W.A. and could be used to avoid disputes between the farmer and the drilling contractor when the former approaches the latter for a quote:

* Enter into a written agreement (an example of which is available from the B.W.A.) with the drilling contractor.
* Insist that the hole is straight and vertical.
* Agree that casing will only be installed where the necessity thereof is indicated by the core record, i.e. excavated material is laid out as excavation progresses, thereby providing a record of the borehole depth profile.
* Ensure that the contractor's equipment is capable of penetration through the rock formations found in the area so that the required depths will be achieved.
* Ensure that the contractor's site representative is suitably experienced.
* Record exact depth to first promising water find, the final depth of the hole and the depth to which the water rises in the borehole. These details are vital for good pumping design.
* Insist on a borehole diameter of 125 mm, although a minimum of 100 mm is acceptable. The 125 mm diameter is very much more practical for the installation of pumping equipment.
* The strength of the borehole must be tested. The officially recognised test is a six hour continuous pumping operation, where pumping is done with a variable capacity pump. When air is pumped through with the water, the delivery rate is adjusted until air is excluded. This adjustment is carried out as necessary over the six-hour period and the capacity of the borehole is the delivery at the expiry of six hours. ***No more than 60% of the tested capacity of the borehole may be used for supply purposes.***

THE STATE DRILLING SERVICE

The Directorate of Soil Conservation and Drilling Services has drilling machines which it makes available to land users at a subsidized rate. For administration purposes the Republic has been divided into sixteen drilling inspectorates. KwaZulu-Natal is served from the Ladysmith office. The drilling inspector can be contacted at P.O. Box 299, Ladysmith, 3370, or by telephoning (0361) 332871. The equipment under his control is allocated to farmers on a priority basis as regards the seriousness of the water shortage. The current (1992) Government drilling fee is R 35/m. The charge for the testing of the borehole is R 28 per hour and that of the casing is R 51.93/m. A subsidy of 55% on the above is applicable.

THE BOREHOLE SUBSIDY SCHEME

The State subsidises the drilling of boreholes by private contractors on a sliding scale, with the following conditions applying:

* Drilling may not commence before official consent is received from the State Drilling Inspector.
* The size of the farm unit on which a subsidy will be paid may not be smaller than 25 ha.
* For a farm situated within the water supply area of a local authority or state body, permission to drill must also have been granted by that body.
* The water to be used must be solely for domestic and/or stockwatering purposes. It is not advisable to irrigate out of boreholes, especially in an area like KwaZulu-Natal, which has a poor record of sub-surface water supplies.
* A valid permit to drill is required if the farm is situated in a Subterranean Water Control Area (SWCA).
  Applications for this permit must be submitted to the Director of Resource Conservation,
  P/Bag X120, Pretoria, 0001. There are at present no SWCAs in KwaZulu-Natal.
* A sliding scale of subsidization applies as follows:
  55% of cost for the first 75 m depth of borehole
  60% of cost for the subsequent 30 m of depth (*i.e.* from 75.1 m to 105 m)
  65% of cost for the subsequent 30 m of depth (*i.e.* from 105.1 m to 135 m)
  70% of cost for the subsequent 30 m of depth(*i.e.* from 135.1 m to 165 m)
  75% of cost for the section deeper than 165 m:
  55% of the cost of casing installed in the borehole
  55% of the cost of the six-hour pumping test, which is mandatory for anyone wanting a subsidy on a borehole. A maximum of R 23.00 per metre depth of borehole casing, and R 23.00 per hour for the pumping test will be paid.

Subsidy payments will be made for drilling up to four boreholes per registered property if the first three are dry. The total amount of subsidy for stockwatering paid under this Scheme is limited to R 25 per large stock unit, based on the official carrying capacity of the veld, with a maximum of R 8 000 per registered property, (*i.e.* for which a separate title deed is held). A further subsidy is payable in respect of the extraction of water from the borehole and the pumping of the water to a permanent reservoir and trough. The Drilling Inspector will advise on procedures to be followed.

TECHNICAL ASSISTANCE WITH PLANTATION ESTABLISHMENT

There are certain restrictions on the large-scale planting of trees as it relates to water consumption. These restrictions are more fully described in the Guideline No. 8.1 in this Series, entitled `Important Aspects Regarding the Establishment of Timber Plantations.'

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Conservation of Farmland in KwaZulu-Natal

WEED AND INVADER PLANT CONTROL

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WEEDS AND INVADER PLANTS

In nature, there is no such thing as a weed. Man describes plants as weeds when they are unpleasant or a nuisance where they are growing. Put another way, a weed is a plant which is incompatible with the management objectives of the land. Farmland is used in different ways, for crops, plantations, roads and firebreaks or left unplanted as veld, forest and watercourse. Undesirable plants (weeds) can grow in any of these situations and might have to be controlled. Any alien (exotic) plant can be declared a weed under the Conservation of Agricultural Resources Act (Act 43 of 1983) if there is evidence that it is affecting the production potential of land. The species listed in the Regulations at present are trees, woody shrubs and climbers, succulents (there are 12 species of cactus), broad leaf herbaceous annuals and perennials, perennial grasses and waterweeds. Invader plants are either indigenous species which spread from their usual habitat, *e.g.* many Thornveld species, or alien plants which are grown as crops but which also spread and cause problems in other areas, *e.g.* pines and wattles. See Appendix 1 for a list of weeds and invader plants as declared in terms of Act 43/1983.

WEEDS AND INVADER PLANTS AFFECT LAND USE IN TWO WAYS:

1 THEY DISRUPT THE NATURAL ECOLOGY OF VELD, INDIGENOUS FOREST AND RIVERINE VEGETATION.

* The competitive forces on indigenous plants are increased. Aliens are often quick-growing and increase the demand for soil moisture, nutrients and light in the plant community. Low-growing plants and tree seedlings can be smothered as the density of the vegetation increases. The number of species (species diversity) will probably decline as some indigenous species are unable to cope with the changed conditions.
* The habitat for wildlife is changed. The sources of food, type of shelter and micro-climate for birds and animals will change, some of those present may migrate, and others take their place. Some insects might die out.
* The intensity of fires is increased. The additional leaf litter and dry material will cause more heat to be generated by fires and the damage to all plants in close proximity to the aliens will increase.
* Stream flow is altered. Alien plants often grow in dense patches. This growth beside streams prevents flood waters dispersing onto the floodplain, and the banks become eroded. Debris accumulates in the water and damages fences and low-level bridges down-stream. In the dry season, water-use by the same plants reduces stream flow. The common water weeds are aliens and their presence in a river or dam can affect the fish population and the quality of water extracted from it.

2 THEY CAUSE EXTRA EXPENSE TO LAND USERS

* Additional weed control is required in annual crops. Only a few annual plants are declared weeds. Those listed require special attention as they produce many seeds and either their fruits contaminate the coats of livestock or the leaves are poisonous. Burr weed is a continuous threat in annual crops because of delayed germination. It forms dense thickets on reverted land which are difficult to eradicate when crops are planted again. There are signs that bugweed seed is so common in places that it could become a nuisance on reverted lands.
* Livestock management is made more difficult. Sprawling shrubs reduce the available grazing, prevent animals reaching all parts of the pasture, delay the collection of stock and can provide cover for predators. Some species are poisonous, *e.g.* Lantana and Ink berry, and Nassella tussock grass destroys Themeda veld in the Eastern Cape

by smothering it.

* Movement of workers in timber plantations is obstructed. Timber plantations are left undisturbed for many years and woody weeds grow unchecked. Often, they must be cut down or killed before workers can tend the trees.
* Visibility is reduced for road users. Tall plants growing beside secondary roads reduce the sight distance of drivers and have to be removed by the authority responsible for the road.

PREVENTION IS BETTER THAN CURE

Alien plants do not become weeds overnight. Many were introduced intentionally or by accident up to 100 years ago. They have become "problem plants" which warrant attention by the State because of ignorance and insufficient control by land users.

1 All land users should be aware of the plants on their land and know which are indigenous and which are alien.

2 All alien plants not required for production or for aesthetic reasons (*e.g.* in parks and gardens) should be eradicated, and, if so desired, can be replaced with indigenous plants. Many weeds were introduced as ornamental plants and new and exotic plants continue to be imported by the nursery trade. Hedge clippings and prunings should be burned and not discarded on public rubbish dumps to cause trouble in the future.

3 Conservation organisations should include alien plants in their responsibilities and request private and public land users to eradicate them where they are not being 'used', and, particularly, where they are spreading.

4 Control or eradication of small areas of a plant does not require large resources and the use of herbicides is not a prerequisite. Adequate knowledge, motivation and a minimum of organisation and labour can achieve a great deal. Repeatedly cutting down a plant close to the ground will eventually kill it and any seedlings that emerge can be easily pulled out.

5 Guidance should be obtained before the control of large infestations is attempted. Contact an Extension Officer of the Department of Agriculture or staff of the Directorate of Resource Conservation for sources of information. The work will take a number of years, and objectives must be set for each year. Include neighbours as well so that a "weed free zone" may be created. There is always a danger that initial enthusiasm will wane and that seedlings will not be removed, with the result that after a few years there will be no visible improvement.

APPENDIX 1:

LIST OF DECLARED INVADER PLANTS AND WEEDS OF LEGAL SIGNIFICANCE ON FARMLAND IN KWAZULU-NATAL

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* **Weeds that may not exist on farmland:**

Dagga	Rock hakea	Silky hakea
Sweet hakea	White tussock	Nassella tussock

* **Weeds that must be controlled if growing on farmland in KwaZulu-Natal:**

Australian albizia	Camel thorn	Mauritius thorn
Queen of the night	Yellow cestrum	Ink berry
Chilean cestrum	Triffid weed	Moon cactus
Lantana	Jointed cactus	Clover broom rape
Barbados gooseberry	American bramble	Red sesbania
Satan's bush	Bugtree	Bitter apple

All the prickly pear (Opuntia) species

* **Invader plants, the spread of which must be controlled in KwaZulu-Natal:**

Rooikrans	Sweet thorn	Australian blackwood
Silver wattle	Golden wattle	Black wattle
Red-heart thorn	Port Jackson willow	Threehook thorn
Umbrella thorn	Cork tree	Wild currant
Rough-leaved raisin	Australian myrtle	Red-spike thorn
Cluster pine	Camphor bush	Silver terminalia

REGULATIONS CONTROLLING THE BURNING OF VELD AND CROP RESIDUE IN KWAZULU-NATAL

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INTRODUCTION

The burning of veld for management purposes, and the burning of crop residue for simplifying both harvesting e.g. sugarcane) and land preparation (*e.g.* maize) is regulated by two different Acts of Parliament, *viz:*

* the Forest Act (No. 122 of 1984) in respect of the burning of firebelts and crop residue as a method of wild-fire control;
* the Conservation of Agricultural Resources Act (No. 43 of 1983) in respect of the burning out of whole grazing camps as part of a veld management strategy.

Predetermined dates for both types of burning practices have been set, and any user of agricultural land should be fully aware of his responsibilities before setting alight any combustible material on his farm. It must be pointed out that these regulations have been based on the findings of, and the experience gained by, grassland scientists over many years.

It should be noted that the veld burning regulations in terms the Conservation of Agricultural Resources Act No. 43/1983 are changed from time to time, and this makes it necessary for all farmers to acquaint themselves with the prevailing rules. Rules presently in force are set out in Table below.

GENERAL PROHIBITIONS ON THE LIGHTING OF FIRES

These are regulated by the Forest Act, and are summarized as follows :

1. In the magisterial districts of Alfred, Bergville, Camperdown, Estcourt, Ixopo, Lions River, Lower Tugela, Mooi River, Mpendle, New Hanover, Pietermaritzburg, Polela, Richmond, Umvoti and Underberg, and during the period stretching from 1 May to 30 November no person shall, from 18:00 on Fridays to 06:00 on Mondays, make a fire in the open air or, if such a fire has been made, allow it to continue to burn or add fuel thereto, other than:-
   a) fires made within a demarcated picnic or camping area or holiday resort, but only at places within such a demarcated area as have been specifically prepared and maintained for that purpose;
   b) fires for the preparation of food on residential stands which have been adequately protected by fire breaks; and
   c) fires to facilitate the harvesting of sugar cane, which is to be allowed from 18:00 on Fridays to 08:00 on Saturdays and from 17:00 on Sundays to 06:00 on Mondays.

2. In the areas mentioned and during the period stretching from 1 June to 31 October, no person shall destroy any ground cover, including any plantation slash or harvest residue, by burning, other than:-
   a) maize harvest residue, which may be destroyed by burning from 14:00 to 24:00 daily, except for the period from 18:00 on Fridays to 15:00 on Mondays.
   This regulation is subject to Regulation 12, promulgated in terms of the Conservation of Agricultural Resources Act, (Act No. 43 of 1983).

3. In the areas mentioned and during the period stretching from 1 August to 30 September, the clearing or maintenance of fire belts by burning, is prohibited. External fire belts, prepared before 1 August, are to be at least nine metres wide and are to be kept clear of combustible material during the dry season.

4. In the areas mentioned and during the period stretching from 1 July to 31 October, the execution of block burns, including the burning is defined as the burning of an area of grassland, which has been adequately protected by an external firebelt with a minimum width of nine metres.
   All block burning practices are to be subject to Regulation 12, promulgated in terms of the Conservation of Agricultural Resources Act, (Act No. 43 of 1983).

It is extremely important to note that the dates mentioned may be altered from year to year, depending upon climatic conditions. The above-mentioned restrictions were in force as at 1 May 1997.

The Regional Director, Department of Water Affairs and Forestry, at Pietermaritzburg or Eshowe, will be able to advise on current prohibitions.

NOTIFICATION OF THE CLEARING OF FIREBELTS

In terms of the Forest Act :

* within a Fire Control Area, every land user must enter into a written agreement with each of his neighbours as to the width, method of clearing, sharing of cost, *etc.*, of their mutual boundary firebelts;
* outside of a Fire Control Area, a land user must notify his neighbour in writing, and the local fire warden, of his intention to clear a firebelt by burning and when he intends burning his veld.

For further particulars regarding Fire Control Areas, see Appendix 1.

The notes given are based on a publication by the Directorate of Forestry of the Department of Water Affairs and Forestry.

BURNING OF VELD FOR MANAGEMENT PURPOSES

In terms of Regulation 12 of the Conservation of Agricultural Resources Act, no land user may:
* burn any veld on his farm unit,
* utilize as grazing any veld that has been burned, without a permit from the Executive Officer appointed in terms of Act 43/1983 to do so. This latter restriction applies equally whether the veld was burned on purpose or as a result of an accidental run-away fire.

The permit will only be granted

* if veld burning is an accepted management practice for the veld type concerned,
* if exceptional circumstances prevailing on the farm warrant the burn,
* subject to the provisions of the Forest Act.

Veld burning is recognized as a necessary veld management tool in most veld types in KwaZulu-Natal, and is to be practised with judicious care for the maintenance of a vigorous sward. Procedures have been put into operation in order to obviate regular requests from land users for permission to burn their camps.

1 The Province of KwaZulu-Natal has been divided into six veld burning control zones, as indicated in Figure 1 to V and in Table 1.

2 Set periods and conditions based on long-term research, have been determined for the burning of veld and for the grazing of burnt veld in all of the veld burning zones except for the Dry Bushveld, where prior permission must be obtained whenever veld needs to be burned.

3 In terms of a proclamation in the Government Gazette No. 14058, land users are granted permission to carry out burning practices within the burning periods indicated in column 2 of Table 1, for the specific veld burning zone indicated in column 1 of Table 1. It is each land user's own responsibility to make sure of the veld burning zone in which the farm on which he plans to burn is situated, and to ensure that he adheres strictly to the periods in which veld may be burnt in that zone.

4. Burning of veld and crop residue can be carried out in accordance with the provisions in Table 1 anywhere in the Province providing that

   i) the land owner intending to burn contacts the local Fire Control Committee or Fire Protection Association and his neighbours
   ii) the landowner has firebelts, cleared of all inflammable material and at least 9 metres in width, round the area he intends burning and along all the boundaries of his property.

5 Any land user who is forced to deviate from the officially recognised dates for burning, as well as land users in the Bushveld burning zone, must submit an application in writing at least 30 days prior to the intended date of burning to the local Extension Officer of the Department of Agriculture furnishing him with the reasons for the need to burn (in the case of the Bushveld) or for the need to deviate from the specific dates (in the case of all the other veld burning zones). All farmers must comply with the provisions of the Forest Act (Act No. 122 of 1984), irrespective of whether special permission has been received to burn veld outside the periods stipulated in Table 2 or not. This implies that land users must still take the necessary precautionary measures before burning, and adhere to the burning prescriptions and procedures as stated in this Act. It also implies that the land user must inform the local

PROPOSED VELD BURNING AREAS OF KWAZULU-NATAL

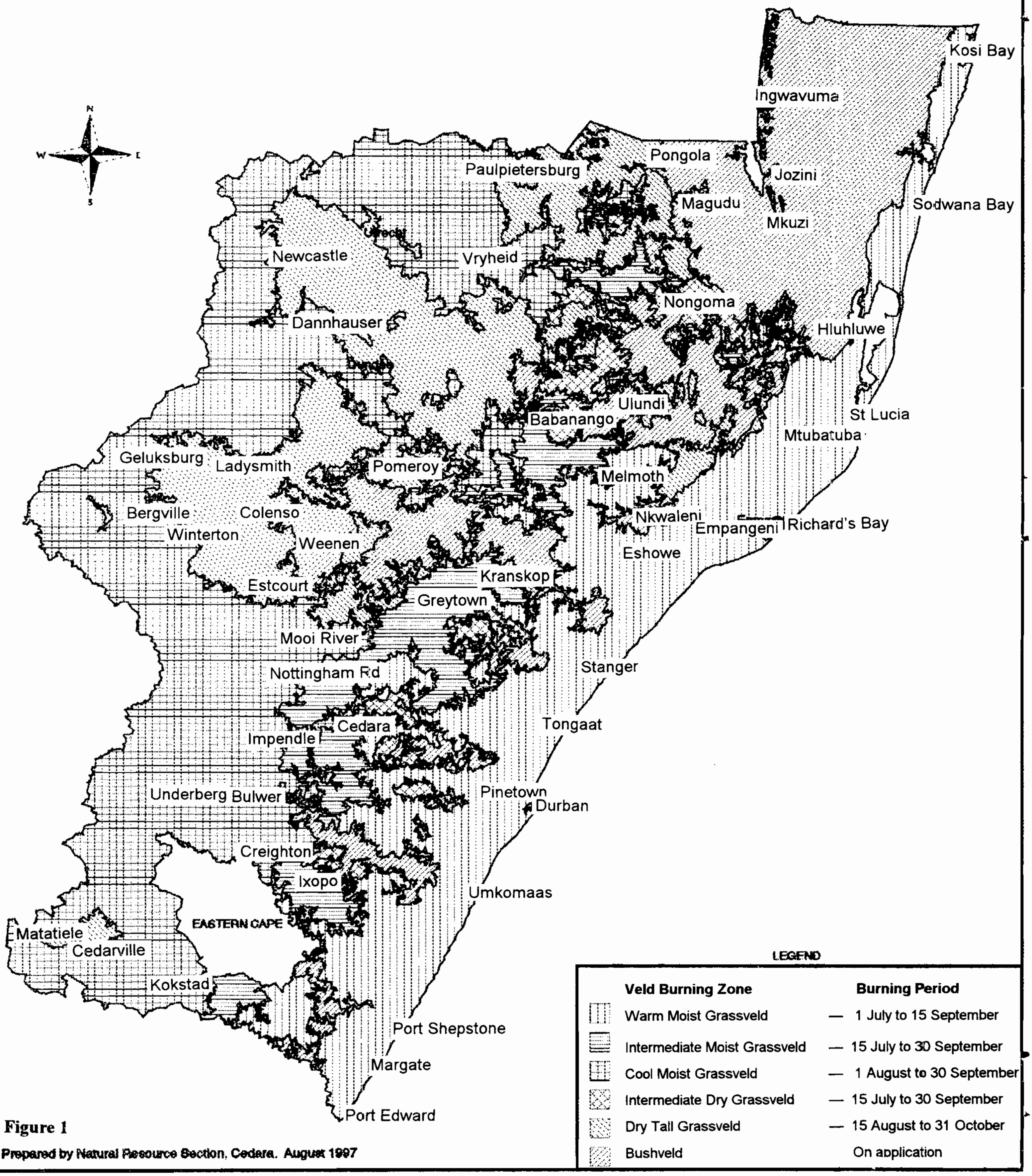
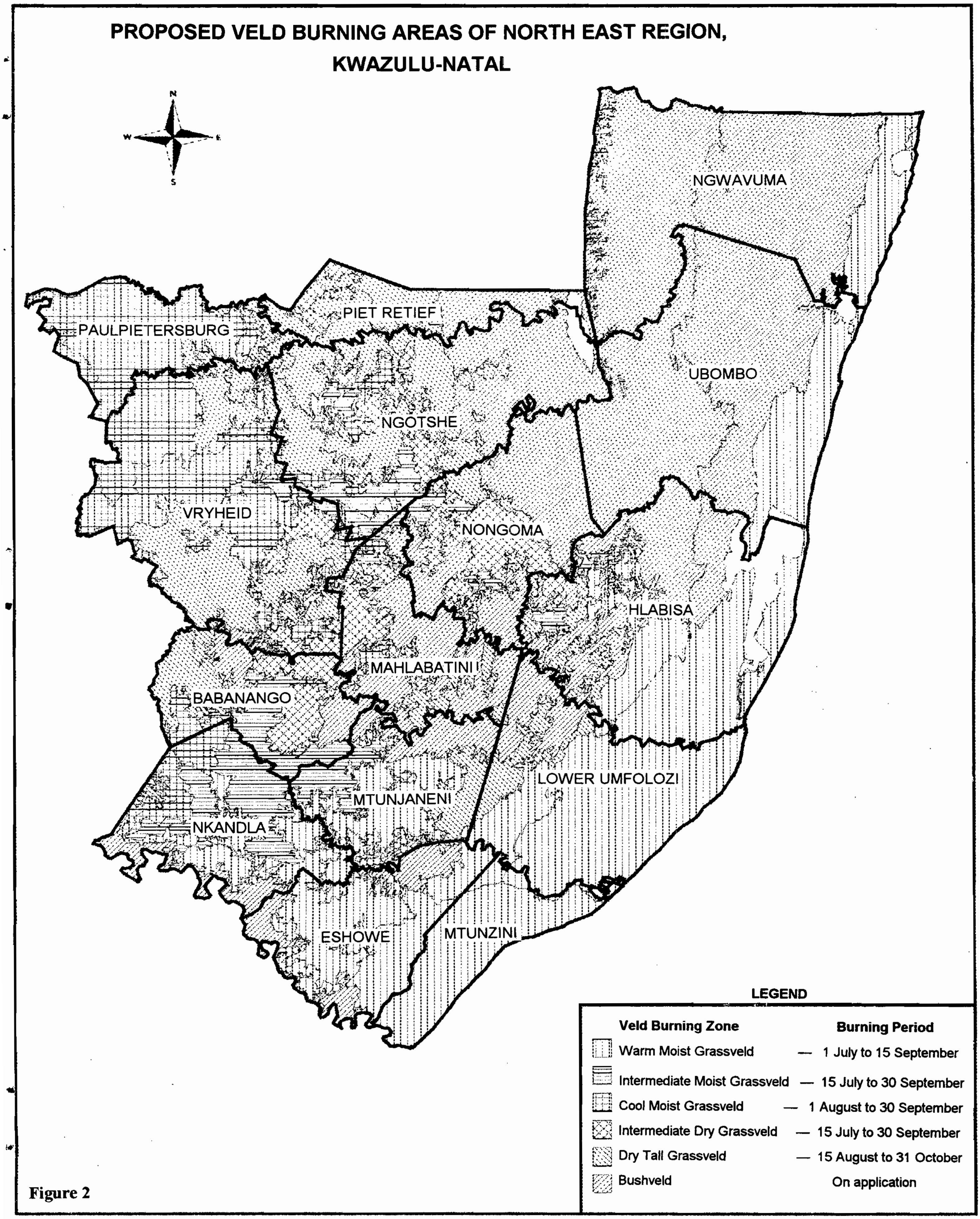


Figure 1

Prepared by Natural Resource Section, Cedara. August 1997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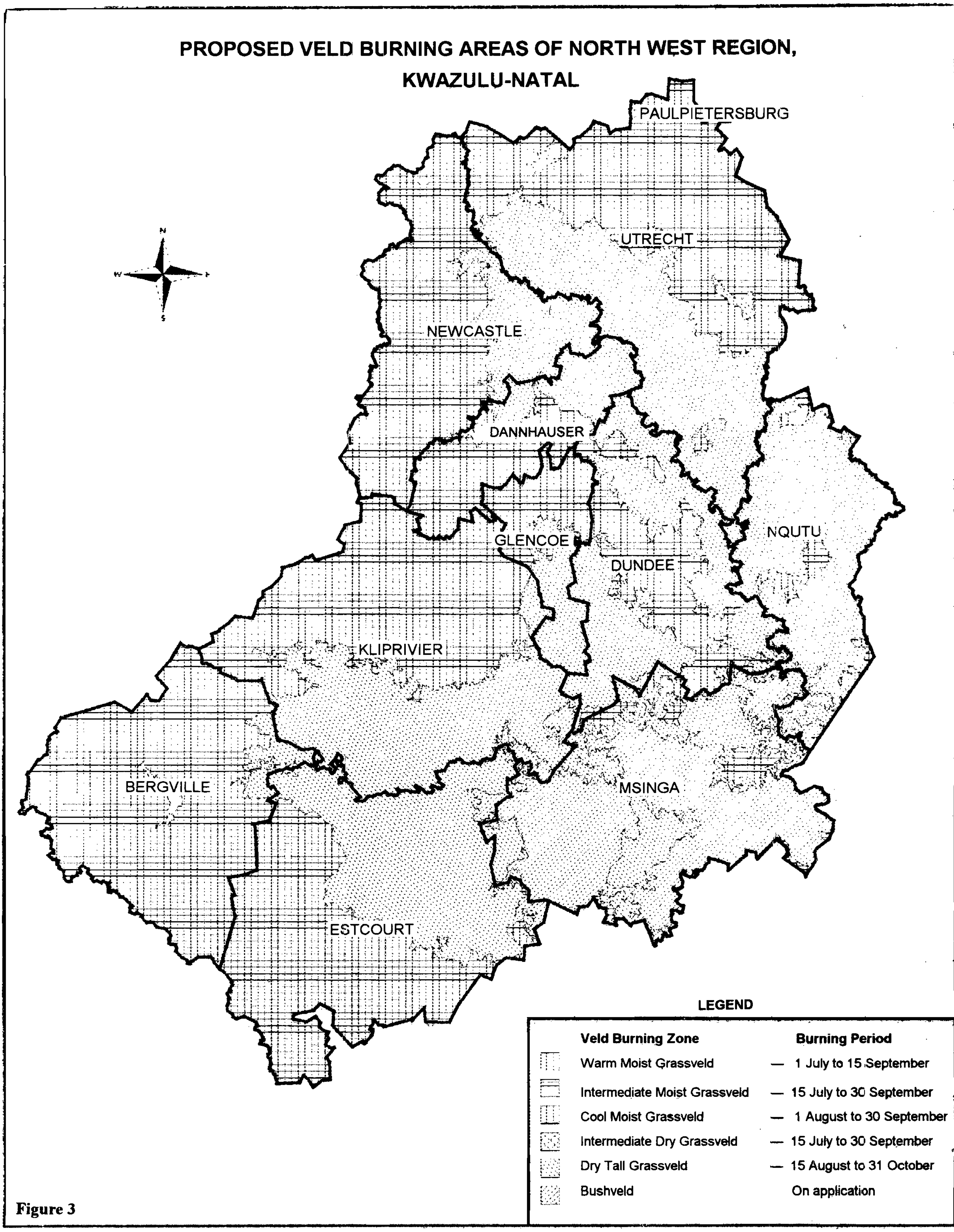
MTUNZINI
LEGEND
Veld Burning Zone
Burning Period
Warm Moist Grassveld — 1 July to 15 September
Intermediate Moist Grassveld — 15 July to 30 September
Cool Moist Grassveld — 1 August to 30 September
Intermediate Dry Grassveld — 15 July to 30 September
Dry Tall Grassveld — 15 August to 31 October
Bushveld On application
Figure 2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BERGVILLE
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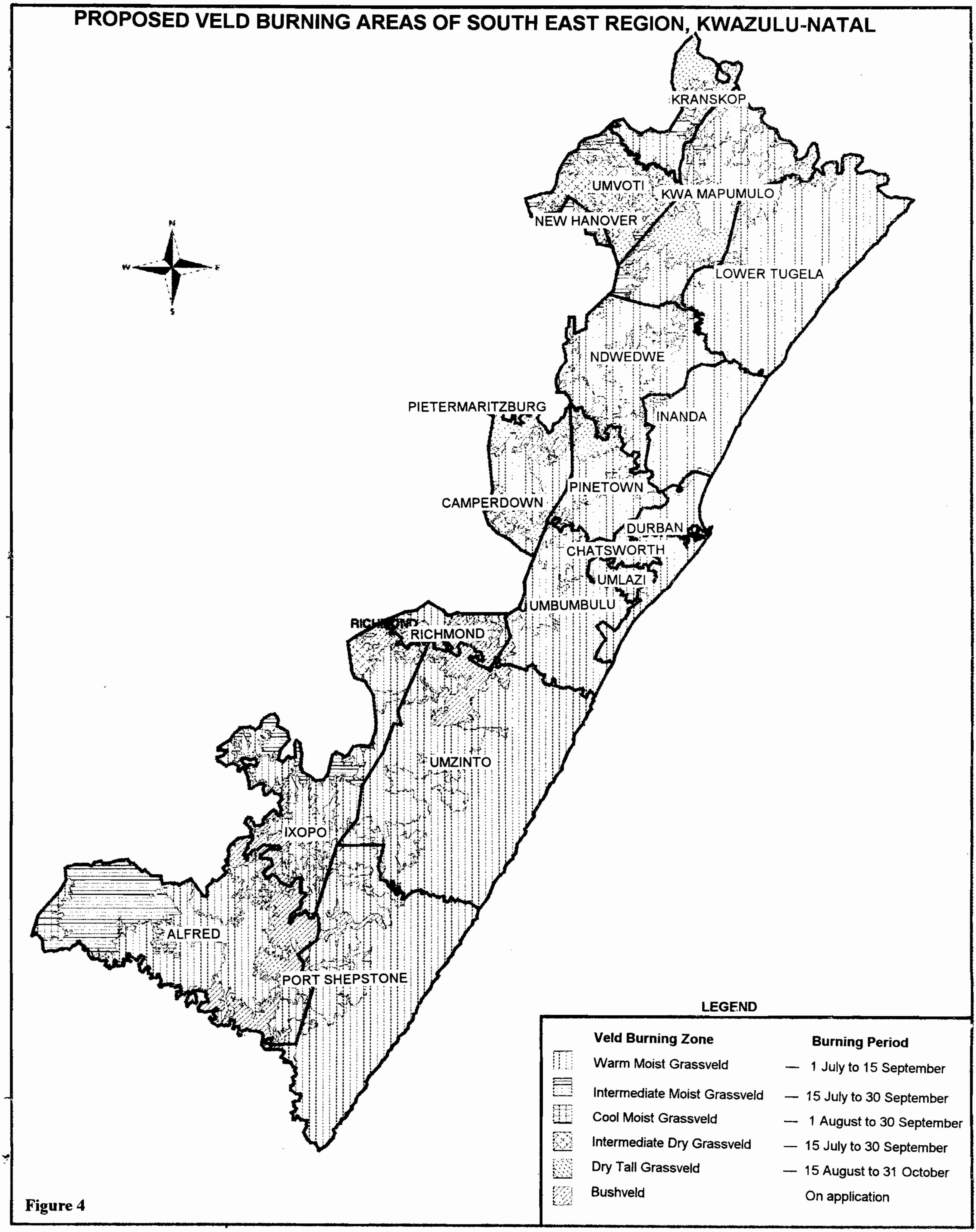
LEGEND
Veld Burning Zone
Burning Period
Warm Moist Grassveld — 1 July to 15 September
Intermediate Moist Grassveld — 15 July to 30 September
Cool Moist Grassveld — 1 August to 30 September
Intermediate Dry Grassveld — 15 July to 30 September
Dry Tall Grassveld — 15 August to 31 October
Bushveld On application

Figure 3


PROPOSED VELD BURNING AREAS OF SOUTH EAST REGION, KWAZULU-NATAL
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CAMPERDOWN
DURBAN
CHATSWORTH
UMLAZI
UMBUMBULU
RICHMOND
UMZINTO
IXOPO
ALFRED
PORT SHEPSTONE
LEGEND
Veld Burning Zone
Burning Period
Warm Moist Grassveld — 1 July to 15 September
Intermediate Moist Grassveld — 15 July to 30 September
Cool Moist Grassveld — 1 August to 30 September
Intermediate Dry Grassveld — 15 July to 30 September
Dry Tall Grassveld — 15 August to 31 October
Bushveld On application

Figure 4

PROPOSED VELD BURNING AREAS OF SOUTH WEST REGION, KWAZULU-NATAL

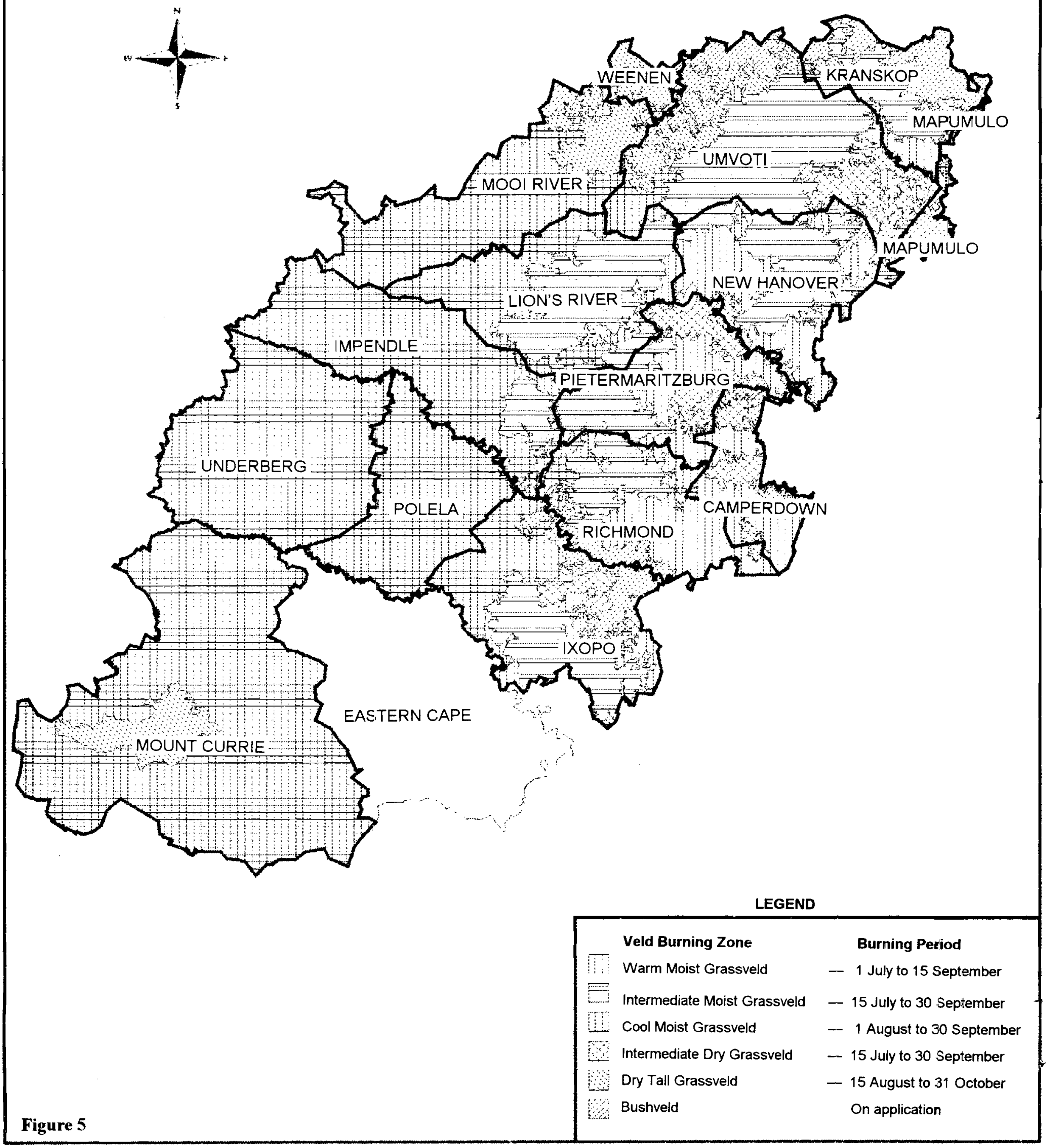

Figure 5

TABLE 1. Conditions, per veld burning zone, under which land users may burn veld

Veld burning zone	Burning period	Recommendations
Warm Moist Grassveld: These are areas of high rainfall (712 mm plus), in warm areas (16.1°C to 21.9 ° C)of mixed and sourveld. They are Bioresource Groups: Moist and Dry Coast, Moist and Dry Ngongoni Veld and Moist Zululand Thornveld.	1 July to 15 September	(i) Veld should be burnt as early as possible within the specified period, but preferably after a rain. (ii) Grazing of burnt veld should only commence once the grass leaves have attained a minimum length of 50 mm.
Intermediate Moist Grassveld: These are areas of relatively high rainfall (738 mm plus), and temperatures of 15.4 °C, on mixed and sourveld. It comprises Bioresource Groups: Moist and Dry Midlands Mistbelt, Northern Mistbelt and Moist Lowland Tall Grassveld.	15 July to 30 September	(i) Veld should be burnt as early as possible within the specific period, but preferably after a rain. (ii) Grazing of burnt veld should only commence once the grass leaves have attained a minimum length of 50 mm.
Cool Moist Grassveld: These areas have mean annual temperatures varying from 7.5 °C to 18.9° C and rainfall from 712 mm to 1 390 mm and include the: Moist and Dry Highland Sourveld, Montane Veld, Moist Transitional Tall Grassveld and Moist Tall Grassveld.	1 August to 30 September	(i) Veld should be burnt as early as possible within the specific period, but preferably after a rain. (ii) Grazing of burnt veld should only commence once the grass leaves have attained a minimum length of 50 mm.
Intermediate Dry Grassveld: The mean annual rainfall of this area varies from 706 mm to 838 mm with mean annual temperatures varying from 17.2°C to 20.8° C. Winter rains are more frequent than in the Dry Tall Grassveld and temperatures higher so early growth is possible. It includes Bioresource Groups Dry Lowland Tall Grassveld and Coast Hinterland Thornveld.	15 July to 30 September	(i) Veld should be burnt as early as possible within the specific period, but it is strongly recommended to burn after rain. (ii) Grazing of burnt veld should only commence once the grass leaves have attained a minimum length of 100 mm.
Dry Tall Grassveld: This area has a mean annual rainfall varying from 645 mm to 788 mm and temperatures from 14.7° C to 21,6°C. It includes the: Dry tall Grassveld, Sour Sandveld, Mixed Thornveld and Dry Zululand Thornveld.	15 August to 31 October	(i) From 15 August to 31 October, veld should only be burnt within a period of 5 days after at least 15 mm of rain has fallen within 24 hours. (ii) Grazing of burnt veld should only commence once the grass leaves have attained a minimum length of 100 mm.
Bushveld: This area has a mean annual rainfall varying from 587 mm to 830 mm and temperatures of 17.1°C to 22.2° C and includes: Valley Bushveld, Lowveld and Sandy Bushveld.	An application must be lodged in the prescribed manner every time the land user wishes to burn a grazing camp. Grazing should only commence once the grass leaves have attained a minimum length of 100 mm.	

NOTE: To cater for adverse weather conditions, a relatively late date after which veld may not be burnt has been stipulated for each zone. Land users are, however, urged to complete burning operations as early as possible within the periods laid down, since serious damage is done to *Themeda triandra* (red grass) and other climax grasses if burnt in an advanced stage of growth. **It is recommended that no grazing land should be burned more frequently than once in three years.** It is also recommended that no veld should be burned before at least 15 mm of rain has fallen within 24 hours, and that the burning, if at all possible, should be done within five days of that rainfall event. As will be evident from Table 1, however, this is no longer a prerequisite except in the case of the Dry Tall Grassveld.

fire control committee (where applicable) of the intended date of burning, and that he must comply with the prescriptions of such fire control committee.

BURNING OUT AREAS OF HIGH RISK

With the extensive afforestation which has taken place in KwaZulu-Natal, the risk of wild fires causing large-scale damage to timber plantations has raised the spectre of crippling claims against grassland farmers who operate adjacent to large timber plantations. The Executive Officer appointed to administer Act 43/1983, and who is the issuing authority for permits, has indicated that he will treat sympathetically applications for early burns of whole camps when the objective is the creation of strategic, community-type firebelts for the protection of large areas of plantations, or to eliminate the fire hazard from pockets of veld within, or adjacent to, timber areas. All of the applications comprising a proposed strategic burn must be lodged simultaneously, together with a map showing the extent of the proposed firebelt, and the high-risk area to be burned. Permission granted in these cases will be subject to the area concerned being withdrawn from grazing until a date which will be specified in the permit.

As the burning of strategic firebreaks will be a community effort, it is suggested that the Farmers' Association or the Fire Control Committee concerned should plan such a submission in consultation with the local Extension Office and the Conservation Committee.

BURNING IN THE DRY BUSHVELD ZONE

Under normal circumstances, the only valid reason for burning veld in the Bushveld Zone should be for the control of either alien plant invaders or encroaching bush. It follows that in this Zone, the only condition under which permission will normally be granted for burning on private farmland is when there is a need to control plant invasion and a reasonable fuel load is present. If there is insufficient grass to cause a fire hot enough to do the job, permission in all probability will not be granted.

OUT-OF-SEASON BURNING BY THE NATAL PARKS BOARD

There are often queries from the farming community regarding out-of-season burning of large tracts of veld by the Natal Parks Board, and this matter is discussed here in order that the public at large may be better informed.
The Natal Parks Board is not in the business of farming, but rather in maintaining a wide diversity of different habitats for conservation and scientific investigative purposes, and for aesthetic and recreational purposes. It burns at different times of the year in order to maintain grassland in good health, to control bush encroachment, or to create or extend important plant communities. For example, proteas in the Drakensberg area need a cool fire in order to stimulate their growth and reproduction. The Natal Parks Board therefore purposely burns such areas when the vegetation is still fairly green, in order to ensure the continued existence of the protea communities.

The burning practices carried out by the Natal Parks Board are not necessarily the best management practices for agricultural production, and could in fact even be detrimental, not only in the farming context where stocking rates are much higher, but also in game reserves where animals are not easily controlled. Staff of the Natal Parks Board are aware of this, and burn outside the legal periods only when it is deemed really necessary. They are required to apply for permission to burn, just like any other user of agricultural land, and are granted a permit only after *in situ* inspections with grassland management scientists from the Department of Agriculture have indicated that no serious damage to the environment will be caused by the burn.

The Veld Burning Areas were compiled from field work by K G T Camp.
Digitizing and map preparation by R G Bennett, Department of Agriculture, KwaZulu-Natal.

REFERENCES

Veld Burning Control Measures in Natal Region, 1985.
Department of Agriculture and Water Supply.

Notice No. 883,
Government Gazette No. 8673, 27th April 1983: Conservation of Agricultural Resources Act No. 43/1983.

Notice No. R1048,
Government Gazette No. 9238, 25th May 1984: Conservation of Agricultural Resources Act No.43/1983.: Regulations.

Notice No. 1783,
Government Gazette No. 9380, 29th August 1984: Forest Act No. 122/1984.

Tainton, N.M. 1981.
Veld and Pasture Management in South Africa. Shuter and Shooter (Pty) Ltd.

APPENDIX 1

REGULATIONS CONTROLLING THE BURNING OF VELD AND CROP RESIDUE IN KWAZULU-NATAL

FIRE CONTROL AREAS

Adapted from a leaflet by P G Reyneke, Forestry Extension, Forestry Branch, Department of Water Affairs and Forestry.

A Fire Control Area is an area declared to be such in accordance with the provisions of the Forest Act (Act 122 of 1984). The declaration is made by the Minister of Water Affairs and Forestry, with the concurrence of the Minister of Agriculture, and is announced by notice in the *Government Gazette.* A Fire Control Area may be declared in any part of South Africa, and not only in those areas where forestry is practised. No land in the area of jurisdiction of a local authority may be included without the consent of the local authority. A Fire Control Area, for instance, may consist of a number of farms only, or it may comprise a magisterial district as a whole.

THE ADVANTAGES OF ESTABLISHING A FIRE CONTROL AREA

In terms of the Forest Act, the advantage to the person whose property is situated **IN** a Fire Control Area is that, should a fire spread from his property to adjoining properties, causing damage which leads to a civil court case, the onus rests on the complainant to prove negligence on the part of the respondent. **OUTSIDE** of Fire Control Areas, negligence is assumed on the part of the owner from whose property the fire has spread, and the onus of proving the contrary rests on that owner.

Land-owners in a Fire Control Area are obliged to enter into agreements with neighbours regarding the clearing and maintenance of firebelts on the boundaries, thereby ensuring the involvement of all the property owners. The land-owners organise themselves in order to take the necessary action in the event of a fire. This increases the general state of preparedness. Such actions and operations are planned and co-ordinated by the members participating in the fire protection scheme.

A Fire Control Committee may also request the Department of Water Affairs and Forestry to impose a prohibition on the making of fires, burning of veld, *etc.* during certain times of the year. Such prohibition will also be included in the fire protection scheme.

In a Fire Control Committee, therefore, the community has a mouthpiece with regard to fires, fire protection/control and the co-ordination of these operations within a Fire Control Area.

A Farmers' Association may co-ordinate the fire control/protection procedure for the area. The Farmers' Association may formulate and implement a fire protection scheme on its own. Thus it is not always necessary that the State be involved. The advantage of the declaration of a Fire Control Area, however, is that certain legal obligations are imposed on **every land-owner** within the area. These owners furthermore enjoy a degree of legal protection, as has been explained. The aim with a Fire Control Committee is to enable the land-owners to organise themselves in such a manner that they will be able to take action effectively against any fire. For further information contact the Directorate of Forestry.

THE IMPLICATIONS OF THE DECLARATION OF A FIRE CONTROL AREA

* The Committee appointed will be responsible for all the administrative work in connection with the Fire Control Area once it is declared.
* A fire protection scheme has to be prepared by the Committee for that area, for approval by the Minister of Water Affairs and Forestry.
* The Committee must create the necessary infrastructure to carry out the provisions contained in the fire protection scheme.
* The Committee must generate the funds needed in order to function and to carry out the provisions of the scheme.

ESTABLISHING A FIRE CONTROL AREA

The Department of Water Affairs and Forestry must be approached with the request that a Fire Control Area be declared. Prior to that, all the owners of property in such area should attend a meeting, with the purpose of formulating the request to be presented to the Department. An interim committee may be appointed at such a meeting to act initially as the mouthpiece of the land-owners and to undertake the initial administrative tasks, namely:

* to choose a name for the Fire Control Area;
* to prepare a fire protection scheme (*pro forma* plans are available on request from the Directorate of Forestry, and on which local particulars and rules for that area may be filled in);
* to prepare a plan on a 1:50 000 topographical map, containing full particulars of farm and fire control boundaries, with proposed firebelts *etc.*;
* to submit these items to the Department for approval.

After declaration of such an area, a **Fire Control Committee** must be constituted within three months. Within thirty days after the constitution of this Committee, a meeting must be called of all the property owners who will be affected by the provisions of the fire protection scheme. Agreements between owners of adjoining land, in respect of the clearing of firebelts on the property boundaries, must be finalised within twelve months of the declaration of a Fire Control Area. The provisions of the fire protection scheme must be taken into consideration when entering into such agreements.

The Committee is obliged by law to meet at least twice a year.

The Committee must finalise and must maintain the fire protection scheme for the area concerned, revising it as the need arises. The committee reports annually to the Directorate of Forestry. This includes an audited financial statement of income and expenditure, a report of tasks performed during the previous year (*i.e.* a completed annual plan), an annual plan of proposed projects and tasks for the coming year, and an annual report by the chairman of the Committee.

The Committee must identify possible sources of financing required, and take the necessary steps to raise the funds.

Acquiring funds is usually a problem. In terms of the Forest Act, the Minister may appropriate an amount of money for the functioning of a Fire Control Committee, although this may not exceed 20% of the intended expenditure. Furthermore, the Committee may apply to the Minister for fees to be levied from every owner in the area. The funds are used by the Committee to implement the fire protection scheme and to defray administrative expenses and allowances.

Further information on this matter can be obtained from any one of the Forestry Extension Officers of the various Forestry Extension offices of the Department of Water Affairs and Forestry. The Department's Head Office in Pretoria may also be contacted:
The Director-General,
Private Bag X93,
PRETORIA, 0001.

TEN GOLDEN RULES
TO PREVENT FIRES FROM GETTING OUT OF CONTROL

1 **MAKE EFFICIENT FIREBELTS ON THE BOUNDARIES OF YOUR PROPERTY**
In this way you will protect your property and prevent a fire from spreading to land of your neighbours.

2 **WARN YOUR NEIGHBOURS WHEN YOU PLAN TO BURN A BOUNDARY BELT**
Warn your neighbours by means of a written notice.

3 **PLAN A FIREBELT SYSTEM IN COLLABORATION WITH YOUR NEIGHBOURS**
Get your neighbours' acceptance of the planned firebelt system.

4 **INSIST ON YOUR NEIGHBOUR BEING PRESENT AT YOUR BURNING ACTIVITIES ON THE BOUNDARY**
In this way the neighbours will be co-responsible for any eventuality.

5 **CHOOSE THE WEATHER DURING WHICH YOU INTEND BURNING**
You may even consider burning at night when the weather is usually more stable.

6 **BURN YOUR FIREBELTS IN GOOD TIME**
Remember that in certain parts of KwaZulu-Natal there are restrictions with regard to the months during which you are allowed to burn firebelts.

7 **DO NOT START A FIRE IN THE OPEN AIR WHICH YOU CANNOT CONTROL**

8 **DO EVERYTHING POSSIBLE TO PREVENT A FIRE FROM SPREADING TO A NEIGHBOURING PROPERTY**
If a fire spreads it may lead to damage with subsequent claims being laid against the owner of the property from which it has spread.

9 **DO NOT LEAVE A FIRE, OR LEAVE IT UNATTENDED BEFORE IT HAS BEEN EXTINGUISHED COMPLETELY**
Remember that a sudden wind may rekindle a smouldering ember.

10 **THE FOREST ACT DETERMINES THAT IN CERTAIN CIRCUMSTANCES NEGLIGENCE FOR DAMAGE IS ASSUMED UNLESS PROVED OTHERWISE**

REMEMBER:

In terms of the Forest Act (Act 122 of 1984);

* ***it is a CRIMINAL OFFENCE for a person not to take the necessary steps in time to prevent a fire from spreading from his property to the neighbouring property (article 75 (2)(b)).***

* ***Any person who leaves unattended a fire which he made or assisted in making, or to which he has added fuel, is GUILTY OF A CRIMINAL OFFENCE (article 75 (2)(b)).***

* ***The owner of a property who does not inform his neighbours in writing of his intention to burn boundary belts, is GUILTY OF A CRIMINAL OFFENCE (article 75(8)).***

* ***Any person who makes a fire within a road reserve other than in a designated fire-place or to make a fire belt, is GUILTY OF A CRIMINAL OFFENCE (article 75 (2)(b)).***

THE COST OF FARMLAND DEGRADATION

W B Russell
KwaZulu-Natal Department of Agriculture

INTRODUCTION

The cost of farmland degradation, to the farmer on whose property it occurs, to the community immediately affected by it, and to the country as a whole, is very clearly evident in some aspects, but not easily visible in others. One regularly hears the figure of 300 000 000 tonnes of topsoil being lost annually from South Africa through rainfall erosion, and this basic statistic is then repeated in the form of an enormous area of land so many millimetres deep, or representing so many average-sized farms washed away annually; or the statement is made that it represents sufficient sediment to fill a line of ten tonne trucks parked bumper to bumper and girdling the equator eight times. This type of statistic is mind-boggling, but the author wishes to point out that it represents neither the complete truth nor the best manner in which to obtain the desired reaction.

This article describes the manner in which some important forms of farmland degradation and their associated side effects impact on the environment and on the activities of Man, touching on the monetary value of some of the losses enumerated, with specific reference to KwaZulu-Natal.

THE HYDROLOGIC CYCLE

In a situation largely undisturbed by the modern and intensified practices of man, water is evaporated by the energy of the rays of the sun, off both the land surface and, to a much greater extent, off the surface of the sea. Winds distribute the water vapour over the surface of the land where, as a result of atmospheric and other meteorologic interactions, a portion of the moisture is deposited on the land surface. A significant quantity of this is in the form of light rains, while the rest occurs as heavy downpours. A large proportion of the energy of the falling rain is absorbed, before it impacts on to the soil surface, by vegetation. The kinetic energy that the rain-drops develop is dissipated on impact with the leaves, twigs and branches of this vegetation. The resultant smaller droplets, having now much less energy, fall onto the soil surface in a more gentle manner. More often than not a litter cover is present on the surface which further protects it from damage. Dense vegetation on the ground surface also slows down the overall movement of the rainwater off the landscape. In this way vast quantities of moisture infiltrate the soil surface fairly rapidly, while some is held on the surface by the vegetation and by local depressions (when it is called surface storage) until it can either evaporate back into the atmosphere or can also infiltrate the soil surface and percolate through the profile. The excess rainfall, now called runoff, moves overland at a pace dependent on slope steepness, the retardation effect of the *in situ* vegetation and the general roughness of the land surface. It flows relatively slowly off the hillsides in a non-erosive manner and with the minimum of sediment content, into streams and rivers, through lakes and wetlands, and ultimately through marine estuaries, to the sea. The rainfall that infiltrated the soil surface fulfils two functions: some of the moisture remains in the upper profile, available for use by the vegetation growing on it, and some of it deep-percolates into the underlying parent material. The latter collects in aquifers which exit elsewhere in the form of springs to strengthen the flow of streams and rivers.

Under this set of natural conditions erosion is minimal, and the soil mantle continues to slowly deepen as the parent material is weathered by the very moisture that the overlying soil makes available. Occasional droughts, the denudation caused by the passage of immense herds of grazing and browsing animals, and heavy flooding, will cause occasional depredations on the vegetation covering the soil. Accelerated soil erosion will occasionally take place, but generally the average rate of soil loss is low and is either less than or equal to the rate of soil generation. ***The sponge-like action of a healthy and well covered soil profile, with its ability to temporarily store moisture made available in the rainy season, and to release it in the dry season, is probably as important to the continued existence of Man on Earth, as is its ability to sustain the growth of vegetation useful to Man.***

Without the soil profile, suitably protected by a stable cover, every rainfall event would be associated with a flood, and the period between events would be characterised by severe moisture stress.

In order to improve his lifestyle, Man has found it necessary to domesticate and herd animals. The resulting concentration of animals leads to the trampling of the soil surface and overgrazing of the vegetation unless effectively managed. Both of these actions lead, in turn, to the reduction of the infiltration capacity of soils, with a concomitant increase in runoff. The vegetation suffers not only from overgrazing but from the reduced soil water available. The increased runoff causes an increased removal of soil and litter from between the grass plants, leading to further deleterious effects on plant growth. The increased runoff concentrates in streams which evolved under a very different hydrologic regime. The increased velocity of flow causes much damage to bottomlands (vleis), which is reflected in the ubiquitous donga, which is so much part of the South African scene today.

In order to further improve his lifestyle, Man has also found it necessary to cultivate special plants, and to do this he has to replace the indigenous vegetation. Furthermore, he has found it necessary to cultivate the soil regularly to remove the competition caused by regrowth of the indigenous vegetation and weeds. ***As soon as the soil cover is removed in favour of clean cultivation, accelerated erosion in two basic forms appears with a vengeance: erosion through excessive rainfall runoff, and erosion of the sandier soils by wind.*** The severe and harmful result of this progress is evident throughout South Africa (and the world): degraded environments with increased flooding, reduced rainfall efficacy and sediment loaded streams, reservoirs and estuaries. Evidence of this degradation on the farm is very clear in some instances (*e.g.* rill and gulley erosion) but not in others (*e.g.* surface wash on cultivated lands). Improved technology, such as better fertilization practices, better weed control and more custom-bred cultivars, have tended to mask the very real loss of fertility that accompanies soil erosion, but input costs to maintain production have simultaneously increased to a marked degree. Garbers (1993) reports that 'between 1950 and 1986 the use of fertilizer for grain production has increased far more rapidly than grain production, and the ratio of grain produced, in tonnes per tonne of fertilizer used, has declined from 46 in 1950 to 36 in 1986.' Continuous accelerated erosion inevitably reduces effective soil depth. Figure 1 reflects the effect of a reduction in yield potential through a reduction in soil depth.

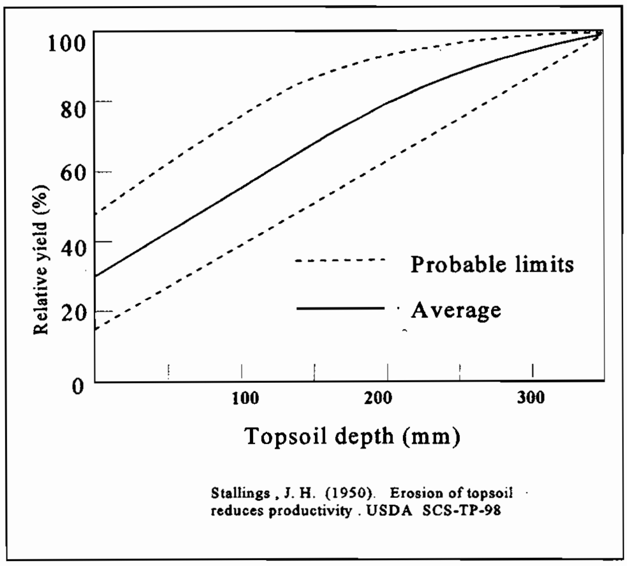

Figure 1. Effect of soil depth on yield

This has been a general background comment on the causes, processes and effects of farmland degradation. In the following discussion particular reference is made to conditions pertaining in KwaZulu-Natal. The author makes bold to state that conditions in other parts of South Africa are, if anything, probably worse on account of the inherent limitations of the natural resources.

THE OVERALL EFFECT OF FARMLAND DEGRADATION

In the context of this document, the negative impact of Man's interference on his environment is classified into the effect on:

* grazing land
* cultivated land
* water supplies
* miscellaneous other factors.

These aspects are all dealt with separately.

THE EFFECT ON GRAZING LAND

Degradation of grazing land by overgrazing and subsequent soil erosion has a number of results. Soil depth is reduced, thereby affecting the potential yield of the sward through insufficient rooting depth and reduced water holding capacity of the soil. Plant cover becomes sparser, resulting in a reduction in total herbage production. Diversity of species composition, the factor that ensures a longer fodder flow of the more palatable grasses through the spring, summer and autumnal months, is reduced (loss of biodiversity). The grazing capacity of a sward determines ultimately both the total mass and quality of meat, wool, milk, *etc.* that can be produced from it. In the province of KwaZulu-Natal there are areas where, through degradation, the grazing capacity has been seriously affected. A survey of the Valley Bushveld area of the Tugela Basin (*i.e.* the Muden and Weenen areas) showed that 27 000 ha of the 150 000 ha have been either totally destroyed or have at least been scalped of topsoil, while another 34 000 ha have degraded to the extent that its grazing capacity has halved (Camp, 1993). If one considers a grazing capacity for this area in a good state of conservation to be 6,5 hectares per large stock unit (lsu), a gross margin of R295 per lsu per annum for beef production (the obvious farming enterprise for the area), and a weaning rate of 75%, the loss of income from the 27 000 ha totally destroyed resource is of the order of R900 000 annually. The area which is in a poor state of conservation has a grazing capacity at present of only 10 ha per lsu. This represents a loss of 65% on the productive capacity of the valley still in a reasonable state of conservation.

In a recent survey of a 3 000 000 ha area of commercial farmland in the interior of KwaZulu-Natal, CADI staff found 50 600 ha of badland erosion and 2 500 000 hectares of veld in a fair to poor condition. The serious economic impact of this situation can be similarly estimated.

THE EFFECT ON CULTIVATED LAND

By virtue of the fact that cash crops are generally grown in rows, and the lands are clean-cultivated, vegetative cover in these fields during early summer is generally minimal, and the loss of both soil and water from these areas can be excessive. Even where conventional conservation measures like contour banks are instituted, soil losses in KwaZulu-Natal have been found to vary from 3 to 10 tonnes per hectare for maize lands, and as much as 50 tonnes per hectare on lands ridged uphill and downhill and planted to tobacco.

The incidence of wind erosion on cultivated lands in KwaZulu-Natal has not been fully investigated, but it certainly does occur in areas such as the Cedarville Flats and in the flat, sandy terrain of northern parts. The pernicious effect of this type of erosion is twofold. The coarser, heavier sand particles which travel at ground level sandblast the young plants, there are instances where whole sections of the field are destroyed and yield is reduced. The lighter fractions of the soil complex become airborne and are driven long distances. Inasmuch as these light particles constitute the clay and humus fraction of the soil complex, and bearing in mind their high fertility value in a sandy soil, the loss in monetary terms is excessive. Sand deposits blown by wind may also cover fences and damage highways.

Similar losses have been recorded by the author on relatively flat lands in northern KwaZulu-Natal when rainfall runoff was the causative factor. On a Longlands sandy loam, with a 6% clay content and on a 3% land slope, runoff plots 22 metres long and planted to maize and soya beans have given an average loss of 2,5 tonnes per hectare of soil loss per annum over a 3 year period. This in itself is not excessive (albeit greater than the rate of soil formation), but the composition of the sediment lost gives cause for great concern. As much as thirteen percent of the sediment comprised clay particles. The soil is typical of large areas of cropland throughout South Africa, with a location exchange capacity (CEC) and very little organic matter to bolster the CEC. What is clearly happening, therefore, on this short length of fairly flat slope, is that the very seat of fertility if moving off the land leaving, ultimately, sterile sand behind. Erosion on this type of site is not dramatic because of the flat slope, and farmers are not aware of the problem developing before their very eyes. Erosion of cultivated land on steeper slopes is much more visible. However, one can lose as much as twenty tonnes per hectare in a single storm through surface wash and not necessarily be aware that significant erosion has taken place.

Table 1. The value in terms of fertilizer costs (1992 Prices), of N, P & K losses from plots planted to maize and subjected to erosion over a seven year period

Tillage method	Soil loss (t/ha)	Cost (1992)
No till	0,4	R7 - 17
Stubble mulch	1,2	R34 - 52
Spring plough	3,4	R54 - 69

It is accepted that not all of the plant nutrients measured are available for plant utilization at any one time. The fact remains, however, that as weathering of the soil continues over time, so all of the non-available nutrients will eventually become available, but this will not be possible if they have been lost through erosion. Certainly a fair portion of the amounts measured had been applied in the form of fertilizer.

Plants need a certain rooting depth in which to flourish and produce. As the soil depth decreases, so the overall capacity of the profile to absorb and hold both air and moisture for use by the plant is reduced. So also is the ability of the profile to drain off excess moisture reduced. As has been seen, erosion removes soil particles which both supply plant nutrients and hold fertilizer available for use by the plant. The removal of these soil and humus particles, together with a reduction in soil depth, leaves a profile with a reduced ability to provide for optimum growth conditions. A decrease in yield must result, as is demonstrated in Figure 1. This fact was further demonstrated by Prof. El Swaify (1985), in an experiment on Hawaii, which showed that as soil depth decreased, so a greater amount of fertilizer was needed in order to maintain yields at a predetermined level.

This is happening in South Africa today, but the reduction in soil productivity is being masked by improvements in cultivation practices such as fertilization, pest and weed control, irrigation and cultivar choice, all of which inevitably raises input costs.

In a survey carried out by CADI staff, of a sample area of 350 000 ha of cultivated land, only 15% was considered as well protected, while more than 100 000 ha were found to have no protection at all (Russell, 1993). The estimated average soil loss from these lands is 26 t/ha/annum, and the loss of productivity therefore unacceptably high in the long term.

Just how far can this state of affairs be allowed to continue? How long can we expect to farm with annual soil losses which regularly exceed the rate of soil generation by several orders of magnitude?

Consider as a very simplistic example an unprotected field under cultivation, with a typical, annual soil loss of 25 tonnes per hectare. This represents an annual removal of 2 to 3 millimetres of soil over the entire field each year. If the depth of topsoil is only 250 mm (once again a typical South African situation) it will only take 100 years for the topsoil to disappear. In point of fact, and with reference to Figure 1, the yield potential will carry on dropping as soil depth decreases, until the farmer is forced into either abandoning the field, going into bankruptcy, or introducing conservation measures as a last resort (!). Unfortunately, adopting conservation measures after the yield potential has been reduced will not return the field to its former state of productivity.

THE EFFECT ON WATER SUPPLIES

The hydrologic cycle and the important part that the soil profile plays in regulating and extending the flow of clean water from the wet season into the dry season was briefly covered in the introduction, as was the brief mention of how farmland degradation interferes with the cycle, to the detriment of Man.

Let us examine the effect on water supplies in more detail. An area of veld on a 20% slope in the Underberg area was studied to determine the quantity and quality of runoff. One portion comprised a stand of highland sourveld in very good condition, while the other was an adjacent piece which had been very heavily overgrazed in the past, and where there was only a 5% cover of vegetation, being mainly weeds. Both areas had recently been pit planted to *Pinus patula*. The study was one which aimed to observe, firstly the effect of overgrazed veld on the environment, and secondly how far that effect carried on as the pine trees grew. The soil loss measured from the overgrazed section for the period January to April 1991 was 2,6 tonnes per hectare, while that for the control plots was virtually zero. Runoff from the former was 105 mm, representing 28% of the rain that fell, while that for the latter was 11 mm, or only 3% of the rainfall measured. In the former situation only 270 mm of rain entered the soil profile, while in the latter, unspoilt area, 364 mm of rainfall was able to move into the water table to replenish perennial streamflow. The intensity of one of the storms was measured at 15 mm in half an hour, and the resulting runoff represented 65% (of the rain that fell) from the degraded area, and only 7% from the veld in good condition.

The difference in effect of these two sites on the hydrologic cycle can be imagined. The overgrazed veld tends to produce sediment laden flood peaks with the regularity of rainfall events, while that in good condition produces a strong, clean flow of water throughout the year. It is left to the reader to decide on preference if we are to strive for sustainable agricultural production and maintain environmental quality.

The South African Department of Water Affairs carries out regular surveys and assessments of the occurrence of sediment which has settled in the large State reservoirs built to augment supplies for farmer and town dweller alike. Table 2 shows the degree to which these dams have been affected by sedimentation in the

Table 2. Sediment deposits in major dams in KwaZulu-Natal (1992)

Dam	River	Volume of sediment deposited (m^3)	% of original capacity	Period (years)
Midmar	Mgeni	204 000	0,1	18
Albert Falls	Mgeni	295 000	0,1	9
Henley	Mzinduzi	355 000	6,2	45
Wagendrift	Bushmans	1 639 000	2,7	20
Chelmsford	Ngagane	2 300 000	1,7	22
Hluhluwe	Hluhluwe	2 517 000	8,0	21
Hazelmere	Mdloti	4 679 000	19,6	12
Spioenkop	Tugela	6 367 000	2,2	14
Shongweni	Mlazi	6 853 000	100	60
Pongolapoort	Pongola	55 656 000	2,2	11

province of KwaZulu-Natal. The situation is even worse in most of the other regions of the country. The Welbedacht Dam on the Caledon River lost 32% of its capacity within three years of construction. It is a well-known fact that the construction of these dams costs the taxpayer many millions of rand, and that most of the favourable sites have already been used. As storage works fill with sediment, so new dams have to be planned on sites that are less economic. The cost of water storage is becoming prohibitive, yet the demand for additional water supplies increases in direct proportion to the increase in population growth. Unfortunately it is also in direct proportion to the rate at which farmland is degrading. Farmland degradation is costing South Africa millions of rand every year in the loss of capacity of storage dams. Scotney (1990) puts the cost of creating new storage to compensate for that lost annually, as varying between R71 500 000 and R104 000 000 per year.

MISCELLANEOUS OTHER FACTORS

Alien plants are spreading in KwaZulu-Natal at an alarming rate. Their spread, while basically resulting from the lack of natural predators, is accelerated, particularly where the indigenous vegetative cover has been reduced to any great extent. Where they take uncontrolled hold they not only tend to smother the indigenous vegetation, but they compete for plant nutrients and for moisture. Some of them, like *Sesbania*, produce seeds which are poisonous to wildlife, and the cost of eradication can run into thousands of rand per hectare. Also, water courses in the higher-lying areas of both southern and northern KwaZulu-Natal are now choked with silver wattle.

Farmland degradation and the results of poor farming practices have negative impacts that affect the lives of virtually everyone. For instance, on a particularly windy washday in September or October the housewife will vilify dust from wind erosion spoiling the once pristine colours of the family's clothing hung out to dry. Ask the people in north-western KwaZulu-Natal on calm days in January and February, when the summer burns for the production of cheap succulent grazing for lambing down ewes in Autumn are turning the veldgrass to black ash, or the housewives on the coast during sugar cane harvesting time about the burnt debris raining down on them. Ask the fisherman who can no longer catch anything because 45 of the 73 estuaries on the KwaZulu-Natal coast (the breeding place of many surfline fish) are filled with sediment.

Finally, ask the holidaymaker who, after a year's earnest work, takes his family to the KwaZulu-Natal coast on holiday, only to find swimming bans enforced because of the danger of sharks in the chocolate brown waters of the Indian Ocean. Such effects on tourism have enormous economic consequences.

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Conservation of Farmland in KwaZulu-Natal

REDUCING RAINFALL AND RUNOFF EROSION ON CULTIVATED LAND

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INTRODUCTION

Nature provides a mantle of vegetation on the soil surface to protect it from the hammering action of the millions of raindrops resulting from summer thunderstorms. When land is ploughed in the conventional manner and planted to row crops, a large proportion of the land surface is laid bare to the climatic elements. The explosive action of the raindrop on the bare soil then :

* seals the soil surface, causing a crust to form, reducing the rate of infiltration of rainwater into the profile, and resulting in increased runoff. The degree to which crust formation takes place, and therefore the degree of influence on infiltration and runoff, is dependent upon a number of soil characteristics, including particle size distribution and lack of organic matter
* dislodges soil particles, causing them to go into suspension in the increased runoff, resulting in an increased soil loss through surface runoff carrying the suspended particles downslope. This results in sheet erosion, which is present on most conventionally cultivated lands. A large proportion of the soil lost comprises the clay and humus fractions of the soil conglomerate which is the basis of soil fertility. Surface wash therefore reduces soil fertility, and the greater the soil loss, the greater the fertility loss. In an experiment conducted at Cedara over a ten-year period, soil, water and nutrient losses were measured on an Inanda clay soil under maize where the soil preparation for planting had been carried out in different ways. Table 1 shows the results averaged out over the ten years. As the plot lengths were approximately equivalent to contour bank spacing, the losses can be considered as the absolute minimum under conventional methods of conservation. On steeper slopes, on longer slope lengths and on more erodible soils, losses will be much greater.

Uninterrupted runoff moves downslope in a thin film over the whole surface, but increased runoff rapidly concentrates into rivulets, causing rill erosion. The steeper the land and the longer the slope length, the greater will be the damage. Uncontrolled rill erosion will eventually develop into gulleys. Gulley erosion dissects the land and reduces the area available for cropping.All three forms of erosion result in pollution of streams and rivers by sediment, destruction of cultivated land and the filling up of storage dams with sediment. They leave behind an impoverished soil which is bereft of a large proportion of its very important clay and humus fractions, with a reduced water-holding capacity as well. Erosion is a problem that is prevalent wherever the original ground cover has been removed and tillage takes place on any regular scale. The problem is exacerbated by steep

Table 1. Ten year average soil and water losses from runoff plots on an Inanda clay soil at Cedara, on a 9% slope, on a 22 metre slope length, and planted to maize

Primary tillage	Soil loss (t/ha / annum)	Water loss (mm/annum)
Direct drill	0,5	22
Stubble mulch tillage	1,6	32
Mouldboard plough in Spring	7,1	55
Mouldboard plough in Autumn	9,9	82

Table 2. The relationship between slope, velocity, and the erosive and transportive power of flowing water

Slope of site (%)	Runoff velocity m/s	Erosive power	Transportive power
V^2	V	V^2	V^5
1	1	1	1
4	2	4	32
9	3	9	243
16	4	16	1024

slopes, by erodible soils, by areas like KwaZulu-Natal which are subject to high intensity and long duration storms, and by crops which do not provide sufficient ground cover.

REDUCING THE IMPACT OF CULTIVATION ON THE ENVIRONMENT

There are a number of methods of reducing the impact of cultivation on the environment, and they are enumerated below:

Restricting annual cultivation to the flatter areas of the farm. Table 2 indicates the rate at which soil loss through surface wash increases with an increase in land slope. The reason for this is that as slope increases, so does the velocity of the runoff water. The capacity of flowing water to transport sediment increases with the fifth power of the velocity. Put another way, if the velocity of runoff doubles, the capacity of that runoff to transport sediment is increased 32 times. Table 2 puts the entire Slope - Velocity - Erosion scenario in perspective.

The Conservation of Agricultural Resources Act (No. 43/1983) does not in itself limit the slope on which cultivation may take place. It merely stipulates that no excessive soil loss may take place, and excessive soil loss is defined as being in the opinion of the Executive Officer who is appointed in terms of the Act. He has set a maximum limit of 5 tonnes per hectare per annum as being the maximum which is allowed to be lost from any site. It therefore behoves the land user to choose farming enterprises and methods which will cause soil losses of no more than that stipulated, and one of the methods is to use the flattest slopes for high erosion hazard crops (such as annual rowcrops), and to use the steeper slopes for the more permanent type of crop such as permanent pasture and long-term tree crops. The soil losses occurring during the periods when cultivation does take place in the latter scenario should then be sufficiently far apart in time so that the long-term annual average soil loss is within the limits specified. Under conventional methods of cultivation and conservation, the maximum slopes recommended for benchmark crops are indicated below. More sophisticated conservation techniques, discussed in the various other leaflets in this series entitled Conservation Tillage, Bench Terraces, and Ridge Tillage, will allow steeper slopes to be cultivated more frequently, while maintaining soil losses within the limit laid down.

Restricting annual cultivation to soils of low erodibility. Different soils erode at different rates, due to a number of inherent soil based characteristics which can not, under conventional farming methods, be altered. These include:

Texture. Generally speaking, the higher the clay content, the lower the erodibility; the lower both the silt and very fine sand content of the soil, the lower the erodibility as well. This is not always the case, however, as the type of clay and its chemical composition also have an influence on erodibility. Those clays which have a high proportion of 2:1 lattice clay minerals and which have

Table 3. Maximum recommended slopes for certain benchmark crops assuming conventional methods of cultivation and conservation

Soil erodibility	Annual row crops	Sugarcane	Timber
Low	10%	30%	40% - 50% #
Moderate	8%	15%	30%
High	4%	10%	20%

The 50% for timberland is for pitting into natural veld, the 40% for an interrupted rip on the plant line down the slope.

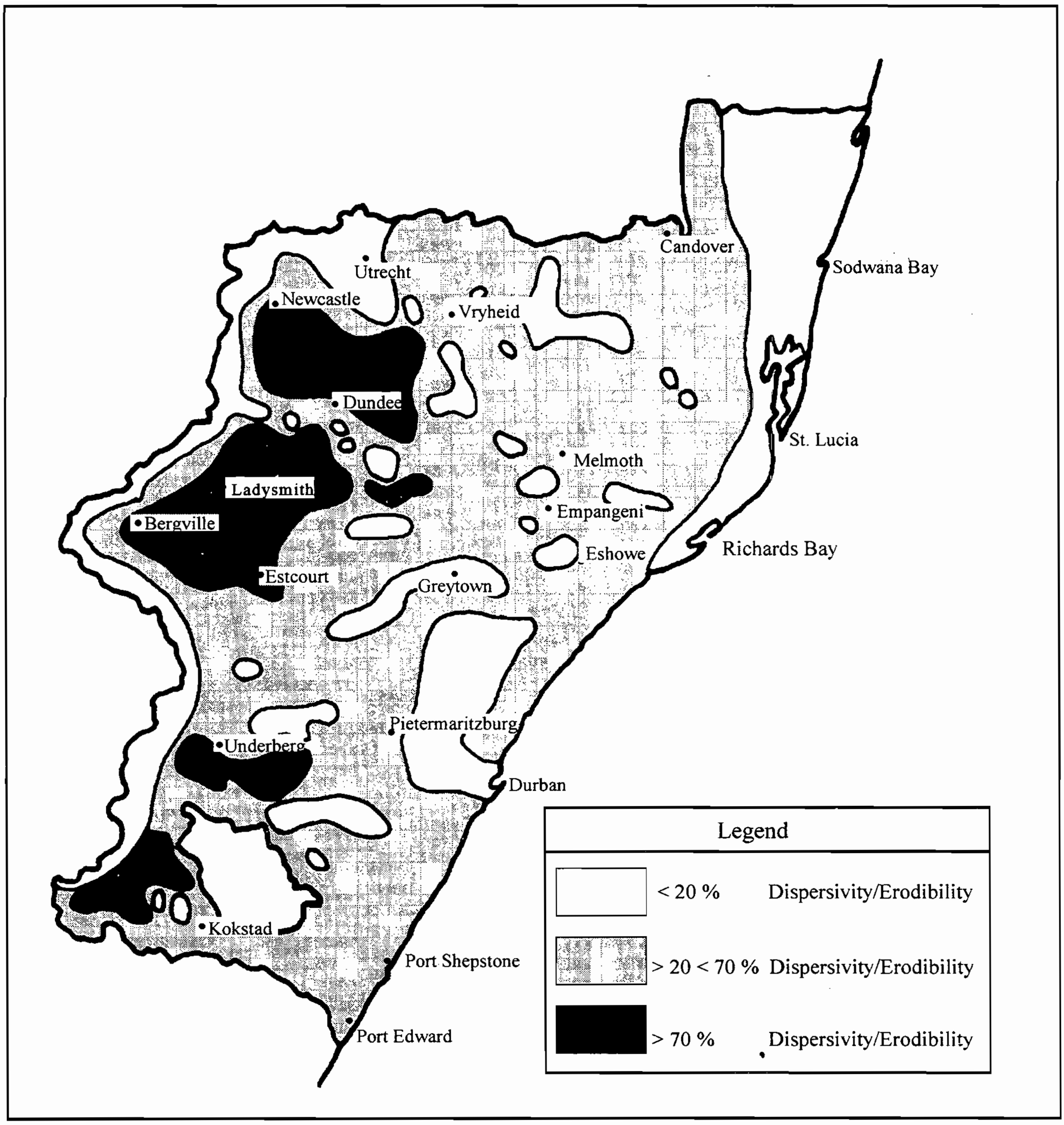

Figure 1. Map of KwaZulu-Natal showing areas of differing erosion hazard due to soil dispersivity ***(Taylor, H.M. 1981. Note on Dispersive/Erodible Soils. Natal Roads Department)***

a high exchangeable sodium percentage in their makeup (*e.g.* illite and montmorillonite) are very prone to erosion because of the phenomenon of dispersivity. Figure 1 shows the areas of KwaZulu-Natal with soils which tend to have varying degrees of dispersivity and therefore of erodibility. Landusers in the areas marked as having soils with a high dispersivity must be extra careful when working their soils.

Organic matter or humus content in the soil. It is a well-known fact that organic matter in the form of humus is not only an extremely important component of the soil matrix as far as soil fertility is concerned but, as has already been mentioned, the organic particles help cause the aggregation of soil particles into a crumb-like structure. This helps maintain a fairly high infiltration rate into the soil, which in turn reduces runoff and therefore erosion. It also assists in reducing the tendency of soils to erode through the action of wind. The land user can ensure a reasonable organic carbon content in the soil (depending upon climatic limitations) by returning crop residue to the soil and by alternating annual crops (soil disturbance promotes soil aeration, which, in turn, promotes breakdown of organic matter) with long-term ley crops. This latter is especially beneficial to the sandier soils which have a low inherent organic carbon content.

Effective soil depth. The shallower the soil, the less its water storage capacity. Low rainfall uptake means greater chances of waterlogging and greater volumes of runoff. Waterlogging as well as a lack of sufficient moisture storage both result in less vegetative cover, and therefore higher erosion potential. Shallow soils should be kept under permanent, sod-forming grasses for greatest yield stability and conservation of the resource.
It is, of course, also possible in some instances to improve effective soil depth by deep subsoiling. This is totally dependent upon the nature of the underlying soil horizons. Where a shallow watertable reduces rooting depth, there are methods discussed in Guideline No. 7.2 of this series, entitled 'Subsurface Drainage' to improve the situation.

Alternating annual row cropping with longer term grass leys. Has been dealt with, in passing, above. There is, however, another advantage to this type of crop rotation which should be mentioned. Evidence is accumulating that monoculture, especially in the annual cropping context, is leading to a build-up of pests and diseases, the effect of which is to reduce crop yields and increase production costs (Farina,1991). This reduction in yield is not readily evident at this stage because of continually improving crop husbandry and better cultivars masking the real reduction. It does hold promise of a very real problem in the future, and perhaps it is time that land users seriously consider attempting crop rotations again in order to bring stability to their croplands.

Mechanical modification of the terrain. This is the conventional method of erosion control carried out in order to reduce either slope length, degree of slope, or both. The various options are as follows:

Contour banks. This traditional method breaks the slope length up into segments, and because the structures are actually surveyed with a slight grade towards a safe discharge point they lead excess runoff away in a safe manner before excessive soil movement occurs. They do not by themselves stop surface wash, but will limit rill and gulley erosion if spaced correctly. Spacing is dependent upon a number of factors which are fully explained in the leaflet No. 2.3 in this series entitled 'A Farmer's Guide to Surveying Contour Banks'. Failure to construct them according to recommended specifications, or failure to maintain them in good repair, will result in their being overtopped and breaking, and damage to the land they were supposed to protect will be severe. The construction and maintenance of contour banks is the subject of another leaflet (No. 2.6) in this Series.

Ridging. Certain crops like tobacco, chicory and pineapples cannot tolerate 'wet feet', and the plants die or become diseased if they are waterlogged for even a short period of time. They are therefore planted on ridges so that the fine feeder roots are not subjected to waterlogging. This practice is also extended to other crops planted in poorly drained and/or cool soils. As long as the ridges are carefully laid out and built to the specification for which they were designed, they should give good results, especially in seasons of above average rainfall. They should preferably have an even gradient towards a suitable disposal site, and be as short in length as possible. Settled ridge height will depend on soil type, crop grown and row spacing, but should not be less than 300 mm. Latest attempts to improve rainfall efficacy in the timber industry have led foresters to align them on the true contour in order to trap all the rain that falls. The greater the infiltration and percolation capacity of the soil, the safer and more effective these structures will be. Ridging is the subject of a separate leaflet (No. 2.10) in this series.

Bench terracing is as old as China, and great interest has been shown in this technique lately, especially in the timber industry. There are large areas of steep land in KwaZulu-Natal which are presently cultivated annually without any form of conservation measure to protect them. There is also little chance that these lands will be withdrawn from annual cultivation because of the pressure for scarce arable land. It is probable that bench terracing is the only way to conserve and develop these lands, and so a separate leaflet (No. 2.12) entitled 'Bench Terracing' will be found in this series.

Conservation tillage is by far the most fail-safe method of erosion control on cultivated land. While contour banks are the conventional, and presently the most popular, method of erosion control on sloping land, they do not stop surface wash. They also require regular maintenance to perform effectively. Despite continual admonitions to land users to build up their contour banks and to repair them where necessary, the situation remains far from satisfactory, and washaways are the order of the day. Conservation tillage, however, improves rainfall infiltration by absorbing the impact of falling raindrops, and reduces the need for mechanical measures. The soil and water loss measurements shown in Table 1 prove conclusively that soil losses under direct drilling with a 75% residue cover are one third that of stubble mulch tillage with a 30% crop residue cover at planting, and a fraction that of conventionally ploughed clean cultivated maize This means, of course, that contour banks can be spaced much wider apart when conservation tillage is practised, as opposed to conventional tillage. Apart from the soil conservation benefit, conservation tillage benefits the land user in a number of other ways. The various methods are discussed in a subsequent leaflet entitled `Conservation Tillage Practices' (see Guideline No. 2.8 in this series). A combination therefore of a well planned and regularly maintained contour bank system, with a recognised system of conservation tillage practised between the structures, and with a well-designed crop rotation conducted to maintain the soil organic matter status, will ensure minimum soil and fertility loss, maximum moisture conservation, and minimum impact of cultivation on the environment.

Table 4 is given as an example of how the inter-relationship of soil erodibility, type of crop, land preparation and conservation practices can be utilized to manipulate maximum slope limits for cultivation in order to keep soil losses within reason. The information in the table is used when considering applications for permits for breaking up virgin ground for the purpose of planting sugar cane.

Table 4. Norms for upper slope limits on sugarcane land

Land preparation and conservation practices	Soil erodibility:	High	Moderate	Low
	SLEMSA Fb rating *	2,5 - 4,0	4,5 - 5,5	6,0 - 7,0
	USLE K value **	0,9 - 0,4	0,4 - 0,2	0,2 - 0,1
		Maximum slope %		
1. Conventional tillage with contour banks, trash burnt and tops scattered		10	15	20
2. Conventional tillage with contour banks and full trashing at harvest		15	20	25
3. Conventional tillage, strip planted, with spillover roads and full trashing at harvest		15	20	25
4. Minimum tillage with contour banks, trash burnt and tops scattered		20	25	30
5. Minimum tillage with contour banks and full trashing at harvest		25	30	30
6. Minimum tillage, strip planted, with spillover roads and full trashing at harvest		-	-	30

* Soil Loss Estimator for Southern Africa erodibility index rating.
** Universal Soil Loss Equation erodibility index rating.

The following should be noted:

1. Spacing of contour banks must be in accordance with the South African Sugar Association Experiment Station nomograph.
2. 'Full trashing' means just that - the practice of burning standing cane and spreading the tops does not qualify in this context.
3. Strip planting means adjacent contour bank intervals planted up with a six-month difference in the age of cane.
4. 30% land slope is considered to be the maximum on which satisfactory structures can be constructed and maintained.
5. If a practice (*e.g.* full trashing) is not a tried and accepted method in an area (*e.g.* KwaZulu-Natal Midlands), then it cannot be used as a condition.

The series of leaflets which follow attempt to provide guidelines for the effective conservation and controlled utilization of cultivated lands.

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Conservation of Farmland in KwaZulu-Natal

RUNOFF CONTROL PLANNING ON CULTIVATED LAND

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INTRODUCTION

The mechanical protection of cultivated land entails the building of diversion structures across the field in order to intercept excess overland flow before it starts forming rill erosion in the field. The structures must discharge the runoff so collected at a site where it can flow into the most convenient and stable watercourse, once again without causing erosion. The diversion structures (called contour banks by some and conservation terraces by others) are spaced at regular intervals down the field (see Figure 1) as required by virtue of the erosion hazard, which is determined by the factors of soil erodibility, land slope and the protection afforded to the soil by the crop grown and the tillage practice. Guideline No. 2.3 in this series entitled 'A Farmer's Guide to Surveying Contour Banks' deals in detail with the determination of contour bank spacing, and with the gradient to use. Guidelines No. 2.4, 2.5 and 2.6 deal with the construction of waterways, the grassing thereof and the construction and maintenance of contour banks, respectively. This guide will deal with how to decide where to place waterways and infield access roads as a basic runoff control planning (R.C.P.) exercise. Infield roads are a very important component of an R.C.P. as, if no provision is made for vehicular travel over and through the field, land users will tend to use the constructed waterway for this purpose. Regular traffic up and down a waterway will cause tracks to form therein, and when concentrated runoff occurs in the waterway, the vehicle tracks get scoured out. A gulley, which can be very difficult to repair, forms in the waterway. On the other hand, if the access road is planned as part of the overall exercise, one often finds that the roadways stay in good repair because runoff disposal is directed away from them.

NATURAL WATERCOURSES

When runoff starts it occurs as a thin film over the surface of the land. It soon gathers and concentrates in depressions which are a natural part of any landscape. The depressions join up to form runnels, the runnels join together to form rivulets and streams, and these will develop into rivers which ultimately reach an ocean. The gradients and cross-sections of these watercourses have developed in such a way that they fulfil a natural function in disposing of surplus runoff efficiently, without excessive erosion. If runoff is diverted from a natural watercourse it will always tend to return to its original path, and often causes great damage in the process. Watercourses must therefore be regarded as the right-of-way for runoff, and be respected as such. They should not be interfered with by farming operations unless there is no other economic and practical alternative. This recognition of the natural pattern forms a basic principle of R.C.P.

APPLICATION OF RUNOFF CONTROL PLANNING

R.C.P. becomes necessary in the following cases:

* where runoff causes erosion and/or flooding of cultivated land,
* where runoff, in intensively cultivated areas, becomes the subject of friction and even litigation between neighbouring farmers,
* where runoff plays an important role in the establishment of roads, railways, townships, *etc.*, and
* where runoff might cause waterlogging and salinisation of cultivated land.

Apart from the above, R.C.P. is advisable in most areas which are intensively cropped, in order to forestall the development of runoff problems in the future.

DEFINITIONS (See Figures 1 and 2)
Contour line: A line on a map connecting all those points on the ground which have the same height. The figures 110, 100, *etc.*, in Figure 2 indicate the heights or elevations of the contour lines in metres.

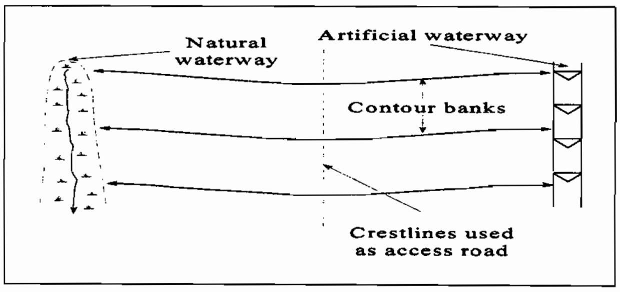

Figure 1. The components of a runoff control plan on a cultivated land

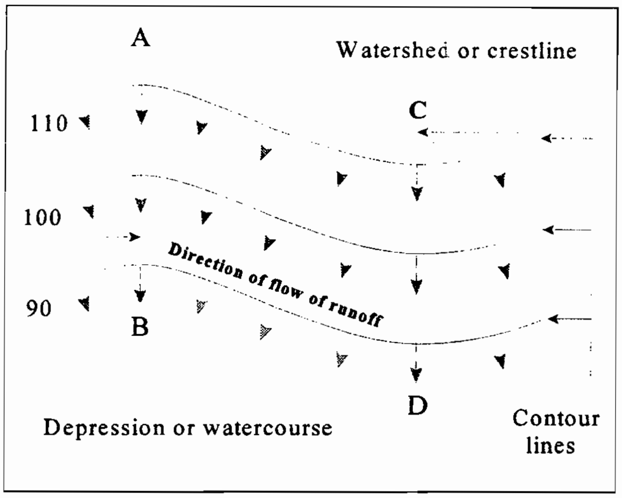

Figure 2. Direction of flow indicated by contour lines. A B indicates the position of a natural waterway, C D that of an infield road

Contour (bank) interval: The vertical difference between successive contour lines (banks).
Direction of flow: Water always tends to flow at right angles to contour lines.
Watercourse: A natural depression in which runoff will tend to concentrate and flow away.
Figure 2 shows how runoff tends to converge towards the watercourse.
Waterway: A channel used for the disposal of runoff from contour banks. A *natural waterway* is situated on the streamline of a watercourse. An *artificial waterway* is a channel specially excavated in a predetermined position in a field for the purpose of conducting excess runoff safely away. There are two basic types of artificial waterways, and these are as follows:
K1-type - sited where no natural concentration of runoff will 'feed' the structure: contour banks will deliver the runoff to it.

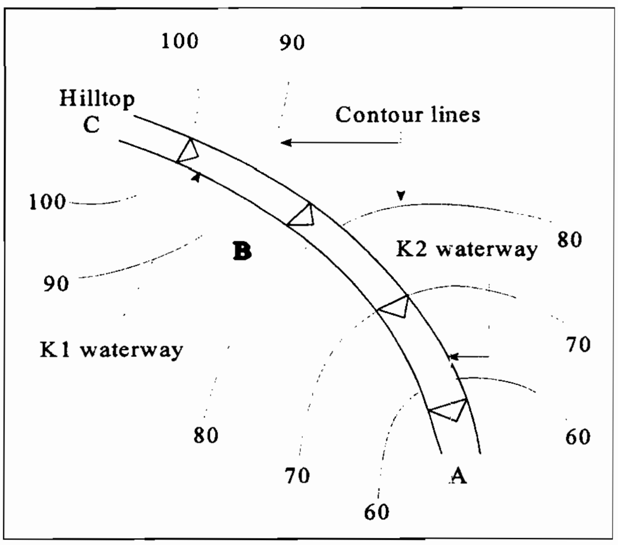

Figure 3. The two basic types of waterways

K2-type - sited in a natural depression, and where runoff would tend to flow towards it.
Catchment: The area which will contribute runoff to a specific point in a watercourse.
Watershed: The boundary of a catchment, or the divide between adjacent catchments. Runoff will tend to diverge from a watershed.

PRINCIPLES OF RUNOFF CONTROL PLANNING

* Natural watercourses should be respected. Wherever possible, they should be used for the disposal of runoff from the adjacent fields. If they have been cultivated they should preferably be withdrawn from cultivation and transformed into a stable, vegetated waterway.
* Watersheds should be respected *and runoff should not be diverted from one catchment to another, except in very special circumstances.*
* The principle of natural liability acceptance (NLA) should be applied. This implies that the owner of lower lying land should accept the fact that he is responsible for receiving and handling runoff from higher lying land, should it reach him *ex natura*, that is, as would be the case in the natural state where there is no interference with the flow of water through human activities. Where landowners have to withdraw land for waterways, the proportion of *ex natura* flood water from each property to reach the waterway should be used as a basis to determine the area of land each owner must withdraw in order to create the waterway.

  Notwithstanding the foregoing principle of natural liability acceptance, it might be illegal to bring about changes in the way runoff reaches lower lying land, causing damage or inconvenience to the lower owner in the process. Runoff control planning, however, often requires that flow which was formerly dispersed reaches lower-lying land in a concentrated form

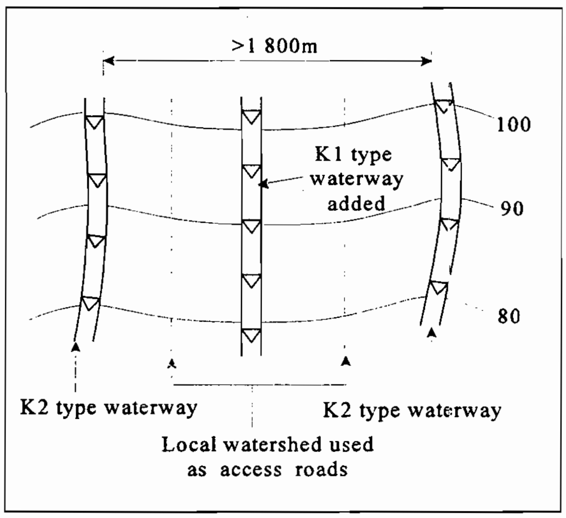

Figure 4. Adding an extra waterway to reduce the length of contour banks

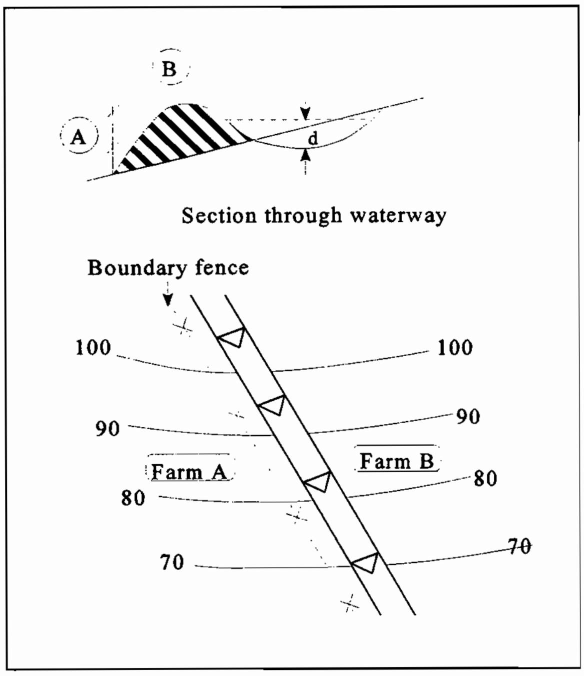

Figure 5. A hanging waterway

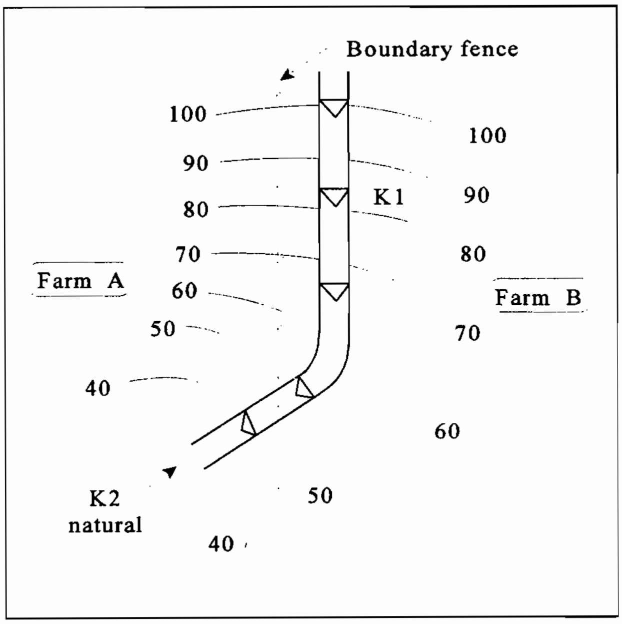

Figure 6. An artificial waterway (K1 type) becomes a natural one (K2 type)

within a waterway, or by a different route. Since litigation on water matters is extremely costly, the application of runoff control planning calls for good understanding among neighbours and, if necessary, for their entering into a legal and binding agreement, even to the extent of a servitude on title deeds.

* The process of runoff control planning normally commences at the top end of a catchment, and proceeds down to a natural watercourse, but implementation (especially where more than one farm unit is involved), starts at the bottom (*i.e.*, the natural watercourse) and is developed in an upslope direction. It is, of course, preferable to carry it out in one operation if at all possible.

THE PLANNING PROCEDURE

There are three scales of planning:

* An entire catchment covering thousands of hectares, involving any number of farms, and affecting public roads and their hydrologic structure: This is beyond the scope of this guide. It is carried out, where necessary, by officers of the Department of Agriculture, in order to solve a community problem.
* Farm scale: This is done whenever Departmental officials plan a farm under the Soil Conservation Scheme (see guideline 1.2 entitled "Financial and Technical Assistance for the Planned Utilization of Agricultural Resources").
* Individual fields: An R.C.P. of such restricted nature is only done in the instances where the topography is such that artificial or constructed waterways debouch into watercourses *within* the farm boundary. In large areas of KwaZulu-Natal, with its rugged to undulating terrain, this is quite possible in most cases.

Runoff control planning requires an accurate map on which to record the position of the recommended structures. For the smaller areas, a map with a scale no smaller than 1:10 000 is necessary. It should also have contour lines marked on it, with vertical intervals no greater than 5 metres. An aerial photo base to the map will help as well. In many instances, when one is searching for the original watercourse in the flatter areas, a soil survey will indicate the true position due to bottomland soils showing up. These generally tend to be darker in colour. It is sometimes necessary to carry out a topographic survey in order to determine the best position for a waterway.

The Process

The maps described above are used to mark the positions of identified crestlines (watersheds), natural depressions and watercourses, the positions of proposed access roads, constructed waterways needed and their possible inlets into watercourses. A stereoscope, used in conjunction with a stereo pair of aerial photos, is often very useful at this stage. If two overlapping aerial photos are viewed simultaneously under this instrument, the topographical features of the study area are seen in an exaggerated, three-dimensional manner. This aids the process of identifying natural depressions and ridges. The various problems which could be identified in the planning process are described in Figures 3 to 8, along with the various types of waterways in use. Figure 3 shows a natural waterway (A to B) extended up onto a ridge to position C (a K 1 waterway) in order to receive discharge from contour banks protecting the upper section of the hill. Note that great care must be taken in bending the waterway in as wide and gentle a curve as possible. Runoff flowing with any reasonable speed does not easily

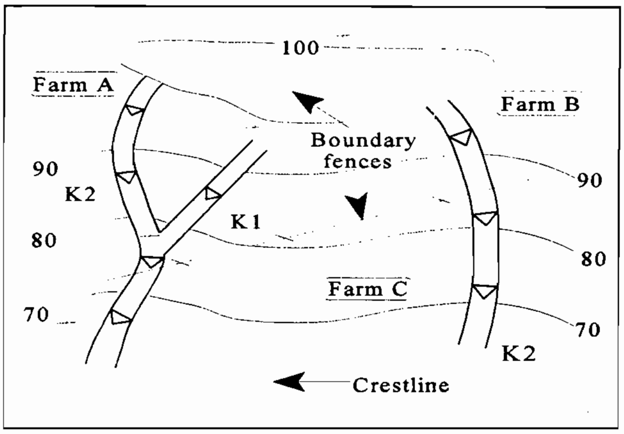

Figure 7. A K2 waterway introduced to obviate taking contour banks across a farm boundary

change direction. A K1-type construction is also often required where contour banks become too long (more than 450 m) in one direction, and there is a need to reduce their length. See Figure 4.

Figure 5 shows a K1-type waterway alongside a boundary fence between two farms. This waterway is hanging in respect of the lands on farm B, and extra care must be taken in its design to ensure that water flowing along it does not jump over the entraining bank into farm A. If a waterway was required on the other side of the fence (*i.e.,* on farm A) this waterway would be hanging negatively and any overflow would tend to flow back into the land. *Such a waterway is considered undesirable.*

Figure 6 shows a K1-type waterway alongside a boundary fence which had to be swung across the boundary into a natural depression where it becomes a natural waterway.

Figure 7 illustrates a particular problem involving three properties where a third waterway (K1-type) is introduced because of the inadvisability of taking contour banks across a boundary from one farm to another.

Figure 8 illustrates the two alternative solutions to a problem that occurs fairly frequently in practice.

Figure 9 shows how important it is, when carrying out runoff control planning, to take account of different soil types. Some soils (*e.g.* Huttons and Avalons) will dry out quicker than others (*e.g.* Westleigh). It is therefore bad practice to include, for example, a Westleigh (a poorly-drained soil) and a Hutton (a well-drained soil) along the same plough line in the same field. In this instance, the two soils could be separated by either a waterway or simply a headland. This will allow the Hutton to be cultivated/planted/topdressed, *etc.*, as soon as it is dry enough after a soaking rain. If the two soils were not separated the farmer would have to wait extra time until the Westleigh became dry enough to allow a tractor over it without bogging down and getting stuck. In the meantime the better-drained soil could have dried out too much for the operation required.

Figure 10 shows an example of an overall runoff control plan, and how farm roads interlink between the various fields in a well designed system.

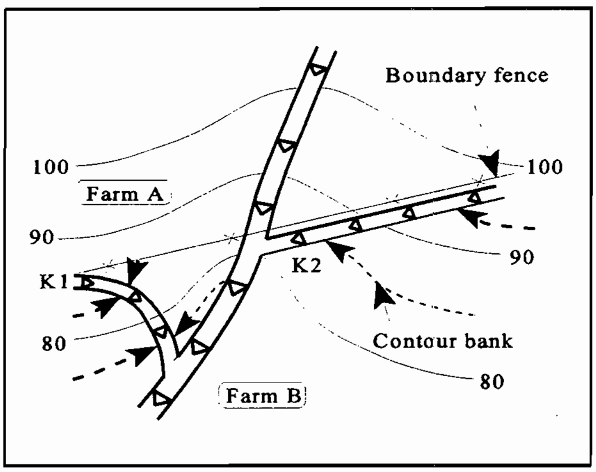

Figure 8. Example of how to keep contour banks from crossing farm boundaries

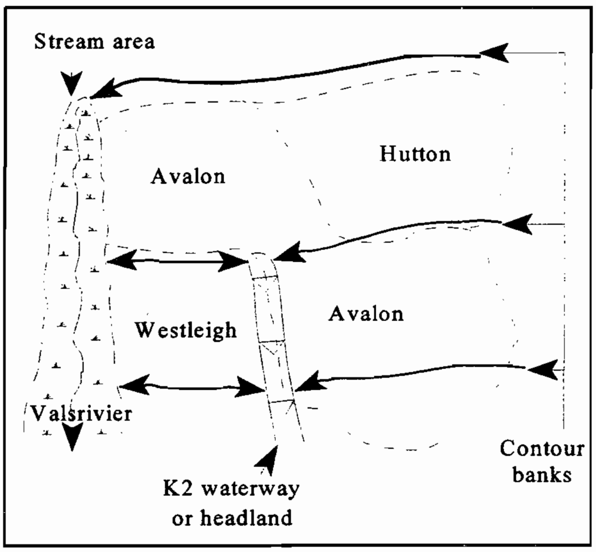

Figure 9. Soil types can dictate the position of runoff control planning structures

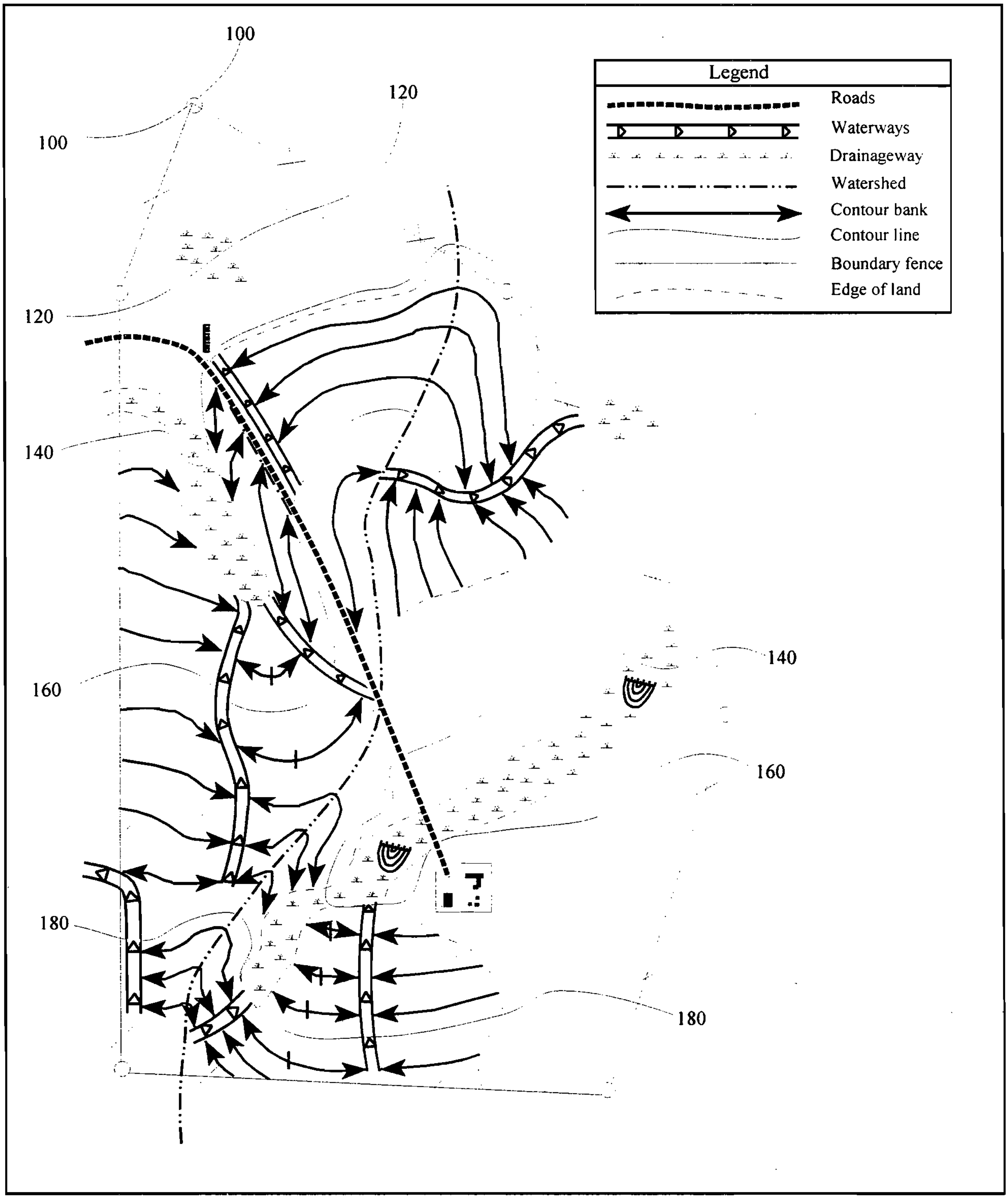

Figure 10. A runoff control plan for a farm

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Conservation of Farmland in KwaZulu-Natal

A FARMER'S GUIDE TO SURVEYING CONTOUR BANKS

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INTRODUCTION

This is the third in a series of leaflets dealing with the protection of cultivated land. Others in the series deal with the construction and maintenance of grassed waterways (no.2.4) and contour banks (no.2.5). Should the farmer contemplating the survey of his own contour banks have difficulty in understanding the procedure described herein, he should consult the Soil Conservation Officer at his local Extension Office.

EQUIPMENT REQUIRED

The normal equipment used is the conventional Dumpy level on a tripod, and a survey staff. This is a rather expensive instrument to purchase solely for the purpose of pegging contour bank lines, and an alternative method is described using an inexpensive instrument called the Abney level. In this case the following is needed :

* Abney level (See Figure 1)
* Instrument support (See Figure 3)
* Elementary staff (See Figure 3)
* Length of twine

For both methods described a set ofpegs is required. Eight gauge (4 mm) wire cut to 600 mm length makes excellent pegs. A piece of flagging material is tied to one end to improve visibility.

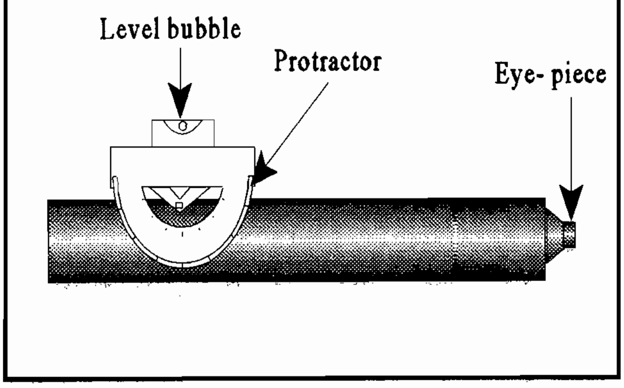

Figure 1. Abney level

The angle reading on the Abney level is set on 0°, the protractor is clamped, and the instrument held up to the eye. It is then tilted up or down until the bubble and the crosshair lie in the same horizontal plane. The crosshair then indicates a level line. See Figure 2. ***Whenever a reading is taken the bubble must be in the middle of its run.***

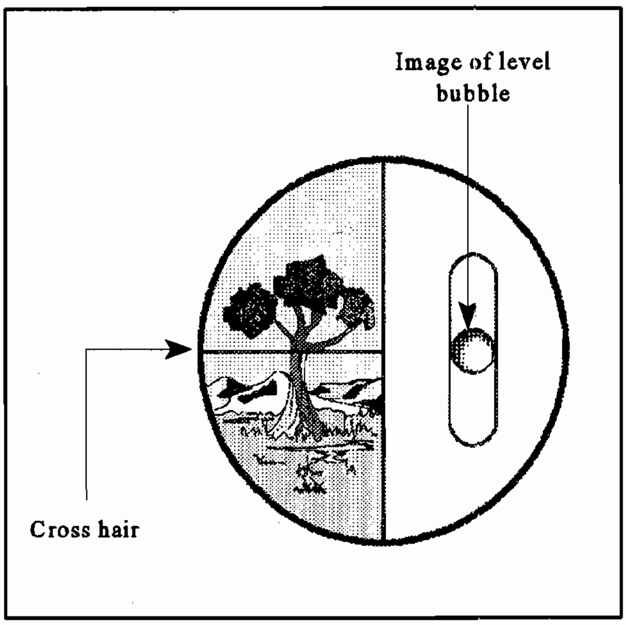

Figure 2. Image viewed through Abney level

* **Instrument Support:** This may be constructed of any rigid material. It comprises a rod 1,5 m long (normally made of wood) with a platform on one end (on which the instrument is clamped) and a footplate on the other. The latter ensures that the rod does not sink into soft earth. (Figure 3).
* **Elementary Staff:** A length of any light material, *e.g.* wood, and approximately 2 metres long may be used as a staff.
  How to graduate the staff: Firstly match the Abney, clamped on its support, to the staff, and make an easily visible mark on the staff at the level

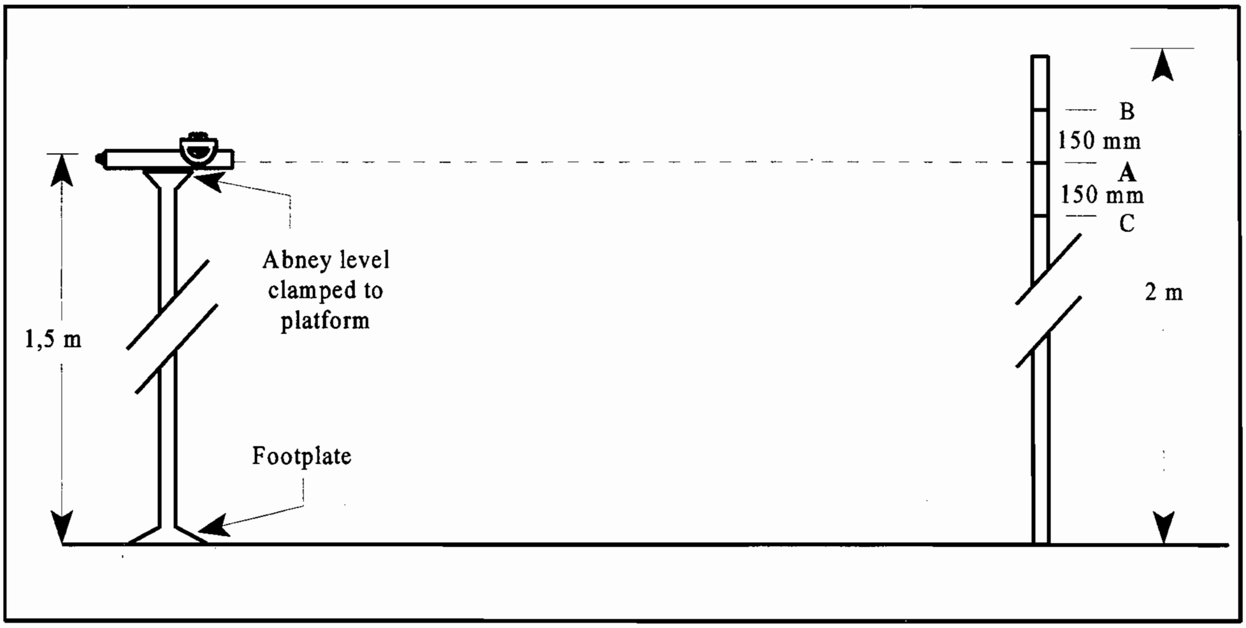

Figure 3. Elementary instrument support and survey staff

corresponding to the height of the Abney eyepiece. This will be called the aiming mark 'A' and will be used for pegging out any level line with the Abney set level (*i.e.* on zero). Ground level at the foot of the instrument support will then always be level with ground level at the foot of the staff if mark 'A' coincides with the crosshair.

Second and third aiming marks 'B' and 'C' spaced 150 mm above and below 'A' are painted onto the staff. These marks will be used in setting out contour banks on a gradient. (See Figure 3.) The three different marks should be made in different colours to reduce the chance of errors in surveying. On the reverse side of the staff paint on a series of graduations all the way up the staff at 100 mm intervals. To simplify reading, use a different colour for each metre height. This face will be used for setting out adjacent contour banks. The different colours are once again used to simplify the survey procedure and to obviate mistakes. ***The Abney level must be checked regularly to ensure accuracy.*** This is done by setting the angle scale on 0°, mounting it in the support at water level on one side of a small dam, and siting onto the staff placed at water level on the other side of the dam. With the bubble in the centre of its run, the crosshair should lie on mark A on the staff. If it does not, consult the local Soil Conservation Officer for assistance in adjusting the bubble.

* **Length of Twine:** A length of twine is attached to the instrument holder and to the staff to ensure an accurate spacing between pegs along the surveyed line. The length of the twine will depend upon the gradient required: see the section on Gradients.
* **Pegs:** A number of clearly visible pegs will be needed to peg out each contour bank. Once the survey has been satisfactorily carried out, a plough furrow is drawn on the surveyed line and the pegs used to mark out the next structure.

THE PRINCIPLES OF CONTOUR BANK SPACING

Contour banks are spaced a certain distance apart in order to intercept runoff before it starts causing excessive erosion. The runoff must then be disposed of in a safe manner at a suitable discharge point. Spacing is therefore a function of slope, rainfall intensity, and a number of soil based parameters, including texture, permeability, organic matter status, and effective soil depth. These soil related parameters effect the erodibility of the soil, and there exists a relationship between soil erodibility and the spacing of contour banks. Further factors effecting spacing are related to the type of tillage practised and the crop. These latter factors require a more sophisticated approach which is not dealt with here.

The most common fault in conservation layouts is to space contour banks too far apart. When this is done and heavy storms occur, excessive sediment is deposited in the canal which can lead to reduced capacity, overtopping of the bank, and disastrous results below the structure.

It is preferable to have the local Soil Conservation Officer determine the spacing of contour banks, but if he is not available, the following method is recommended, and involves the determination of soil erodibility, the slope of the land, and the mean annual rainfall of the site.

* **Soil Erodibility:** A simple method of comparing the erodibility of different soils is to allocate values to them based upon the parameters mentioned above. Such a scale has been determined which ranges between 1,5 and 7,0. The lower the value the

Table 1. Field sheet for determination of soil erodibility (F_b rating)

1. TEXTURE OF 'A' HORIZON				
Light 0 - 15% clay		Medium 15 - 35% clay		Heavy >35% clay
Fine sand	Medium or coarse sand	Fine sand	Medium or coarse sand	All sand
3,5	4,0	4,5	5,0	6,0
2. PERMEABILITY OF SUBSOIL HORIZON				
Slightly restricted		Moderately restricted		Heavily restricted
- 0,5		- 1,0		- 2,0
3. DEGREE OF LEACHING (EXCLUDE BOTTOMLANDS)				
Dystrophic soils, medium or heavy texture		Mesotrophic soils		Eutrophic or calcareous soils Medium or heavy texture
+ 0,5		0		- 0,5
4. ORGANIC MATTER STATUS				
Organic A - Horizon			Humic A - Horizon	
+ 0,5			+ 0,5	
5. A - HORIZON LIMITATIONS				
Surface crusting			Excessive sand / High swell - shrink / Self-mulching	
- 0,5			- 0,5	
6 EFFECTIVE SOIL DEPTH				
Very shallow < 250 mm			Shallow 250 - 500 mm	
- 1,0			- 0,5	
			F_b = INITIAL VALUE - ADJUSTMENT VALUES =	

	SOIL PIT		
	1	**2**	**3**
INITIAL VALUE			
ADJUSTMENT VALUES ±			

the greater the erodibility. The method involves the allocation of a basic value dependant on the texture of the soil, and the adjustment of this basic value according to the soil-related parameters mentioned. Table 1 is a user-friendly table which guides the user in determining a relative erodibility value for the soil type under consideration.

FIELD TESTS IN DETERMINING SOIL ERODIBILITY

The following paragraphs numbered 1 - 7 assist the reader in the carrying out of field tests in order to arrive at soil erodibility.

* **Texture:** The recommended field method for determination of clay percentage in a soil sample is by means of the 'sausage' method: A small sample of the soil is taken in the cupped hand, and sufficient moisture added in order to make the sample pliable without it being overly wet. It is well kneaded with the hands to ensure an even mix of soil and water, and then certain shapes are attempted. The relationship between shape and clay percentage is shown in Table 2.

Table 2. Determination of clay percentage

Shape attained	% Clay
Forms a ball but cannot form a sausage	0-5
Possible to form a 5 mm diameter sausage but will not bend without breaking	5-15
Sausage will bend slightly before cracking	15-35
The sausage will bend into a U-shape before cracking	35-55
The sausage will form a complete circle without cracking	>55

* **The grade of sand** in the sample is not easy to judge in the field, but for the purposes of this exercise a moist sample is rubbed between the fingers in order to 'feel' the sand fraction. Coarse sand has a diameter which varies from 0,5 mm to 2,0 mm and is therefore easily identified as a very gritty component of the sample. Fine sand on the other hand is akin in feel to the finest particles. An absence of a gritty feeling when rubbing the moist sample is therefore indicative of a fine grade of sand. Medium sized sand grain particles have therefore an intermediate feeling of grittiness to them.
* **The permeability of a soil profile** is indicated by a number of characteristics of the soil material in the profile. Table 3 illustrates this. Water absorption is determined by dropping five drops of water in quick succession onto a moist clod of the soil and measuring the time taken for all the water to be absorbed.
* **The degree to which the profile has been leached of exchangeable base-forming cations** can be measured only in a laboratory. Whenever a soil sample is analyzed for soil fertility, this condition (called the S-factor) is given as a measure in a 100 g of clay in the soil. The S-values relate to leaching as indicated in Table 4. If the S-value is not available, mean annual precipitation may be used as a very rough guide.
* **Organic matter** in the topsoil assists in the aggregation of soil particles. This, in turn, assists in resisting the sealing action of heavy raindrops, thereby reducing both runoff and soil loss. Any soils which are therefore inherently high in organic matter should automatically be more resistant to erosion than those with a low organic matter status.
  — Organic O horizons are those that, apart from other considerations, have sufficient organic carbon to ensure an average content of at least 10 % throughout a vertical distance of 300 mm.
  — Only those Humic A horizons which contain more than 2 % organic carbon over a depth of at least 450 mm are considered to have sufficient organic carbon present to warrant upgrading them.

Table 3. Classification of soil characteristics for permeability classes

Permeability Class	Degree of Restriction			
Soil characteristic	none	slight	moderate	severe
Texture	Sand to sandy clay loam	Clay loam	Sandy clay	Clay
Consistency (moist)	friable	slightly firm	firm	very firm
Structure	none	weak	moderate	strong
Colour	red - yellow	brown	black - grey	blue - white
Mottling	none	weak	moderate	strong
Water absorption rate	1 - 5 secs.	6 - 15 secs.	16 - 60 secs.	> 60 secs.

Table 4. Determination of degree of leaching of base minerals in a soil profile

Degree of leaching	Dystrophic	Mesotrophic	Eutrophic
S - value / 100 g of clay	<5	5 - 15	> 15
Mean annual rainfall (mm)	> 900	700 - 900	< 700

* Some soils are quick to form **surface crusts** during storms of even fairly light intensity. Others have other characteristics which are conducive to very much lower infiltration rates once they are cultivated. These soils must be downgraded.
* Root development, to a large extent, is determined by the physical characteristics of the soil. When the air-moisture regime to a certain depth is such that root development is not appreciably restricted, that part is still considered as effective. The **effective depth** is therefore taken to be as far as a layer or horizon which can be considered as restrictive to root development. The latter will include all cutanic, plinthic, E and G horizons as well as saprolite and rock.

    Having determined an F_b rating as indicated in Table 1, the soil can be placed in an erodibility class by consulting Table 5.

Table 5. Determination of erodibility class based on F_b rating

F_b rating	Erodibility
1,5 - 3,0	High
3,5 - 5,0	Moderate
5,5 - 7,0	Low

OTHER COMPONENTS OF A CONTOUR BANK SYSTEM

* Determining land slope: Place the staff in a position that is representative of the general slope of the area. Move the Abney on its support up/downslope until, with the bubble in the middle of its run the crosshair intersects the foot of the staff. The distance between staff and instrument is then measured in metres, and

$$\% \; LAND\ SLOPE = \frac{1{,}5 \times 100}{distance}$$

Lands do not always have an even slope throughout, and it will be necessary to check the slope at different sites and to work out the average across the field. This must be done from time to time as one progresses down the slope as well.

* **Contour bank spacing:** The three main parameters of soil erodibility, land slope and mean annual precipitation are now available, and the relevant graph in Figure 4 is consulted for vertical spacing between contour banks on land planted to annual crops, and Figure 5 for land on which sugarcane is grown.
* **Gradient of contour banks:** The gradient of the canal must be such that it allows excess runoff to be safely diverted to the discharge point. It should not be so flat that pools form behind the bank, but it should also not be so steep that the diverted runoff scours the canal. The following grades are recommended:

Clay soil 1 : 100 Loam 1 : 200 Sandy soil 1 : 300

* **Using the Abney level:** Since marks 'B' and 'C' have been spaced 150 mm either side of mark 'A' on the staff (see the section headed elementary staff above), the relevant gradient can be obtained by controlling the distance between pegs, *e.g.*

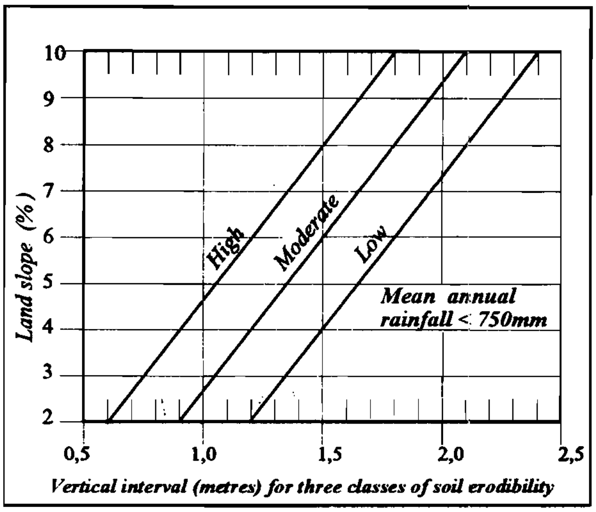

Figure 4.1 Graph for determination of contour bank spacing in low rainfall areas

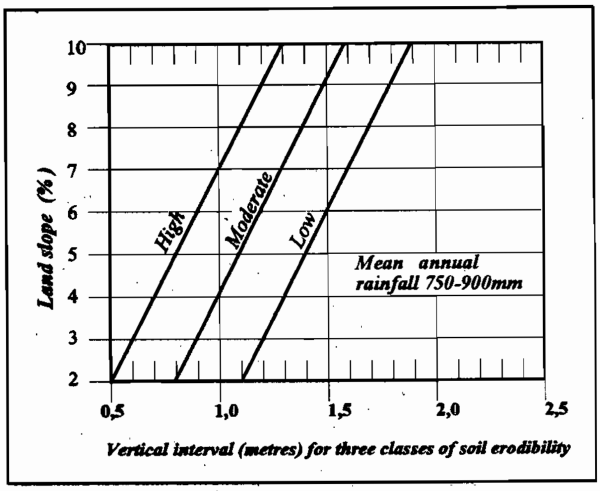

Figure 4.2 Graph for determination of contour bank spacing in high rainfall areas

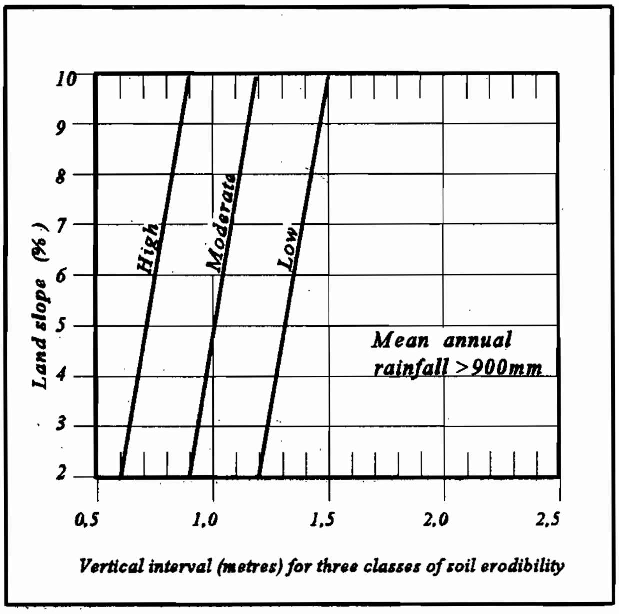

Figure 4.3 Graph for determination of contour bank spacing in high rainfall areas

Gradient	Height Difference	Distance between pegs
1 : 100	150 mm	15 m
1 : 200	150 mm	30 m

Distance between pegs is the length of twine joining the staff to instrument support.
If the distance between pegs is increased in order to save time, then the distance between marks A to B and A to C (*i.e.* height difference) must be adjusted accordingly.

SURVEY PROCEDURE

Only the method using the Abney Level will be dealt with, as most people who own a dumpy level know how to survey a gradient. If not, the local Soil Conservation Officer will assist.

Requirements: Instrument and staff
Approximately 25 pegs
Staff bearer plus 3 farm workers
Tractor, plough and driver
Ensure that the land surface is smooth. Land planing will ensure a better layout.

The basic planning of the layout and the relevant contour bank spacings have been determined, the necessary waterways have been constructed and stabilized, and the crest roads have been marked with a ploughline. The gradient has been determined as well as the distance between staff and instrument support fixed by the length of twine as indicated above.

The following procedure is carried out when surveying from the waterway (or any other suitable discharge point) to the crest. (See Figure 6). The staff is positioned at the outlet point of the contour bank, a peg put in (peg 1) and the surveyor places himself the required distance away, assisted by the twine. The staff is then sighted through the Abney level and the surveyor moves himself up or down the slope until he sights the crosshair of the Abney on the aiming mark 'B', which is 150 mm above the instrument level mark 'A'. A peg (peg 2) is then placed in the ground at the foot of the instrument support.

The staff bearer then moves to the second peg and the surveyor moves along the contour towards the ridge, a twine length away and repeats the procedure for peg 3. The survey process is repeated until the crestline is reached. This method enables the surveyor to

* select the peg position accurately by taking into account small undulations in the land,
  and
* to make minor adjustments to peg positions where the odd peg wavers out of the general line of pegs.

Once the contour bank line has been pegged the tractor draws a furrow along the line while the pegs are removed from its path by a farm worker to enable the pegs to be re-used.

When surveying from the ridge to the waterway: The staff bearer holds the staff on the position on the contour at the crest and the surveyor positions himself the twine length away and in the direction of the waterway. The surveyor then sights on the aiming mark 'C' which is 150 mm below level mark 'A', moving himself up or downslope until, with the bubble in the centre of its run, the crosshair intersects mark 'C'. Pegs are put in at both the staff and the instrument positions. Both persons move as before, the staff bearer to the second peg, and the surveyor along the contour a twine length away from the staff bearer. The process is repeated until the outlet is reached.

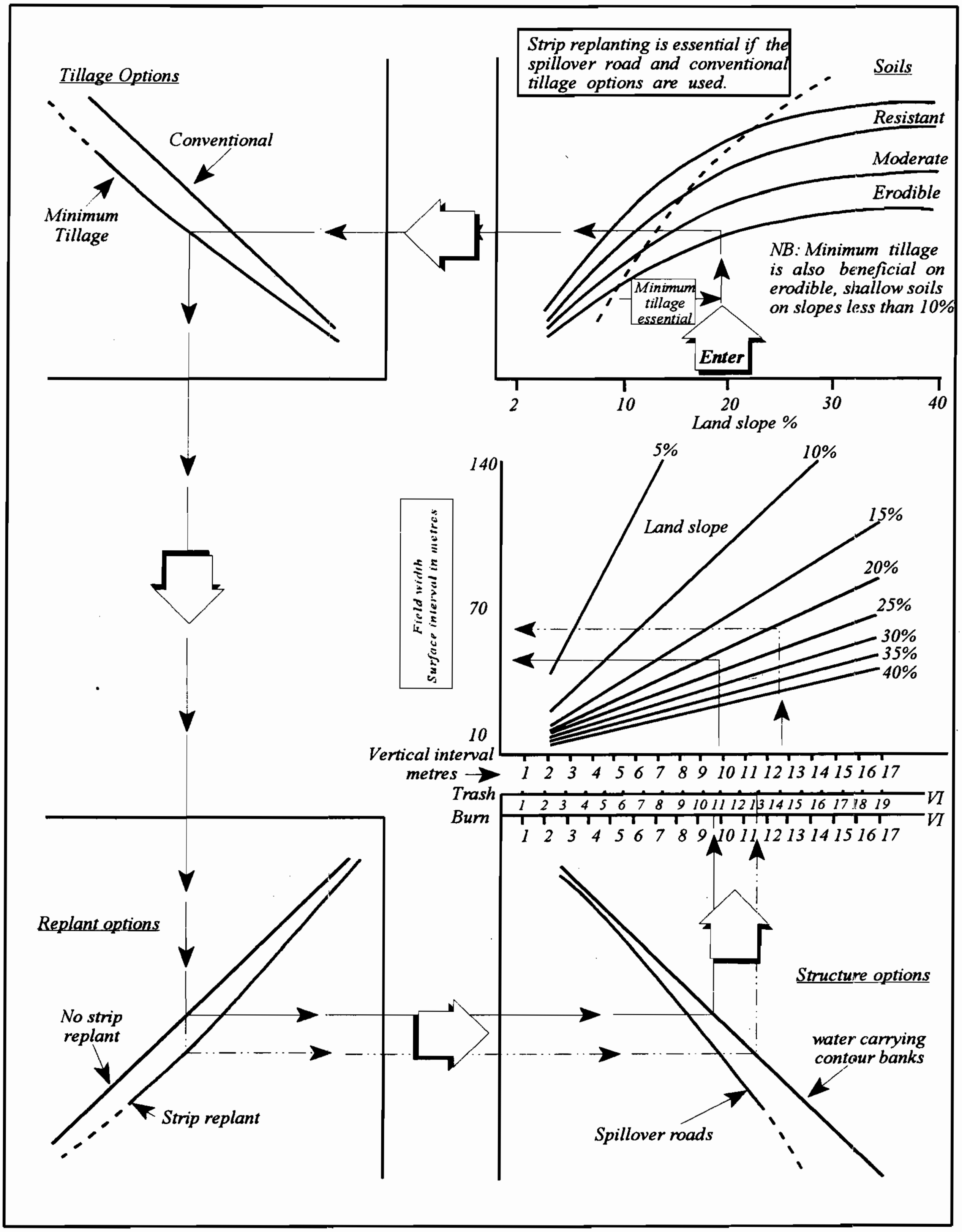

Figure 5. Nomograph for the spacing of contour banks on sugarcane fields

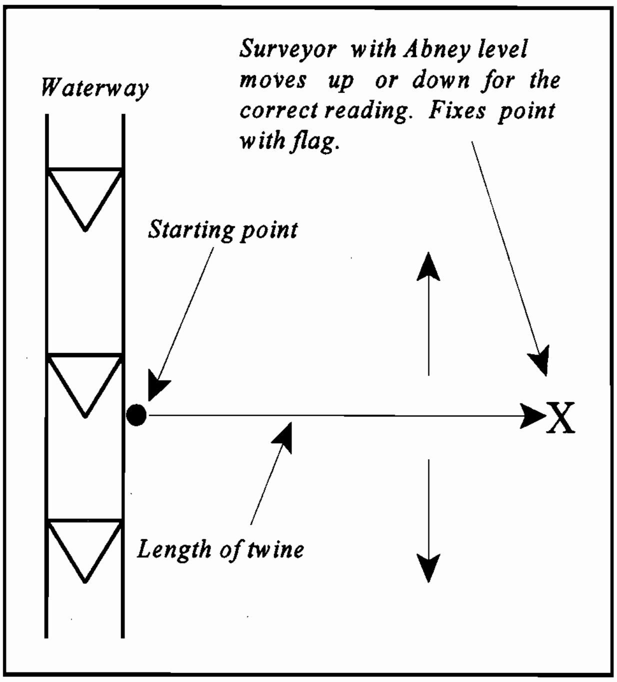

Figure 6. Procedure for surveying from the waterway towards the crest

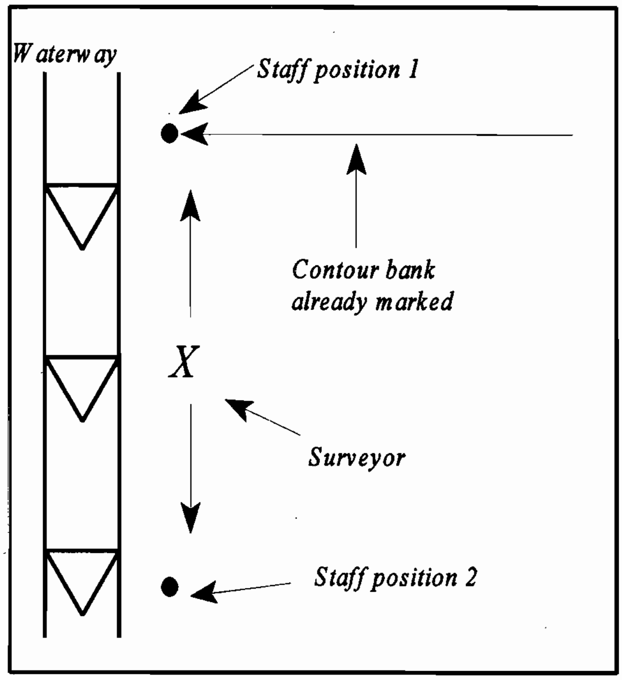

Figure 7. Procedure for marking successive contour bank positions

MARKING OUT SUCCEEDING CONTOUR BANKS
(See Figure 7)

Having marked the line of the first contour bank, it is now necessary to determine the position of the next one. ***It may be done at any point along the previous surveyed line, but must be done exactly at right angles to it. It is preferably done near the discharge point where it is possible to measure at right angles to the previous line.***

Position the staff on the chosen starting point along the previously surveyed line, with the fully graduated side of the staff facing downslope. The surveyor then positions himself directly downslope until he reads onto the foot of the staff with zero reading on the protractor and with the bubble in the middle of its run. The staff is then moved downslope until the crosshair intercepts the reading on the staff equal to the vertical interval read off the graphs in Figure 4. If this was less than 1,5 m the second line will be between the previous line and the surveyor. If greater than 1,5 m, the surveyor will have to turn around to read the staff downslope from his position. This will be the starting point for the survey of the next contour bank.

CONTOUR BANK CONSTRUCTION AND MAINTENANCE

The survey of contour banks is but one step in the process of protecting cultivated land from erosion. It is very important that sufficient attention be given to both the correct construction and maintenance of the structures. For further information on these two aspects, the reader is referred to the guideline in this Departmental series entitled Construction and Maintenance of Contour Banks.

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Conservation of Farmland in KwaZulu-Natal

THE CONSTRUCTION OF GRASSED WATERWAYS AND INFIELD ACCESS ROADS

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INTRODUCTION

The grassed waterway, which is needed as part of the surface water management system for the cultivated land on a farm, is of vital importance. Once established and in operation, it must carry all of the runoff which previously ran uncontrolled down the adjacent land. Great care is therefore necessary in:

* shaping it to hold all of the expected runoff, thus ensuring that it does not spill over into the land and cause erosion;
* stabilizing it with a good grass cover to ensure that it does not erode into a deep gulley, and
* ensuring its continued existence by regular maintenance.

The first-mentioned is the subject of this pamphlet. Grassing and maintenance will be dealt with in a separate one - see Leaflet No. 2.5 "Grassing and Maintenance of Artificial Waterways".

It should be apparent that the sizing of a waterway is very important, and it is strongly recommended therefore that the land user obtain the dimensions from a qualified soil conservation officer or engineer before attempting construction.

The most suitable time of the year in which to construct the waterway is from mid-February to mid-April in the Summer Rainfall Area, but early Spring in the warmer areas may also be suitable, especially if irrigation water is available to allow early grass planting, and if weed control is effective.

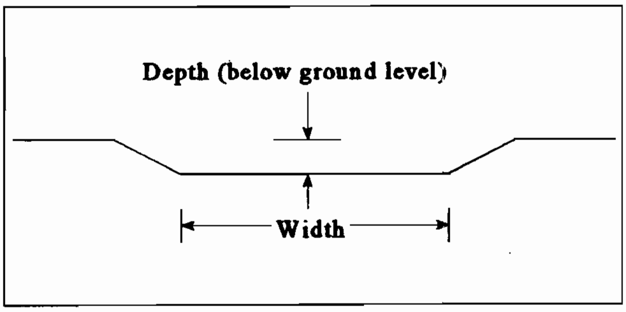

Figure 1. Flat-bottomed waterway

Construction in between these two periods is hazardous due to high rainfall intensities and extreme temperatures. High rainfall intensities can result in damage to the newly excavated site, and extreme temperatures in damage to the establishment of the seedlings.

Two basic shapes are recognised: the parabolic and the flat-bottomed, but for reasons of economy and safety the latter shape is the one most favoured, and therefore the shape discussed here. See Figure 1. Waterways of parabolic cross section are much more prone to erosion than waterways of trapezoidal section, especially if the subsoil is erodible.

Construction may be accomplished using a variety of implements normally in use on the farm, but no single implement is capable of successfully executing the task alone. The various techniques are discussed separately, but a few points, common to all, need to be made :

* The dimensions given are based on an investigation of all relevant factors, and can be considered the minimum specifications. They should not be altered without discussing the alterations with the designer.
* An attempt should be made to use some of the topsoil for topdressing the excavation.
* The waterway must not be used, under any circumstances, as a roadway. On the other hand, the soil excavated to form the waterway can be most gainfully used in constructing a crest road for proper access to the land and/or filling in gulleys in the land.
* Specifications will have included width and depth at various points along the proposed centre-line of the waterway. This centre-line must be marked on the ground using flagged pegs, ensuring that the waterway is at right angles to the contourline throughout its length. The outer widths are then flagged at the relevant distances, and a plough line is drawn along the perimeter, on both sides of the waterway. It will normally increase gradually from

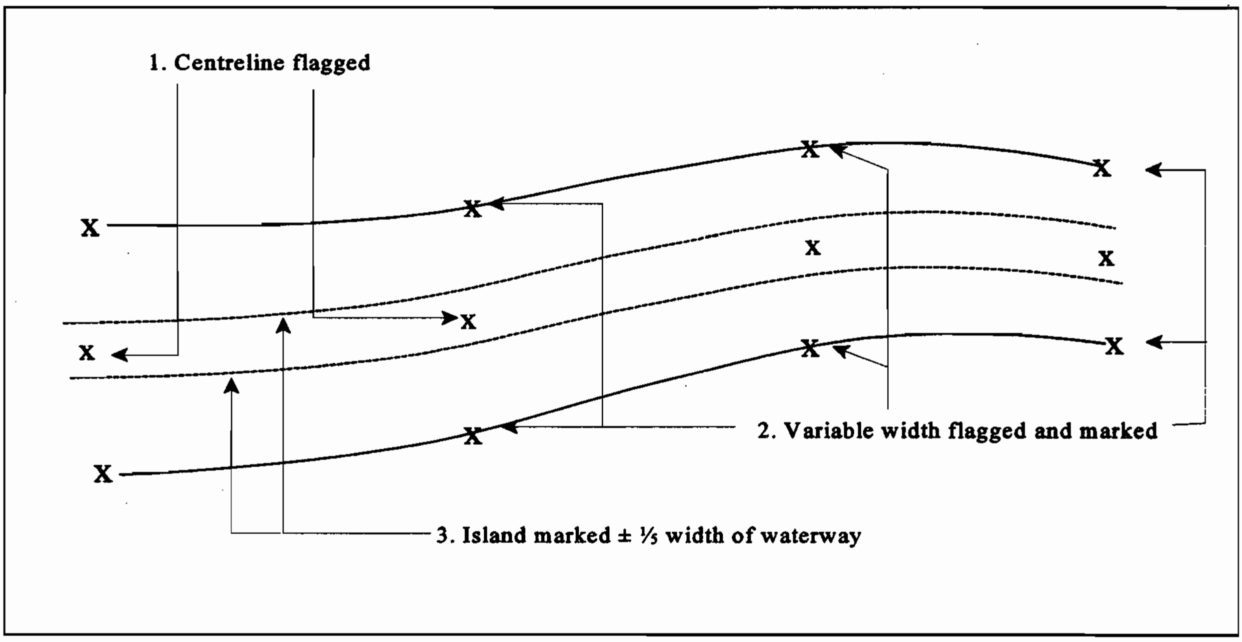

Figure 2. Marking the waterway in the field

a narrow initial width at the top of the land to the widest at the outlet at the bottom end of the field, although changes in soil type, landslope and field shape could influence this. See Figure 2.

* An island is also marked straddling the centre-line so that the width is approximately one-fifth of the waterway at all points. This is to make a source of topsoil available close at hand to spread over the completed excavation. See Figure 2. *For this reason it is necessary to excavate at least 100 mm deeper than the design depth required.*
* It is essential that the shape, width and depth be checked regularly during construction. The base of the waterway must be level in cross section.

The only practical way to control construction is with pegs that have been set out on the level. See Figure 3. These pegs are placed a convenient distance *outside* the required construction width so that equipment does not displace them. The operator is told how far he must excavate from these pegs, *i.e. width is controlled.*

To control depth, a mark is made on one of the pegs. This mark must be a convenient height ("y" in Figure 3) above the average level of the ground between that pair of pegs. The exact level of this mark is transferred onto the other peg with a similar mark using a dumpy level. A string pulled tightly between these marks will be level. Measuring down from this string will control the depth of excavation. For example, if a 300 mm depth is required,

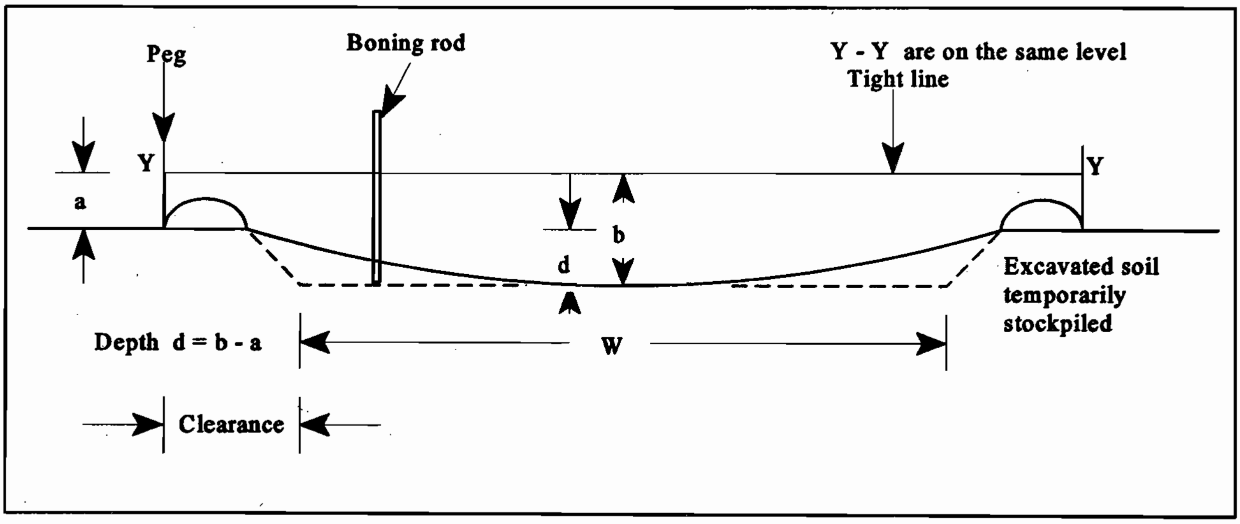

Figure 3. Checking the depth of excavation using boning rods

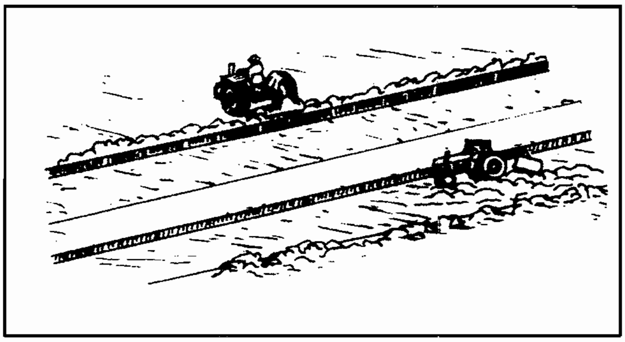

Figure 4. Construction using a grader blade

measurement with a "boning rod" 300 mm longer than length "a" must be carried out. Boning across the width of the waterway will ensure that the excavation is made level and has the required depth.

Pegs are placed at regular intervals, *e.g.* every 25 m along the waterway.

Moving the string and boning ahead of the construction machinery enables the operator to control excavation *during excavation.* If the *design* depth of the waterway varies along its length, this variation can be achieved by manipulating the levels of the pegs. This ensures that the length of the boning rod does not have to be adjusted *at all* i.e. the depth below the string remains *constant throughout.*

CONSTRUCTION USING VARIOUS IMPLEMENTS

Using a Grader / Grader Blade: The waterway area (excluding the island) is ploughed up-and-downslope to the depth of excavation required, plus 100 mm. If the soil is heavy, dry and/or hard, it may be useful, first of all, to loosen it with a subsoiler, ripper or chisel plough, depending upon implements available and the depth required. With the blade angled at 45° start on the perimeter of the waterway and move parallel to it, pushing the soil sideways to the edge where it is temporarily stockpiled. Successive "slices" of soil are moved outwards by successive passes in this manner, using boning rods to check on resulting depth and shape. Once the latter is achieved, plough out and grade the island soil (using the grader blade or disc harrow) over the construction area, to form the required seedbed. Figure 4 applies. The grader can then be used in a transverse manner to spread the stockpiled soil thinly over the adjacent land, thus avoiding any bank alongside the waterway which will inhibit runoff entering the waterway.

Using a bulldozer. Figure 5 shows the method.

Using a Dam Scoop or a Front End Loader: Of all the implements described, the front end loader and the dam scoop are the two implements which will allow the most efficient movement of the soil excavated. The area between the waterway perimeter and the island is ploughed / ripped / subsoiled to the depth required and the scoop or front end loader used to load the soil and transport it away.

The Front End Loader (FEL) is best used to load the soil onto a truck or trailer for transporting and depositing the soil where needed: either in gulleys in the field or along the line of the chosen crest road.

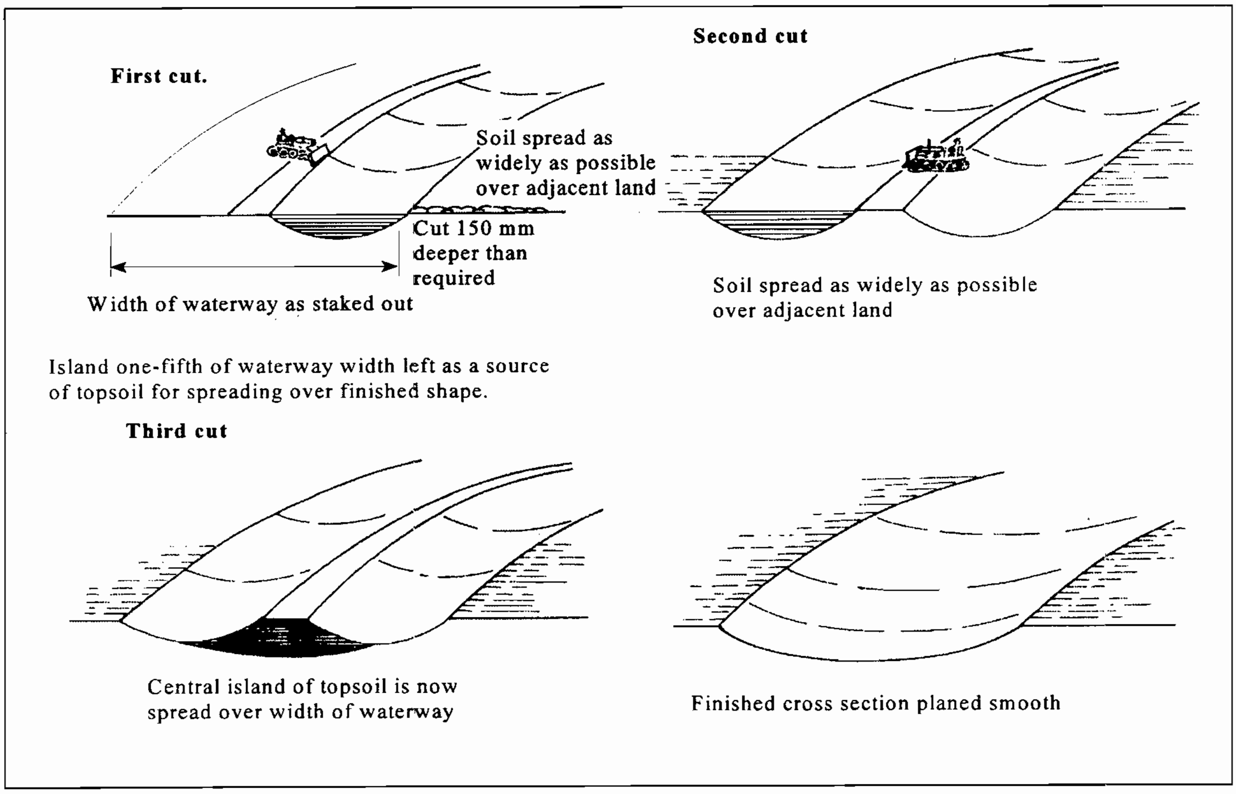

Figure 5. Waterway construction using a bulldozer

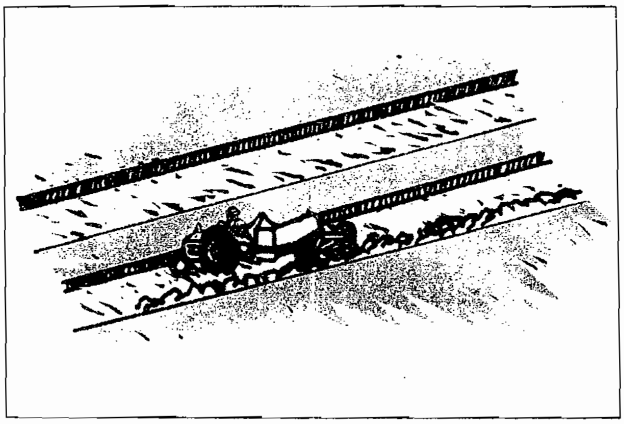

Figure 6. Construction using a dam scoop

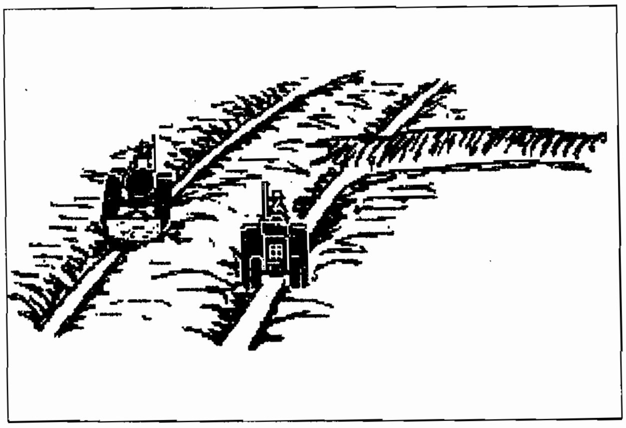

Figure 7. Construction of in-field roads using a plough

construction. If the front end loader is used in conjunction with a tip-trailer the excavation will proceed most rapidly and effectively. Because of this ease of operation, these implements are those most highly recommended for waterway construction. A grader blade or disc harrow will be needed to give the final seedbed shape to the excavation, although a skilled operator should be able to accomplish this with a scoop alone. See Figure 6.

ACCESS / INFIELD ROADS

Access roads are vital components of any runoff control layout, but they must be correctly sited in order to reduce maintenance and storm damage. Two types are recognised in the annual cropping areas : contour roads and crest roads. In both situations they are automatically protected from storm damage, and maintenance is therefore reduced.

Contour roads

These may be sited on top of the contour bank or just below it. In the former instance it merely means a contour bank built with a wider crest (recommended 3 metres wide). In the latter it means a road positioned below the conservation structure. If the soil is poorly drained, or high in clay content, it may not be a good idea to use the canal itself for this purpose.

Crest roads

These are always positioned on the highest point of a ridge where direction of flow of contour banks were changed during the survey stage. The road is built up above the surrounding ground level and cambered in order to shed water. It is tied into the contour banks in such a way that the contour bank canals actually divert the runoff away from the roads. The compacted road should stand approximately 300 mm above the surrounding land.

Construction with a dam scoop or front end loader

Soil is brought from the waterway excavation (or from high spots in the land) and dumped in thin layers (approx. 150 mm thick) along the staked line. Construction traffic is planned to help in the compaction of the earth fill, and a grader blade is needed to finish it off. Best compaction will be obtained when the moisture content of the soil is 2% either side of optimum. To the farmer this means it must be as damp as possible but not so damp as to stick to the implements.

Construction with a plough

Construction entails leaving an island three metres wide and ploughing clockwise around it, thereby forcing soil onto the island and moving it further on in successive passes to meet in the middle. See Figure 7.

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GRASSING AND MAINTENANCE OF ARTIFICIAL WATERWAYS

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INTRODUCTION

Artificial waterways are permanent structures excavated to design specifications. Their function is to convey stormwater safely from the cultivated field to the natural watercourse. Waterways must be constructed and well established to a suitable grass cover before contour banks, stormwater drains or any other water-bearing structures are connected to them. The importance of adequate construction and grass establishment cannot be overstressed, as reconstruction or repair work to waterways, once they form part of a functioning runoff disposal network, is achieved only at risk of severe erosion in the waterway itself. Several species of grasses are suitable for use in waterways. The choice of grass type must be based on the climate, rainfall, soil type and the gradient of the waterway itself. It is up to the land user to decide what his priorities are. When a waterway is designed by the departmental Soil Conservation Service, his preference will have been taken into account. It is then imperative that he establish the grass for which the waterway was designed, otherwise he must ask for a re-design. Of the two basic growth types of grasses, namely bunch (or tufted) type and creeping type, the latter, because of its far superior soil binding characteristics, finds greater favour. Creeping grasses withstand higher flow velocities than tufted species and their use results in a narrower, although deeper, waterway than that which would be required if bunch grasses were used. Consequently less cultivated land is needed for the waterway. On the other hand, some of the creeping grasses become invasive and can become a nuisance in the cultivated land. Although the grass cover of the waterway may be suitable for forage, this must be considered to be of secondary importance in the choice of species. It will, however, be necessary to defoliate the grass in some way or other during the growing season, and so the waterway(s), depending on their size, can become an important part of the fodder flow on a farm. Maintenance of a good sward is discussed later.

The following grass species are suitable for use in waterways subject to local climatic conditions and soil types:

Paspalum notatum (Lawn paspalum)
A sod-forming, low growing, creeping perennial which does particularly well where conditions are moist and fertile. It is an aggressive invader via the seed it produces. It is not a high producer of vegetation, but provides excellent cover when conditions are suitable. Establishment is simple and relatively inexpensive because it is established by seed.

Pennisetum clandestinum (Kikuyu)
A robust creeping perennial species providing excellent soil cover even on steep slopes. It does especially well in the higher rainfall areas, *e.g.* above 750 mm, where it is probably the most successful of all the species which may be used for soil conservation works. It is, however, not completely suitable along the KwaZulu-Natal Coast north of the Tugela because of high summer temperatures. It is planted most commonly by runners, although a seeded variety is available. It tends to become invasive through the implements picking up roots at the edge of the land, and dropping them in the land on the return trip. Kikuyu is, however, easily controlled chemically. It can provide good quality herbage if properly fertilized.

Eragrostis curvula (Weeping lovegrass)
A tufted perennial widely used as a hay crop throughout South Africa. It is easy to establish by seed, but because of its tufted growth habit requires a high level of management in order to maintain a reasonable ground cover. For this reason this species is not recommended for waterways where the land slope is in excess of 5%. Where it is used it should be mown regularly during the growing season to encourage thickening of the bunches in order to reduce the bare spaces between the plants.

Cynodon dactylon (Couch grass, Kweek)
A hardy creeping perennial, widely adapted to a large variety of soil and climatic conditions. It may colonise

cultivated lands, especially in the drier areas where it is difficult to eradicate. For this reason, although it does best on sandy soils, it is not the most sought-after waterway cover where an alternative grass type can be used. Several improved varieties exist, *e.g.* Coast Cross (KII) and Star grass. It is normally established using runners, but a seeded variety, NK 37, is also available. The improved varieties were bred for herbage production.

Acroceras macrum (Nile grass)
A perennial creeping grass which forms a dense sod. It is especially suited to moist or wet sites, although this is not a prerequisite for successful establishment. It does not spread as vigorously as the other creeping species described, is easy to eradicate, and is therefore not a threat to cultivated lands. It is slow to recover in spring after cold winters.

Axonopus compressus (American carpet grass)
A perennial creeping species established both by seed and by runners. This grass has a relatively low fertility requirement and does not pose a threat as an invader of cultivated land. It is not very drought resistant, however, and should not be used where the annual rainfall is less than 700 mm.

Dactyloctenium australae
A perennial creeping species for use where rainfall exceeds 1000 mm per annum. This grass type can handle shady conditions, is not a vigorous producer, but provides a low dense mat. It is more suited to the coastal area due to limited cold tolerance.

Stenotaphrum secondatum (Coastal buffalo grass)
A creeping perennial with extensive runners, adapted to the coastal area, especially on sandy soils. It forms a dense, coarse mat and is hardy and persistent.

ESTABLISHMENT OF GRASSES

A high fertility status is important in order to attain as quick a basal cover as possible. In this regard it is advisable to have the soil analyzed for fertility beforehand. As with any pasture establishment, the preparation of a suitable seedbed for the type of grass to be planted is essential. If the waterway is to be seeded, a finely prepared, firm seedbed, moist and free of weeds, is a prerequisite. The seed must be broadcast and not sown in rows down the slope. In the case of the planting of runners, the chopped runners can either be disced or rotovated into the soil before rolling, or they can be manually established by planting in furrows hoed across the width of the waterway at 250 to 500 mm spacing. Where the risk of damage by stormwater to the newly prepared waterway exists, runners can be planted in holes punched into a firmly prepared surface using a metal rod. This type of establishment, however, is limited to the higher rainfall areas. Whatever method of planting is employed, tramping down and rolling the planted area is important to ensure adequate soil and moisture contact. The surface of a newly-planted waterway will generate its own runoff during stormy weather. This runoff can cause damage to the waterway, especially if it is long and/or steep. Earthen berms should be erected across the waterway at intervals of 30 to 50 m and angled to divert runoff into the adjacent land. Once the grass has established and the danger of damage has declined, the berms must be removed and grass established where they were. If the waterway is to be planted during a dry spell, supplementary irrigation should be considered to ensure rapid cover. The grass should be planted at least 1 metre wide on the shoulder of the excavation to protect it. It is, in fact, preferable to create a 5 m wide headland on either side of the canal to provide even better protection. Control of weeds until the grass cover is well established is very important. If possible, establishment should take place after mid-summer, when weed competition is considerably reduced, when the soil is warm and moist, and when the high-intensity storms of summer are past.

MAINTENANCE

Once the waterway is well established it is vitally important that regular maintenance is not neglected, in order to maintain a vigorous grass cover. Waterways should be mown periodically if there is any danger of the vegetation becoming rank, as this will cause clogging and eventual overflowing of the structure. The grass itself will no longer be able to protect the soil surface to the same degree, if it is allowed to become moribund. Annual maintenance applications of fertilizer, as prescribed, will be necessary to keep the grass cover in prime condition. Grazing should only be allowed for the purpose of reducing rank vegetation and should be carefully controlled. *It is preferable to mow the grass, rather than have grazing animals trampling the moist soil.* Waterways should preferably not be used as head-lands, and never as roads.
It is advisable to contact the local Soil Conservation Officer who will be able to assist with advice if there are aspects of the design, construction, establishment, and maintenance of waterways which are not clear.

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Conservation of Farmland in KwaZulu-Natal

CONSTRUCTION AND MAINTENANCE OF CONTOUR BANKS

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INTRODUCTION

Contour bank structures are built at intervals down the slope of cultivated land in order to intercept runoff before it causes rill erosion, and to lead it off the land to a safe discharge point. During a heavy downpour the contour bank canal carries an enormous quantity of water. If the bank should break, large scale damage will ensue. It is extremely important that the structures be built correctly in order that they perform their function adequately. Attention to detail in construction will reduce the degree of annual maintenance required.

Before any contour banks are pegged the land should be properly prepared. Dead furrows, rills and gulleys should be filled in, and compacted, high spots removed, and the surface generally levelled as much as possible. The land should be free of excessive crop residue and/or clods which will interfere with the construction process. The surveyed lines must have had their kinks smoothed out before construction commences. A further point which should be borne in mind is that the surveyed line should preferably indicate the position of the centre line of the completed flow channel. To obtain this it is necessary to move the soil down the slope and away from the surveyed line.

At the time of construction the soil must be moist, without being so wet that it sticks to the discs or shares of the implements used in construction.

There are many different methods of construction, but the following are recommended as they are generally easier for the operator to follow, and give good results. The implements recommended for construction are generally in use on the farm. The methods are named according to the implement used.

RECOMMENDED METHODS OF CONSTRUCTION

This guideline deals with the construction of contour banks using a plough as the construction implement. There are only two types of ploughs that can be used for the purpose, and they are the disc and the mouldboard ploughs, *i.e.,* ploughs that move soil. Whatever type of plough is used for contour bank construction work, the following points will aid in the construction process:

* There should be sufficient tractive power to operate the plough at speeds in excess of normal ploughing speed. This may mean the removal of a disc or mouldboard share in order to reduce power demand, and then extra rounds will be required to complete the job.
* The rear wheels of the tractor should be set to a track width that is compatible with the particular requirements of the plough to be used. The plough will otherwise be difficult or impossible to control, especially when travelling in loose soil on the contour bank. The recommended wheel track settings are always stated in the operating manual for the plough. The conventionally-mounted three-furrow disc plough, for instance, usually requires a tractor rear wheel track setting (centre to centre of tyres) of 1,42 m.
* The front wheels of the tractor should be set 50 mm wider than the rear wheels. This will give the tractor a greater degree of stability and better control of the plough in the loose soil, particularly at speed.
* All the tyre pressures must be correct, as for ploughing work.
* Check that the plough discs are undamaged and are of similar overall diameter.
* Check that the plough has a tail wheel fitted and that the disc of the tail wheel is in good condition.

* **The Fixed Direction Plough**

  The best implement for the task is a disc plough. A mouldboard plough can also be used, but it does not 'throw' the soil as well as does a disc plough, especially uphill, thus requiring more rounds to achieve the desired result. The contour bank therefore becomes more costly to build with a mouldboard plough. The method is explained in Figures 1 to 3. It may be necessary to repeat stage 3 at a later date if the correct size has not been achieved, and once rain has settled the constructed fill and improved the moisture content of the soil.

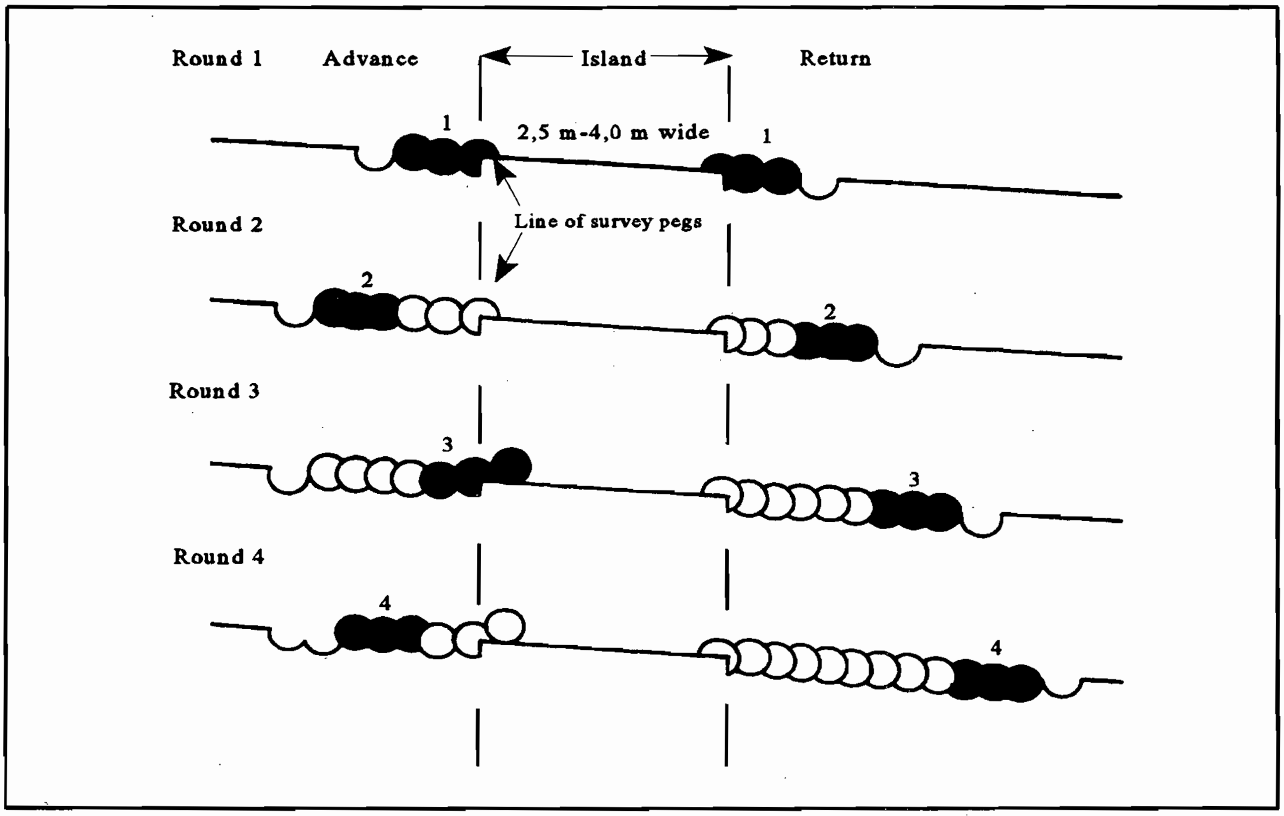


Figure 1. Stage 1 in the construction process, using a 3-furrow disc plough

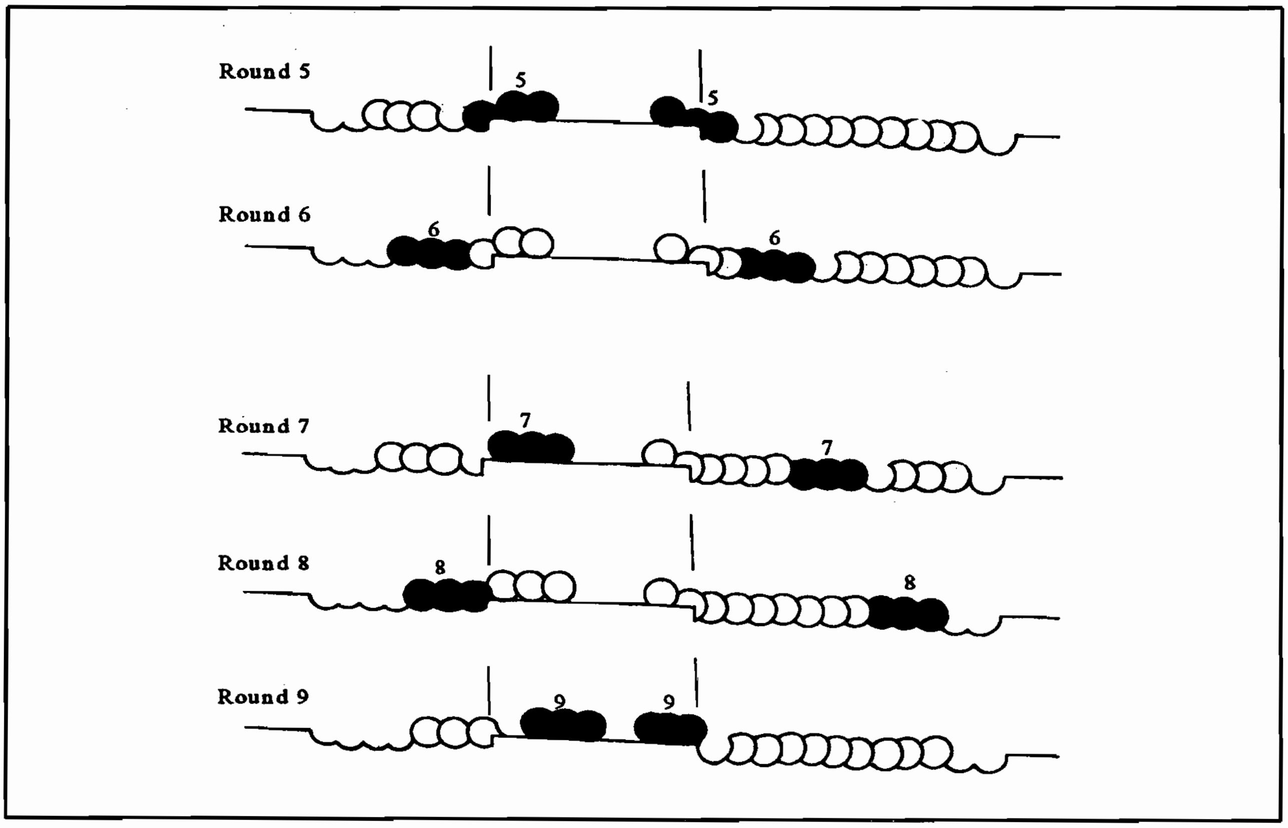


Figure 2. Stage 2 in the construction process

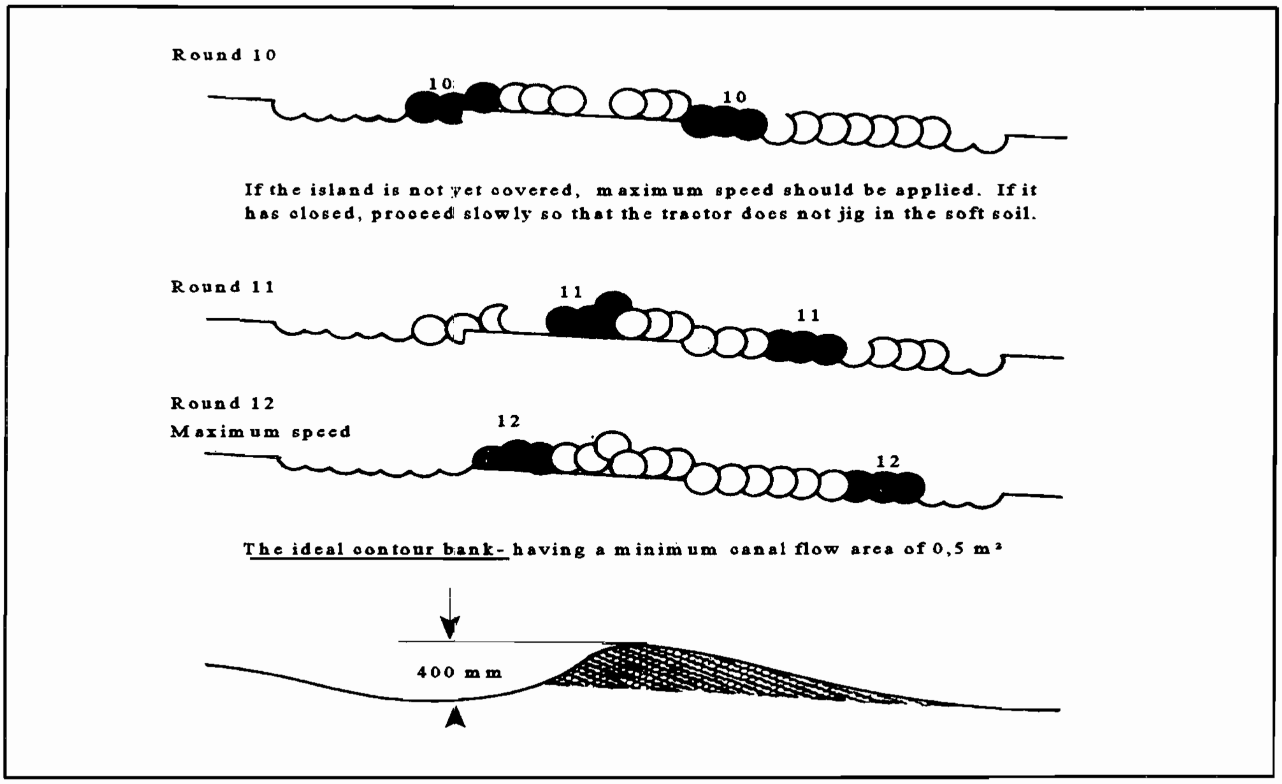


Figure 3. Stage 3 in the construction process, completing the structure

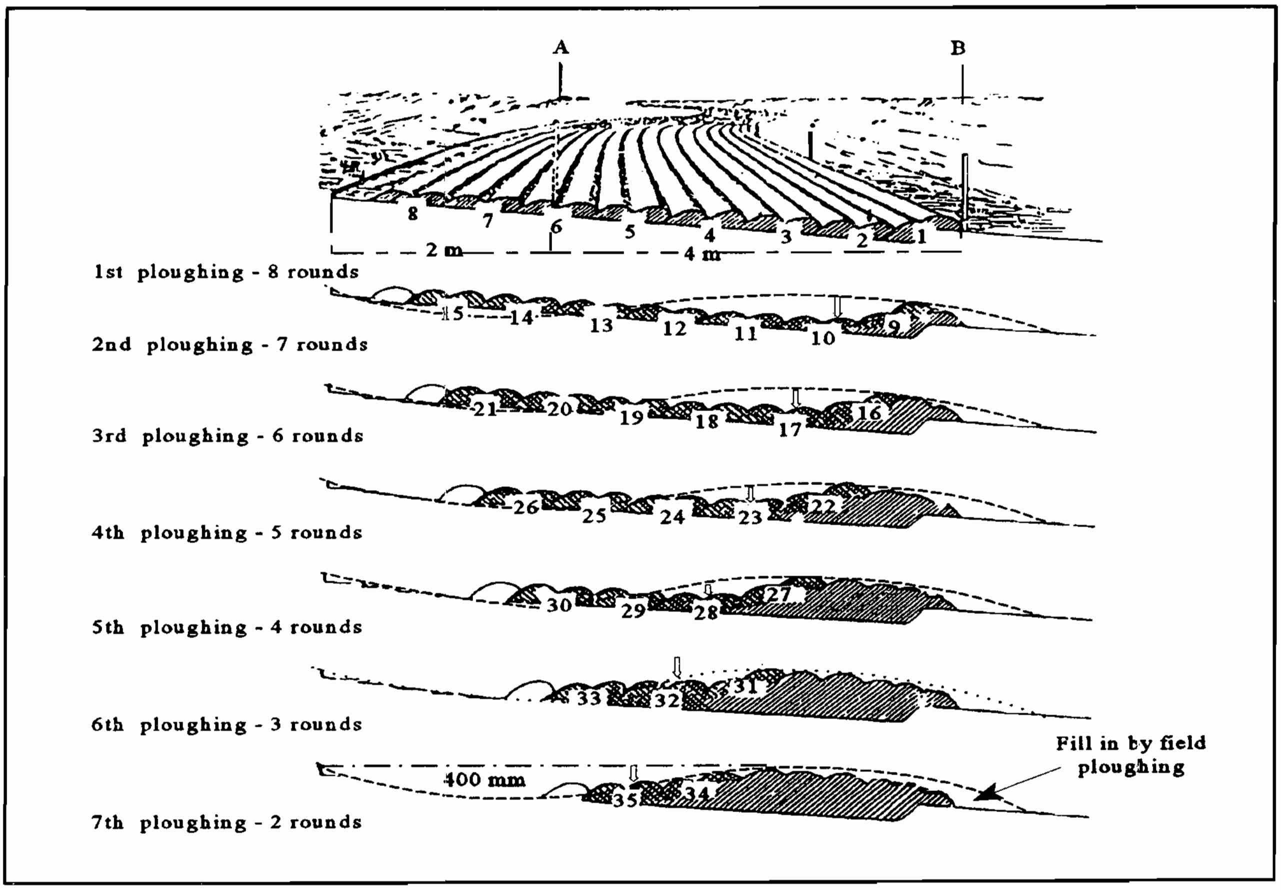


Figure 4.. Method for contour bank construction with a two-furrow reversible plough.
Note: A indicates the surveyed line

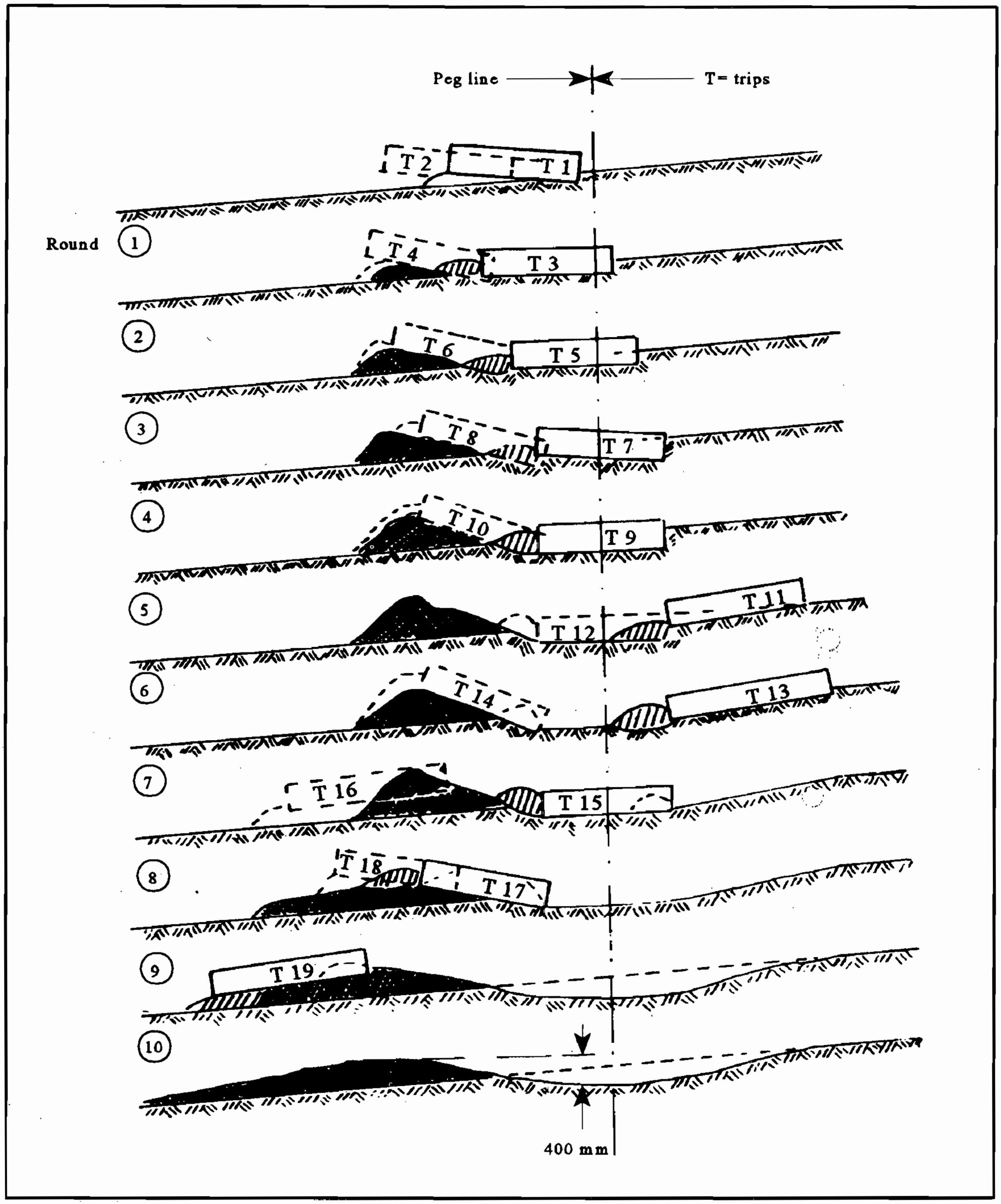


Figure 5. Construction of a contour bank with a grader

* **The Reversible Plough**
  In this method, soil is moved downslope only. Once again an island is marked downslope of the surveyed line (A), as illustrated in Figure 4. Ploughing commences along the lower line. By ploughing out the extra 2 m width upslope of the surveyed line, this latter then falls within the canal. The number of rounds will depend on the size of the plough. The illustration is for a two-furrow implement. A three-furrow plough should require fewer rounds but a more powerful tractor. All other tractor, plough and soil-related pointers for effective construction, mentioned in the previous section, will apply. If a mouldboard plough is used, one extra round per ploughing may be needed.

* **The Grader Blade**
  The procedure is best illustrated by the sketch in Figure 5. There are two problems associated with this method if care is not taken :
  - if the canal shape ends up as a triangular section instead of a flatbottomed or parabolic shape, scouring of the canal will occur, and
  - if the bank is not properly consolidated by regular passes over it during construction, the bank will settle, reducing canal capacity and leading to failure of the structure during a storm.

FINISHING OFF THE CONTOUR BANK STRUCTURE

The Shape

The best contour bank to have is one with sufficient capacity to take large amounts of stormwater without overtopping. At the same time it should blend into the landscape so that cultivation implements can work on it. In other words, it should be as wide as possible, with gentle changes of slope. The ideal is a contour bank which will allow cropping in the canal (if the soil is well drained) and on the backslope of the bank. In this way the minimum of land is lost to production and the contour bank becomes part of the topography of the land. Unproductive area is thereby minimised. Whichever construction method was used, it may be necessary to use one of the other implements to finish off the contour bank to the recommended shape.

The Outlets

These are extremely important for the safety of the system. They must be turned down into the discharge area and be kept free of obstructions. Even though extra gradient is usually given over the last 30 m during pegging, when the tractor is approximately one tractor length from the last peg it is imperative that it turns sharply down the slope towards the discharge area. Conversely, the contour bank must be turned up the slope onto a crest-road.

Correct Functioning

Following the first good rains after construction, every contour bank should be inspected over its entire length, to

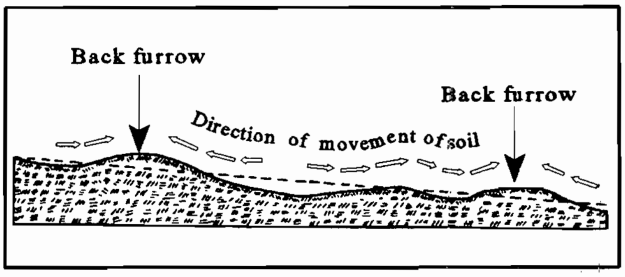


Figure 6. How the one-way plough method tends to deform the land profile if care is not taken in alternating plough direction

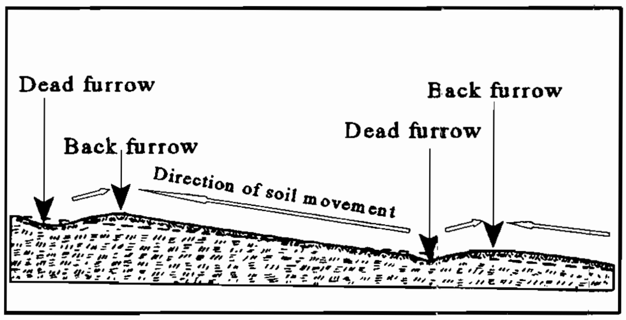


Figure 7. The two-way plough method, using a reversible plough, will assist in maintaining the land profile

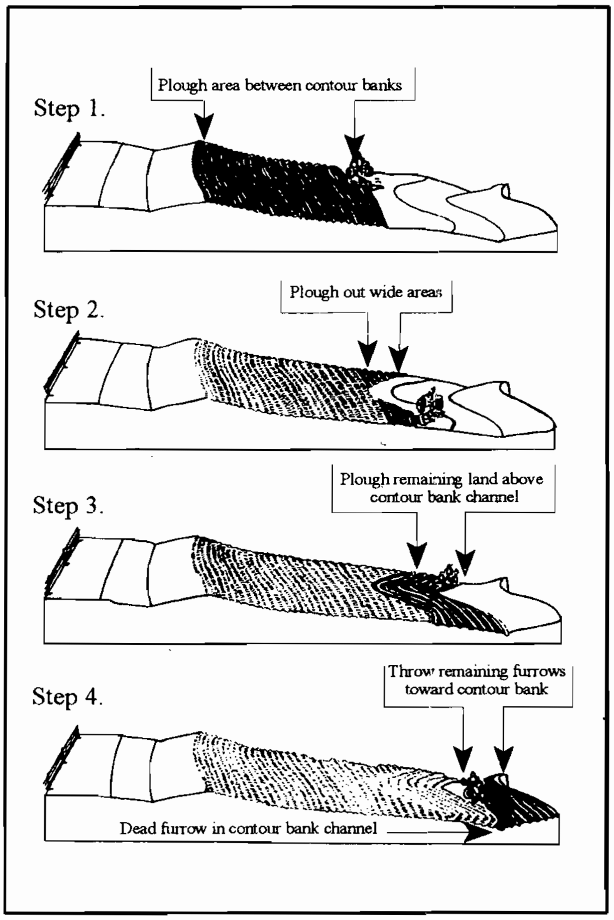


Figure 8. A method for ploughing land with a reversible plough

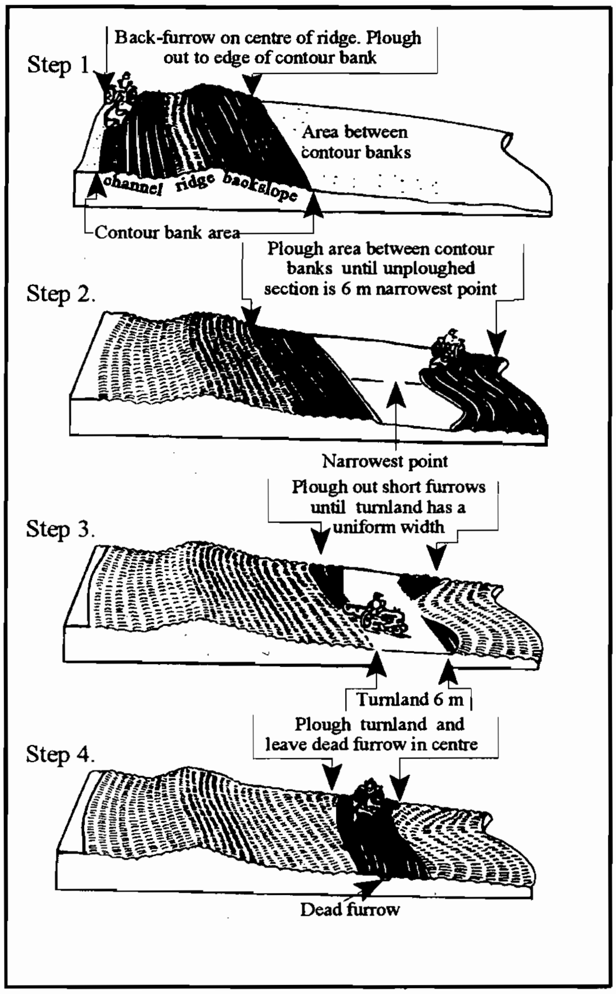


Figure 9. Method 1. Ploughing contoured land with a conventional one-way plough

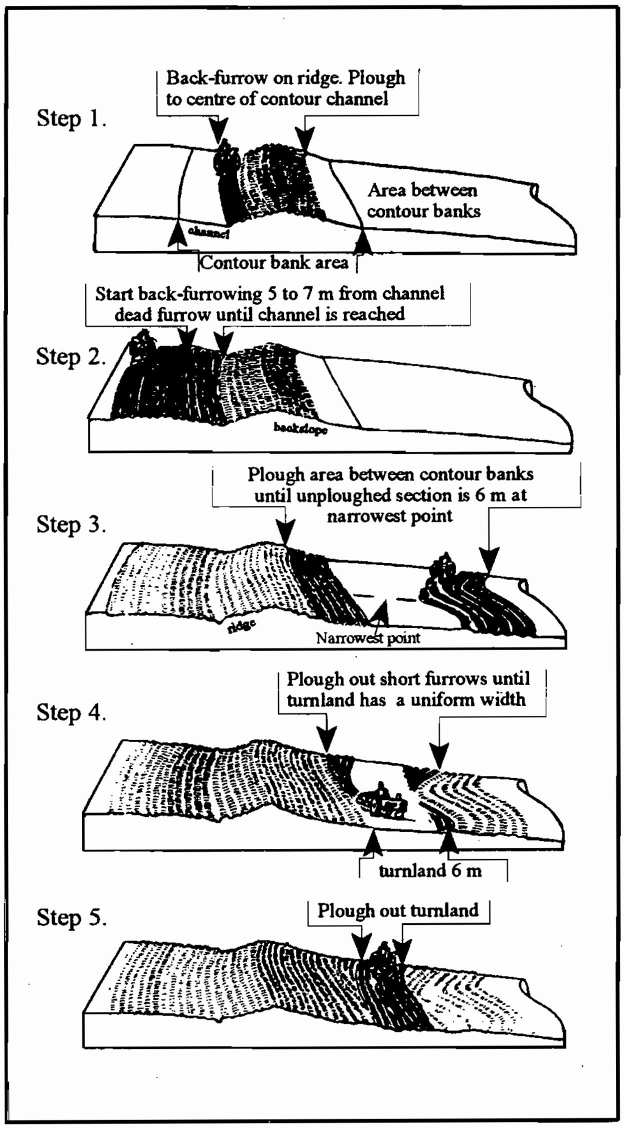


Figure 10. Method 2. Ploughing contoured land with a conventional one-way plough, leaving the dead furrow in the contour bank canal

find out where the high and low spots are. The high spotsmust be removed and the banks built up opposite the low spots. In-filling the low spots is also recommended to obviate the creation of wet spots.

Maintenance

Contour banks cannot be considered as permanent structures. They must be inspected after every heavy rain, the breaks repaired and sediment and other obstructions cleared out. Breaks must be specially strengthened to prevent recurrent damage. Annual maintenance should be regarded as part of the seasonal land preparation. Contour banks must be worked over to upgrade them during annual ploughing, but it is as important to maintain the land profile at the same time. Ploughing with a one-way (or fixed direction) plough in the conventional manner, *i.e.*, starting on the top of the bank and ploughing out, year after year, causes the profile to become dished, as illustrated in Figure 6. This ultimately leads to failure of the system.

The profile can best be maintained by using a reversible plough. When using a fixed direction plough the sequence of operations has to be adapted, depending on the amount of profile deformation that has taken place during previous cultivation operations. Tined implements move the minimum of soil and are always to be preferred. When using a two-way (or reversible) plough, the basic principle is that back furrows are made onto the ridge and dead furrows are left in the channel. See Figure 7. This will be changed only when the land area between structures starts to change shape. Irregularly-shaped areas and short rows are ploughed before the ploughing operation is completed, to obviate turning the tractor on ploughed land. See Figure 8.

To maintain the profile using a one-way plough the same principles of making back furrows on the contour bank ridge and leaving the dead furrow in the channel must be observed as often as possible, but without changing the profile shape. When dead furrows are made in between contour banks they must be eliminated during the

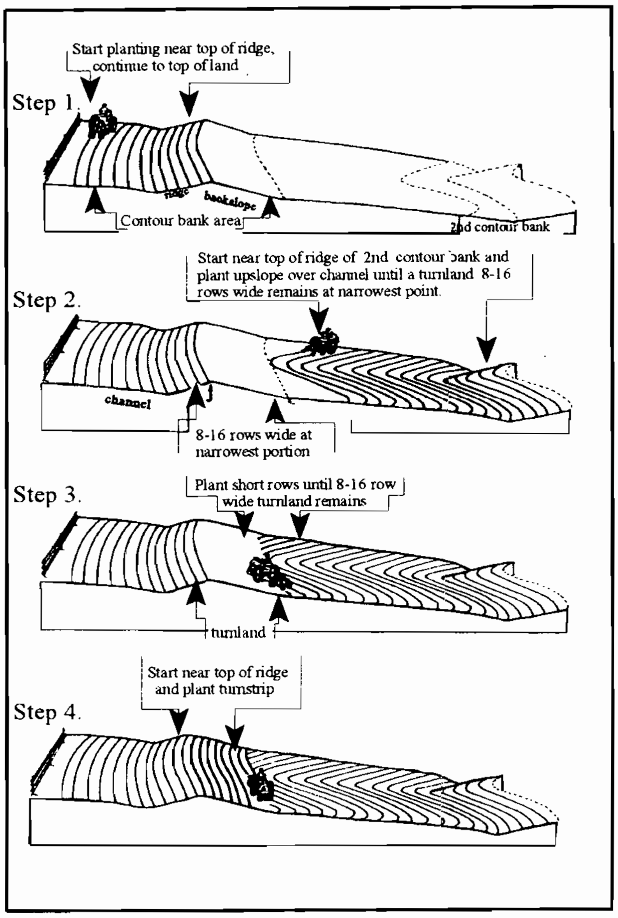


Figure 11. Planting a contoured field, method 1. Short rows below the contour bank

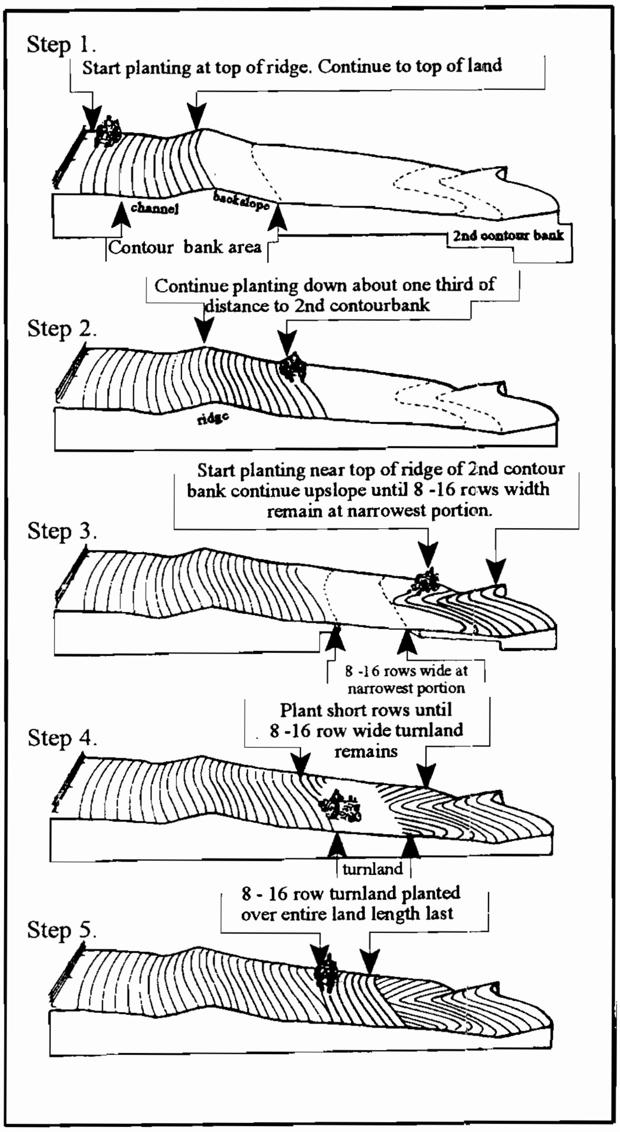


Figure 12. Planting a contoured filed, method 2. Short rows above the contour bank canal

subsequent harrowing or a subsequent ploughing. In the latter instance the back furrow is ploughed into the dead furrow of the previous ploughing and vice versa. Two methods are illustrated and these should be alternated to ensure maintenance of, and to prevent deterioration to, the profile. See Figures 9 and 10.

If tined implements are used for cultivation between the structures it is still necessary to use an inverting plough in order to build up the contour bank and clear the channel. Plough the structure clockwise around the crest so that the dead furrow is formed in the channel.

Planting Contoured Lands

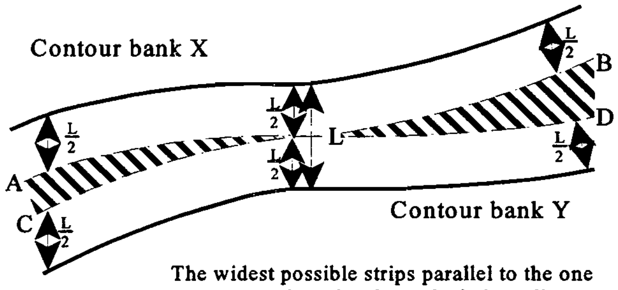
Planting row crops on non-parallel contour banks can be a problem. The methods demonstrated in Figures 11 to 13 are suggested to help alleviate the problem.

The parallel section of the field which is planted last should be 8 rows wide for a four-row planter and 16 rows wide for an eight-row planter. The parallel strips are harvested first.

On large relatively flat lands, planting and tillage operations can be carried out parallel to the top contour banks or upslope and downslope from the central contour bank for 2 or 3 contour banks, even if it means crossing an adjacent structure. If the gradient of the plant lines becomes too steep, however, (*i.e.*, more than 2%), or if they cross the contour bank at too much of an angle, planting direction must be corrected to run parallel to the following contour bank. It must be remembered that any tillage which crosses the contour bank will tend to flatten it. This must be compensated for during construction and maintenance. For this reason it is recommended that all tillage operations be carried out parallel to the structures, especially on slopes over 3%. Row crops parallel to the contour bank all help to increase water absorption and to reduce runoff velocity.

Repairs to Damaged Contour Banks

By the very nature of their structure and the typical, intermittent type of damage which generally occurs, most repair work involves hand labour to a large degree. It is therefore far more sensible to maintain structures in good order by working them up as part of the annual land preparation for cultivation, than to skimp on this aspect and have to carry out expensive repair work during the wet season. Where damage has occurred, reparations have generally to be carried out by hand. Compacting the new fill can then be a problem.



The widest possible strips parallel to the one structure and to the channel of the adjacent structure downslope are planted to row crops. The non-uniform sections are planted to a perennial crop.

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Conservation of Farmland in KwaZulu-Natal

REDUCING WIND EROSION ON CULTIVATED LAND

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This article is taken verbatim out of Bulletin No. 399 (ISBN 0 621 082589) : A Primer on Soil Conservation, published by the Department of Agricultural Development. Inclusions of importance to KwaZulu-Natal farmers are added in italics.

INTRODUCTION

The power of the wind to cause erosion is not always recognised. Wind with a velocity of 40 km per hour can remove 150 tons of dry soil from one hectare of fallow land in one hour depending upon the soil texture. In the case of erosion caused by water, a loss of that magnitude over a whole year is considered excessive and will be cause for alarm. Much of the soil of the western Free State, the Cape Province north of the Orange River, and the north-western Transvaal, has been blown there from elsewhere by the wind; and it can just as easily be blown away again. ***The flat sandy areas of the Cedarville Flats and the larger portion of Northern KwaZulu-Natal are just as vulnerable.***

SOIL MOVEMENT BY WIND

There are three distinct ways in which soil is moved by the wind, namely:

* **Suspension:** The finest particles are taken up in suspension in the air and may be blown to great heights and over long distances. Dust storms are typical examples of soil movement by suspension.
* **Creep:** The largest soil particles that can be moved by wind are rolled along the surface of the ground.
* **Saltation:** This is the movement of soil by means of a series of low bounces over the surface. It is the most important of the three methods of movement. The soil particles bounce into the air to a height of 300 to 900 mm. They are then carried before the wind for a distance of 3 to 10 metres (depending upon the wind velocity) before striking the ground with considerable force, and then rebound and repeat the process. Where they strike the soil, other soil particles are dislodged from the soil mass, causing them to join the process of wind erosion. These bouncing particles are also responsible for damage to tender vegetation such as emerging crops. It has been proven that by controlling the bouncing particles, wind erosion can be drastically reduced. Practices for the control of wind erosion, therefore, concentrate mainly on keeping the heavier particles in place.

DAMAGE CAUSED BY WIND EROSION

The actual loss of soil from the land is the most serious damage caused by wind erosion. Under conditions favourable to wind erosion, a windstorm of several days' duration could remove all the topsoil from a ploughed land, right down to plough depth. Wind has a grading or screening effect on the grains of soil. The finer particles are removed first and may be blown over long distances. These fine particles usually contain a lot of plant nutrients. In a certain case, analysis of a sample showed that the dust blown away contained three times as much organic material and phosphoric oxide, and 26 times as much potassium as the original soil. Apart from the loss of fertility, these finer particles consist of the colloidal substances which cement soil particles together to form granules. The fewer soil granules there are, the more susceptible the soil will be to further wind erosion. If the wind erosion process is allowed to go unchecked, the fine and medium sized particles may ultimately be removed entirely, and a gravelly surface will remain, with particles larger than 2 mm - a so-called desert pavement of no use for cropping.

The product of wind erosion, *i.e.*, the blown or drifting soil, is able to cause considerable damage and to have considerable nuisance value:

* A tender crop can be damaged by abrasion through soil particles being blown against it. Seeds and

emerging seedlings may be blown out of the soil. Plants may be buried in soil drifts. Weed seeds may be distributed along with the drifting and blown soil.

* Drifting soil will collect wherever there are obstructions such as fences, vegetated turning strips along the edges of lands, road verges, road and railway fills and cuts. Often these drifts have to be removed at great cost in the interests of safety and/or convenience.
* Blown dust may cause damage or inconvenience over large areas, some even far away from the source of the dust. In 1966, housewives in Bloemfontein had to cope with the nuisance caused by dust from the north-western Free State. Further concern has been voiced over the nuisance, especially in the last couple of years. The cost of damage to farm machinery, motor cars and factories by dust arising from agricultural land can only be guessed at.

FACTORS CAUSING WIND EROSION

The following factors will determine the degree of wind erosion that may occur on a specific land:

* the susceptibility of the soil to wind erosion, by virtue of texture and moisture content at the time of the windstorm,
* the local wind conditions,
* the roughness of the soil surface,
* the length of the land in the direction of the prevailing winds,
* the vegetative cover.

Soil characteristics

Soil subject to blowing is usually a light, fine sandy mix with little of the structure-forming or soil-binding components such as organic material and clay. Some heavier soils which contain a high percentage of fine sand (particles and organic matter smaller than 0,2 mm in diameter) may also erode at times ***and wind erosion is regularly observed in the heavier soils of the KwaZulu-Natal Midlands.*** Even a soil relatively resistant to wind erosion can gradually become more vulnerable if it is left exposed to erosive wind, due to the progressive removal of the finer soil-binding components. Coastal and river bed sands which have practically no soil-binding components are also examples of vulnerable soils.

In some soils of the Springbok Flats, the north-western and northern Free State, ***and in northern and southern KwaZulu-Natal,*** raindrop impact seems to play a role in initiating blowing. It appears that the raindrop action causes a separation of the silt, clay and sand fractions in the surface layers of the soil. The clay and silt are deposited in a dense crust with the sand on top. If the wind should start to blow when the top layers of the soil have dried off after a day or two, the sand particles on top start to move by saltation. Great damage can be caused to young crops by this sand. Farmers in these areas have found that this process can be controlled if the surface crust is broken up *(but not pulverized)* with a suitable implement, such as a rolling cultivator, as soon as there are signs of blowing.

Wind conditions

The erosivity of wind varies with the cube of its velocity. This means that if the velocity of the wind is doubled, the volume of soil that can be moved is increased eight fold. Conversely, halving the wind velocity can reduce the volume of soil moved to one eighth of what it was moving. Winds that are gusty and often change direction are a greater danger to the soil than steady winds.

Surface roughness

A rough surface, such as cloddy soil or plough furrows, will cause eddies near the ground surface if a wind blows across it. These eddies will retard the velocity of the wind in contact with the soil and thus reduce the ability of the wind to move the soil.

Length of land

The rate of soil movement increases with distance from the windward edge of a land. This means that the greater the length of a field in the prevailing wind direction, the greater the rate of wind erosion and ***vice versa.***

Vegetation

Close-growing vegetation close to surface of the soil will prevent virtually any soil movement, because the wind does not come into direct contact with the soil. Crop residue and mulches can fulfil the same function, especially if they are anchored into the soil.

Vegetation which does **not** cover the soil, and which varies from tufted grasses, small grains such as wheat, taller vegetation such as maize, sorghum and shrubs, up to the tallest trees, can control wind velocity in the following ways:

* by filtering and slowing down the wind through the stems, branches and leaves,
* by the turbulence created when the wind passes through the vegetation,
* by deflecting the rest of the wind upward.

See leaflet No. 2.9 entitled Windbreaks for Farms in KwaZulu-Natal for further information on this aspect.

CONTROL OF WIND EROSION ON ARABLE LANDS

The following measures can be employed to control wind erosion:

Control of soil factors

Control of the soil factors consists mainly in applying practices that will improve the structure of the soil, and in avoiding those that will destroy the structure. The organic matter in the soil should be maintained at a high level by leaving crop residue on the land; by applications of manure and/or compost; and by suitable crop rotations. The structure can also be improved by judicious applications of fertilizer and lime.

Wrong tillage practices are responsible for much of the destruction of soil structure. Practices such as the following must be avoided:

* Tilling dry soil. Tillage should be performed as soon as practical after a rain.
* Tilling practices and implements that pulverise the soil. Among these are high cultivation speeds (in excess of 6 km/h) and disc ploughs, disc harrows and rotovators.
* Trampling of the soil by animals grazing on crop residue also cause pulverization which leads to erosion by wind (and water).

A moist soil will blow much less than a dry soil. Every effort should be made to increase infiltration and reduce evaporation by practices such as contour cultivation, contour banks and mulching to improve the moisture status of the soil and thereby its resistance to wind erosion.

Surface roughness

A rough cloddy surface is effective in preventing blowing. A fine seed bed may be excellent from the point of view of germination, but may be disastrous from the point of view of wind erosion. Clods may be formed by ploughing the soil when it is still relatively moist.

If the surface has already lost most of its clay particles so that firm clods are no longer formed with shallow cultivation, clods can be created by ploughing deeply with a chisel plough or subsoiler. A large number of small clods are more effective than a few large ones. Ploughing up clods may be self-defeating if other control measures are not employed at the same time, as it will mean that new soil will be exposed, only to be stripped of its finer elements, until a stage is reached when there is nothing left with which to cement the clods.

Roughness can be created by ploughing ridges at right angles to the main wind direction. Even ridges as low as 300 mm in height may have a pronounced effect. Ridgers or listers can throw up ridges 200 - 300 mm high, spaced at 400 - 600 mm, which are very suitable for this purpose. If the ridges are cloddy, so much the better. Heavy rains tend to crust and smooth the surface of bare soil and blowing may start a day or so after rains. If such erosion starts, ridges should be constructed as soon as possible, or the crust broken with a rolling cultivator, as emergency measures.

Ridging should be supplemented by other measures, otherwise the furrows between ridges may fill up with blown soil. Ridging may also have to be repeated several times during the season, depending upon soil condition and the weather.

Vegetative control

The maintenance of a protective cover on the surface of the soil is the most important factor in wind erosion control. In this respect the following practices should be followed:

* **Strip cropping**

  If a crop does not give sufficient cover during the most windy period, it should be rotated with crops which do. With such rotations different crops are usually planted in strips (a minimum of 10 m wide to be of any benefit) across the wind direction. This will ensure that at least part of the area is protected and that soil blown from the vulnerable strips will be caught and held by the other strips. The maximum distance a particle will bounce is approximately 10 m. The chances are good that a bouncing particle will land in the well-vegetated strip where it will stay. The height of the vegetation does not play a great role here. In this way clean-tilled row crops which are vulnerable to wind erosion could be rotated with close-growing grain crops. In the western parts of the Cape Province, *i.e.*, those parts situated near the west coast, a form of strip cropping has been developed whereby the natural shrub is left intact in strips approximately 10 m wide, and 10 m wide strips in between are cultivated. Where such systems have been well managed, wind erosion is completely controlled. A common error committed by local farmers is to encroach with the plough into the uncultivated strips, thus making them progressively narrower. When this occurs they quickly lose their efficiency. Uncontrolled grazing of these lands will also damage the shrub strips and make them less effective.

* **Stubble mulching**

  The maximum use should be made of **crop residue.** The residue stubble from the previous crop should be left standing on the land for as long as practical. The higher and denser the stubble is, the better it will protect the soil. Wheat stubble, for instance, should be cut as high as possible when harvesting. If possible, the next crop should be planted in the stubble of the previous year. The old stubble should be flattened or incorporated in the soil only when the new crop has reached the stage where it can protect the soil by itself. When cultivation must take place before the windy season is passed, an attempt should be made to ensure that at least one third is firmly anchored. If the crop is rotated in alternate strips with intact stubble between, the advantages of both strip cropping and stubble mulching will be combined.

* **Windbreaks**

  Windbreaks may vary from strips of grass or shrubs of approximately 500 mm high, up to rows of trees 15 m high. Windbreaks are able to reduce wind velocities for distances of up to 5 to 10 times their height on the windward side and 10 - 30 times their height on the leeward side. For planning purposes it may be taken that a windbreak will shelter a distance equal to 5 times the height on the windward side and a distance equal to 15 times the height on the leeward side.

  Windbreaks should consist of several rows of plants and should have a uniform density from ground level to top. This can be achieved by using different trees

and shrubs. Sometimes even one or two rows of trees will give satisfactory results. There must, however, be no gaps through which wind can funnel as this causes a venturi effect.

Information on trees suitable for windbreaks can be obtained from the Forestry Branch of the Department of Water Affairs and Forestry. The reader is also referred to leaflet No. 2.9 in this series entitled 'Windbreaks for Farms in KwaZulu-Natal'.

* **Tillage**
The golden rule is to till as little as possible. In the case of row crops, only the strip taken up by the plant row need be cultivated. Weedkillers can be used to control weeds. The use of the correct tillage implements is most important. Implements that invert the soil, such as mouldboard and disc ploughs, should be used only in humid and sub-humid areas. Disc harrows should be used only to chop and partly bury crop residue. They should never be used to cultivate smooth bare soil which has a tendency to blow. Spike-tooth harrows should be avoided because they pulverise the soil. Spring-tooth harrows are better because they penetrate deeper into the soil, bring clods to the surface, and result in some ridging effect. Duck-foot cultivators, chisel-type tools, V-blades and rod weeders can do a good job of destroying weeds and bringing up clods, with little disturbance of the surface.

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Conservation of Farmland in KwaZulu-Natal

CONSERVATION TILLAGE PRACTICES

Compiled from various articles written on different aspects of the subject. Each article is identified separately.

WHAT IS CONSERVATION TILLAGE ?

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Contill No. 1. 1984. Department of Agriculture and Water Supply.

Conservation tillage (contill) is any form of tillage which has as its aim the conservation of the tilled soil and of its moisture. It generally has a spinoff of reduced fuel requirements as well. Terms such as 'reduced' and 'minimum tillage' do not convey the specific aim of conservation tillage and some of these forms may, in fact, not even help to conserve either of these resources. For example, one can cite the case of the rotovator, it is often possible to create a fine seedbed condition in one single pass over the land (reduced tillage), but the seedbed so formed could be in a very vulnerable condition, especially if all crop residues from the previous season have been removed. Contill in its true form makes maximum use of crop residues left on the soil surface to break the impact of raindrop splash on the cultivated soil and to slow down the velocity of surface runoff. It relies heavily on chemical control of weeds, although mechanical weed control is not excluded from contill.

The different types of contill include:

* **No till** : No cultivation takes place at all. An example is the slashing of the residue from a previous crop followed by the broadcast of seed (*e.g.* wheat) and fertilizer. The land is then rolled and irrigated to encourage germination. The term no till is often used erroneously, when direct drill is meant.
* **Direct drill** : No overall cultivation takes place. A heavy planter fitted with a special cutting blade cuts open a slot in the ground into which seed and fertilizer is deposited. A following pressure wheel covers up the slot.
* **Strip tillage** : A narrow band of cultivation takes place along the plant line, usually on a ridge. The inter-row is left uncultivated, but mechanical weed control can take place.
* **Minimum till in sugarcane** : The old cane plants are killed *in situ* using glyphosate or by being hoed, and a furrow is drawn between the rows of dead cane, into which the new seedcane and fertilizer is deposited.
* **Stubble mulch tillage** : This is probably the most widely used form of conservation tillage. Crop residue is chopped up and left lying on the soil surface. A chisel plough is used for overall cultivation, and weed control may be accomplished either chemically, by use of a tined cultivator, or by a combination of both.

The advantages of contill include :

* **Soil conservation** : Erosion by both wind and water is drastically reduced. Runoff plots at Cedara have proven a 2½ to 7 times reduction in soil loss over conventional tillage, depending on the type of contill. Such is the effect of contill on soil loss that in many instances a change-over from conventional tillage could result in a much wider spacing of contour banks for erosion control.
* **Moisture conservation** : Increased yields in dry years and in drier areas are brought about through increased infiltration and better subsurface storage. A 2½ to 3½ fold increase in rainfall efficiency has been observed on runoff trials at Cedara.
* **Plant protection** : Wind damage to plants conventionally tilled on lighter textured soils by sandblasting results in a lower net plant population and therefore lower yields. Litter on the surface reduces wind damage and therefore ensures increased yields where wind damage is a problem.
* **Time saving** : Many farmers who have adopted contill practices confirm the fact that, because of increased organic matter in the topsoil, improved soil moisture status at the beginning of the season, and less concern for a fine tilled seedbed, the planting season is not the 'pressure' time it used to be.
* **Lower mechanisation costs** : The 'combing' action of tined implements requires a lower power input per unit area than do the implements which turn the sod over. Allied to this is a lower fuel requirement. In trials in the U.S.A., fuel savings over conventional tillage ranged from 50% to 75%. It is a fact however that a change-over from conventional tillage to contill could require a more powerful tractor because of the wider cut of the chisel plough.
* **Soil movement on slopes is reduced** : Conventional tillage using fixed direction ploughs (as against reversible ploughs) tends to result in a gradual movement of soil down the slope. This results in the

terracing effect one observes in between contour banks in many areas of the region. Tined implements do not have this effect, and so contour bank maintenance is reduced.

* **Soil compaction is reduced:** By virtue of normally fewer machine passes over the land and the type of implements used, compaction on sandy soils is markedly reduced.

There are some disadvantages in contill and they must be mentioned:

* **Management:** The success in contill is largely based on chemical weed control, and some weeds (notably watergrass and late germinating grasses such as *Digitaria sanguinalis*) can prove a problem. ***Management must therefore be better than that required for conventional tillage.***

  Watergrass is a particular problem as the most cost-effective means at present of combating the weed is through a thorough mixing of the registered weedkiller with the topsoil - this can be accomplished but it requires extra care.
* **Stover conditioning:** Stalk choppers are not all that effective, especially during relatively wet winters.
* **Liming:** The best implement for mixing lime in the soil remains at present one of the sod-turning ploughs. This should rarely be a problem as it would appear that an occasional plough over (once in 5 - 8 years) could prove beneficial in a number of respects.
* **Plant diseases:** The cause of outbreaks of various plant diseases in maize has been blamed on contill because of the carry-over of the diseases, in the stalks, from one year to the next. There are, however, cultivars available which are fairly disease-resistant, and better ones are continually being developed. It remains a better option to practise crop rotations (with grass leys included) which will help overcome the problem by breaking the breeding cycle of pests and diseases.
* **Stover utilization:** Contill is based on the use of stover to provide a protective cover to the soil surface. Most of the maize producers in KwaZulu-Natal either cut maize for silage or they use the stover for winter grazing. In either case a minimum of litter is available for the following planting season. This is a very real drawback for contill, but it points once again to the need for the rationalization of practices and the design of farming systems which will cater for both production and conservation requirements.
* **Soil types:** Contill always results in improved water infiltration efficiency, and the more stover left on the surface, the more efficient the water infiltration into the soil. This can pose problems on poorly drained soils. At this stage it is not recommended, for instance, that no till or direct drill be practised on sandy, duplex soils. These soils should preferably be under a permanent crop cover.

MATCHING TILLAGE SYSTEMS TO SOILS.

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Yields alone should not be the deciding factor when choosing a tillage system. The total long-term economic advantage should determine the choice of systems. The choice of tillage system should never result in a financial loss, irrespective of its advantages in terms of conservation. While experience worldwide has indicated that the greater relative benefits from conservation tillage, and particularly no till systems, is obtained during seasons where drought stress is experienced, the system chosen ***should never result in depressed yields (relative to the other systems) during 'bumper' seasons***, as those years are vital to farmers to stabilize themselves after incurring debt accrued during the poor seasons. No attempts have, as yet, been made to classify soils in the Republic according to their suitability for different tillage systems, nor has any research been done with this in mind. The hypothesis put forward for such a grouping of soils is conjecture, but can serve as a guide and as a basis for further investigation.

Soil-related factors limiting choice of systems.

* **Compaction:** This aspect is dealt with separately by Dr. J B Mallett in the next chapter.

  — Excess moisture: This can be caused by a number of factors:
  — Effective depth: The shallower the profile, the lower the storage capacity, the sooner the profile will become saturated. A sandy soil, *e.g.* with an effective depth of one metre and dried out to permanent wilting point, would require 60 mm of rain to become saturated. On the other hand, the same soil with a depth of 500 mm would require only 30 mm of rain to reach saturation point.
  — Texture: The lower the clay percentage, the lower the water-holding capacity and the sooner the profile will become saturated. A clay soil, for example, one metre deep and dried out to wilting point, will require up to 180 mm of rain before saturation, while a sandy soil of the same depth and same moisture status would require only 60 mm before saturation point.
  — Internal drainage: The poorer the internal drainage, the sooner the profile will become saturated.
  — Slope: The flatter the slope, the lower the runoff, the longer surface water is available to infiltrate, the greater the opportunity to saturate the profile. The steeper the slope, the greater the runoff, the greater the chance of reducing the incidence of saturation.

- — Position in the landscape: Fields in a bottomland position may be subject to flooding, thereby increasing the hazard of waterlogging.

* **Temperatures:** Residue will retard the warming-up of soils after winter. With the first spring rains, cool, wet conditions might occur which would be intensified by residue cover, and which would affect root development, and as a result, nutrient uptake (particularly phosphates and nitrogen), would be inhibited, leading to poor seedling development and poor early growth.

Effects of excess moisture.

* **Reduces temperatures:** Increased amounts of energy are required to heat the soil.
* **Aeration of soil:** Excess moisture impairs the ready diffusion of oxygen to, and carbon dioxide from, the roots. It also reduces the activity of the aerobic organisms in the soil which, in turn, adversely affect the availability of nutrients such as nitrogen.
* **De-nitrification:** Nitrogen is taken up by the plant mainly in the form of NO_3. In the anaerobic conditions created by waterlogging, the soil organisms obtain oxygen from the NO_3, changing some of it to the unavailable NO_2 form, and some to the gas N_2 which can escape to the atmosphere. ***Prolonged saturation of the soil can result in severe nitrogen losses.***
* **A proposal for KwaZulu-Natal:** In considering the suitability of KwaZulu-Natal soils for the various tillage systems, soils are placed in the grouping which would allow the greatest possible amount of residue cover without any deleterious effect to practising agriculture on them.

Cognisance must be taken of the rainfall zone under which soils normally occur. Table 1 reflects soil groupings where effective depth is a limitation. It must be emphasised that compaction has not been taken into account in the recommended grouping. Having chosen the tillage system it is necessary to consider the texture of the soil and the implications of compaction and modify tillage operations accordingly.

THE PROBLEM OF COMPACTION

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'At first thought, the compaction of agricultural soils may appear to be a relatively simple concept, an easily described and measured soil property. This is not the case. Actually, it is a most complex and involved soil feature and has significant inter-relationships with most of the recognized physical, chemical and biological properties of soils, as well as with environmental factors such as climate, weather, tillage and agronomic treatments and crop use. Further, the state of compaction of a soil largely determines the physical and related chemical soil conditions that control the responses of crop plants required for effective farming and that control the conservation of soil and water needed for permanent agriculture. The state of compaction of a soil largely establishes the air, water and temperature relationships and largely influences seed germination, seedling emergence, root growth and, in fact, all phases of crop growth and production.

The design, selection and management of tillage equipment and cropping systems must be directed toward producing the optimum state of compaction, at the

Table 1. Grouping of soils according to tillage system recommended, and based on an effective depth of between 500 and 800 mm

SOILS				TILLAGE SYSTEMS
Well-drained soils :				
Bainsvlei	Fernwood	Hutton	Clovelly	No till or Direct drill
Griffin	Oakleaf	Inhoek	Shortlands	
Well-drained humic soils :				Stubble mulch tillage, strip or ridge tillage (because of soil temperature problems).
Kranskop	Inanda	Magwa	Normanci	
Moderately well-drained soils :				
Pinedene	Glencoe	Avalon	Cartref	Stubble-mulch tillage
Swartland	Rensburg	Valsrivier	Sterkspruit	
Constantia	Vila Fontes	Shepstone		
Poorly-drained soils :				
Katspruit	Willowbrook	Bonheim	Wasbank	Conventional tillage
Longlands	Westleigh	Estcourt	Kroonstad	

Under certain conditions the groupings in Table 1 may be modified, as follows :
Consider the next highest category (humic soils excluded), if:

* Effective depth exceeds 800 mm, or
* Slope exceeds 8%, or
* Subsurface drainage is installed.

different positions in the soil volume throughout the period of crop production.

An understanding of the processes by which the state of compaction of soils may be modified and controlled and knowledge of means of measuring the state of compaction are essential elements of an effective and permanent agriculture.

The compaction process is basically a simple operation - a change in volume of a given mass of soil. This change is variously designated as a change in bulk density, void ratio or porosity. However, because of the highly complex character and almost infinite variability of soils and the natural and man-imposed forces acting on soils, understanding the soil compaction process has challenged both the best practical farmers and the most capable agricultural scientists.' E G McKibben 1971

Crop interaction.

Soil compaction will either slow or stop root growth. Soil, water and nutrients in or below compacted zones are therefore not directly available to the plant. In South Africa, where the supply and availability of water plays such an overriding role in yield determination, a thorough understanding of the factors causing and associated with compaction is therefore extremely important.

Compaction can also occur in the form of surface crusts which interfere with seedling emergence and rainfall infiltration, with potentially disastrous consequences in both cases.

The measurement of the bulk density of a soil is a fairly simple but tedious and painstaking task. Unfortunately, however, densities that are known to cause problems in one soil might present little or no root growth problems in another. Bulk density *per se* is, therefore, not the ideal measures of compaction. Another method frequently used by agriculturists to measure compaction is to use a penetrometer. This involves forcing a metal rod, tipped with a cone of standard dimensions into the soil, thereby either obtaining an indication of sub-surface conditions or more precisely measuring the pressure required to force the penetrometer into the soil at a constant speed. Soil strength is, however, a function of soil water content so that calibration curves should be prepared for each soil, relating penetration force to water content. Soil water determinations must then be made at the time of the penetrometer recordings if the soil strength data is to be meaningful. Because of the complexity of this procedure the penetrometer is seldom used properly. However, if a cone or rod is forced into the soil when the profile is at or close to field capacity it is possible to obtain fairly consistent and reliable results.

The most reliable and practical method of identifying compaction problems is to dig a pit and study the crop's roots. For maize this should be done any time after flowering but preferably before the crop dies off. Normal healthy roots are well branched and fairly fine. Thickened contorted roots or roots growing horizontally indicate problems. If aluminium toxicity, eelworm or temporary watertable problems do not exist then one can be fairly sure that the problem is due to compaction. Having identified the problem one is then in a better position to plan counter-measures.

Causes of compaction.

Although not very often the case, compaction can be a natural (genetic) phenomenon and is usually a function of the particle size distribution. Fortunately natural compaction is uncommon in KwaZulu-Natal.

Compaction is more often than not a man-made problem. Disturbed soil is more susceptible to compaction than undisturbed soil and the first pass of a tractor over disturbed soil will result in soil being compacted to 80% of its potential for the existing soil water content. Remembering that ***wet soils compact more easily than dry soils,*** more serious compaction problems are likely to arise if tillage takes place when soils are wet. Fortunately in South Africa most of the primary tillage takes place when soils are fairly dry, so that many of the tillage-induced compaction problems experienced in countries with all-year rainfall are fortunately seldom encountered here.

Man-induced compaction in cropped lands is therefore mainly caused by the wheels of tractors, trailers and implements and the ground engaging parts of the implements themselves. ***The driven wheels of tractors are by far the major culprits, with the tractor wheel in the plough furrow being the chief felon.*** Excessive wheel slip and tyre pressure add to the problem. So-called 'plough pans' which form just below the depth of ploughing, are usually due to tractor wheel forces rather than the action of the plough.

Water dropping onto bare soil, even from a watering can, can cause the dispersion of soil particles and rapid sealing of surface pores. This sealing of the soil surface is also a form of compaction but limited to a thin layer. Despite its thinness, this layer will dry so hard on some soils that seedlings cannot emerge. On most soils this water drop induced surface sealing will restrict infiltration and increase runoff. Rain falling on bare, loosened soil can cause a 15% increase in density of the top 25 mm.

Soils.

All soils will compact if loaded sufficiently at the correct water content. Unless they have self-mulching characteristics like vertisols they usually stay compacted until mechanically loosened or eventually re-loosened by rot and earthworm action. In countries with severe winters, freezing and thawing is reported to relieve compaction.

Sands will compact at lower water contents than clays and the most sensitive of all are the fine wind-blown sands that compact when almost dry.

From the above it can be seen that the soils most likely to have serious compaction problems are the fine wind-blown sands, while clay loams, provided they are not tilled when wet, can be considered relatively vice-free in this regard. The compaction : clay content interaction details listed below will act as a guide to potential compaction proneness. Exceptions will, however, always be found to exist.

Fine sands compact easier than coarse sands (fine 0,0-0,2 mm, medium 0,2-0,5 mm and coarse 0,5-2,0 mm).

Soils with: 5% clay content compact very easily, even when dry
5 - 10% clay content also compact easily, especially if the sand is fine
10 - 20% clay content will compact but needs to be moist
20 - 35% clay content will compact, but the potential to do so depends largely on the water content.
35% clay content normally display few compaction problems under dryland conditions.

Particle size distribution within the soil is also important. There are ideal ratios between clay, silt and sand that theoretically result in very dense soils with little room for root growth. Organic matter and soil structure tend to counter the effects of so-called ideal particle size distribution for optimum compaction. The problem fortunately seldom arises in KwaZulu-Natal.

Action.
If compaction has been identified as a problem then it should also be possible to determine the cause. Remedial action will depend upon the cause:

* On very sandy soils that compact readily, rip-under-row and controlled traffic techniques are essential.
* Where soils are somewhat heavier but still display compaction problems, then overall ripping or subsoiling periodically might suffice. Some form of controlled traffic system should also be adopted.
* When plough pans tend to develop, mouldboard and disc ploughs should be replaced with chisel ploughs, or on-land hitches should be used to avoid allowing the tractor wheel to run in the open furrow.
* Where compaction is not a problem almost any tillage system can be used ***(as long as it does not result in excessive soil loss - Editor).***

PLANT NUTRITION IN CONSERVATION TILLAGE

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Contill No. 6. 1984. Department of Agriculture and Water Supply.

Introduction.
In order to quantify any influence conservation tillage has on the nutrition requirements of crops, it is necessary to define the term 'conservation tillage'. One of the most apt definitions is that given by the Resource Conservation Glossary: 'Conservation tillage is any tillage system that reduces loss of soil and water relative to conventional tillage; often a form of non-inversion tillage that retains protective amounts of residue mulch on the surface.'

There are thus two important concepts relating to conservation tillage:

* Maintenance of some of the previous season's crop residue on the surface and
* conservation of both soil and moisture. No till may be regarded as the ultimate form of conservation tillage since it maximises both these concepts.

Possible problems relating to conservation tillage practices.
The non-inversion of the topsoil and presence of subsurface crop residue might bring about changes in soil physical and chemical conditions (soil bulk density, degree of aggregation, organic matter content) as well as increasing soil moisture content under the mulch (affects aeration, drainage, leaching, nitrification and denitrification, *etc*). Most of these changes are manifested in the topsoil (0 - 150 mm). Since nutrient uptake depends on factors influencing root distribution, oxygen concentration and soil water content and movement, it is likely that conservation tillage will influence nutrient uptake to varying extents and for different reasons, depending upon soil type and environmental conditions. Problems might arise due to:

* Higher bulk densities near the soil surface, restricting root growth. This might be due to mechanical impedance and reduced porosity, and is likely to be more of a problem in direct-drilling into sandy soils.
* Leaching of the more mobile nutrients due to the higher soil-water contents under the mulch, mainly in sandier soils.
* Water-logging in heavy-textured soils or any soils with subsurface drainage problems.
* Denitrification losses due to more anaerobic conditions. This is likely to be more serious on heavier soils.
* Immobilization of Nitrogen by micro-organisms in the process of breaking down the crop residue.
* Stratification of organic matter and less mobile nutrients by biocycling and buildup of acid layer near the soil surface.

Although this list suggests that plant uptake of nutrients will be adversely affected by conservation tillage systems, and no tillage in particular, research has shown that, in general, these problems apply to only a few of the essential elements and can usually be overcome with good management.

Effect of conservation tillage on the uptake of plant nutrients.

* **Nitrogen (N).**
N is taken up by the plant roots in NO_3 form. NO_3 is very mobile and able to move to plant roots by

diffusion in continuous films of water, and by bulk diffusion as water moves through the soil.

Water-logging in heavy soils and leaching in lighter-textured soils are most likely to affect N availability. Visual symptoms of limited N supply in direct-drilled crops in the early stages of establishment are usually ascribed to slower N mineralisation and greater denitrification, especially on heavier soils, due to limited oxygen supply. On sandy soils, leaching beyond the root zone can result in low N nutrition, but water-logging can also be a problem on these soils if they are underlain by a relatively shallow impervious clay or compact layer.

* **Phosphorus (P) and potassium (K).**
  Potassium and phosphorus are relatively immobile, being held as cations in response to negative charges on clay colloids, so plant roots move towards them rather than the nutrients diffusing towards the roots. They are thus strongly influenced by soil structure, which affects root growth. P and K tend to accumulate near the surface in many reduced-tillage situations, due to reduced incorporation of fertilizers and natural biocycling where P and K taken up by plant roots are deposited on the surface with the residue. Under drying conditions not favourable to root growth, this can result in reduced uptake. Often this stratification of nutrients is followed by an increase in plant roots in these areas due to the higher moisture content under normal precipitation conditions, so availability is not affected.
* **Micronutrients.**
  There is little evidence indicating yield losses due to reduced micronutrient uptake in conservation tillage systems. Where their uptake is borderline or low with conventional tillage, problems are likely to be more severe in direct-drilled crops, where no tillage has been shown to reduce uptake of Cu, Zn, B and Mn. This has been ascribed mainly to reduced root proliferation deeper in the profile and cooler, wetter conditions early in the season under no tillage which would make certain micro-nutrients less available.
* **Soil acidity.**
  Continued use of conservation systems will cause the accumulation of fertilizers, herbicides and organic matter near the surface, which can encourage the development of acid conditions in the seed zone. For example, Maryland researchers found that the application of 180 kg/ha of nitrogen in no tillage maize caused the pH to drop by 1,5 units within a matter of weeks. Unless corrected by liming, such acid conditions can impose such stress factors as:

  — reduced availability of essential nutrients (high exchangeable Al).
  — Increased solubility of Al and other toxic elements to levels toxic to the plant.
  — Reduced activity of beneficial micro-organisms and increased activity of detrimental ones that thrive under acid conditions.
  — Poor herbicide performance (esp. triazines) and yield losses due to weed infestation.

  Soil pH is reported to be one of the single most important factors affecting fertilizer performance, so that liming can enhance the performance of fertilizers.

Trends in conservation tillage fertilization.

The observed trend has been for conventionally-established crops to perform better at low levels of N and for direct-drilled crops to continue to respond to N after the yields of conventionally-tilled crops have peaked. Research in the USA has shown that at sub-optimal N rates (below about 90 kg/ha), the probability for highest yields lies with conventional tillage (64-69%). At more optimal rates of about 135 kg N/ha and above for the test soils, no tillage had the greatest probability for highest yields (67-78%). Early work in the USA showed that after 6 years of contrasting cultivation, concentrations of extractable P and K in the upper soil layers were greater with no tillage than with deep cultivation, in which the P and K was evenly distributed in the profile. There was no evidence to suggest that crops suffered during drought periods because of desiccation of the surface soil. It has also been shown that direct-drilled maize absorbed surface-applied P as well as when P was deeply incorporated, although results in this regard are conflicting. ***It appears that crops grown in conservation systems require similar P and K fertilization to those conventionally established.*** Researchers in the UK recommend that when comparing yields from contrasting cultivation systems, comparisons should be made of yields resulting from optimum levels of N from each treatment.

Fertilizer placement in conservation tillage.

While some research has shown that broadcast fertilizers produce yields similar to those from sub-surface applied fertilizers, ***most researchers report improved yields for sub-surface banding***. This has the added advantage that it helps to reduce nutrient stratification to some extent. Evidence indicates that N, P and S are used more efficiently with sub-surface banding, and yield increases of 1570 kg/ha have been reported for winter wheat relative to broadcasting.

Because of the mobility of NO_3 in the soil, it is reported to be beneficial to split N fertilizer applications, applying at planting and at 6-8 weeks before the crop is too tall. Although yield improvements have not always resulted from split applications, it has never been shown to cause yield reductions. In the USA, marked responses to starter fertilizers such as P_2O_5 at relatively low rates (25 kg/ha) have often been reported in conservation tillage systems, due mainly to the cooler, moist conditions. Whether this would happen in South Africa is debatable. Recent work in Indiana suggests that starter responses could be expected over 50% of the time in no tillage.

Care must be taken to ensure sufficient separation between seed and fertilizer to avoid adverse effects on germination and seedling vigour. Weed control is also favoured by banding near seed rows with the minimum soil disturbance, as are residue clearance, seed placement, moisture conservation and fuel and equipment requirements, especially if one-pass operations are used. Should it become necessary to correct sub-surface K and soil acidity, this can be accomplished by occasional deep placement of K and lime, say every 5-10 years.

Soil sampling.
As a result of stratification of immobile nutrients, organic matter and soil acidity, ***it may be necessary to change the depth of sampling for soil testing in conservation tillage, especially no tillage.*** Most researchers recommended sampling to a depth of 100 mm in no tillage, while others suggest a standard 150 mm sample with a separate shallow (50 mm) sample to monitor pH changes. ***Where reduced tillage systems involving chiselling-and-disc harrowing are used, samples should be taken to three-quarters of the tillage depth before tillage is performed.***

EFFECTS OF TILLAGE PRACTICES ON WEEDS.

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In trashy lands weed emergence is erratic and slower than on trash-free lands. This might be due to the lower temperature in trash and/or to the trash hampering germination and emergence. This often results in weeds germinating when some pre-emergence herbicides are no longer effective. Different tillage systems give rise to a variety of weed problems.

Conventional tillage.
Ploughing and harrowing usually control winter weeds, volunteer crops and any other weed flushes up to planting time. Existing weed control methods are well known and understood. Although some weeds might escape they can be controlled by mechanical or chemical means. Most farmers are familiar with the equipment and chemicals used to control weeds on conventionally tilled lands. In most instances the best system to use will be a combination of mechanical and chemical weed control.

Conservation tillage.
These lands are usually prepared with tined equipment, leaving most of the trash on top of the soil. There might be a greater need for herbicides to control some persistent weeds or volunteer maize or other crops. As conservation tillage practices do not normally include disc harrowing, products like Eptam, Sutan or Agro-Neet cannot be effectively incorporated. However, methods have been developed for injecting or dribbling these herbicides into lighter soils, but heavy trash might still present problems with the clogging of injection tines. Clogging can be reduced or overcome by using implements with 3 or 4 high-clearance beams which result in fewer, widely-spaced tines per beam that allow trash to flow more readily through the implement between the tines.
Most conservation tillage weed-control practices can be flexible and thus retain most of the advantages of trash farming, as long as the cultivating equipment does not bury too much trash. Therefore, rolling tine, or fixed tine equipment is preferred, as they leave most stubble on the soil surface. Due to the presence of trash there might be more problems with mid-to-late-season weeds on trashy than on ploughed lands. These weeds can, however, be controlled either with tines fitted with sweeps or with herbicides.

No till or direct drilling.
No till relies completely on herbicides for weed and volunteer maize control. Generally speaking, more herbicides will have to be used initially to control weeds. Even where high doses of pre-emergence herbicides are used, mid-to-late-season weeds (mainly grasses) might be a problem. These weeds can be controlled by normal doses of pre-emergence herbicides, followed by over-the-top or directed post-emergence herbicides which have been registered for this purpose.

The weed research programme at Cedara has been directed at controlling weeds in conservation tilled maize. Over the past ten years a number of herbicide treatments and sequential treatments have been developed and made known.

THE DIPLODIA COB ROT, MAIZE STUBBLE INTERACTION.

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ABSTRACT

Maize residue is reported to encourage ***Stenocarpella maydis*** spore production during the fallow winter months. Also commonly known as diplodia, this pathogen is the main cause of maize cob rot in South Africa. Timeous removal of residue or ploughing under, is claimed to limit spore production thereby helping to control cob rot. Clean cultivation, however, encourages runoff and soil loss resulting in lower yields and soil degradation which can eventually lead to devastation of the landscape. An investigation was therefore launched to determine what strategies could be adopted by the farmer to enable him to continue practising conservation tillage without exposing his maize to unnecessarily high cob rot risk.

Although crop rotations are reported to break the cob rot cycle, preliminary investigations suggest that where maize residue loads are high, as is normally the case at Cedara, a single crop of soya beans does not provide a long enough break to guarantee cob rot protection when stubble tillage is practised.

Tests revealed that all of the maize cultivars available on the South African market displayed an increase in diplodia cob rot when planted in maize stubble. However, from this work it was possible to identify a small group of cultivars that were consistently and markedly more

tolerant than the rest. Also apparent were a group that were consistently very much more susceptible to diplodia cob rot, in fact in even clean cultivated conditions they invariably displayed more cob rot than tolerant cultivars when grown in maize stubble. ***White cultivars as a group were more cob rot tolerant than yellow cultivars.***

It was found that tolerant cultivars do exist and if these are used then it should not be necessary to have to abandon conservation tillage, although where no till is practised the chances of encountering cob rot problems are definitely higher given the existing available cultivars. The final solution to the problem, however, is in the hands of the maize breeders.

INTRODUCTION

The worsening and widespread outbreaks of diplodia cob rot (***Stenocarpella maydis***) which led to the 1986/87 epidemic resulted in serious financial losses to the maize industry. In some quarters the blame was put squarely on the gradual increase in the area under conservation tillage that had taken place over the previous ten to fifteen years. Diplodia cob rot depends upon host plant residue and the spores produced constitute an important source of inoculum for infecting the next crop (Nowell, 1988). Immediately after the disastrous 1986/87 season, farmers were advised to either burn all residue or make sure that it was ploughed under, or alternatively introduce crop rotations. The limited availability of financially viable alternative crops resulted in little incentive for rotations. Little or no accurate information regarding cob rot tolerant maize cultivars was available so that burning and/or ploughing under of residue seemed the only option left to combat the problem. The vast majority of farmers who had adopted conservation tillage therefore reverted to clean cultivation.

Stubble tillage systems conserve soil-water and prevent soil losses due to erosion (Unger and McCalla, 1980). The retrogressive move back to conventional mouldboard ploughing in the South African maize industry therefore caused alarm among those concerned about the degradation of the Republic's already scarce and fragile arable soils (see Huntley, Siegfried and Sunter, 1989). An investigation of strategies that might allow for the maintenance of surface residue, while at the same time reducing the potential for associated cob rot damage, became an urgent priority.

A perusal of American literature revealed little concern for diplodia cob rot in maize produced under conservation tillage. This could be due to a combination of the fact that the severe North American winters ensure greatly reduced mycelial and pycnidia survival which in turn result in a reduction of subsequent spore production, as well as the fact that many American crop farmers rotate their maize with soya beans and/or wheat. In Zimbabwe where many commercial farmers practise crop rotations and where winter conditions are relatively mild, being similar to those in South Africa, stubble tillage has made significant strides since 1986, but as yet there have been no reports of a diplodia cob rot problem. Rotations would seem to be the common factor, although the role played by cob rot tolerant cultivars, which are known to be widely used in Zimbabwe, should not be underestimated.

In the Republic the gradual adoption of stubble tillage systems possibly exacerbated the potential for cob rot inoculum production, although the total area under conservation tillage was never great and certainly never large enough to be totally responsible for the 1986/87 cob rot epidemic. Other factors must therefore have contributed to the problem.

The organism responsible for diplodia cob rot is endemic to South Africa, but from the late seventies onwards reports of isolated and sometimes serious cob rot outbreaks were, from time to time, reported from various parts of the country. These incidents were frequently associated with stubble tillage practices. However, in the Grain Crops Research Institute's tillage trials which began in 1976, where stubble and clean cultivated treatments were compared, the cob rot problem in the stubble plots was not considered to be serious enough to cause alarm during the early years of the programme. Our interest and suspicion was aroused when the names of certain hybrids cropped up more frequently than others in farmer cob rot reports. It was therefore decided to embark upon a cob rot/cultivar screening programme which was duly started in the 1984/85 season and which revealed a wide range of tolerance among South African maize cultivars. Gevers, Lake and McNab (1990) have recently positively identified a number of inbred lines that are highly susceptible to diplodia cob rot. It has further been established that a large proportion of the 1986/87 maize crop was planted to cultivars containing these cot rot susceptible inbred lines. The area planted to these sensitive cultivars had increased significantly over the period leading up to 1986. Adopting an understandably defensive attitude at that time, seed traders were almost unanimous in blaming stubble for the cob rot epidemic. The stance of others who also condemned stubble but were not involved in the seed trade was more difficult to understand.

Weather conditions are also known to have a significant effect upon the incidence of cob rot, as illustrated by the differences in the severity of infestations from one year to the next, or in the same season between crops planted at different times.

A combination of the wide use of highly susceptible cultivars, stubble tillage practices and weather conditions particularly favourable for the development of diplodia cob rot appear to have contributed to the disastrous 1986/87 epidemic. Quite obviously most of the seed trade had not fully anticipated the potential seriousness of the problem that was developing.

We the present temporary stewards of the soil have a duty to preserve it for future generations and are therefore duty bound to encourage stubble tillage practices. It would be highly irresponsible of us not to do so. The maize breeders have a leading role to play in this drama.

This report covers the results of several tillage, cultivar and cob rot related investigations conducted over a number of seasons at Cedara and other sites in KwaZulu-Natal.

MATERIAL AND METHODS

Tillage and stubble management

The Grain Crops Research Institute has been involved in an intensive tillage research programme since 1976. An important aspect of the investigation has been the effect of varying degrees of surface stubble maintenance upon soil-water conservation, soil conservation and grain yield. Cob rot counts were routinely made but until the 1983/84 season the condition has not given cause for concern. In KwaZulu-Natal, tillage trials were conducted at Cedara (Hutton/Doveton soil), Winterton (Avalon/Bergville soil) and (Hutton/Msinga soil), Geluksburg (Avalon/Normandien soil) and Dundee (Avalon/Sandy Avalon soil).

Workers at Potchefstroon (Flett and Wehner, 1988) reported that significantly more diplodia inoculum was produced if maize stalks were not shattered, as they claimed that diplodia was a poor competitor with other plant residue rotting organisms and survived better if protected from competition in unexposed pith. A trial was therefore conducted comparing the incidence of cob rot in maize growth in whole stalk residue versus maize growth in surface residue that had been cut and shattered, the assumption being that the incidence of cob rot should be greater in the whole stalk plots.

Cultivar evaluation

It was decided to look at the susceptibility of individual hybrids after receiving reports of levels of diplodia cob rot in commercial conservation tillage fields that were sometimes very much higher than we were experiencing in the stubble plots of our tillage trials. During the 1984/85 season the National Maize Cultivar Trial with 49 entries and planted annually at numerous locations throughout the Republic was duplicated at Cedara with one complete trial on a mouldboard ploughed clean cultivated site and another on an adjacent no till site with maize plant residue effecting 70% ground cover. Since that time particular note has been made of the incidence of cob rot in the National Cultivar Trial planted at Cedara each year.

Crop rotations

The effect upon the incidence of cob rot after rotating maize with soya beans, where the crops were alternated each season versus maize continuous, was investigated.

Table 1. Soil loss and runoff from tillage plots on a Hutton Doveton soil (2,7% slope) at Cedara after one hour of simulated rainfall (63,5 mm). From Mallett, McPhee, Russell and Mottram, 1981

Tillage treatment	% Residue cover	% Runoff	Soil loss ratio
Mouldboard plough	8	29	20,3
Offset disc and chisel	23	12	10,3
Chisel plough	49	1	1,0
No till	87	5	4,0

Table 2. The incidence of diplodia cob rot over a number of seasons in the Cedara tillage trial

Season	Cultivar	Diplodia cob rot	Comments
1978/79	PNR536	not recorded	
1979/80	PNR473	not recorded	
1980/81	SX16	not recorded	
1981/82	RO422	not recorded	
1982/83	TX24	NS between treats	3,7% mean
1983/84	CG4502	NS between treats	7,6% mean
1984/85	SNK2244	Sig. (0.01)	n-t 14,1% rest 8,3%
1985/86	RS5206	NS between treats	5,7% mean
1986/87	PNR6549	NS between treats	18,7% mean
1987/88	KDU9046	NS between treats	40,4% mean
1988/89	RS5205	NS between treats	10,1% mean
1989/90	RS5206	NS between treats	12,0% mean

Table 3. The mean incidence of diplodia cob rot and the mean grain yields for each of the tillage treatments in the four KwaZulu-Natal tillage trials for the 1986/87 season

Tillage treatment	% diplodia	grain yield (kg/ha)
Mouldboard plough	19,6%	4984
Disc harrow and chisel	20,9%	5263
Chisel	23.3%	6289
No till	34,6%	5855

Table 4. The effect of a one year maize, soya bean rotation upon the incidence of diplodia cob rot in a stubble tillage environment

Treatment	1988/89	1989/90
Maize continuous	8,37%	30,62%
Maize following soyas	12,29%	36,08
Mean	10,53%	33,35%
	NIL	NS

A cob rot susceptible cultivar was used in order to allow the disease to express itself. Conservation tillage was applied to both the soya beans and maize and no mouldboard ploughing or disc harrowing took place at any stage. Maize yields were of the order of seven tonnes per hectare which resulted in heavy residue loads.

Fungicide treatment

This investigation was planned in order to establish approximately when infection was taking place during the maize crop's growth cycle, and in order to do this, systemic fungicide benomyl was sprayed onto maize plants at different times during the season thus allowing the interaction between spray timing and the resultant severity of cob rot to be studied. Benomyl in the form of benlate wettable powder was mixed at the rate of 50g per 100 litres of water plus 0.2% Bladbuff (buffer/spreader). Using a knapsack sprayer the plants were thoroughly wetted until runoff occurred.

Weather studies

Weather conditions during the growing season were monitored in order to identify weather patterns that favour the occurrence of diplodia cob rot. The method used was to plant every two weeks and then attempt to associate the degree of cob rot recorded at harvest time with the timing of dry spells which would be at different growth stages for each of the plantings.

RESULTS

Tillage and stubble management

In Table 1 the results of a number of tillage plots at Cedara that were subjected to a standard erosion and runoff test using a Swanson (1965) rainfall simulator are reported. It can be seen that the volume of runoff and soil loss increased as the surface residue levels decreased with clean mouldboard cultivation, representing a serious environmental hazard. In a review paper reporting the findings of a number of investigations Mallett, Lang and Berry (1985) clearly demonstrated the further advantages to be gained from the adoption of stubble-based tillage systems. During the early years of the tillage programme, the incidence of cob rot was so insignificant that it was not reported upon. However, as accounts of isolated outbreaks of diplodia cob rot were received in the early 80s it was decided to take special note of the problem. A listing of observations made in the Cedara tillage trial, where a range of stubble tillage treatments (see Table 1) were being compared, is presented in Table 2 The mean diplodia cob rot for the four tillage treatments in the trials at Cedara (PNR6549), Winterton (PNR6549), Dundee (PNR394) and Geluksburg (RS5206) during the 1986/87 epidemic season are presented in Table 3.

In the whole stalk versus shattered stubble trial which was repeated over two seasons, it was not possible to establish any statistically significant difference in the incidence of cob rot between the two treatments. It was therefore concluded that under Cedara conditions, ***Stenocarpella maydis*** survived equally well in whole or shattered maize residue.

Cultivar evaluation

On average the 1984/85 clean cultivated National Cultivar Trial had less cob rot (5,7%) than the no till National Cultivar Trial (13,6%) planted adjacent to it and on the same day. Big differences, however, occurred between cultivars, and those that showed relatively more cob rot on the ploughed site displayed a very much higher incidence of cob rot on the no till site.

The 1985/86 National Cultivar Trial conducted at Cedara on a clean cultivated site displayed cob rot readings varying from 6,5 to 43,0%, and in an identical trial planted at Winterton the range was from 8,1 to 40,0%. Diplodia cob rot information was collected each year thereafter thus making it possible to identify a small group of cultivars that consistently performed well, and another that consistently performed poorly regarding cob rot tolerance. This data was used to assist in making recommendations for cultivars suitable for planting in conservation tillage situations.

At Cedara this past season (1989/90) the National Cultivar Trial was, as in the 1984/85 season, again planted on a no till and a clean cultivated site. As in the early trial all cultivars again displayed a higher incidence of diplodia cob rot in the no till plots (27,7%) than the ploughed plots (13%). In no till the diplodia ranged from 7,0% (RS5232 to 55,4% (CRN4502) while in the clean plots the range was from 4,1% (PNR6479) to 39,4% (AX305W).

Those cultivars that over the years consistently showed the least tolerance to diplodia cob rot were: CRN4502, SNK2232, CRN4410, PRN6528, SNK2244, SNK2340, CRN4526 and AX305W. Note that there is

Table 5. The influence of time of application of the systematic fungicide benomyl on the incidence of diplodia cob rot

Treatment	% cob rot
Control	34,72
Benomyl 14 days before silking	14,44
Benomyl at 80% silking	21,23
Benomyl 14 days after silking	30,24
Mean	25,16
CV %	16,60
LSD (0,05)	6,67
(0,01)	9,59

only one white cultivar among this group.

The cultivars that showed the highest degree of tolerance to diplodia cob rot were:
HL2, RS5232, PNR6479, TX561, RS5206, PNR6549, PNR6463 and CRN7560.

These groupings are consistent with the data published by the Summer Grain Centre (Du Toit and Nordier, 1990) for other sites in the Republic where the National Cultivar Trial was planted.

Crop rotation

Using soya beans as a one season rotation crop with maize resulted in no reduction in the incidence of cob rot when compared with maize continuous (see Table 4). Had the soyas been planted for a longer period there is no doubt that differences in cob rot would have manifested themselves. This trial emphasized the fact that a short term rotation in a conservation tillage system cannot be relied upon to effectively break the cob rot cycle.

Fungicide treatment

The spraying of the systemic fungicide benomyl at two weekly intervals starting before silking to two weeks after silking resulted in a significant reduction of diplodia cob rot for the spray carried out two weeks before silking (see Table 5). *As spraying was delayed so the control became less effective.* In earlier work, very much later spray applications effected virtually no cob rot control. The results of this investigation strongly suggest that cob rot infection takes place during the period immediately before silking. A similar study carried out by the American workers Warren and Von Oualen (1986) also led them to conclude that ear rot pathogens were infecting the host shortly prior to anthesis.

Weather studies

In a time-of-planting experiment at Cedara in the 1989/90 season where a susceptible maize cultivar was no till planted into heavy stubble at six roughly equivalent heat unit intervals, the earliest planting, which experienced water stress from silking through the first fourteen days of grain filling, displayed significantly more cob rot than the latter plantings which were stressed before but not after silking (see table 6).

Table 6. The effect of moisture stress at different growth stages, as a consequence of serial plantings, upon the incidence of diplodia cob rot

Planting date	% cob rot	timing of stress
89 10 23	63,05	silk to + 7d
89 11 06	53,08	silk
89 11 13	56,62	- 7d to silk
89 11 23	48,38	before silk
89 12 04	33,54	before silk
89 12 13	24,21	before silk
Mean	46,48	
CV %	10,60	
LSD (0,05)	6,53	
(0,01)	8,91	

These results suggest that the maize plant is at its most vulnerable to the diplodia cob rot pathogen when stressed during the period at, and immediately after, silking. It is therefore not surprising that the most beneficial fungicide spray was the one applied immediately prior to this period which supposedly would, by then, have actively interfered with the invading organism. This work only provides circumstantial evidence for the above suggestion which would need to be confirmed by a thorough pathological study.

CONCLUSIONS

Even during favourable rainfall seasons some cob rot is likely to occur with the less tolerant cultivars displaying more infestation than tolerant cultivars. Should drought together with abnormally high temperatures occur, resulting in stress soon after silking, as happened during the 1986/87 season, then even clean cultivation together with the use of a tolerant cultivar will not be a guarantee against the occurrence of diplodia cob rot.

Tests carried out at Cedara and elsewhere revealed that all of the maize cultivars available on the South African market displayed an increase in diplodia cob rot when planted in heavy maize stubble such as occurs in no till situations. From this work it was fairly easy to identify a small group of cultivars that was consistently and markedly more tolerant than the rest. Also apparent was a group that was consistently very much more susceptible to diplodia cob rot. The white cultivars as a group were decidedly more cob rot tolerant than the yellow cultivars.

Where conservation tillage is practised therefore, only tolerant cultivars should be used, while cob rot sensitive cultivars should be avoided at all cost. Our experience suggests that if this condition is met then the chances of experiencing excessive cob rot damage with conservation tillage will be greatly reduced. No till, however, definitely increases the diplodia cob rot risk factor.

During the 1986/87 season, particularly in the eastern parts of the country where weather conditions that year favoured cob rot development, the disease reached epidemic proportions even on farms that had never ever been subjected to stubble tillage practices. As the farmer has no control over the weather and can also not forecast cob rot favourable seasons he should therefore ensure that he always plants tolerant cultivars irrespective of tillage practice.

The maize breeders have a major role to play in the ultimate solution to the diplodia cob rot problem in South Africa.

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STALK CHOPPERS

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Planters might be the most important equipment in any mechanical crop production system, but their successful operation, particularly in maize stubble mulched lands, will, similar to tined tillage implements, depend primarily on the correct selection of stalk chopping equipment to suit conditions applicable at stalk chopping and for the period thereafter until the primary tillage system is initiated.

Stalk condition after harvesting, climatic circumstances and nature of soils are the main factors on which a decision for the selection of a specific stalk-chopper should be based, as different methods of harvesting, high humidity, strong winds, soft or hard soil conditions will all have a direct bearing on the effectiveness of equipment used for stalk chopping.

The condition of the maize stalk after harvesting, and therefore the complexity of stalk chopping, will, in the first instance, be dictated by the particular harvesting method used.

Three basic maize grain harvesting systems are in common use today:

Hand harvesting.
This procedure is usual in the case of smaller farms and maize seed contract growers, and does create a somewhat difficult situation for stalk chopping, due to the standing full-length stalks, a situation aggravated when grazing by cattle occurs.

Harvesting by combines fitted with a snapperhead.
This is probably the most commonly-practised harvesting system in use today, and one that does not present any undue stalk chopping difficulties, as snapperhead-equipped combines leave medium height, reasonably straight standing stalks in the row, and the remaining plant residue scattered over the rows, as a mixture of short to medium cut length stalks, pieces of cob, leaves and chaff. Some snapperhead combines can, due to their snapper-roll design, pre-chop, snap or severely crimp a fair percentage of the stalks as they pass down through the snapperhead rolls onto the ground, and so complement the stalkchopping operation.

Harvesting with combines having vertical intake type heads.
In South Africa, combines of the so-called pull-type were, until a few years ago, exclusively fitted with vertical-type whole-plant intake heads, which eliminates the need for stalk chopping, as stalks are cut low to the ground, and residue of the originally whole plant, after passing through the combine, is deposited as coarse stover and chaff between the rows.

Trailed combines fitted with snapperheads.
When compared to similar equipped self-propelled combines, these tend to leave a relatively long and not so upright standing stalk in the row, and less stover but more fine chaff spread in a narrow band between the rows.

When harvested fields are grazed by cattle before stalks are chopped, a further complication arises, as any standing stalks are bent, flattened and disarranged in all directions, making the stalk chopper requirement perhaps different to that of one solely selected to suit the particular harvesting method used.

When full or nearly full-length standing stalks are left after harvesting, and no grazing is to occur, some stalk chopping equipment, in order to work more efficiently, will require those stalks to be knocked down at an angle to the direction of stalk chopper travel. Devices used for knocking down stalks are usually of the D.I.Y. type.

Underslung combination harvester-stalk choppers.
As most maize crops are harvested by self-propelled combines the use of this type of underslung rotary slasher stalk chopper unit would seem to be logical, as these units cut stalks at the same time as harvesting grain, obviating the need, expense, time and additional equipment required for a separate stalk chopping operation. On average, but depending on the particular ratio of chopper drive gearing used, a combine underslung chopper will cut maize stalks into random lengths, ranging from 60 mm up to 340 mm.

Combination stalk chopper-chisel plough.
Another piece of equipment that can obviate the need of separate stalk chopping operations, is the tractor-trailed combination stalk chopper-chisel plough, a primary tillage implement designed specifically for operation in lands where stubble mulch tillage techniques are practised. They are particularly effective in combine-harvested lands. However, before use in hand harvested lands, although not essential, it might be more convenient for the stalks to be knocked down at an angle to the direction of intended travel, for the implement's stalk slicer discs to be fully effective. In one pass, these combination units will leave the soil well tilled and adequately covered with crop residue, as burial of surface residue during primary tillage is estimated to be only 10 to 15%.

When circumstances dictate that separate stalk chopping operations are necessary, two basic types of equipment can be used. Semi-mounted and trailed rolling-drum choppers, or tractor mounted and trailed P.T.O.-driven flail-type chopper-shredders are in general use.

Rolling-drum stalk choppers.
Rolling-drum stalk choppers might be single drum or of the combination type which have a front gang of disc cutters and a rear chopper drum. These implements work best in areas where stalks dry out fairly rapidly after harvest. A combination disc-and-drum stalk chopper has an advantage over a single drum chopper in that it is able to cut stalks of a higher moisture content and stalks lying at almost any angle to the direction of travel, due to the action and additional width of its front disc gang.

When surface soils are soft, the use of rolling-drum choppers is not recommended, as the cutting pressure applied on stalks by the chopping blades can be higher than the resistance offered by the soil, resulting in partially or completely uncut stalks, due to the soft soil acting as a cushion, instead of a firm chopping base. A higher degree of chopper blade soil throwing will also occur in soft soils.

In lands whose soils are prone to the risk of wind erosion the use of rolling-drum choppers can be advantageous, as the lengths of stalk cut are relatively long and heavy and therefore reasonably stable, offering a high degree of protection to the soil.
Burial of crop residue using rolling-drum choppers is virtually nil under most conditions.

P.T.O.-driven stalk choppers.
Tractor mounted and trailed P.T.O.-driven flail-type stalk choppers of the horizontal rotor design with vertical, free-swinging cutting blades, are used for the difficult stalk chopping conditions which do not favour the use of rolling drum choppers, conditions such as soft soils and humid climatic areas. ***These rotary choppers should not be used in areas which are subject to wind erosion, as they invariably produce a high percentage of short-length shredded material, which, being of light nature, is susceptible to removal by wind.***

Burial of crop residue using correctly set P.T.O.-driven stalk choppers is nil. Deflector hoods are provided to control the spreading pattern of the high-velocity ejected material. Most maize farmers, however, operate the chopper with the deflector hood either removed or in a fully open position, as a closed or partially closed hood substantially increases the amount of finer cut crop material.

Offset disc harrows.
Offset disc harrows are used by many farmers for stalk chopping operations, but there is a snag in that this type of harrow can cause a 60 to 70 percent incorporation of the surface residue through the discs' tillage effect, even when the harrow is fitted with scalloped discs set at a relatively negative angle. A follow-up operation by a tined implement fitted with duck-foot sweeps would then be necessary to lift the stover out of the ground.

For stalk chopping to be effective a fairly substantial pressure is required at the disc's cutting edge. Mounted offset disc harrows are at a disadvantage here, as their individual disc cutting pressure is on average only 25 to 30 kg. Semi-mounted and trailed offset disc harrows are more effective, as with disc pressures of from 70 to 200 kg they can cut stalks in one pass, providing that stalks are lying at an angle to the direction of travel.

Table 1. Average performance data of different stalk chopping implements

UNIT	Stalk chop length (mm)	Power needed (kW)	Working width (m)	Operating speed (km/h)	Work rate (ha/h)
Combination chopper chisel plough (7 tine)	200	49 - 84	1,8	8,0	1,2
P.T.O.-driven rotor chopper (rotor speed 2310 r/min at 540 P.T.O. r/min)	100	37 - 45	1,94	8,0	1,2
SP combine underslung chopper (4 x 762 mm row)	60 - 340	12 - 24	2,3	8,0	1,5
Combination rolling chopper	150 - 450	30	2,0	12 - 14	2,1
Single rolling drum chopper	230 - 600	30	2,0	12 - 14	2,1
P.T.O.-driven rotary slasher	?	45	1,5	9	1,1
Offset disc harrow	225 - 360	70	2,2	8	1,5

Slashers.
Slashers are not considered as being ideal for maize stalk chopping as when operated in hand harvested, ungrazed fields of standing stalks, the slasher has a tendency to flatten most of the stalks to the ground, and if the particular slasher in use cannot be set to cut very low, a fair percentage of flat lying stalks will not be cut. The same will apply when stalks remaining after any other method of harvesting are flattened by in-field grain trailers or grazing cattle.

Slashers are also noted for rechopping cut material already in the slasher housing. This characteristic, in combination with the inability to cut flat-on-the-ground stalks, results in an end-product comprising fine residue and mainly long uncut or partially cut stalks, lying in all directions, an unfavourable condition for following tined implement operations.

ECONOMICS OF MAIZE TILLAGE SYSTEMS

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This article discusses the costs involved in four maize tillage systems and the results of a maize no till versus conventional tillage survey. The four tillage practices analyzed are conventional tillage, chisel and disc harrow, stubble mulch tillage and direct drilling.

It is assumed that fertilizer applications remained constant for all systems. The equipment used is summarized in Table 1. The pesticide programme followed for all four cases is 125 ml/ha Ambush and 0,75 l/ha Nuvacron. The herbicide programmes followed are 4 l/ha Eptam Super plus 4 l/ha Gardomil Super 700 for both the conventional and the chisel-and-disc tillage operations, while 1 l/ha Dual 9305, 3,6 l/ha Gardomil Super 700, and 2 l/ha Gramoxone and 2 l/ha Bladex Plus is used for the direct drilling operation. It is also assumed that there is no aluminium or compaction problem, and harvesting costs are not taken into account. All costs given are as at January 1, 1994.

The use of trademarks in the budgets is purely for information. The chemicals mentioned are those used on Cedara trials and can, therefore, change according to area planted, soil type, weeds, *etc.* The type of chemical and the way it is used must thus be determined in consultation with experts. Tables 3 to 6 give the breakdown on the fixed and variable costs of the various practices, while Table 7 summarizes the overall situation.

The results of the survey point out that conservation tillage requires a lower capital outlay than conventional

Table 1. Equipment used

Operation	Implement type	Tractor used (kW)
Topdress	Fertilizer spreader	46
Disc harrow	2.4 m offset disc harrow	60
Plough	4 furrow mouldboard plough (mounted)	60
Disc harrow and weedicides	Disc harrow plus 3 m boom, 400 ℓ	
Planting and weedicide	4 row mounted planter plus 3 m boom	60
Chisel	7 tine chisel plough (mounted)	46
Chop stalks	Stalk chopper	60
		60

Table 2. Cost of tractors and implements

Equipment	Cost (R)
45 kW Tractor	87 125
60 kW Tractor	110 450
Offset disc	26 700
4 furrow mouldboard plough	4 470
4 row planter	25 815
Fertilizer spreader	3 900
Chisel plough	8 750
Stalk chopper	13 225
Boom sprayer	5 900

Table 3. Conventional tillage costs

Operation	Total variable costs (R/ha)	Total fixed costs (R/ha)	Total costs (R/ha)
Disc harrow	15.06	16.88	31.94
Plough	52.78	39.76	92.54
Disc harrow	15.06	16.88	31.94
Disc harrow and weedicide	17.03	20.39	37.41
Plant and weedicide	13.81	18.21	32.02
Topdress	11.06	9.06	20.12
Total (R/ha)	124.79	121.16	245.95
Weedicide costs = R192.45/ha			Pesticide cost = R 43.38/ha

Table 4. Chisel-and-disc tillage costs

Operation	Total variable costs (R/ha)	Total fixed costs (R/ha)	Total costs (R/ha)
Disc harrow	15.06	16.88	31.94
Chisel plough	13.04	11.28	24.31
Disc harrow and weedicide	17.03	20.39	37.41
Plant and weedicide	13.81	18.21	32.02
Topdress	11.06	9.06	20.12
Total (R/ha)	69.99	75.80	145.79
Weedicide cost = R192.45/ha			Pesticide cost = R43.38/ha

Table 5. Stubble mulch tillage costs

Operation	Total variable costs (R/ha)	Total fixed costs (R/ha)	Total costs (R/ha)
Stalk chopping	11.43	13.54	24.97
Chisel plough	13.04	11.28	24.31
Weed control with chisel plough and sweep	13.58	12.68	26.26
Plant and weed control	13.81	18.21	32.02
Topdress	11.06	9.06	20.12
Total (R/ha)	62.91	64.77	127.67
Weedicide cost = R 193.46/ha			Pesticide cost = R 43.38/ha

Table 6. Direct drill costs

Operation	Total variable costs (R/ha)	Total fixed costs (R/ha)	Total costs (R/ha)
Winter control	11.07	10.25	21.32
Plant and weed control	13.81	18.21	32.02
Topdress	11.06	9.06	20.12
Total (R/ha)	35.94	37.52	73.46
Herbicide cost = R 251.28/ha			Pesticide cost = R 43.38/ha

Table 7. Summary of costs

Tillage operation	Machinery (R/ha)	Herbicide (R/ha)	Pesticide (R/ha)	Total variable cost (R/ha)	Total capital outlay (R)
Conventional	245.95	192.45	43.38	481.79	264 360
Chisel-and-disc	145.79	192.45	43.38	381.62	268 640
Stubble mulch	127.67	193.46	43.38	364.52	259 665
Direct drill	73.45	269.69	43.38	386.52	122 740

tillage, with the cost of direct drill being less than half that of any of the other three investigated. The total variable costs of chisel-and-disc, stubble mulch tillage and direct drill are approximately R100 per hectare less than that of conventional tillage. The other advantages of conservation tillage have been spelled out in the first article in this series. Against these facts must be weighed the increased management expertise required of conservation tillage and the problems of disease control.

A NEW USE FOR YOUR MOULDBOARD PLOUGH

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Contill No. 5. Undated. Department of Agriculture and Water Supply.

INTRODUCTION

A chisel plough has been constructed using a three-furrow Saffim mouldboard plough as a basis. The performance of this plough (locally called a Miller Tiller) is discussed. Since the conversion is aimed at the smaller farmer, a standard, mounted, frame-type plough was used. In order to increase the width of operation and prevent 'crabbing' of the tractor, the frame of a fourth frame was bolted onto the right hand side of the plough. No changes were made to the basic frame and all the construction work involved can be done in an ordinary farm workshop.

CONSTRUCTION

The mouldboards were all removed from the shanks. An adaptor, illustrated in Figure 1, was constructed, using a 6 mm mild steel plate and 10 mm x 30 mm flat iron. Apart from holding the tine in place the adaptor also serves two other purposes, namely to protect the shank against wear and to increase the ground clearance. For the latter purpose the adaptor was lengthened to form a 'false shank', giving an underframe clearance of 670 mm. The shape of the adaptor was dictated by the shape of the tine to be accommodated, bearing in mind the angle at which the tine is to enter the soil.

A template was used to cut the two side plates and the holes were drilled accurately to match those in the shank. The flat iron was then cut and bent and the adaptors were made to accommodate both chisel points and sweeps. The adaptors are simply bolted onto the shank and can be removed very quickly, allowing chisel points to be swopped for sweeps, or even mouldboards to be replaced,

Weather studies

In a time-of-planting experiment at Cedara in the 1989/90 season where a susceptible maize cultivar was no till planted into heavy stubble at six roughly equivalent heat unit intervals, the earliest planting, which experienced water stress from silking through the first fourteen days of grain filling, displayed significantly more cob rot than the latter.

In order to obtain a better seedbed a basket roller was constructed. Eight 300 mm diameter discs were cut out of 3,15 mm plate. On each disc 12 equidistant 12 mm

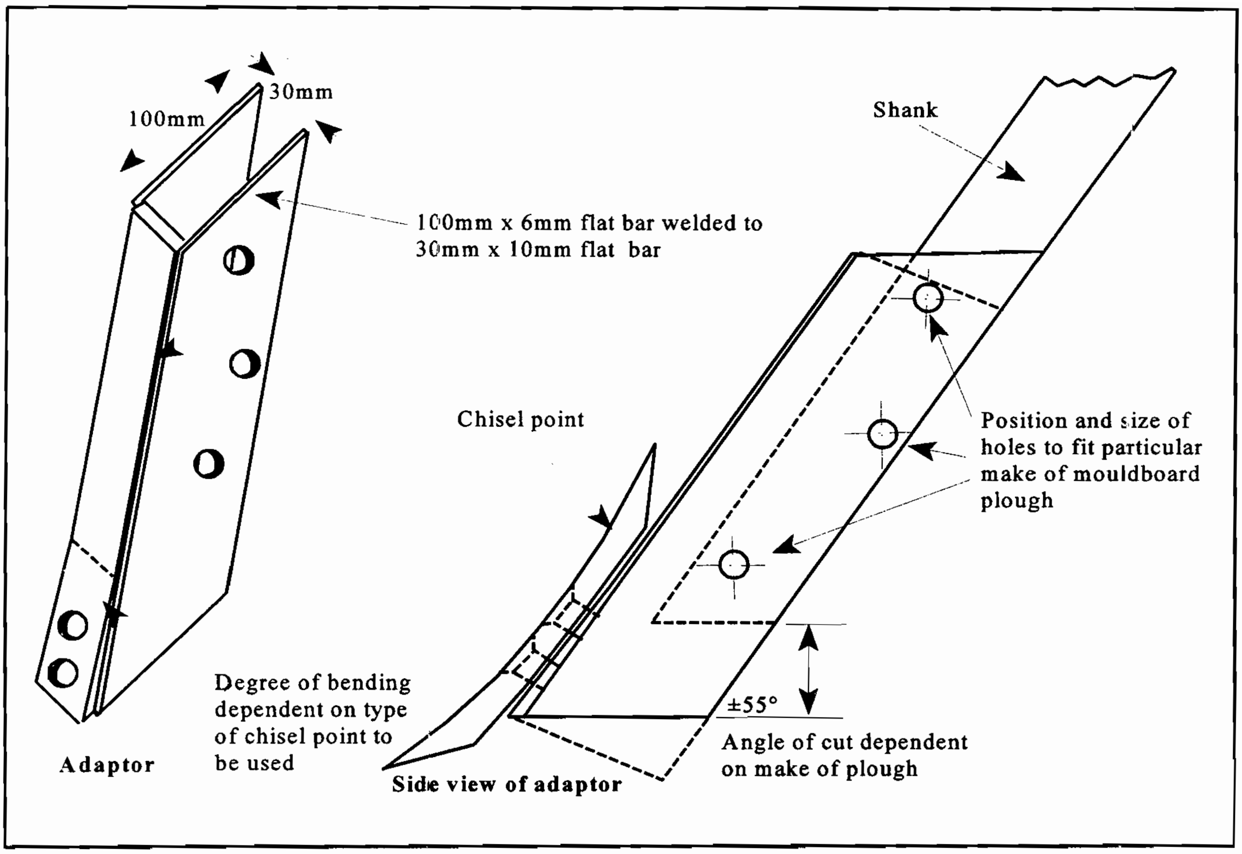

Figure 1. The adaptor, shaped to fit the shank of the plough and the point to be used

diameter holes were drilled at 280 mm pitch diameter, as shown in Figure 2.

The discs were then re-cut to a diameter of 280 mm, to obtain 12 semi-circular openings on the circumference. A hole was drilled in the centre of each disc for an axle consisting of 1,61 m of 40 mm steel piping with steel shafting welded on each end. The ends were turned to fit two bearings which were available.

Forty-two lengths of 12 mm rod were cut, each about 250 mm long. The roller was then constructed by lining the discs up along the axle at 230 mm centres, making sure that the semi-circular holes lined up, tack welding them into position and then welding the 12 mm rods into position, to form a zig-zag pattern, as illustrated in the two photographs. The roller was then mounted behind the plough, as illustrated, using angle and channel sections, and providing a spring loading facility. The actual mounting will depend on the plough frame used. The photograph (Figure 3) shows the completed plough. The sweeps in the photographs have been modified and fitted with nozzles for Eptam application.

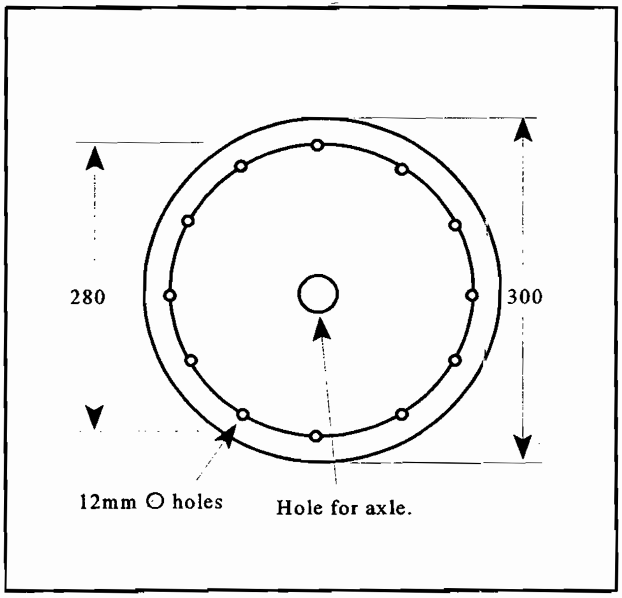

Figure 2. Dimensions of the basket roller discs

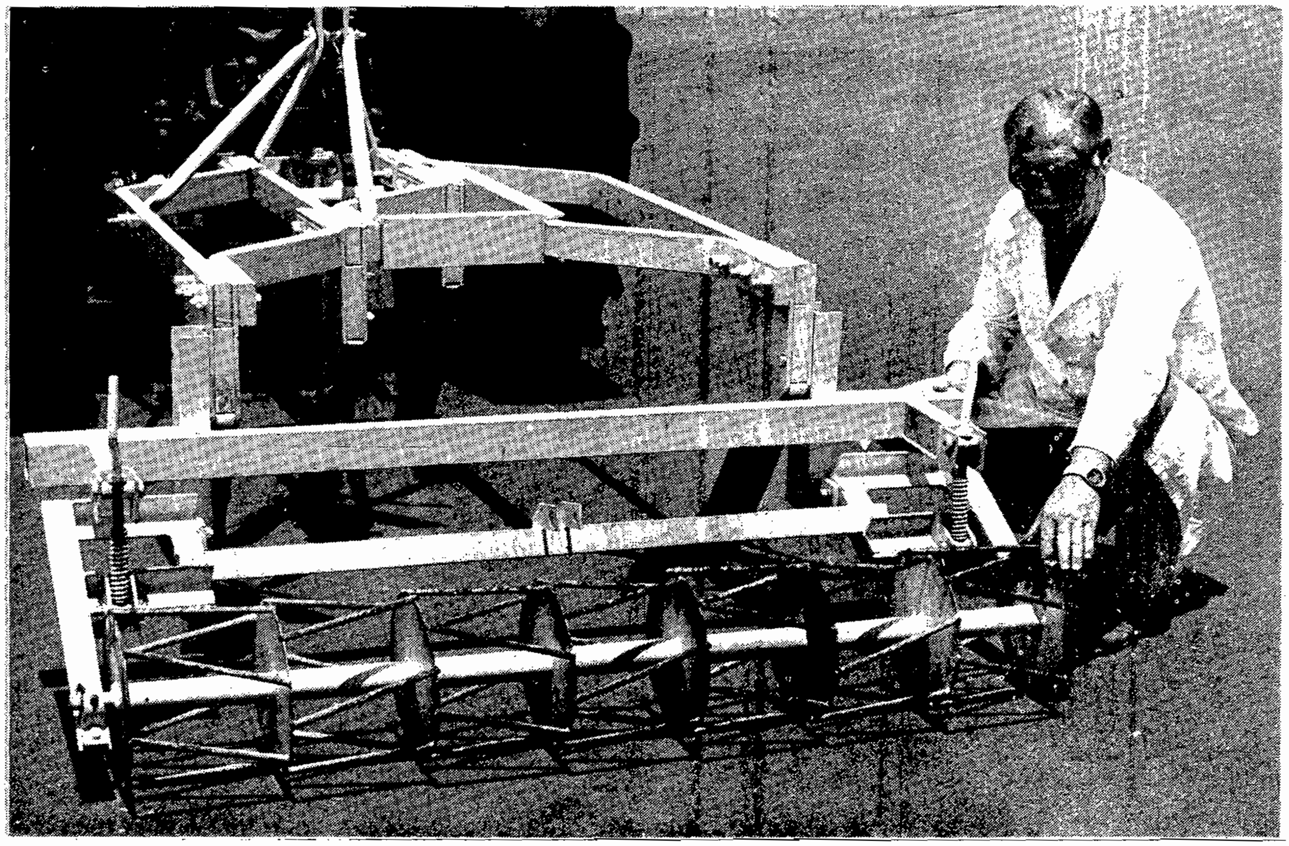

Figure 3. The Miller Tiller with the developer, Mr Des Miller

Conservation of Farmland in KwaZulu-Natal

WINDBREAKS FOR FARMS IN KWAZULU-NATAL

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INTRODUCTION

Many parts of KwaZulu-Natal are exposed to hot, dry winds in summer and bitterly cold winds in winter, making the provision of shelter for stock, crops and homesteads essential. Trees serve the important purpose of making man's environment more hospitable, and enhancing the value and appearance of his property. This guideline discusses the advantages and disadvantages, the design, establishment and maintenance of windbreaks. It also gives a list of trees suitable for use as windbreaks.

THE VALUE OF WINDBREAKS

The systematic planting of windbreaks on a farm brings the following benefits to various farming enterprises:

* wind speed is greatly reduced, preventing physical damage to flowers, fruit and plants by dust, hail, snow and abrasion. Both the quantity and the quality of the crop is improved by the planting of windbreaks.
* The pernicious damage by wind erosion to the soil resource, which results in a lowering of soil fertility, is reduced,
* Lowering wind speed reduces the chill factor, resulting in higher stock survival,
* Lower wind speeds reduce evapotranspiration, resulting in more efficient use of available soil moisture,
* Low wind speeds facilitate pollination by bees, which is important where grain or fruit is produced,
* Shelter is provided for desirable birds and animals,
* Protection from wind prevents lodging of crops such as maize,
* Windbreaks can supply products such as timber, poles and firewood and provide nectar and pollen for honey production, and
* Windbreaks add to the attractiveness of a farm.

While many of the advantages of windbreaks are intangible or difficult to measure, the following direct benefits have been reported:

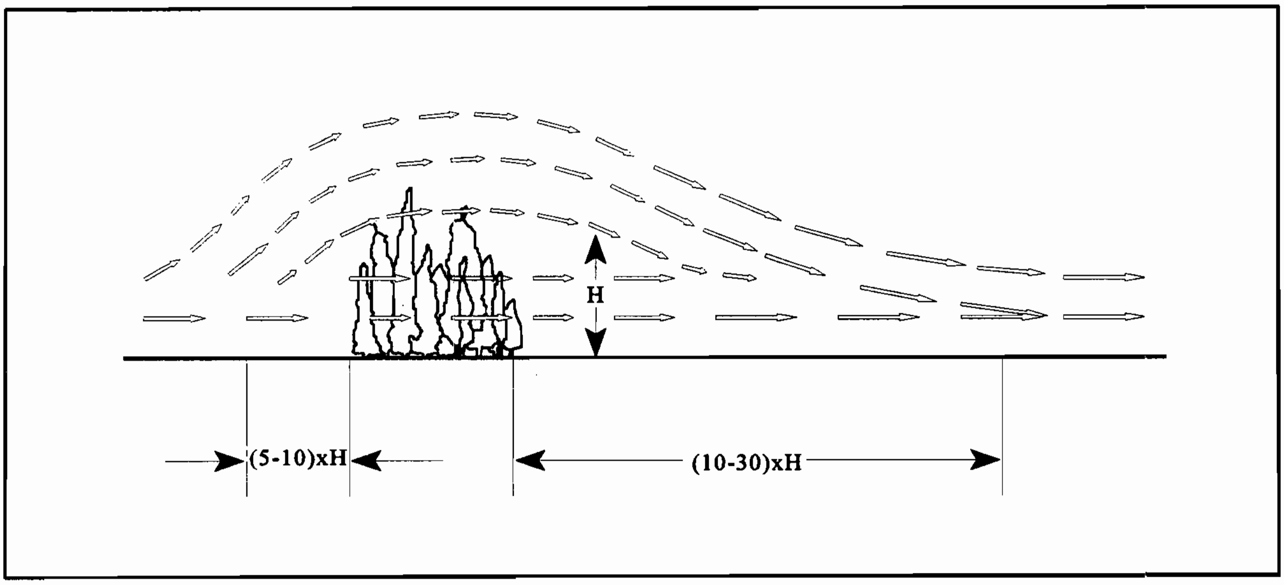

Figure 1. How a windbreak works

* In Denmark crop yield was increased 4,5 times more than what was sacrificed in providing shelter,
* In the United States the leafage of maize increased by 90% and the grain yield by 100 to 150%, while under drought conditions lucerne protected by windbreaks produced up to three times the yield achieved without windbreak protection, and
* Windscar blemishes in citrus can be reduced from 40% to 10% by providing suitable windbreaks. This has a very large economic significance to the exporter.

It is estimated that 5% of a farm can be planted to windbreaks without reducing the overall yield.

DISADVANTAGES OF WINDBREAKS

* Windbreaks planted on the contour can trap cold air (resulting in frost pockets), or hot air (resulting in heat scorch), both of which can cause crop damage.
* Windbreaks running east-west will shade the southern side all day, reducing crop growth and slowing down the drying out of roads and poorly drained lands after rain.
* Land which would otherwise be under crops is taken up by trees.
* Tree roots can affect the productivity of the adjoining land for a distance of approximately their own height. This effect can, however, be greatly reduced by annually ripping a single deep line parallel to, and 3 to 4 metres away from, the tree line to keep tree roots away from the crop.
* Undesirable birds, such as finches, find shelter in windbreaks.
* Too dense a barrier can result in winds becoming turbulent in the lee of windbreaks, causing physical damage to crops.
* If the wrong tree species is chosen it may invade adjoining areas.

HOW DOES A WINDBREAK WORK?

When wind approaches a windbreak, part of the moving air filters through the leaves and branches, reducing its speed and forming an air cushion on either side of the windbreak. The remaining air is deflected over the windbreak and the leeward air cushion helps to keep it away from ground level for a considerable distance. The area of reduced wind speed may be up to 5 times the height of the trees on the windward side and up to 20 times the height on the leeward side, depending on wind speed, topography and other factors. See Figures 1 and 2. Thus, a windbreak 10 m high could provide shelter over a total distance of up to 250 m, but a closer spacing is desirable to prevent the wind speed building up to more than half its original speed. The height of the crop must also be taken into consideration as this reduces the effective height of the windbreak. For example, with a 10 m high windbreak and orchard trees 4 metres high, the effective height of the windbreak is only 6 metres.
When the wind speed is reduced by one quarter, its force is reduced by approximately one half, greatly reducing mechanical damage by abrasion.
A windbreak is most efficient when it is at right angles to the main, damaging wind direction. It should not be at more than 30 degrees to the ideal position, otherwise cross windbreaks will be necessary.

WINDBREAK DESIGN

Density
The denser a windbreak the more it reduces wind speed, but the greater the hazard of turbulence, and the sooner the wind returns to original speed. Very dense windbreaks are of most value around buildings, where high protection is needed over a small area. Too permeable a windbreak is of little use - a permeability of 40% to 50% is ideal.

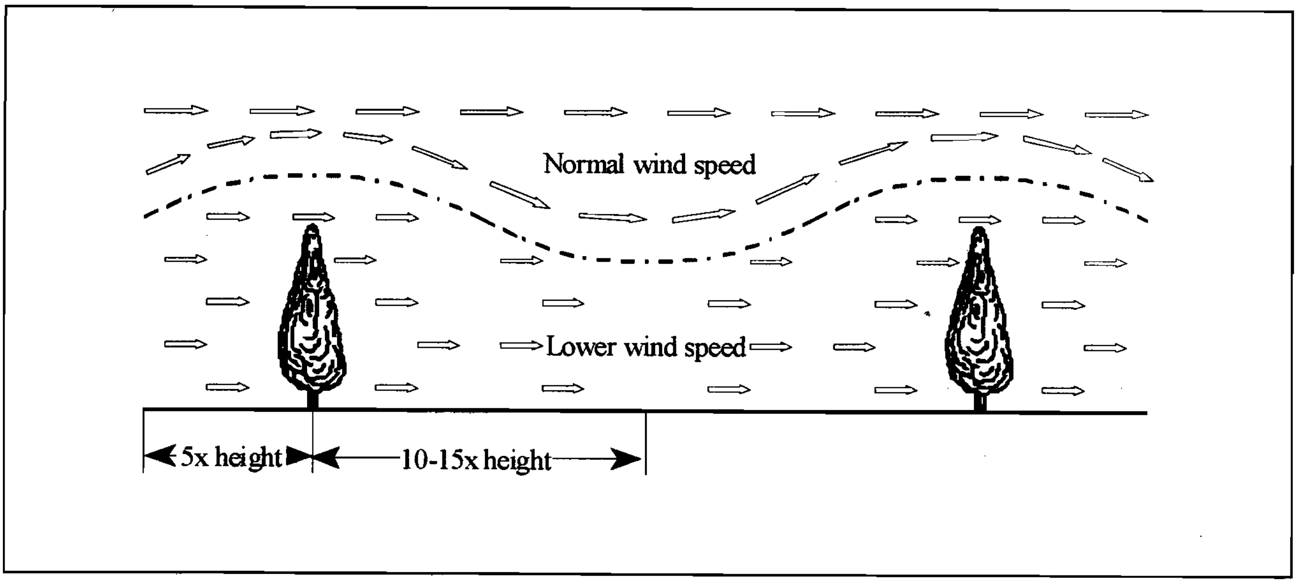

Figure 2. How a windbreak works

The density of a windbreak can be controlled by choice of tree species, the espacement of trees in the row, the distance between rows and by the number of rows planted. A single row may be adequate in many cases but this is not advocated, as the death of a tree will create a gap with wind tunnel effects and consequent turbulence and high wind speed. Two to four rows are best, depending on the space available. Wider windbreaks become, in fact, woodlots, with timber production playing an important role.

The normal spacing within the row is 2 m to 4 m and the distance between rows 4 m to 5 m, depending on the ultimate height of the trees and the width of their crowns. The windbreak can be made more effective by staggered planting, *i.e.*, trees in one row are placed opposite the gap between trees in the next row. See Figure 3.

Advantage may be taken of rocky ridges, etc., using otherwise useless land for windbreaks. Where roads run along windbreaks they should be on the northern or western side of the windbreak so that they will dry quicker after rain.

Overall planning

Just as wind will funnel through gaps, it also travels faster and more turbulently around the ends of windbreaks. This is best reduced or prevented by making windbreaks as long as possible and by planting cross windbreaks to create a closed square pattern. This will also cater for winds not at right angles to the main windbreak. Ideally, all the farmers in a community should plan and create interlocking windbreak patterns.

Windbreaks can be normally spaced on level terrain but must be spaced closer on windward slopes and on crests. On the leeward side of hills they should be spaced closer near the top but can be further apart than normal at the bottom of the slope and in valleys, as these areas are in any case sheltered. On leeward slopes the best position for the main windbreaks is more or less on the contour.

Where gaps in windbreaks are essential, for example, where a road crosses a windbreak the effects can be reduced by making this a meeting point with cross windbreaks. Power lines are a serious problem - where possible, have them located along roads, along windbreaks or in valley bottoms.

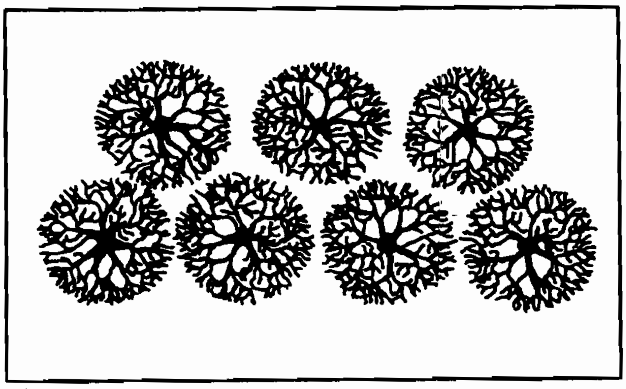

Figure 3. Staggered planting

ESTABLISHMENT

Site Preparation

The better the site preparation, the better and faster the trees will grow. Ploughing and discing with deep ripping along the tree lines is ideal. On steep or rocky sites, however, pitting will have to be practised, *i.e.*, clearing a 1 m diameter circle of grass or weeds and digging over the central 250 mm to a depth.

Planting

The best time to plant is when the soil is moist and rain is expected. Winter planting is proving very successful in summer-rainfall areas, provided that the soil is reasonably moist or the trees are watered occasionally. Any seedlings that die must be replaced immediately - within two months - otherwise they will never catch up.

Sturdy, woody plants should be used, and they should be planted deep to ensure that the roots are in moist soil.

A mulch of dead vegetation or black plastic around the tree is very beneficial in retaining moisture in the soil and in preventing the germination of weed seeds. See Figure 4.

MAINTENANCE AND PROTECTION

Keep the young trees free of weeds to promote fast growth and retain low branches down to ground level. The windbreak must be fenced to keep out stock as the trees are sensitive to damage by browsing, trampling, abrasion and bark biting. Fire-belts must be prepared in good time each year and should be wide enough to prevent the heat from a fire scorching and killing foliage. Light thinning can be carried out to remove unhealthy and suppressed trees, but be careful not to create a gap. Pruning of inside trees of multi-row windbreaks to 2.5 m or more may be done if stock are to be sheltered in the windbreak. See Figures 5 and 6.

Windbreaks should receive the same fertilizer and irrigation as the crops or orchards to avoid them competing for nutrients and moisture in the adjacent lands.

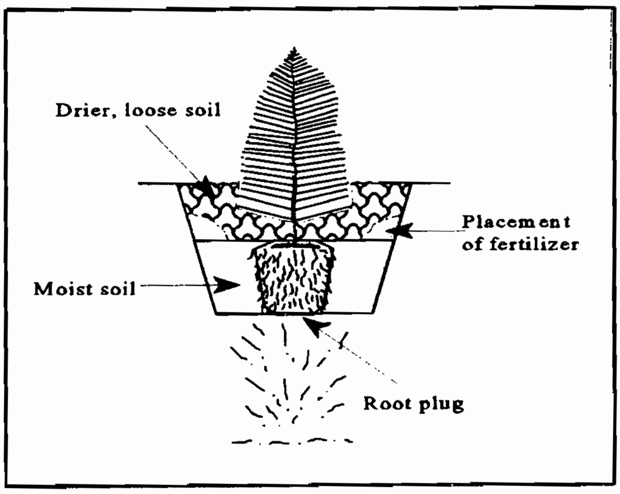

Figure 4. Deep planting

REPLACEMENT

Windbreaks must be replanted in good time to ensure that there is always a healthy vigorous barrier which will provide protection. An option which may be used to achieve this aim is to plant 4 rows and then re-establish two rows at a time. The difference in age between the pairs of rows should be half the optimum age of the species used, *i.e.*

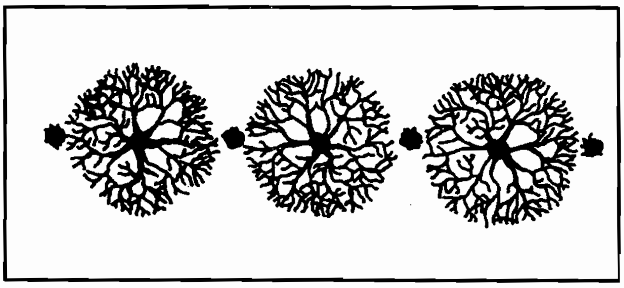

Figure 5. Pruning only 50% of the trees in a narrow windbreak

TREE SPECIES	OPTIMUM AGE (years)	FELL HALF BELT WIDTH EVERY:
Eucalyptus species	10 - 15	5 - 7 years
Syncarpia species	20	10 years
Pinus species	20 - 30	10 - 15 years
Cupressus and Callitris species	30	15 years
Casuarina species	20	10 years

HIGH-VALUE TIMBER FROM WINDBREAKS

The production of high-value timber for veneer or furniture use requires early and regular pruning to avoid knots in the wood. This is usually considered to be incompatible with windbreak planting where the primary objective is to keep a live and healthy crown down to ground level. Work in New Zealand has, however, indicated that the two objectives can be combined. This is done by a variety of systems which involve pruning only about half the trees.

* With two or more rows the unpruned trees may be of the same or slower-growing species. Plant staggered rows. See Figure 3.
* In a single row windbreak every second tree may be pruned, with the branches of the unpruned trees spreading to close the gaps. See Figure 5.

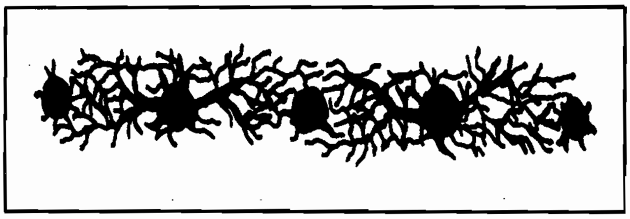

Figure 6. Planning a very narrow windbreak

If a very narrow windbreak is required the branches of the unpruned trees need only be retained in the tree line. See Figure 6.

* If more than three rows are to be planted, the two outer rows can be left unpruned and the inside rows pruned normally for saw timber.

The trees to be grown for high-value timber must be pruned to at least 7 m on a rotation of probably 30 years or more in order to get the large diameters required. The following pruning schedule is suggested:

Prune to: 1,5 m when the trees are 4 m tall
3,0 m " " " " 6 m tall
5,0 m " " " " 9 m tall
7,0 m " " " " 12 m tall

Species for high-value timber production are limited to the following:

* Pines such as ***Pinus patula, P.elliottii, P.taeda, P.radiata***
* ***Cryptomeria japonica*** (Japanese cedar)
* ***Sequoia sempervirens*** (Californian redwood)
* ***Cedrus deodara*** (deodar)
* ***Acacia melanoxylon*** (blackwood)
* ***Quercus acutissima*** (sawtooth oak)

CHOICE OF TREES

Species normally grown as hedge plants, with a maximum height of about 7 m, have been excluded from this leaflet as they provide shelter to too small an area to be suitable for field crops, orchards or stock. Choice of species depends on altitude, rainfall, soil and other factors such as tolerance to frost,hail damage and sea winds. Table 1 lists tree species suitable for the summer rainfall regions according to their hardiness to frost and drought. Further information may be obtained from the forestry extension officer.

The normal preference is for evergreen species, which provide the maximum protection during winter. Good success can, however, be obtained with deciduous trees. Their interlocked branches and twigs, although leafless in winter, reduce wind speed considerably. Such trees have the advantage of being very attractive in their autumn colours and fresh spring foliage. IIn deciduous windbreaks a reduction of windbreak density in winter will allow some air movement and reduce the formation of frost pockets in orchards.

TABLE 1 TREES FOR WINDBREAKS IN SUMMER RAINFALL REGIONS

* Specially recommended species
\+ Bioclimatic region in brackets

FROST-FREE AREAS Humid and Sub-humid (1)+	Semi-arid (10 in Zululand)+
Acacia elata * *Alnus cordata* * *Casuarina equisetifolia* *Eucalyptus grandis* * *Grevillea robusta* *Pinus elliottii* * *Syncarpia glomulifera* * *S. hillii*	*Callitris glauca* *Casuarina cunninghamiana* *Eucalyptus camaldulensis* *E. cladocalyx* *Rhus lancea* *R. viminalis*
LIGHT FROST Humid and Sub-humid (2)+	Semi-arid (9)+
* *Alnus cordata* *Acacia elata* *A. melanoxylon* * *Casuarina cunninghamiana* * *Cupressus lusitanica* * *C. sempervirens* *Eucalyptus grandis* *Grevillea robusta* *Pinus elliottii*	*Brachychiton populneus* *Callitris glauca* *Casuarina cunninghamiana* *Cupressus glabra* *C. sempervirens* *Eucalyptus camaldulensis* *E. cladocalyx* *Rhus lancea*
MODERATE FROST Humid and Sub-humid (3 & 6)+	Semi-arid and Arid (Rest of 10 & 11)+
Acacia mearnsii * *Casuarina cunninghamiana* * *Cedrus deodara* *Chamaecyparis lawsoniana* *Cryptomeria japonica* *C. japonica v. elegans* * *Cupressus lusitanica* * *C. torulosa* * *Eucalyptus cinerea* *E. fastigata* *E. sideroxylon* * *Pinus patula*	*Brachychiton populneus* *Callitris glauca* *Casuarina cunninghamiana* *Cupressus glabra* *Eucalyptus sideroxylon* *Rhus lancea* * *Pinus roxburghii* *Populus nigra* *Quercus acutissima* *Q. palustris* *Sequoia sempervirens*

SEVERE FROST Humid and Sub-humid (4)+	Semi-arid (8)+
* *Cedrus deodara* *Chamaecyparis lawsoniana* *Cryptomeria japonica* * *Cupressus torulosa* * *Eucalyptus cinerea* *E. fastigata* *E. pauciflora* *E. sideroxylon* * *Pinus patula* * *P. radiata* * *P. roxburghii* * *Populus nigra* *Quercus acutissima* * *Q. palustris*	*Cupressus glabra* *Juniperus virginiana* *Rhus lancea* *R. viminalis* *Schinus molle*

Conservation of Farmland in KwaZulu-Natal

PLANNING STOCKWATERING FACILITIES

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INTRODUCTION

This guideline examines the options a land user has in deciding on the best management practices for supplying a clean, permanent supply of water to each of his veld grazing camps in order to support a proper grazing management system on his farm. It also details the minimum criteria for determining the size of each facility planned.

THE SUPPLY OPTIONS

Water for stockwatering may be obtained from a number of sources. It is up to the planner to decide, based mainly on economic considerations, which is the best option. In planning a stockwatering scheme, Table 1 below may be used as a guide to water requirements by grazing animals. The water must preferably be permanent, potable, non-aggressive and suitable for construction purposes as well. Where there is doubt as to its suitability the local veterinarian should be consulted.

Table 1. Water requirements of domesticated stock

Type of stock	Water requirements (litres/day)
Large stock	50
Cows in milk	90
Small stock	5

The following sources of water may be available to the land user, and in the discussion below the pros and cons of using these sources are discussed.

* **A free flowing perennial stream:** It is very seldom that a stream will meander throughout the farm in such a manner that it will provide watering for each and every grazing camp. There will normally be some camps on the farm which, because of the physical needs of conservation planning (*e.g.* separating aspects and veld types), will not be fed by the stream. Water will therefore have to be pumped or gravitated from the stream to these disadvantaged camps. This method of supply is described elsewhere. A few important aspects of aligning fences to allow direct access by stock to streams are as follows:

- fences constructed alongside streams tend to be damaged, if not destroyed entirely, during flooding of the stream. The fences should be placed taking cognisance of the general flood level,
- fencing which necessarily follows streamlines must be sited in such a manner as to facilitate ease of access by stock to the water. Animals moving to and from the water must also not damage streambank vegetation, and
- fences crossing streams are subject to damage by flooding. There are four recognised methods of reducing the impact of flood damage on the fence crossings:
  - o Fix strong straining posts either side of the stream, and fasten a weak, inexpensive fence between them which will wash away during flood peaks, but without damaging the straining posts. The land user in this case accepts that he will have to replace the crossing every couple of years. A close alternative to this is to fasten a concertina gate to these straining posts, one fastening being made purposefully weak, which will break during floods, allowing the gate to swing open. Repair work then merely entails closing and fastening the gate again.
  - o With the same two straining posts in position, a cable is stretched between them which will be above flood level. A series of chains is hung from the cable, approximately 250 mm apart and long enough so that they do not quite touch ground or water level. An electric power pack is installed and the cable and chains are energized during the period when animals are grazing either camp adjacent to the fence crossing. This method has been used to great effect.
  - o With the same straining posts and cable installed, sheets of corrugated iron are hung from the cable. In this instance the sheets should touch ground level in such a way that they are angled slightly downstream. Any rise in stream level will tend to make them swing

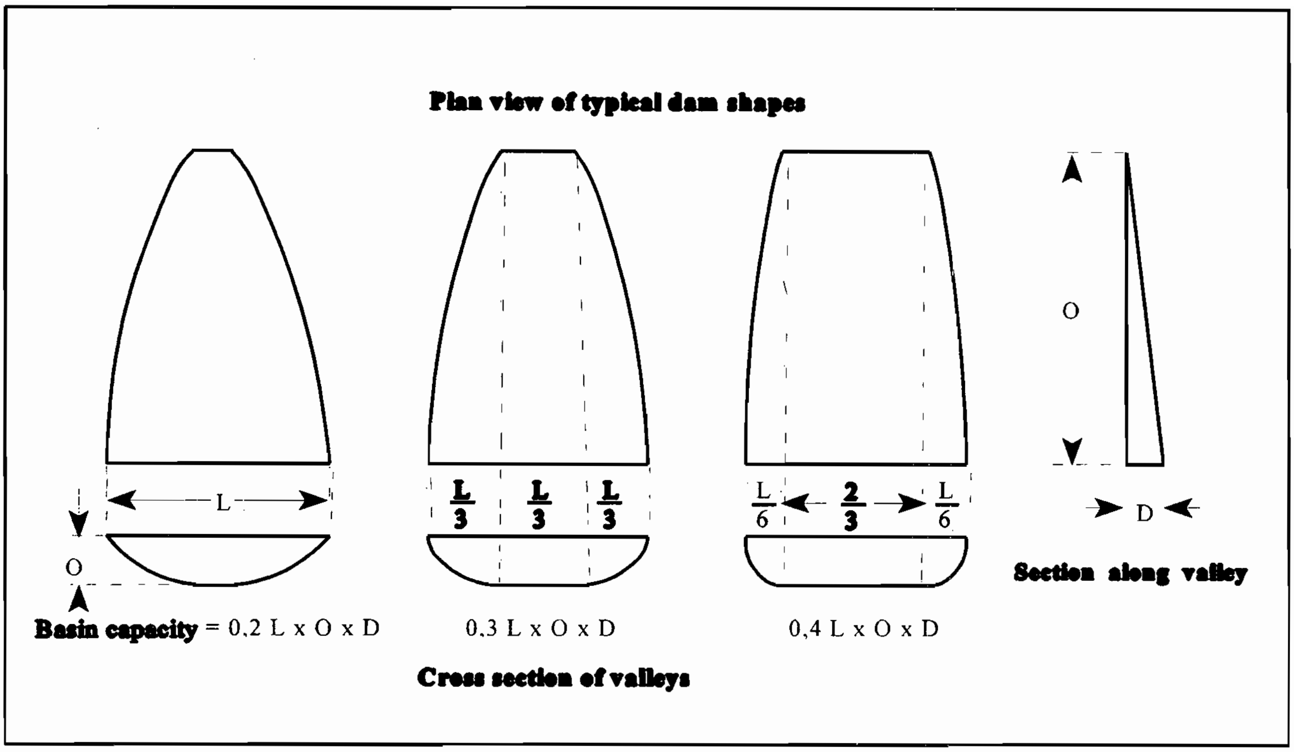


Figure 1. Assessing basin storage

down stream and lift, allowing the floodwaters to pass underneath. With a drop in flood level the sheets close the gap again. In practice it has been found necessary to drill a large number of small holes through the sheets to make them unsuitable as roofing material, and therefore not worth stealing.

- Where dams are built across the stream it is sometimes possible to route the fence along their crests with minimal damage during flooding.

* **A storage dam:** As long as the dam forms a permanent supply of water, the only possible objections to it being used as a water facility would be as a result of the quality of water stored (see below), and/or the fact that its normal siting will cause footpaths to be trampled towards it, which could result in donga-formation, with sediment from the erosion accumulating in the dam basin. If the dam is to be used in this way, the approaches to the dam must be stable. From many different aspects it is, however, preferable to pipe water from the dam to a drinking trough at the most suitable spot, and to fence the dam off.

The size of storage is important, both in relation to the number of stock required to water from it, and in relation to the volume of runoff that can reasonably be expected from the catchment supplying the stored water. Figure 1 shows a simple but effective method of assessing the basin capacity of a storage dam (whether it be an existing or a proposed stockwatering facility), while Figure 2 assists the landuse planner in determining whether the catchment will provide sufficient runoff to keep the dam reasonably supplied.

Especially in the drier areas of the country, it is not advisable to have dams, formed by earthen embankments, standing empty for too long, as termites are known to build nests in the embankment material when it dries out. This could lead to failure of the embankment through tunnelling once the dam refills. A similar type of problem could result from allowing trees to grow on the earth bank of a dam. When the tree dies the decayed roots cause channels which could also cause failure by tunnelling. Figure 3 assists the planner in estimating the volume of earthwork needed to construct a small earthen dam of given dimensions.

A recognised norm for the capacity of dams is that they should store no more than two-thirds of the calculated long-term annual average runoff from the catchment. There are further conditions attached to the choice of site for constructing a storage dam, but these are enumerated more fully in guideline No. 3.2, 'Brief Specifications for the Construction of Small Earthen Dams'. Evaporation losses are an important aspect of water storage and this must, therefore, also receive due consideration when planning the construction of a dam. A minimum water depth of 2 m is considered essential.

There are three methods of utilizing the water in a storage dam:

- allowing animals to drink from the dam while standing in the water. This is considered to be the poorest option due to the probability of disease transmission from one animal to another via the dunging action,
- pumping water out of the dam to the best possible site must be the best option, and is covered more

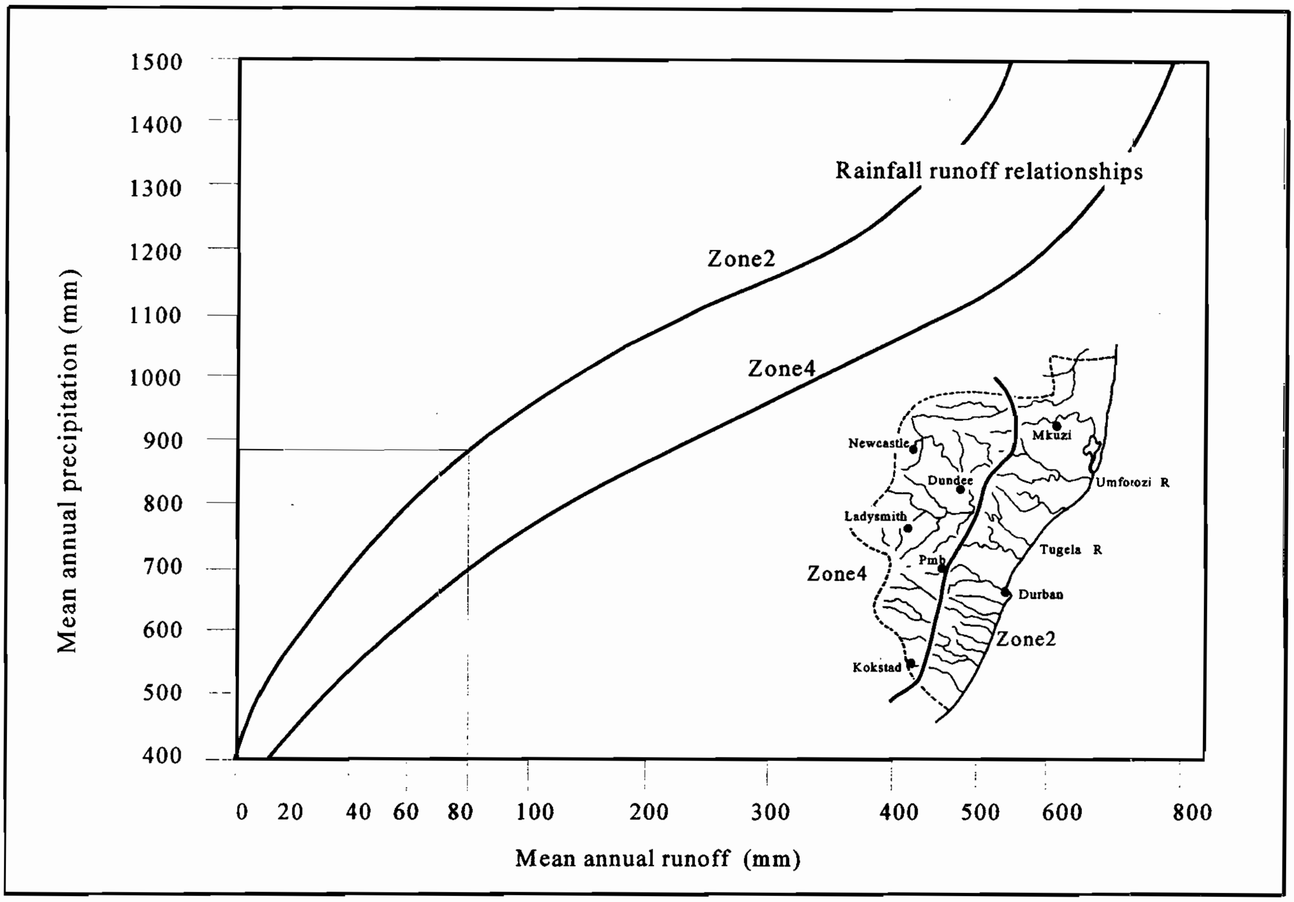


Figure 2. Method of assessing mean annual runoff

fully elsewhere, and

- if the dam has an outlet pipe under the embankment, this will allow reticulation by gravity to suitably sited drinking troughs in grazing camps at a lower level downstream. This can also be achieved if the dam does not have an outlet pipe, but only in instances where there is sufficient slope downstream of the dam to allow a siphon to perate. Figure 4 shows how to remove an airlock in a siphon operating over a dam wall. The diameter of the siphon will have to be calculated for specific requirements.

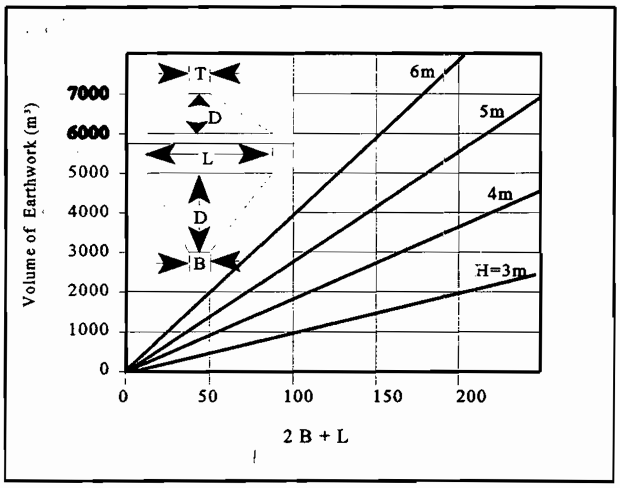


Figure 3. Approximate earthbank volumes for T=3m, side slopes 1:2 and 1:3

Finally, it must be emphasised that the construction of effective storage dams is a specialized job; it is expensive, there are controls on dam-building contained in the Water Act, and a land user contemplating the construction of one should call upon his local Soil Conservation Officer for advice before he commences.

* **A spring or fountain.** These are very valuable sources of water and can provide inexpensive stock water. The underground aquifer forms a storage compartment which is fairly safe from losses through evaporation. Some springs are weak and some are strong; some are perennial and others seasonal. These factors must be taken into account when contemplating their use. *It is recommended that only a portion of their measured delivery rate be used in designing a stockwatering facility.* If measured during the months of August to October, one may rely on three-quarters of the delivery rate measured during a 24-hour period. If measured at any other time of the year, only one half of the tested 24-hour delivery rate should be used. Figure 5 shows a typical method of trapping fountain and seepage water in order to guide it into a storage facility or drinking trough. If the delivery rate is strong enough, one may connect

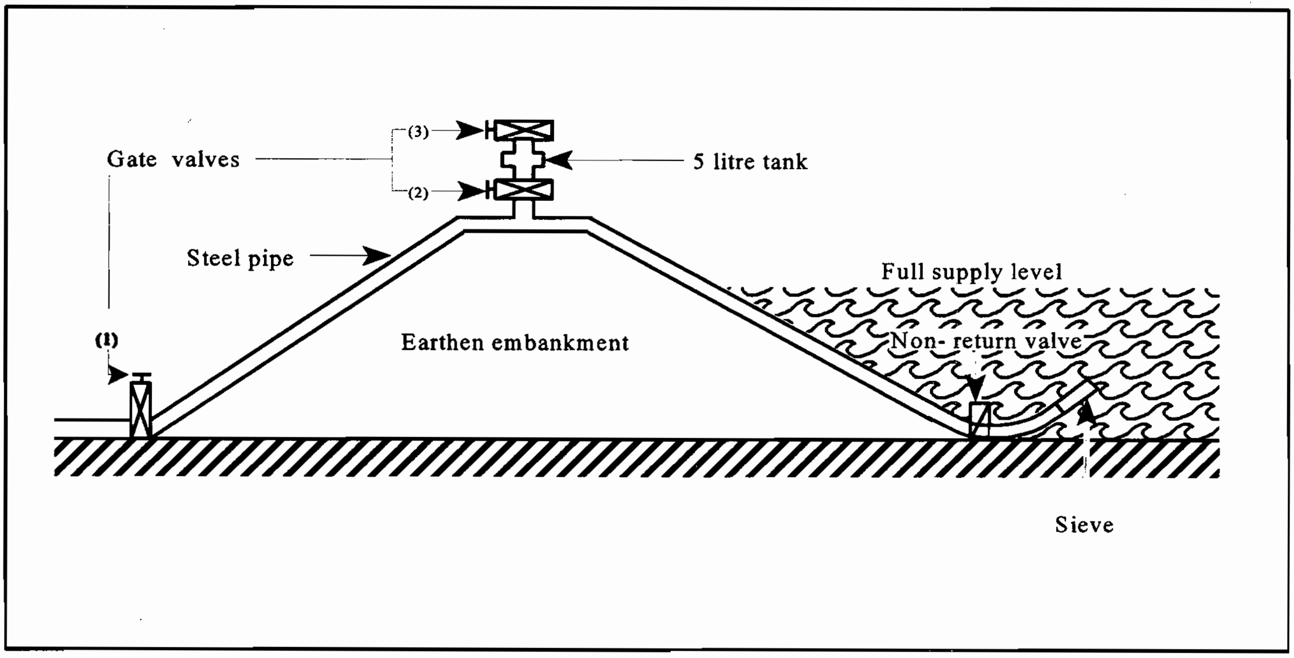


Figure 4. Syphon over dam wall

the fountain straight to the drinking trough. If not strong enough, one will have to calculate the total amount of water needed over the projected grazing period, and construct a storage facility large enough to contain this amount of water. The storage facility will fill up during the period of absence of grazing animals from the camp. The area surrounding the fountain should be fenced off and the drinking trough placed at least fifty metres from it. Further considerations as to pumping or gravitating will be discussed.

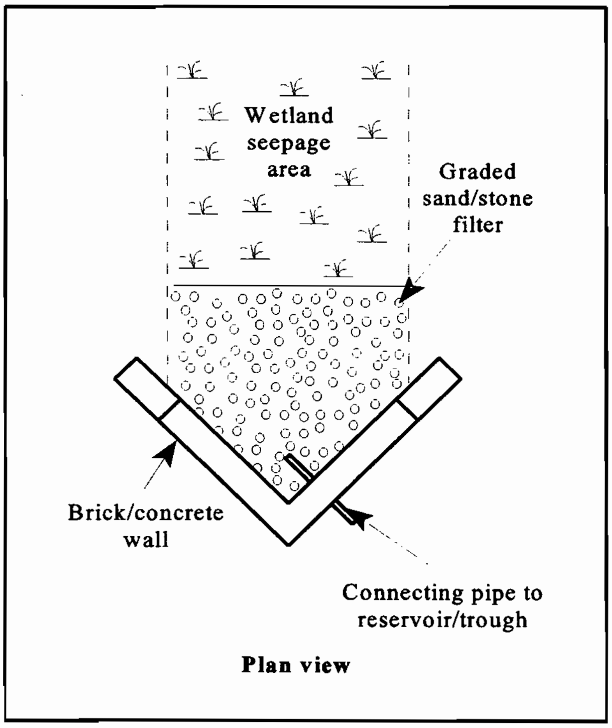


Figure 5.1. Trapping fountain/seepage water

* **A borehole**. Boreholes are the standard source of stockwatering in the largest portion of South Africa, but there are areas in KwaZulu-Natal where the underground water is unreliable. If the planner is contemplating the drilling of a borehole, he should consult leaflet 1.2 in this series entitled `Financial and Technical Assistance for the Planned Utilization of the Agricultural Resources'. This leaflet deals with the recommended procedure for having a borehole drilled, as well as the financial assistance available.

Depending upon individual requirements, water can be lifted out of the borehole and stored in a reservoir alongside, or it can be pumped over distances and heights to storage facilities more suitably placed. It is most unwise to pump at a rate greater than $^2/_3$ of the tested maximum delivery rate of the borehole measured over a 6-hour period.

* **Water harvesting.** In exactly the same way that many people in South Africa guide rainfall from the roofs of houses and outbuildings into storage tanks for later domestic use, so is it possible for a stock farmer to seal off a portion of higher-lying ground, and lead the almost 100% runoff into a storage facility. The method of sealing the soil surface can range from suitably protected plastic film, through the macadam to concrete. It is a matter of economics. This technique has wide practice in the drier areas of the world. It should work much better in the wetter parts, such as are found in KwaZulu-Natal. In order to plan the facility properly, one needs accurate, long-term rainfall records and stocking rates. It is then merely a question of determining the size of both runoff apron and storage facility, which in the long term will supply the necessary water. Once again it must be stressed that this could be considered an option based upon the cost implications compared with those of other, more conventional methods of water supply.

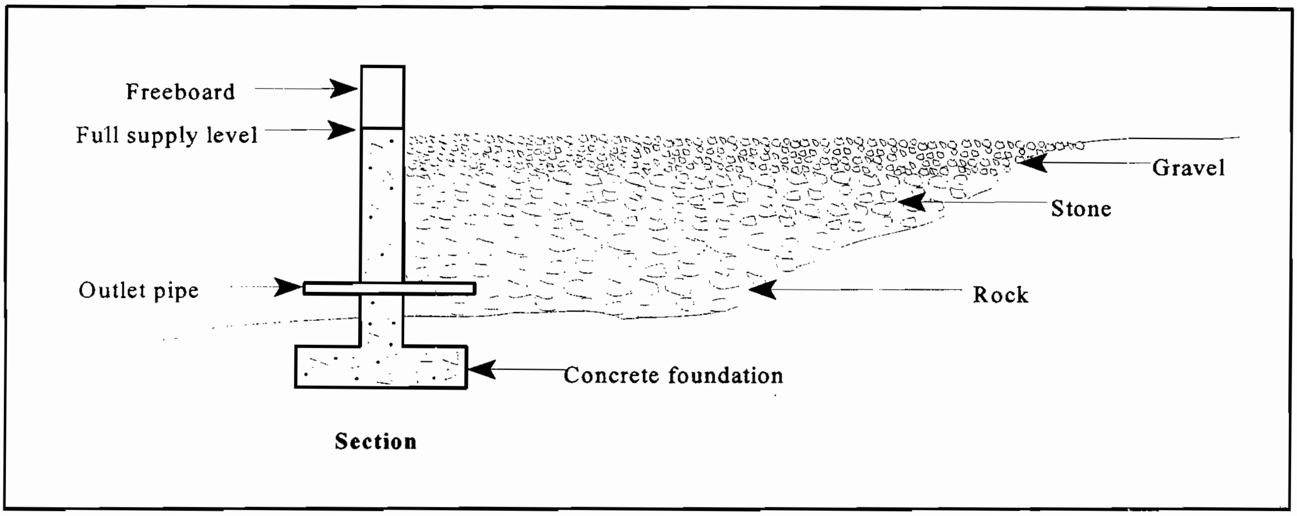


Figure 5.2. Trapping fountain/seepage water

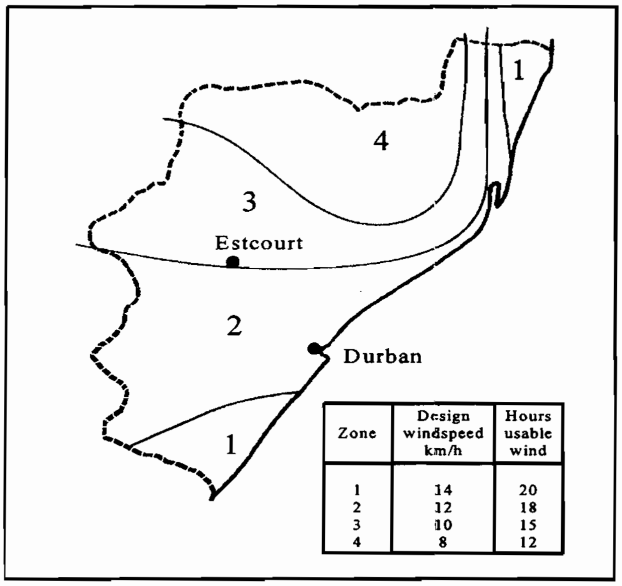
WATERING POINTS AND THEIR DISTRIBUTION

Watering points should ideally promote an even utilization of the grazing camp. The best distribution is, therefore, when one has a watering point at each end of the camp, so that the farm animals automatically graze from one end of the camp to the other, and back again, *i.e.*, from one watering point to the other, and back again. When, because of economics, it is not possible to place a watering point at each end, the best site would, of course, normally be at the centre of the camp. The exception to the rule is when the camp comprises a steep slope. In this instance, and in order to encourage grazing in the upper elevations, the watering point should be positioned two-thirds to three-quarters of the way up the slope.

The best form of watering point is the drinking trough constructed out of brick and concrete, steel, plastic or fibre glass. It is then supplied with water *via* a pipeline with a float valve to control supply. The positioning of the watering point is thereby simplified. The best site in rolling country is on the top of a ridge where there is no concentration of floodwaters to cause erosion. A rock slab forms an ideal site from an erosion control point of view but, where this is not possible, the surrounds of a trough should be paved with rocks. Large rocks forming a cobbled finish will discourage stock from storming the trough and pushing each other into it. Animals do not like warm water, so shade trees are an important consideration when planning watering sites.

Drinking troughs may be rectangular or circular, the former making for easier cleaning and cooler water, while the latter provides storage capacity at a cheaper unit cost. The ball or float valve controlling the supply of water must be protected from idle animal curiosity and wave action during heavy winds by building it into a separate compartment with a heavy lid on it. The size of a trough in an extensive grazing situation should take account of the size of the herd. *The design width of drinking space for cattle at a trough is reckoned at 100 mm for polled animals and 150 mm for those with horns.*

Delivery rates to drinking troughs are very important, and should allow all animals in the herd to get their total daily requirements within 4 to 6 hours. As delivery rate is dependent upon pipe diameter, gradient and type of pipe material, a proper survey should be carried out in order to determine the correct diameter. This should be done by a competent person trained in hydraulics. Where long and flat gradients require large and expensive diameter piping, cost investigations taking into account the use of buffer reservoirs should be carried out. Buffer reservoirs should be constructed to hold two days supply of water, and the daily watering requirements of the herd should be delivered to them within 18 to 20 hours. Cost reductions on piping water under gravity can also be realized in mountainous regions by the judicious use of in-line pressure breakers. The local Soil Conservation Officer can be of assistance here.



Zone	Design windspeed km/h	Hours usable wind
1	14	20
2	12	18
3	10	15
4	8	12

Figure 6. Windrun map of KwaZulu-Natal showing areas of differing windrun

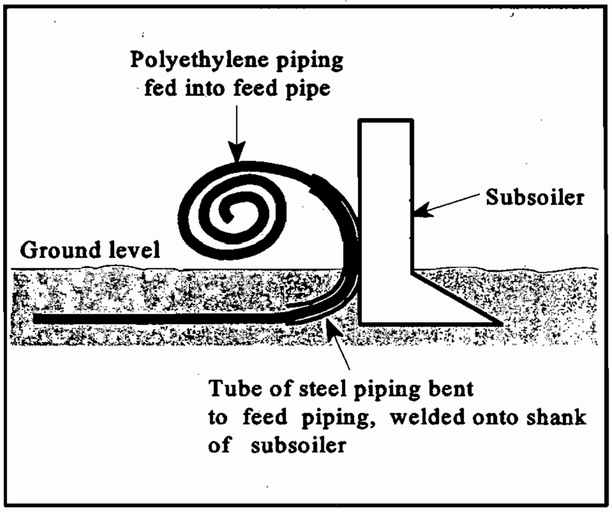


Figure 7. An implement for laying polyethylene piping

PUMPED STORAGE FACILITIES

This comprises a pump, a pumpline and a storage reservoir, together with one or more drinking troughs. The storage reservoirs are normally circular in shape, generally not more than 2 metres in height (sometimes only 1,2 m), and designed to hold 10 to 14 days supply of water. The choice of construction material depends generally on cost, which depends on availability of construction material, and the accessibility of the site chosen. The KwaZulu-Natal Department of Agriculture has construction pamphlets available for distribution to interested persons.

The material of which they are built varies from the conventional brick and concrete structures, to pre-fabricated panel reservoirs, to those made of corrugated iron. The latter must be fenced off to stop animals causing damage to them. Where water is aggressive the inside walls may have to be protected with special preparations.

A cost-effective method of construction entails the excavation of a waterhole and the lining of it with either an ultra-violet resistant plastic film or a geotextile lining impregnated with bitumen emulsion.

PUMPS

There are many different types of pumps, and their basic characteristics are briefly discussed below.

* **Windmills :** As either a lift or screw-type pump, best results are obtained where the pump can be mounted directly over the watersource, be it a borehole or an open water surface such as a storage dam. Its efficiency is also dependent upon wheel diameter (ranging from 1,8 m to 4,8 m) and size of cylinder. Some areas of the country are more suitable to windmills than others, and the map in Figure 6 gives an indication of the suitability based on windrun measured in KwaZulu-Natal. It is preferable to over-design when choosing a windmill so that it operates in the lightest of winds. The larger the windmill wheel, the greater the power it is capable of developing. The larger the cylinder the more water it can pump. This, of course, all depends on the strength of the wind supplying power to the unit.
* **Rampumps** need large volumes of driving water and a reasonable driving fall to push some of that water to the storage facility. Generally speaking, rampumps are not suitable for large herds, unless there is a plentiful supply of driving water.
* **Centrifugal pumps:** There is a wide variety of these pumps. They are capable of pushing large volumes of water to great heights.
* **Piston pumps** give a lower delivery, but push water to the highest heads.

PIPING

Once again, this is largely a question of economics and the demands of the terrain. The following types of piping are available, and they are discussed separately :

* **Polyethylene piping (P)** is available in 100-m lengths, and is made to a number of different pressure classes. Both low-density and high-density polythene is used, and also pipes that conform to various SABS standards as well as those which do not (Utility Class). A proper design takes account of these different characteristics. This piping must be buried at least 250 mm underground to protect it from the sun, the cold and veld fires.
* **Unplasticized polyvinylchloride piping (PVC)** is the semi-rigid `plastic' piping which can be purchased in standard 6-m lengths. Pressure and SABS utility classes are available, and the piping needs the same protection as for polyethylene piping. Although this piping is more cost effective in the larger diameters (*i.e.* greater than 32 mm diameter) than polyethylene, extra care must be taken in laying the pipe. This could overcome the price difference.
* **Galvanized steel.** The conventional screwed and socketed piping is not at all cost-effective, as the pipe wall has necessarily to be made thicker to provide for the cutting of the thread. A new type on the market does away with this type of join, and the piping is therefore much lighter and therefore cheaper. The use of this type of pipe is re commended where the cost of burying P and PVC piping is prohibitive. It also replaces the aforementioned when operating pressures are in excess of 160 m manometric head.
* **Fibre reinforced or asbestos-cement (AS).** This type tends to be rather heavy and brittle. It is generally only competitive in diameters greater than 150 mm, and therefore not recommended for stockwatering.

BRIEF SPECIFICATIONS FOR THE CONSTRUCTION OF SMALL EARTH DAMS

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KwaZulu-Natal Department of Agriculture

INTRODUCTION

One of the causes of veld degradation is as a result of the long distances grazing stock have to walk in order to drink water. Footpaths divert and concentrate runoff, causing gully erosion. Excessive trampling around insufficient drinking facilities causes surface denudation and erosion. Lack of suitable and permanent watering facilities precludes the farmer from carrying out recommended veld management practices, which leads, in turn, to farmland degradation. The strategic placing of stockwatering facilities is, therefore, one of the prime considerations in carrying out a conservation farm plan. It is also the reason why Government is prepared to share the cost of construction of earth dams for stockwatering, as part of an overall conservation farm plan. The following is an attempt to instruct the land user in the construction of just such a facility, after a competent person (*e.g.* the local Soil Conservation Officer) has surveyed and designed the structure, and provided the necessary specifications. Attention to the details of construction and adherence to specifications are fully as important as adequate investigations and substantial design of these structures. An entirely safe design might be rendered worthless by careless and shoddy construction, and failure of the dam might result. Good construction is important, regardless of the magnitude and cost of the dam. These written specifications relate to the drawings provided by the Department of Agriculture when its officers are requested to survey a dam for stockwatering. Please note, however, that while due care has been taken in the survey and design, the Department does not hold itself liable for any claim that might arise out of the construction or possible failure of the dam. The best time of the year to construct is from March to May, as the soil then should still be fairly moist, but the danger of heavy rains causing problems is reduced.

MARKING OUT THE EARTHBANK BASE

The pegs driven in at the time of survey indicate the centreline of the embankment, the end of the wingwall, and the spillway, while a separate peg is put in away from the embankment to act as a point of reference, and is called the benchmark. All these pegs are indicated on the plan which is supplied by the Department. The base width of the embankment depends on the ultimate height of the embankment, crest width and required slopes on the upstream and downstream faces, as is indicated on the drawing of the cross-section of the embankment. On the plan the distance to the outer edge of the base upstream and downstream from each centre line peg is given. These distances are set out at right angles to the centre line and the base thus pegged out is then clearly marked by ploughing along the line of these pegs. See Figure 1. In the same way the wingwall must be marked by ploughing out the spillway pegs. To ensure the correct shape of the structure during construction, it is necessary that the original centre-line can be repegged whenever necessary. Supplementary reference pegs are, therefore, fixed in positions where they will not interfere with construction. ***The benchmark(s) must in no circumstances be disturbed, as the embankment dimensions are checked against it during construction and after completion.*** The method described for pegging out the base of the embankment will be accurate only if the embankment is pegged out on flat or gently sloping ground. If the fall at right angles to the centreline is more than 2%, the local Soil Conservation Officer should be requested to peg out the base and make corrections for slope.

CLEARING THE BASE OF THE EMBANKMENT AND BORROW AREAS

The whole area on which the embankment is to be constructed, as well as the borrow areas (which will normally include the spillway excavation), must be ploughed or ripped and the surface layers containing vegetative matter removed. On no account must this topsoil be utilized in the construction of the bank. It must be stockpiled for later use on the surface of the finished dam wall, where it will greatly facilitate the establishment of grass on the embankment. See Figure 1. Apart from topsoil, all porous layers such as river sand and gravel

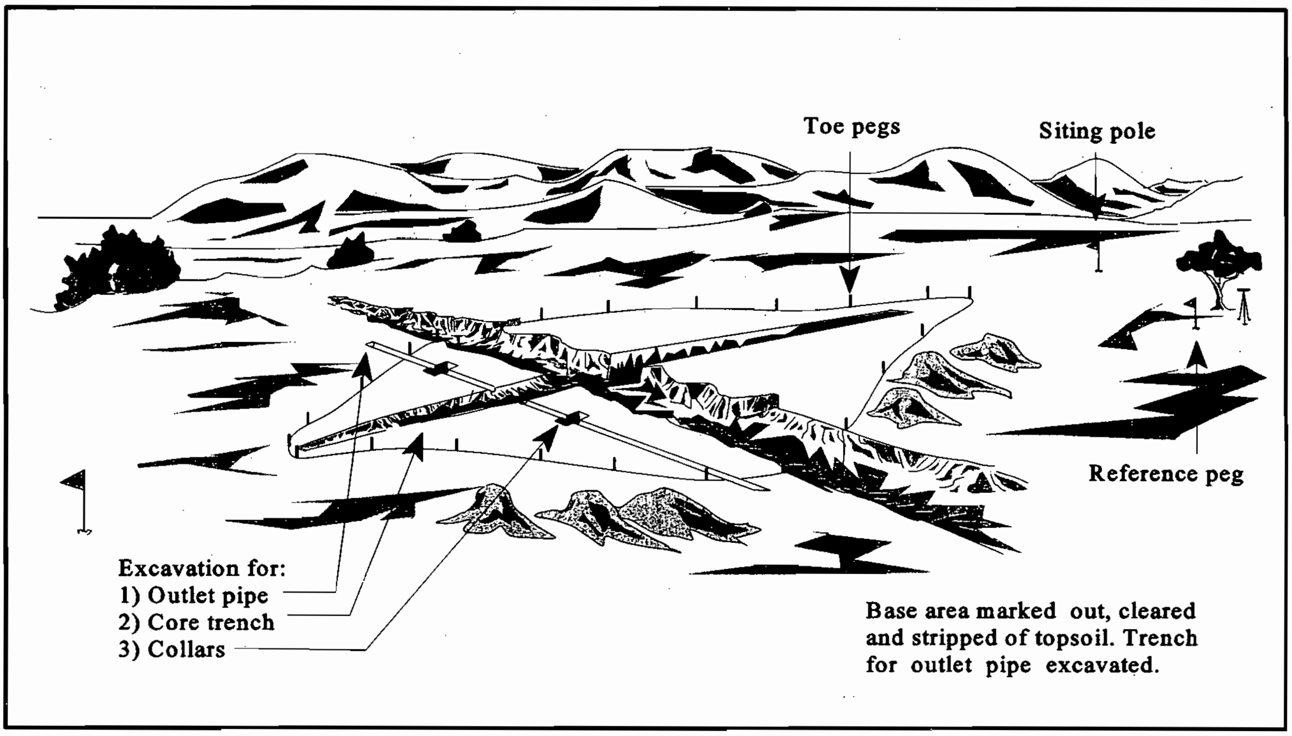

Figure 1. Preparation of site

must also be removed from the base area, especially where no core hearting is specified. *Any vertical or near vertical banks must be worked down to at least a 1 : 1 slope to ensure good bonding of the embankment with the base.* See Figure 2. This is especially important, as failure to do so will result in transverse cracking of the completed embankment which could lead, in turn, to structural failure or the dam leaking. Runoff water entering the site from the catchment can cause damage and delays, and it is because of this that construction should preferably take place in autumn. A further problem is caused when perennial or summer flow is present in the water course being dammed. This flow must be blocked off upstream and pumped away from the site or led away in a canal to bypass both the embankment base and borrow areas.

THE CORE TRENCH

A core trench is always specified unless the foundation comprises a solid rock sheet, when a concrete cut-off wall will be specified on the plan. It is vitally important that any underground passages and permeable layers which could cause leakages are cut through and blocked off. If this is not done seepage could reduce the value of the dam

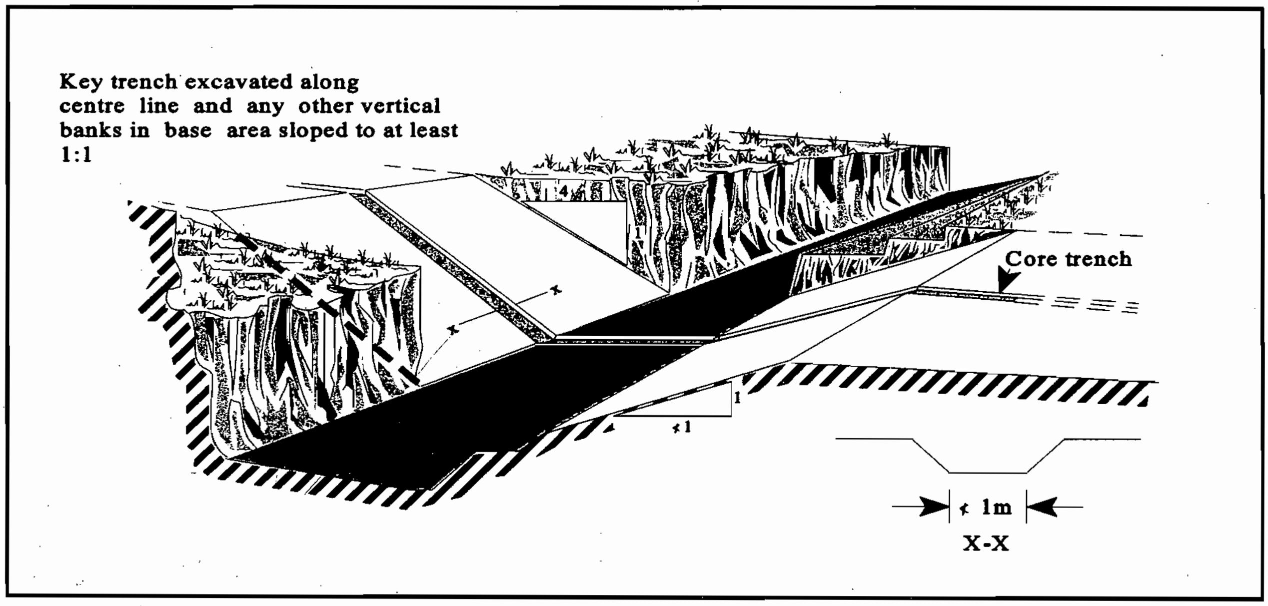

Figure 2. Excavating the core trench

or even result in its failure. The depth to which the trench must be excavated will depend on the subsoil formation. It must be excavated down to an impervious layer and must extend at least 600 mm into such a layer. The minimum bottom width of the clay core must be one metre, unless otherwise specified, and must be tapered wider towards the surface to ensure proper bonding of the fill material with the foundation. This also makes for safe working conditions in the trench. Actual dimensions will depend on the machinery used, and it is normal practice to make it wide enough to accommodate a tractor and scoop. See Figure 2.

The material used for filling should be the best clay obtainable within a reasonable distance of the site. It must be at optimum moisture content and must be free of vegetable or slushy matter or an undue proportion of grit. Table 1 shows the optimum moisture content for the compaction of various soils. The clay must be backfilled in layers not more than 150 mm thick and be well puddled into position so that it will form a uniform plastic mass. The whole process of filling should be carried out as rapidly as possible to prevent drying and shrinkage of the clay. It often happens that underground seepage enters the core trench before it can be filled. When this happens there is no alternative to using a pump to remove the water as fast as it enters the trench. If the clay core is to extend above ground level into the embankment, every attempt must be made to ensure proper bonding and consolidation of the clay with the earth fill. Figure 3 shows the various ways in which a core trench is used in the design of the earth bank.

OUTLET PIPE

Where an outlet pipe is specified, the trench for the outlet pipe must be excavated in natural formation beneath the base of the embankment at the point indicated on the plan, so that the inlet will be at least 1 metre above the bed of the stream or gully. To prevent seepage along the pipe, collars or baffles are cast around the pipe, as shown in the cross-section detail. The best result will be obtained if the pipe is encased in concrete using a 1 pocket cement : 100 litre sand : 100 litre stone, to a thickness of at least 150 mm around the pipe. The second best option is to firmly puddle clay around the pipe and collars in such a manner that seepage along the pipe is prevented. ***The outlet pipe and its immediate soil surround is a potential weak spot in the wall. Be very careful to obtain maximum compaction here.***

CONSTRUCTION OF THE EMBANKMENT

Proper compaction will only be obtained if the soil is moist. ***Never build an embankment with dry soil or soil that is overly wet.*** The construction material should be moist enough to form a stable ball when worked in the hand, but not so wet that it sticks to the implements. Ideally, the moisture content should be controlled by regular laboratory analysis. This is not really feasible for the farmer, however. A field test involves the rolling of a 3 mm diameter (matchstick size) spindle between the fingers. If it can be formed without disintegrating, the moisture content is near optimum. Table 1 shows some values for optimum soil moisture for diagnostic soil material of importance in dam building. Where it is necessary to increase the soil moisture, ***the construction material must be moistened in the borrow area and not on the bank itself.*** It should be sprayed with water and mixed with a plough and/or disc harrow until it has an even moisture content throughout. If gypsum has to be added to the construction material, this is the time and place to add it. (The addition of gypsum is specified if the dispersivity of the construction material is such as to be cause for concern. The specifications will prescribe the rate of application in kg/m^3) of the construction material.

The material used in constructing the bank must be placed in layers 100 - 150 mm thick along its length, and movement of machines regulated in such a way that maximum compaction is obtained by construction vehicles moving regularly over recently-deposited material. This is easily achieved by moving machines in a rough figure of eight. As the cost of construction is largely a function of the speed with which soil can be moved, the construction tracks to and from the embankment must be kept in good condition by regular draining and smoothing. (See Figures 4 and 5.) The bank should be slightly dished towards the centre (in cross section) during construction, but slightly convex in longitudinal section.

Where a choice of building material exists, the best impervious material, *i.e.* that containing the largest percentage of clay, must be used in the middle third of the embankment. For the third of the embankment on the water side a relatively impervious but compactible soil, *i.e.* low in clay and containing a high percentage of sand (approx. 1 : 3) is preferable. This type of soil will not crack on drying, which is important. For the downstream third of the embankment a stable pervious soil, *i.e.* sandy soil or mixture of gravel and soil, should be selected if available. ***On the upstream side, earth must not be excavated in the basin closer to the foot of the embankment than four times its height, with a minimum of 6 metres.***

ENSURING THE CORRECT SIDE SLOPES

It is very important, when building stable embankments, to ensure that the side slopes are correct. The best method is to erect batter boards along which the machine operator can sight when depositing material. (See Figure 5.) Another method is the use of right-angled wooden triangles of a large enough size cut to the required slopes so that they may be used in conjunction with a spirit level to determine whether the slopes are correct or not. See Figure 5.

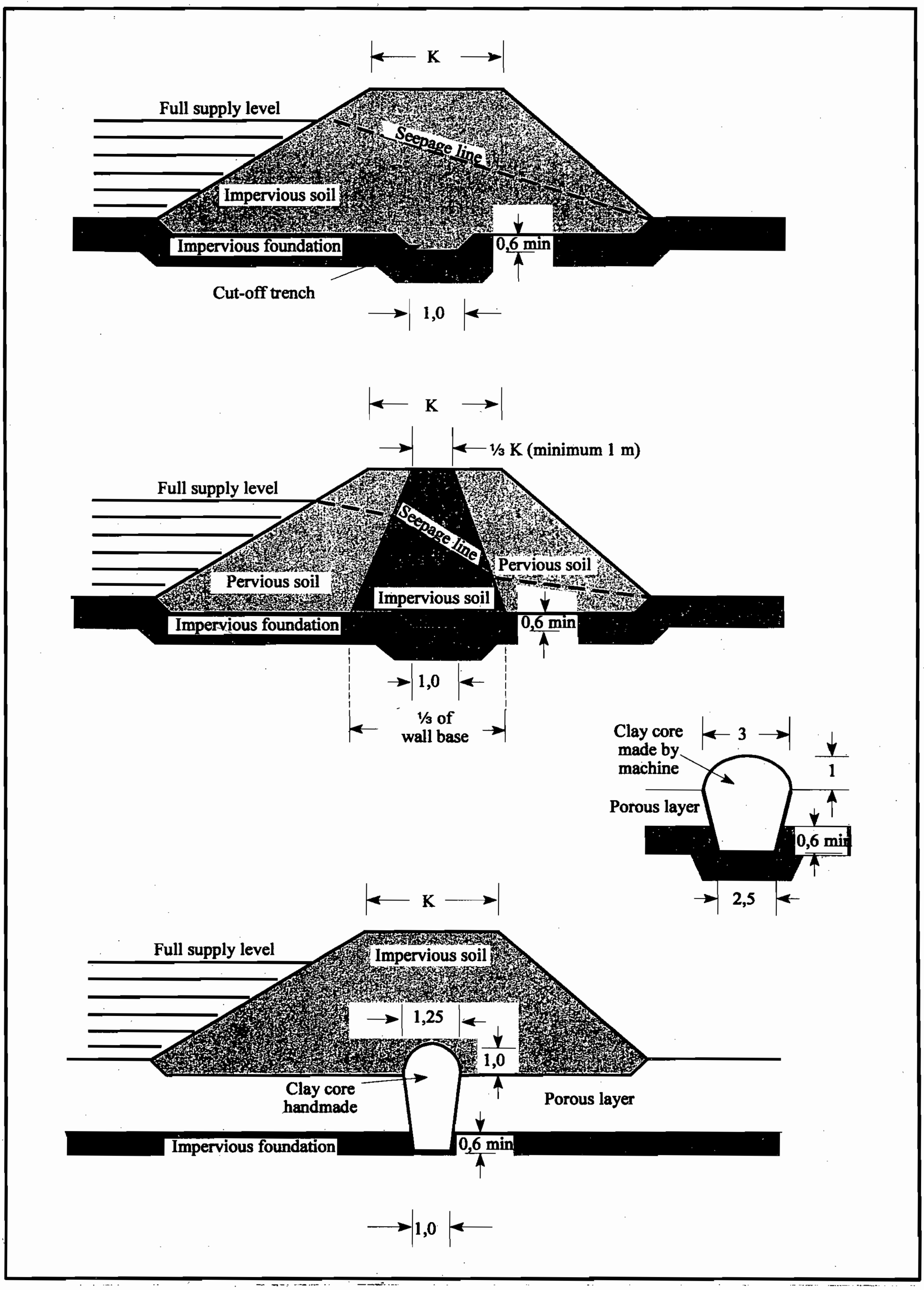

Figure 3. Various designs of core trenches. All measurements in metres

Table 1. Physical properties of selected diagnostic soil materials (Scotney, *et al.*)

DIAGNOSTIC SOIL MATERIALS		SOIL PROPERTIES								
		Particle size analysis				Texture class	Shrink - swell potential	Dispersion coeff. %	Proctor values	
TOPSOIL HORIZON	FORM	Clay %	Silt %	Sand					Dry density kg/m^3	Optimum moisture content %
				%	Grade					
MELANIC	Bonheim	41,6	11,4	47	f	sandy clay	high	83,3	1 550	20,5
	Milkwood	53,8	17,2	29	f	clay	very high	20,0	1 305	31,5
VERTIC	Rensburg	63,6	12,4	24	f	clay	very high	81,3	1 370	28,0
	Rensburg	53,0	14,0	33	f	clay	very high	24,5	1 455	24,0
ORTHIC	Kroonstad	9,1	4,9	86	m	loamy sand	low	57,1	1 879	9,1
	Kroonstad	10,2	3,8	86	m	loamy sand	low	5,0	1 877	9,9
	Estcourt	19,4	6,6	74	f	sandy loam	low	56,2	1 877	10,3
	Avalon	27,2	9,8	63	f	sandy clay loam	low	31,1	1 715	14,5
	Glenrosa	29,6	14,4	52	m	sandy clay loam	low	0	1 714	17,0
	Kroonstad	45,0	23,0	32	f	clay	low	58,1	1 433	20,6
SUBSOIL HORIZONS										
E HORIZON	Cartref	10,3	4,7	85	m	loamy sand	low	46,7	1 867	9,4
	Cartref	27,1	11,9	61	f	sandy clay loam	low	48,8	1 855	12,0
	Estcourt	23,3	16,7	55	f	sandy clay loam	low	24,4	1 815	12,5
G HORIZON	Willowbrook	37,3	13,0	49,7	f	clay loam	high	58,1	1 650	19,0
	Katspruit	48,6	19,0	32,4	f	clay	high	5,3	1 470	23,3
	Rensburg	55,4	10,6	34	f	clay	very high	18,9	1 545	23,0
RED APEDAL B	Hutton	9,9	3,1	87	m	loamy sand	low	3,5	1 840	12,0
	Hutton	21,2	6,8	72	f	sandy clay loam	low	12,3	1 842	12,4
	Hutton	15,6	1,4	83	m	sandy loam	low	100	1 867	11,5
	Hutton	37,4	14,1	48,5	f	clay loam	high	11,9	1 650	19,0
	Hutton	40,6	6,9	52,5	f	sandy clay	low	4,2	1 720	17,8
	Hutton	59,5	6,5	34	f	clay	low	22,5	1 400	28,9
	Hutton	62,5	11,5	26	f	clay	low	0	1 390	33,0

Table 1 (Continued)

DIAGNOSTIC SOIL MATERIALS		SOIL PROPERTIES									
TOPSOIL HORIZON	FORM	Particle size analysis				Texture class	Shrink-swell potential	Dispersion Coeff %	Proctor values	
		Clay %	Silt %	Sand					Dry density kg/m³	Optimum moisture content %
				%	Grade					
RED STRUCTURED B	Shortlands	39,9	8,1	52	f	sandy clay	very high	13,9	1 368	31,9
	Shortlands	60,2	7,8	32	f	clay	very high	92,6	1 420	27,0
YELLOW-BROWN APEDAL B	Avalon	9,2	0,8	90	m	sand	low	13,2	1 668	16,3
	Avalon	24,0	2,0	74	f	sandy clay loam	medium	7,8	1 820	13,5
	Avalon	37,0	12,0	51	f	clay loam	low	0	1 580	22,0
	Avalon	22,8	7,2	70	f	sandy clay loam	low	2,3	1 850	13,0
	Clovelly	50,3	13,7	36	f	clay	low	5,9	1 475	24,5
	Clovelly	58,2	12,8	29	f	clay	low	27,0	1 463	24,8
SOFT PLINTHIC B	Avalon	3,1	0	96,9	m	sand	low	66,7	1 653	15,1
	Avalon	17,2	6,0	76,8	f	sandy loam	low	10,4	1 975	11,0
	Avalon	31,0	4,0	64,7	f	sandy clay loam	low	5,9	1 665	18,0
	Avalon	21,6	8,4	70	f	sandy clay loam	low	0	1 655	19,5
GLEYCUTANIC B	Kroonstad	17,4	6,4	76,2	m	sandy loam	low	55,6	2 073	8,7
	Kroonstad	57,3	10,0	32,7	f	clay	low	83,3	1 638	20,3
PRISMACUTANIC B	Estcourt	47,3	6,0	46,7	f	clay	very high	85,5	1 630	20,5
	Sterkspruit	60,4	7,0	32,6	f	clay	very high	38,5	1 457	26,1
PEDOCUTANIC B	Bonheim	37,7	4,3	58	f	sandy clay loam	very high	10,4	1 619	21,7
	Bonheim	69,8	12,7	17,5	f	clay	very high	31,3	1 400	29,0
	Bonheim	52,2	9,8	38	f	clay	very high	45,2	1 576	22,2
LITHOCUTANIC B	Glenrosa	42,5	13,5	44	f	clay	high	14,8	1 565	22,0
NEOCUTANIC B	Oakleaf	29,2	13,8	57	f	sandy clay loam	high	83,3	1 697	18,3
	Oakleaf	48,2	15,8	36	f	clay	low	10,2	1 640	20,9

Note : Some of the soils mentioned are not suitable for dam construction. They are, however, mentioned for the sake of completeness.

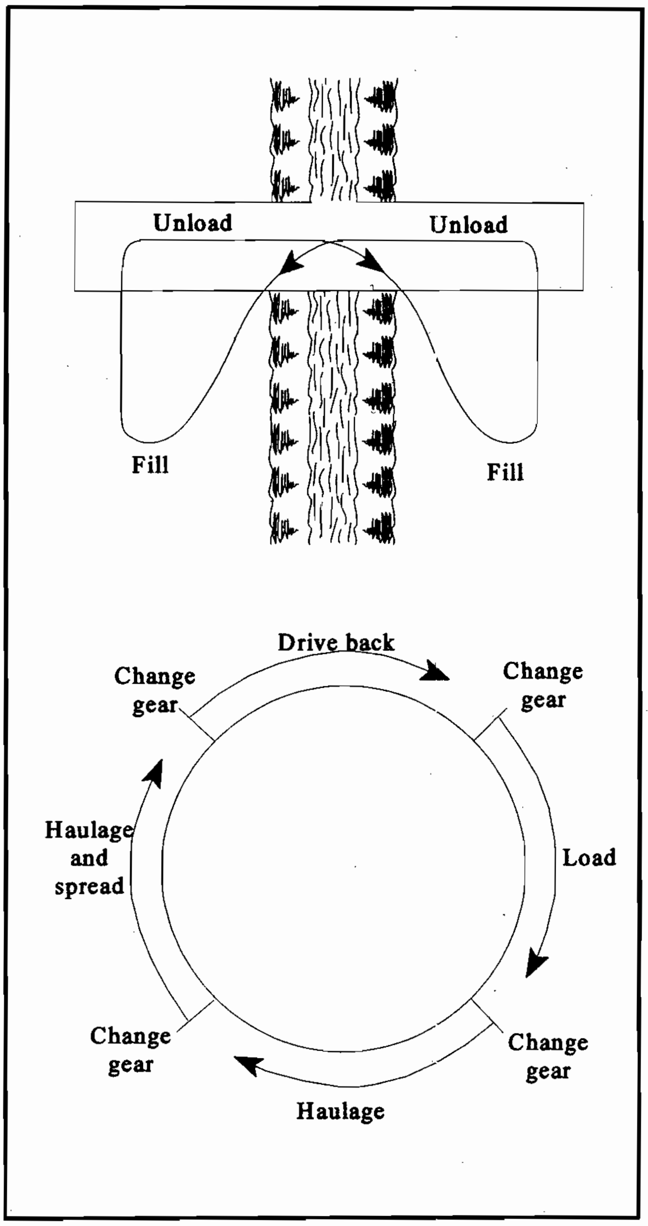

Figure 4. The construction cycle

THE SPILLWAY (See Figure 6.)

The spillway must be excavated to a uniform level over its full design width and over a level crest of about 5 metres width on the upstream side of the centre line, to ensure a complete spread of flood water. From this level crest it should slope back to the water side at 2% to 3% to allow for drainage and to stop plant growth establishing where it could block the free flow of water into the spillway. On the downstream side of the level crest it should have a slight fall of 1%. Every effort must be made to establish a mat of strong-rooted, sod-forming grass in the spillway, and along the slope down which flood water will return to the stream bed below the dam wall. It is important to start excavating the spillway area as soon as possible, so that by the time the embankment is completed, the spillway is completed as well. The topsoil from the spillway area must be stockpiled, but if the rest of the excavated material is suitable it may be used immediately as fill. Excavate 250 mm below the full supply level and then backfill and compact with the topsoil previously removed in order to prepare for the grassing of the spillway. It needs to be stated at this point that bulldozers are **not** the most suitable machines for building dams, especially where the soils are not the most suitable for water-retaining structures. Bulldozer compaction capabilities are very low. They should be used solely for ripping up and loosening material in the borrow area, for smoothing out dumped material, and for repairing access tracks. Wheeled tractors and hoofed animals provide far better compaction than a tracked machine.

TRAINING BANK OR WINGWALL

The training bank should be constructed for a sufficient length downstream of the embankment to ensure that flood water will not damage the toe of the embankment when it returns to the streambed from the side spillway. The sloping face, if exposed to fast flowing water, might

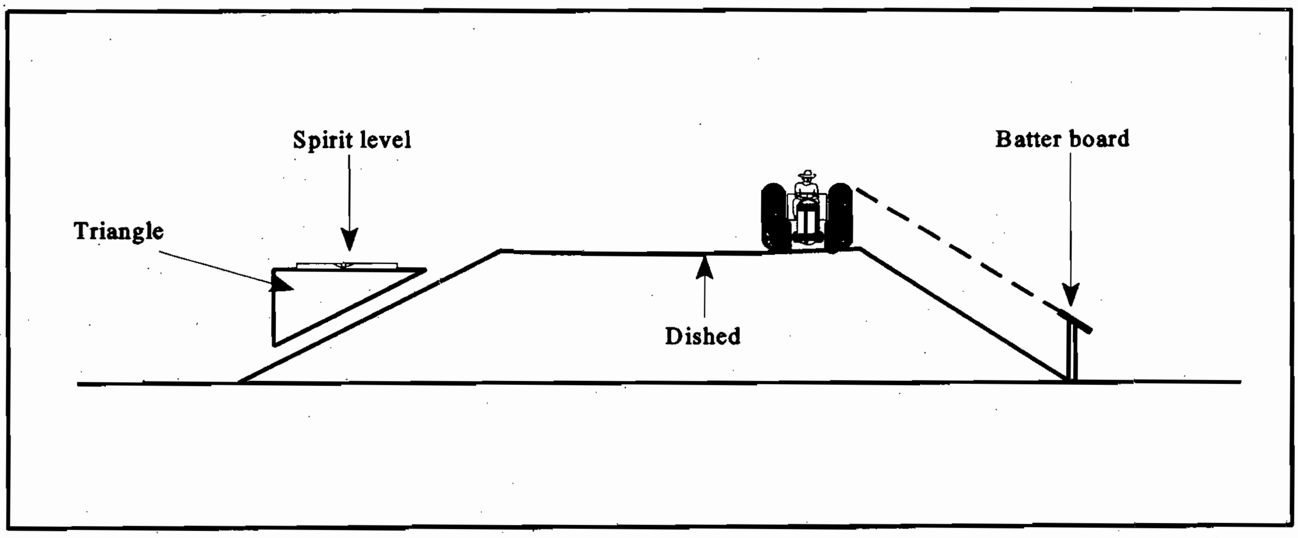

Figure 5. Using a sighting frame (batter board) or right-angled triangle to achieve the correct side slope

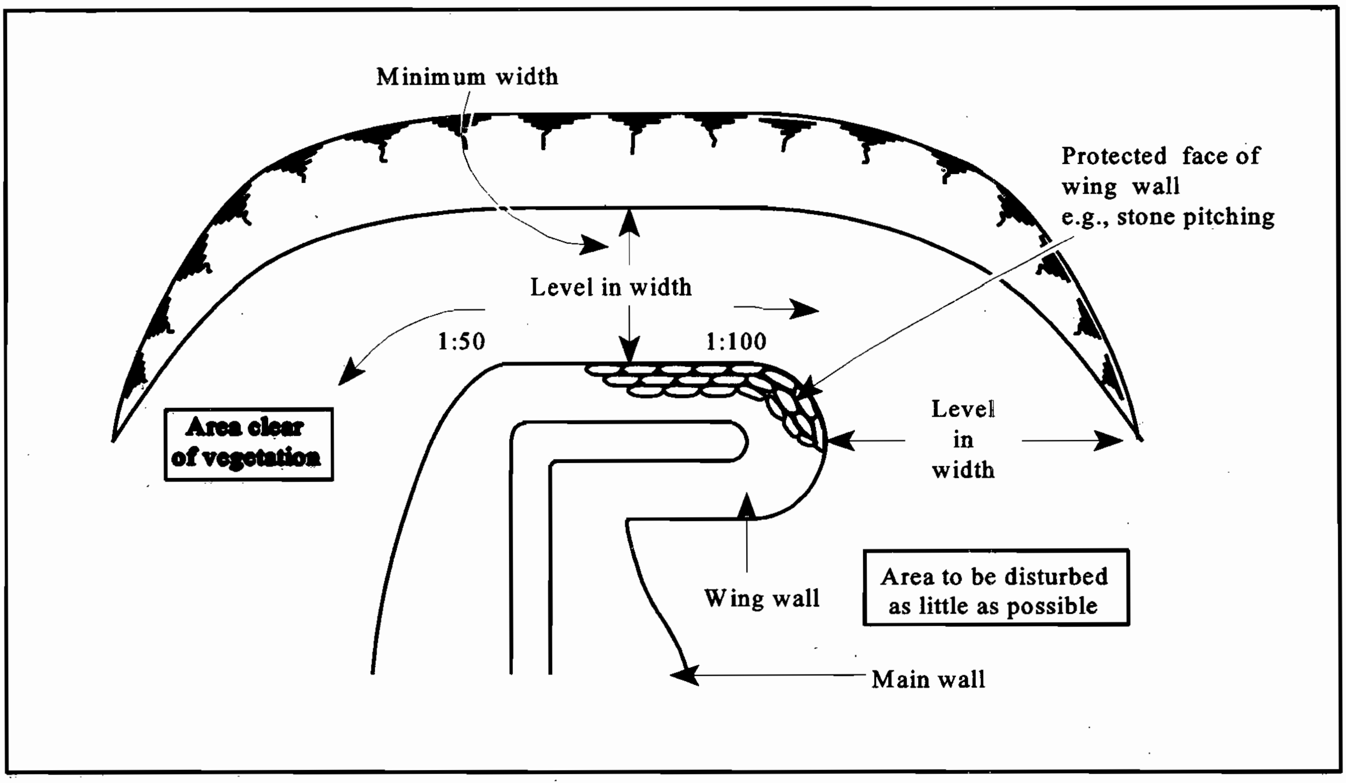

Figure 6. The spillway area

need to be protected from scour. This could take the form of grass sodding, stone-pitching, gabion work, or even concrete lining, depending upon the velocity of the flood waters flowing through the spillway. This is a design consideration.

PERMANENT OR "TRICKLE FLOW"

Permanent or "trickle flow" must not be permitted to flow through the earth spillway. When this happens, a saturated, unstable return to stream will develop, which will be damaged by scouring during storm discharge. If a gulley develops in the spillway this could ultimately lead to failure of the entire dam. Permanent flow must either be conducted through the spillway and returned to the stream in a constructed concrete or masonry drain along its edge, or be led under the embankment through a pipe of suitable size.

PROTECTING THE DAM

Construction of an earth dam is expensive, and yet no matter how well the construction is carried out, it will need regular care and maintenance thereafter. When the

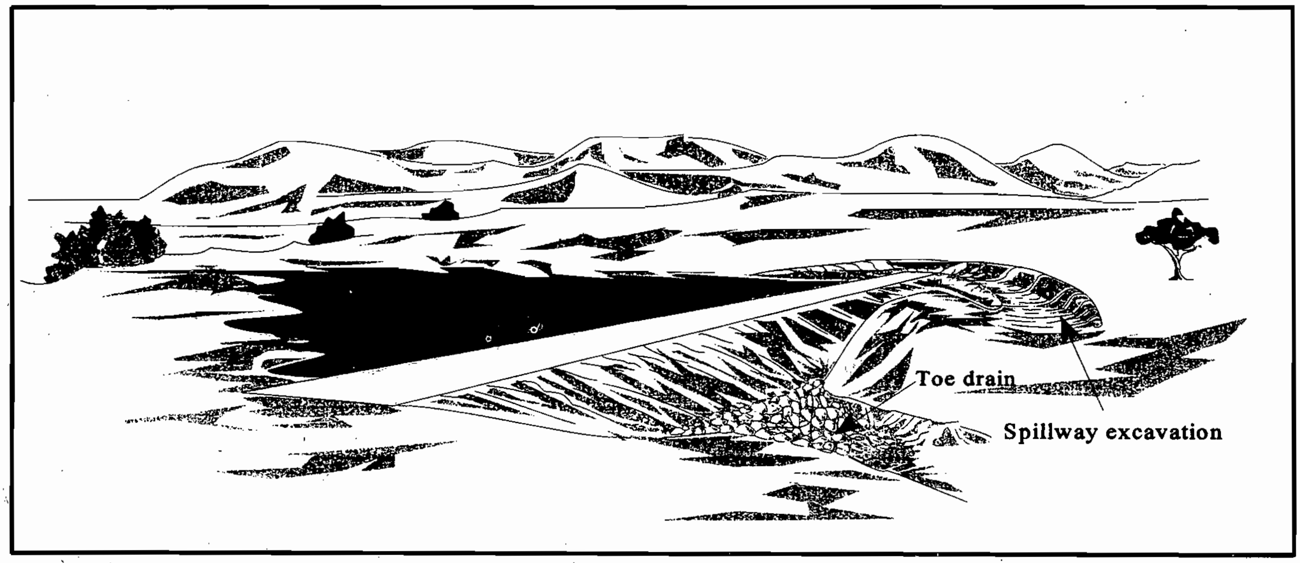

Figure 7. The final structure

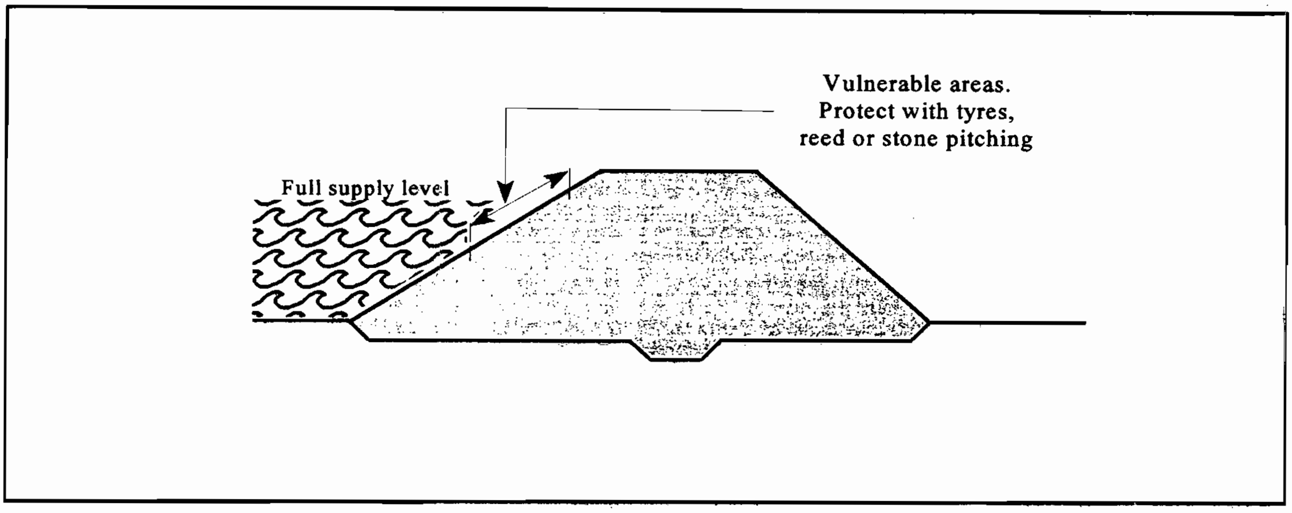

Figure 8. Protect from wave action

throwback of the reservoir is long, is in the direction from which prevailing winds blow, and/or the construction material the least bit unstable, the water side of the wall should be protected from wave action, at the very least along the full supply level, if not over the entire waterside face of the bank. See Figure 8.

This can be accomplished using various materials:

* a network of discarded motor vehicle tyres fastened to each other by some durable means,
* planted to common reed (*Phragmites australis*). This reed should also be planted in any sediment that is deposited at the entrance to the dam basin, so that it will filter out further sediment issuing out of the catchment, or
* stone pitching. Whenever practicable the pitching should not be laid until the embankment has had a period in which to settle. Only sound durable stone should be used and it is roughly dressed, if necessary, to ensure a tight fit, in order to provide a complete cover to the soil it has to protect. For the first course at the base of the pitching, big stones are used, and these are dug in about 250 mm deeper than the pitching stones abutting on them. A sizable proportion of the stone should be as big as practicable, and minimum thickness of the pitching must be 150 mm. The whole is then tightly wedged by driving single stones into each interstice between the tops of the stones, and the remaining small interstices then completely filled with rubble or gravel. In the case where grouting is specified, the last filling with rubble or gravel is carried out to within 50 mm of the surface, and the interstices filled with a cement/sand mortar of the specified mix. The mortar should be thoroughly worked into all joints and openings. The spillway and return to stream are liable to damage by animal footpaths. Animals also tend to congregate on the bank, and in so doing cause damage to the steep side slopes. It is essential that at least the bank, spillway and return to stream be fenced off to reduce maintenance. It is also preferable to exclude animals from the pond area as well, to prevent contamination of the water by their excretions. It makes good hygiene sense to fence the whole pond off and provide clean drinking water *via* the outlet pipe at a drinking trough controlled by a float valve.

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Conservation of Farmland in KwaZulu-Natal

REPAIRING A DAMAGED EARTH DAM

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INTRODUCTION

There are generally four ways in which an earth dam fails, and they are discussed separately below. In each case the scenario is set, followed by a recommended solution.

EROSION THROUGH THE SPILLWAY

Due to inadequate cover and/or insufficient width in the return to stream area, or erodible soil on a steep slope, a gulley head cuts back through the spillway into the pond behind the bank, thereby draining it. This can also be caused by perennial or semi-perennial flow trickling through the spillway and causing an unstable situation in the return to stream area due to waterlogging.

If the damage is caused by waterlogging in the spillway, the flow of water must first of all be removed, either by allowing it to pass through the outlet pipe, or by constructing a channel, suitably lined, through the spillway and return to stream.

Solutions:

* Backfill the gulley in layers 150 mm thick, with soil at optimum moisture content see Table 2, to original ground level, fertilize well and plant a suitable sodforming grass, or stabilize by covering with a rock-filled wire netting mattress or gabion approximately 350 mm thick;
* Extend the wingwall at a 1% gradient beyond the original discharge point to a more suitable disposal point. The spillway excavation must then follow this same line. See Figure 1.
* If the catchment is big, and the gulley of a large size, it might be necessary to design a special, permanent drop spillway or concrete chute to accommodate the expected flood peaks or portions thereof. In this instance the services of a qualified soil conservation officer or engineer will be necessary.

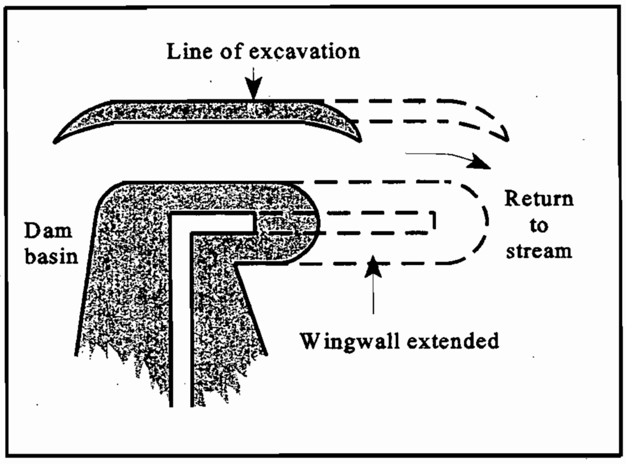

Figure 1. Extending the wingwall and spillway excavation to a safer discharge

SLIP CIRCLES ON THE DOWNSTREAM FACE LEAD TO THE COLLAPSE OF THE EMBANKMENT

Solutions:

* If this was caused by dispersive clays being used in construction, call in expert advice and have the soil analyzed. It may be that the dam should not have been built in the first place. If this is the case the cost of repairs should be weighed against the creation of a better, more suitable source of water. It might be possible to cut off the seepage by the insertion of an impermeable membrane in a broadened earthen bank. See Figure 2.
* Failure could have resulted due to the side slopes just being too steep. The line of saturation through the bank then emerges above the natural ground level on the downstream side slope causing a wet, unstable area on the downstream face of the wall, which eventually slumps. The dam should ideally be emptied and the wall reconstructed on both sides. An alternative but poorer option is for the downstream side slope to be flattened by increasing the base width of the embankment. Building must take place from the bottom, keying the new earthwork into the old one, as indicated in Figure 3. The generally recommended side slopes and crest widths are given in Table 1.

Table 1 : Maximum recommended side slopes for earth dam embankments

Height of wall in metres	Side Slopes: Ratio vertical to horizontal		
	Downstream	Upstream	
		Stone pitched	Unpitched
0 - 2,5	1 : 2	1 : 1½	1 : 2
2,5 - 3,5	1 : 2	1 : 2	1 : 2½
3,5 - 5,0 *	1 : 2	1 : 2½	1 : 3

* *Dams constructed to greater heights must be specially designed by a competent person.*

TUNNELLING ALONG THE OUTLET PIPE

This normally happens when suitable clayey material at the correct moisture content has not been properly compacted around the pipe during construction, and seepage along the pipe has opened up a tunnel along it. Another reason could be the absence of collars around the pipe normally installed to increase the length of the seepage line along it. Proper repairs will entail the breaking down of the tunnelled embankment and building it up from scratch around the pipe, the necessary collars having been installed. See Figure 4.

A BREACH THROUGH OVERTOPPING OF THE EMBANKMENT

Overtopping is the usual cause of earth dam failure. The spillway has insufficient capacity for a given flood peak and runoff builds up in the basin because of restricted flow through the spillway. The embankment is overtopped and ultimately a section of wall is washed away. Another reason is that insufficient compaction during construction results in the settlement of the structure, and through the years the crest level of the embankment is lowered, thereby reducing the freeboard.

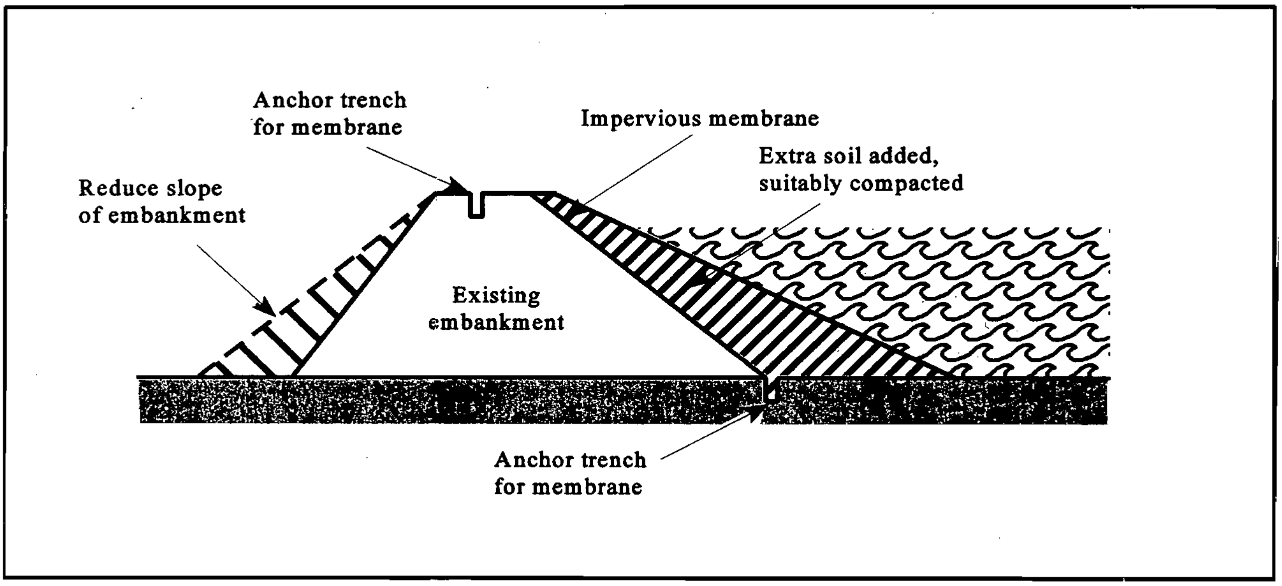

Figure 2. Repairing the downstream collapse of the wall caused by seepage through the wall

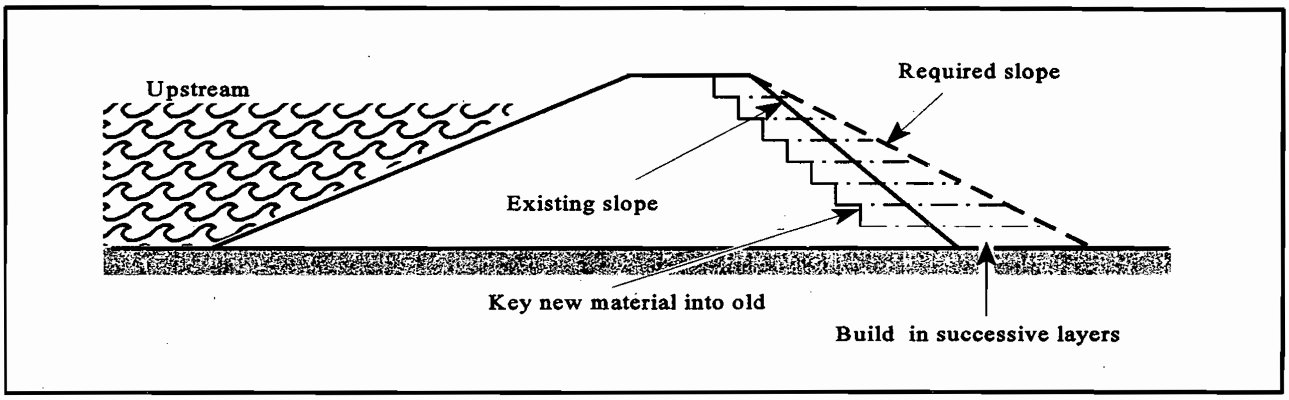

Figure 3. Building up the downstream slope

The resultant overtopping of the embankment erodes the downstream embankment face. In severe cases the erosion continues until the bank is breached, draining the basin of the dam. The breach must be filled in by the method already described and the required freeboard built up. *It is vital that a complete bond between the old and the new bank be achieved whenever repairs are carried out on an existing earth dam.* To this end any vertical walls of the breach must be graded to at least a 1 : 1 slope, and the new construction material (at the correct moisture content) mixed and compacted with the old material in a step-wise manner, as indicated in Figure 4.

A settlement allowance of at least 10% of bank height must be added to the final level of the crest of the embankment to obviate settlement reducing once again the design freeboard. If the cause was insufficient spillway capacity, this of course must also be rectified. It sometimes happens that the breach resulted from trees which established themselves on the embankment. Their roots colonize the bank, and when the tree dies and the roots decompose, passages or pipes are left in the structure through which the stored water can move. From this explanation it should be clear that trees and shrubs should **not** be allowed to establish themselves on or near the embankment. Finally, footpaths over the embankment can also lead to low spots and decreased freeboard, and it makes good sense to fence off at least all dam walls, their spillways and returns to stream, in order to protect them from damage.

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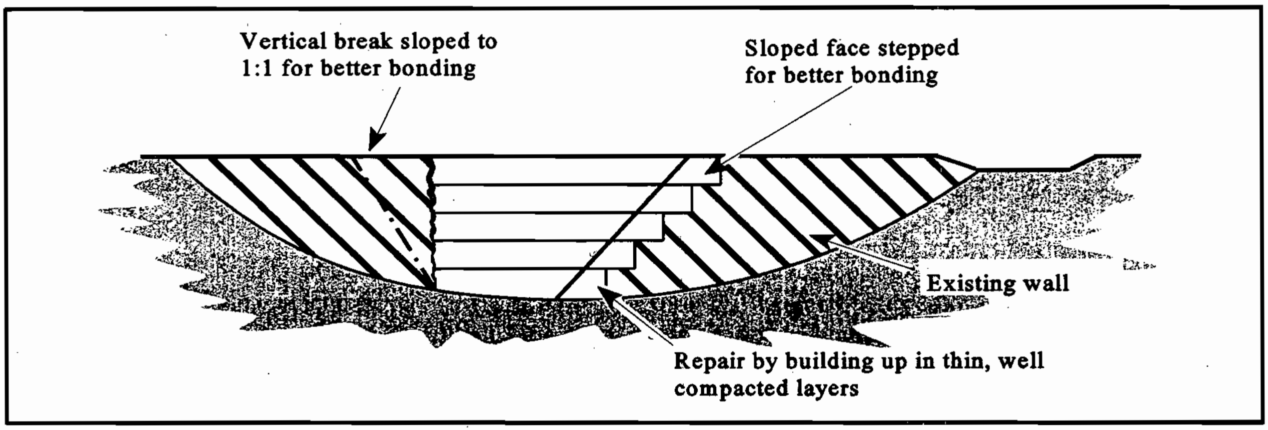

Figure 4. Steps in rebuilding a break in an earth dam wall

Conservation of Farmland in KwaZulu-Natal

SEALING A LEAKING EARTH DAM

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INTRODUCTION

Storage dams which leak result in three major problems to the farmer :

* he does not derive full benefit from his investment
* the seepage water could cause waterlogging and/or salinisation problems downstream
* if the seepage takes place through the dam wall, it could cause the dam wall to collapse, with resultant damage downstream.

Leakages can take place either through the wall itself, through the foundation, or through the storage basin. In this leaflet the various methods of sealing these leaks are discussed.

A LEAK THROUGH THE EARTH DAM WALL

This can either be as a result of unsuitable permeable material having been used in the construction of the embankment, or because the side slopes of the embankment are too steep. No earth embankment is entirely impermeable, and when water builds up against it, seepage takes place laterally into the embankment. It has a downward tendency under gravitational attraction as well. All the material below the so-called line of saturation is unstable, and the idea in designing an earth dam wall is to make sure that this line of saturation does not intercept the downstream sideslope. If it does, the soil surface below it (see Figure 1) will be unstable, seepage is accelerated and a slip circle could cause the collapse of the embankment. There are three methods of reducing this type of seepage :

* drain the dam and treat the waterside face with one of the preparations discussed later in treating seepage through the basin (Figure 1)
* cover the waterside face with an impervious membrane of butyl rubber or plastic (Figure 2)
* broaden the downstream width of the wall in order to cover the line of saturation (Figure 1).

The additional earthwork must be carried out in the recommended fashion, removing all vegetative material prior to construction, using soil at optimum moisture content, and working in a horizontal, stepwise manner, keying the new earthfill to the old one.

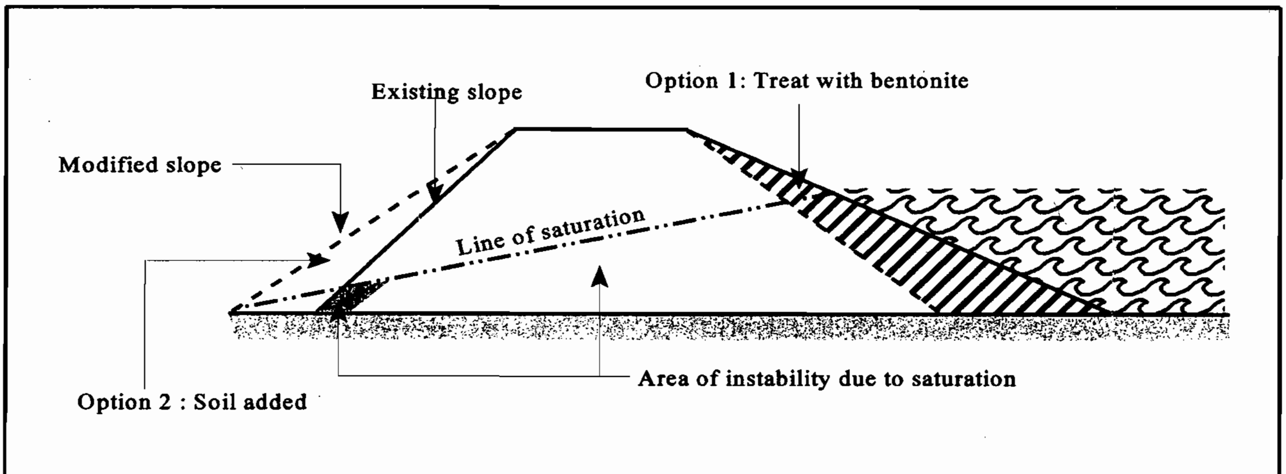

Figure 1. Cross section through dam wall showing how too steep a side slope can cause instability

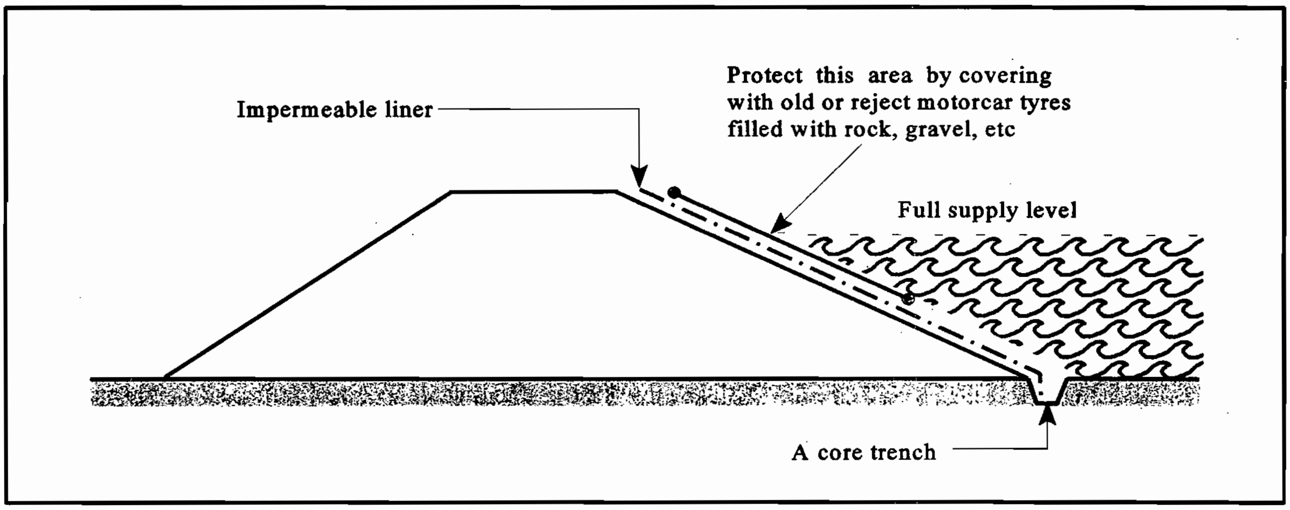

Figure 2. Fitting an impermeable liner to a dam wall to stop seepage through the embankment

A LEAK THROUGH THE FOUNDATIONS

This would generally be the result of stored water escaping underneath the dam wall along a porous ubstrate layer which was not sealed during construction. A core trench ***is always*** necessary along the centre of the base of an earth dam wall. The idea is to excavate it down through pervious substrata, also cutting off subterranean tunnels caused by insects, animals and tree roots, and backfilling with a strong clay at optimum moisture capacity. If this was not done during construction, or not done sufficiently well, a new core trench will have to be excavated and backfilled along the ***upstream*** toe of the embankment. Figure 3 explains what must be done.

SEEPAGE THROUGH THE BASIN

There are a number of methods and preparations available for sealing the basin of a pond, and these are discussed separately. Bear in mind that the basin is not necessarily porous over its entire area. It may be that only a part of the area causes the stored water to leak out, and the sealing of dams is expensive. A proper site inspection is needed to ascertain the true state of affairs before sealing is contemplated.

* A clay blanket of at least 250 mm depth is brought in from an outside source, and this is well compacted at optimum moisture content over the entire basin (or affected area of the basin). The clay must have a sufficient moisture so that a 3 mm φ spindle can be rolled without it breaking. Depending upon the distance that the material has to be transported, this method can be fairly expensive. One cubic metre of compacted clay (about 1,5 tonne) will only cover 3,5 square metres to a depth of 250 mm.

* The product Calgon (sodium hexametaphosphate), obtainable through most chemists, is used as a deflocculant in soil laboratories. When mixed with water and shaken up, it causes the clay particles in a soil to separate from each other, instead of assisting

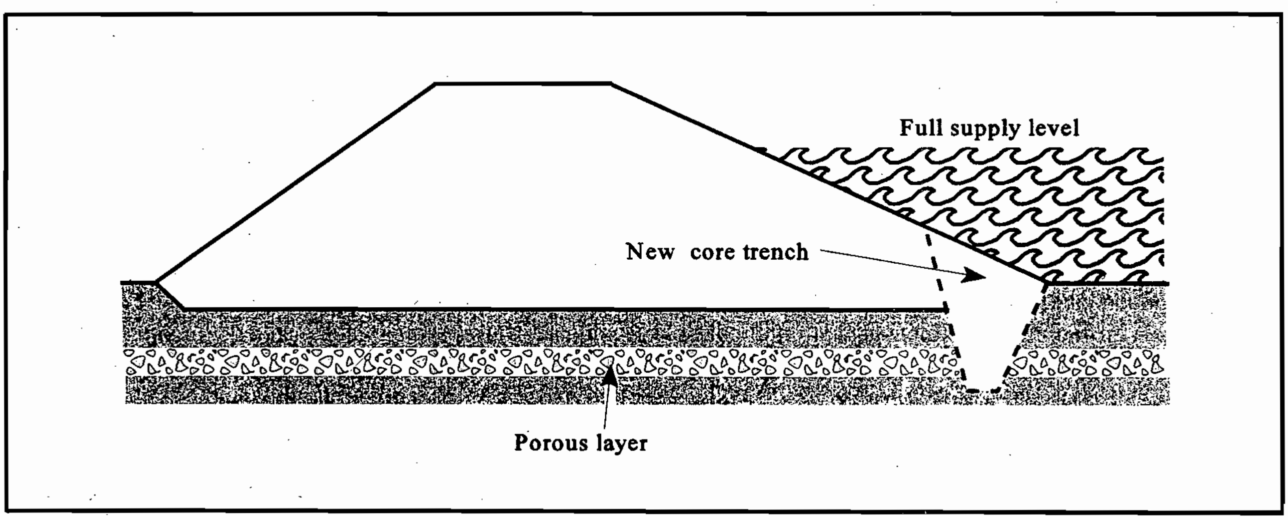

Figure 3. Cutting a core trench into an existing dam

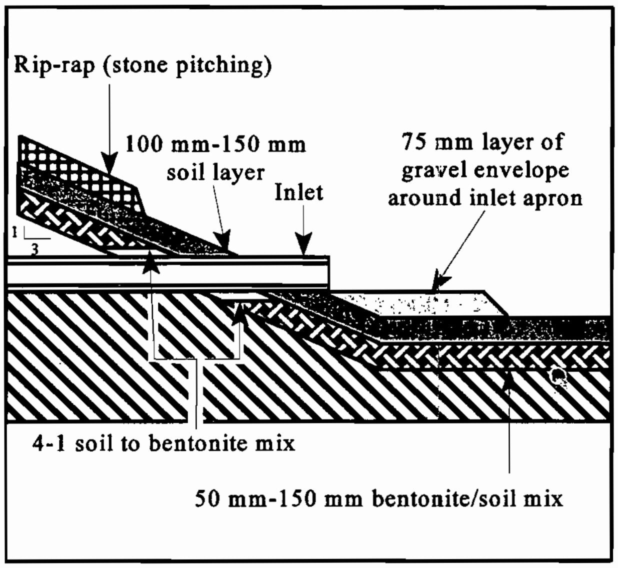

Figure 4. Sealing pipes with bentonite

the coarser particles to adhere to each other in the formation of a crumb-like structure. These separated clay particles can then move with seepage water into a soil profile, blocking the interstices and sealing the surface. In an experiment at Cedara using a rainfall simulator, rainfall infiltration into the land surface of an Inanda clay soil was reduced from 42 mm/hr to 24 mm/hr through the application of Calgon sprayed onto the ground surface at the rate of 200 kg per hectare.

* Organic matter can work in the same way as that mentioned above. Karroo farmers have for many years sealed storage ponds by fencing off the dam at full supply level and feeding stock in the enclosure with hay throughout the winter. Dung and vegetative material is thereby trampled into the basin surface, effectively sealing it. Another similar method is to just pack hay bales throughout the basin, and as the hay rots and the water seeps away the organic material moves into the soil surface, swells, and seals the interstices. There is, of course, a pollution problem to this solution.
* Sodium bentonite is a chemical with the appearance of very fine clay which swells to fifteen times its own size when coming into contact with water. When mixed with well-drained soil in the correct proportions it radically reduces the capacity for water to move through that soil. There are two ways in which bentonite can be used: the mixed blanket technique and the pure blanket method. Irrespective of the method used, however, there are a few rules that are basic to both:
  — the treatment does not appear to work very well on gradients in excess of 1 in 3 (vertical to horizontal),
  — the area to be treated must be free of vegetation and rocks,
  — never start an area larger than can be completed in one day,
  — carefully seal off all installations that will penetrate through the treated layer, such as concrete works, pipes, *etc*. This can be done by carefully hand-applying and hand compacting a mixture of 1 part bentonite to 4 parts of damp (but not wet) soil, along all the edges of such installations, and to a depth of at least 100 mm. (Figures 4 and 5),
  — be very careful to join the new day's work to that of the previous day, otherwise leakages will continue,
  — leave the treated area undisturbed for at least four days for the chemical hydration to take place, and
  — divide the area to be treated into suitably sized squares, each one large enough to require one standard 40 kg bag of bentonite at the recommended rate. Ensure an even spread of the chemical over the given panel.

The two different methods are as follows, and all the steps enumerated must be completed in one day on any given area. It is preferable that no work with bentonite take place on a windy day.

* **The Pure Blanket Method:**
  — wet the surface to be treated to optimum moisture content and compact firmly with either a vibratory or steel wheel roller,
  — having marked out a grid system of 2 metre x 2 metre squares, spread the contents of a 40 kg bag evenly over each one, giving a uniform thickness of 10 to 15 mm, and
  —cover the bentonite film with a layer of soil 250 mm thick, moisten and compact.

* **The Mixed Blanket Method:** This method should be more cost effective than the previous one, but requires an estimation of the quantity of bentonite required for the specific soil type. One supplier recommends an

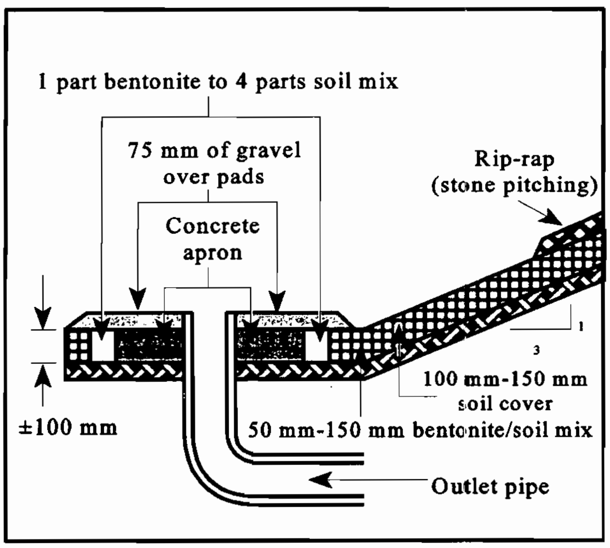

Figure 5. Sealing pipes and embankment with bentonite.

application rate of 40 kg per 3 square metres for 'average soil with no gravel in it'. On the other hand a 5 kg sample sent to them for analysis will give the more accurate rate of application. The method is as follows:

- wet the soil (to 150 mm depth) to optimum moisture content,
- loosen the top 150 mm with a plough or harrow,
- mark out the grid and spread the chemical evenly,
- mix the soil and chemical thoroughly using a disc harrow or rotary tiller, and
- compact and cover with 100 mm of imported soil.

Bentonite can be applied in granular form for emergency repairs as a water surface application when the dam contains water, although success is not certain. For further information and assistance the reader is referred to the following suppliers of bentonite:

Cullinan Minerals Ltd, Olifantsfontein, Gauteng.
Boland Base Minerals, Milnerton, Cape.
Aquasave Sealants Natal, Durban, KwaZulu-Natal.
James Panton Associates, Hillcrest, KwaZulu-Natal.

* Rubberised geofabric liner: A non-woven polyester liner impregnated with a water-based bitumen emulsion containing rubber latex (called Viaseal) is reported to have a high puncture resistance. It is also reported to be resistant to attack by a wide range of chemicals. The base of the pond is cleared of rocks and vegetation, smoothed and compacted, and the geofabric rolled out with 150 mm overlaps for sealing adjacent widths. As a first coat a 1 : 1 mixture of Viaseal and water is squeegeed on and into the fabric and allowed to dry. Two subsequent coats of the undiluted product are then applied, with an allowance for drying time in between. One litre per square metre of Viaseal is the average application rate.
The product is obtainable from Jeffco Marketing, Jacobs, Durban, KwaZulu-Natal.

* Bitumen emulsion: This is a bituminous product (called Agrimuls) which is soluble in water. It is used to treat a dam already containing water. Agrimuls is diluted 1 : 9 with water, and poured into the pond at the rate of up to a half litre of Agrimuls (or 4,5 ℓ of the diluted mixture) per square metre of dam surface. This figure applies to sandy soils. Soils with greater clay content will require less. If the water in a dam is not urgently needed, one could try a low rate, giving it a long enough period for the Agrimuls to work into the soil. The rate of seepage is then checked, and if it is still too high, more Agrimuls can be added. Care must be taken to get as even a spread of the solute as possible. As the water in the dam seeps away, so the individual particles of bitumen adhere to the soil granules it comes into contact with, and builds up an impervious asphalt lining. Agrimuls can be obtained from African Bitumen Emulsions (Pty) Ltd, Jacobs, Durban.

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RECLAMATION OF WETLAND AREAS DAMAGED BY GULLEY EROSION

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1 There are many instances throughout KwaZulu-Natal where, through a gulley head eating back along the watercourse and into the wetland, the water table has been lowered, and in a large number of cases the entire wetland has dried out. A complete vegetation change has then come about, and the area no longer functions as a wetland. The solution in most cases is an engineering one. In order to re-instate the water table, the gulley must be blocked by a dam wall constructed so that the spillway level re-instates, as near as possible, the original situation. The typical construction is a concrete structure which spans the gulley, and it is normally built in the form of an overflow weir, although chutes and drop inlets can be used in conjunction with an earth embankment. Once it is built, it will cause the lifting of the streambed, which will result in flooding of the relic wetland. Earth embankments are constructed on either side in order to prevent floodwaters from bypassing the structure and causing new headcuts where the floodwaters re-enter the gulley downstream. Figure 1 illustrates the typical solution.

A concrete structure of this nature normally requires a solid rock foundation, and the site for the key work is therefore usually dictated by the availability of just such a foundation. Latest design technology however, allows one to construct a reinforced concrete foundation upon which the weir is built. The key work can then be placed in the correct position, albeit at a greater cost because of the reinforced concrete raft foundation if no rock foundation is available.

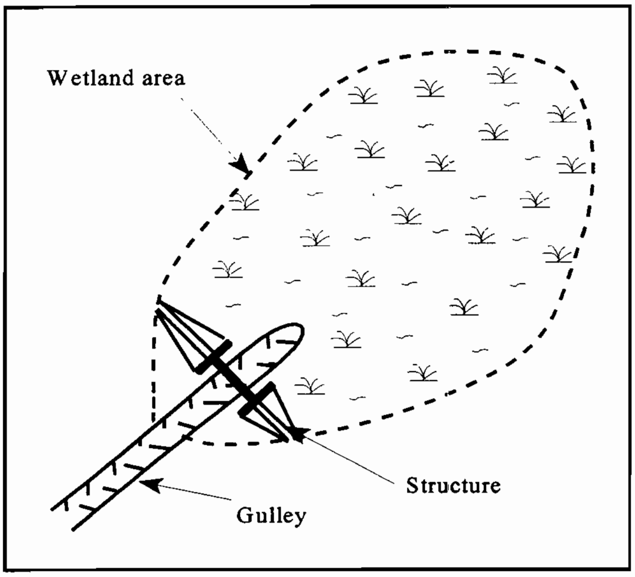

Figure 1. Reclaiming a damaged wetland with an overflow weir

If the catchment area is in a degraded state and a large volume of sediment is derived from it, it may be necessary to delay the construction of the dam until soil conservation work in the catchment has resulted in a reduction in sediment delivery. Failure to do this could result in excessive sediment being deposited in the newly created wetland area, to the detriment of the existing and/or establishing vegetation.

Where the relic wetland was severely eroded into a so-called badland situation, it will be necessary to utilize whatever sediment is forthcoming in order to backfill the dam formed by the structure with the sediment. The trap-efficiency of such a gulley stabilization structure is dependent upon the dam being empty (or nearly so) at the time of sediment-laden floodwaters reaching the site. When this happens, the velocity of runoff is reduced, and so is the capacity of the runoff to transport sediment. The runoff drops a large proportion of its load. If the need is for large volumes of sediment in order to reclaim badland gulley erosion, the overflow weir is built with an open outlet pipe which will allow the runoff to pass through the structure at a slower pace, once it has lost its greatest burden of sediment. In this type of situation it will probably be necessary for wetland vegetation to be artificially established. The Natal Parks Board zone officer will assist in this regard. See also Table 1.

2 Watercourses themselves can be considered as very narrow wetlands, and the need often arises for the banks of streams and rivers to be stabilized in order that they are protected during periods of damaging flood peaks.

A large number of unstable streambanks in KwaZulu-Natal arises from the destruction, either by physical removal, by overgrazing, or by fire damage,

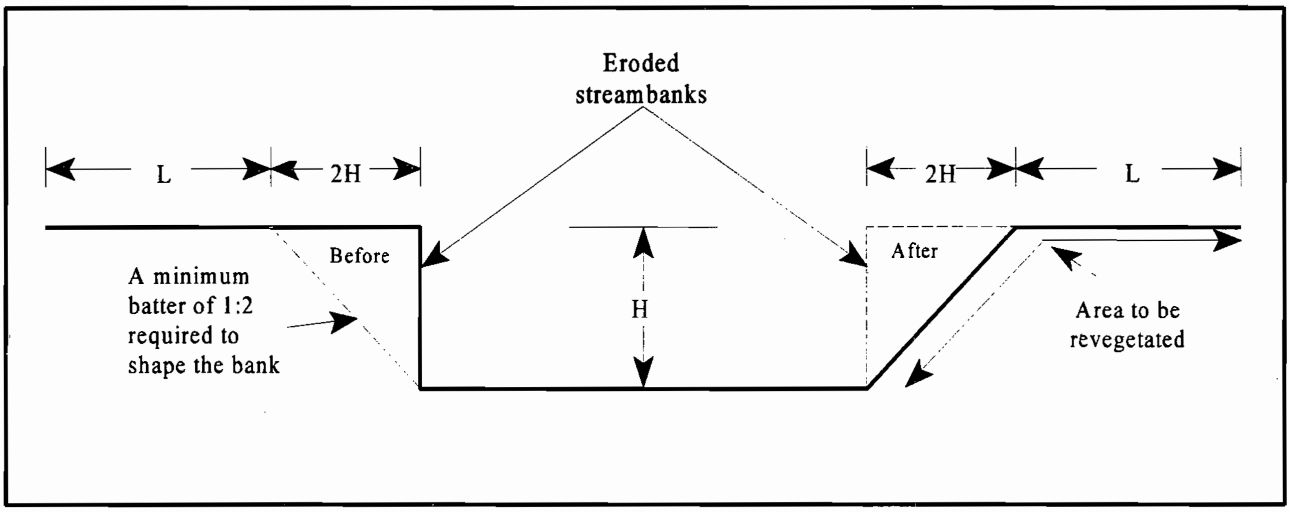

Figure 2. Re-shaping an eroded streambank. The distance L is site-specific

of the vegetation that formerly protected them. The reader is reminded that, in terms of Act 43/1983, it is an offence to remove vegetation from streambanks or within ten metres of the flood area of water courses, without a permit to do so. Although these may be highly productive soils, there is a large hidden cost to the community as a whole as a result of the pollution of river water by pesticides, fertilizer and sediment when agriculture takes place too close to the streambank.

Mechanical structures may or may not be needed in this instance, but in all cases the aim should be to provide an environment where suitable vegetation will be encouraged to carry out the long term protection of the streambanks.

2.1 Simple revegetation: In the simplest scenario, it may be possible to achieve the aim of a stable bank merely by replanting suitable vegetation. This will of course be the most inexpensive method. Table 1 contains a list of plants drawn up by the S. A. Sugar Association Experiment Station at Mt Edgecombe (SASEX) in collaboration with the Natal Parks Board. The plants listed may be used within the limitations mentioned.

2.2 Shaping streambanks: It may be that only the shaping of vertical streambanks followed by the planting of protective vegetation is needed. Inasmuch as the idea involves the mechanical disturbance of soil and vegetation within the prohibited water course zone, a permit will be required. The land user is referred to his local Extension Office for the necessary permit. The permit will state the conditions under which the permit will be granted, and will, in all probability, encompass the following: shaping and withdrawal from cultivation of an area as indicated in Figure 2 below, withdrawal from cultivation of a further distance which will be specific to the site, and revegetation of the area to the plants recommended by SASEX and/or Natal Parks Board. (See Tables 1 and 2).

2.3 Mechanical structures to counteract undermining: Where the instability occurs in the outside bend of a stream or river, it is generally the velocity of floodwaters which is causing the problem, and soil shaping and revegetating alone will not always solve the problem. There are two methods of addressing the problem:

2.3.1 Stabilizing the length of the undercut with suitable material:

* rock-filled wire baskets (called gabions), packed on top of each other in a common or gardenwall bond. The lining is built as high as the expected flood levels, and as long as the damaged section extends. See Figure 3.
* the same area is sloped to a 1:2 slope (vertical to horizontal) and the affected area lined with gabion mattresses. These are similar to gabion baskets but much shallower. Another material that may be used for the same purpose is concrete brick that is held together with steel cables threaded through specially prepared holes in the bricks. Discarded tyres can be fastened together into a net for the same purpose, but the whole must be well-anchored to stop it being washed away. See Figure 3.
* river jacks, made either of pre-cast concrete or of treated poles, and wired in series along the curve will slow down the velocity of the floodflow and cause deposition of sediment. Suitable vegetation must then be planted in the sediment to stabilize it. See Figure 4.

2.3.2 Stabilizing the affected area by directing the force of the stream away from it: This is used generally on the wider rivers. Groynes made up of gabions are built out from the unstable bank into the stream in order to force the flow of water away from the river banks. See Figure 5. The groynes form protected areas alongside

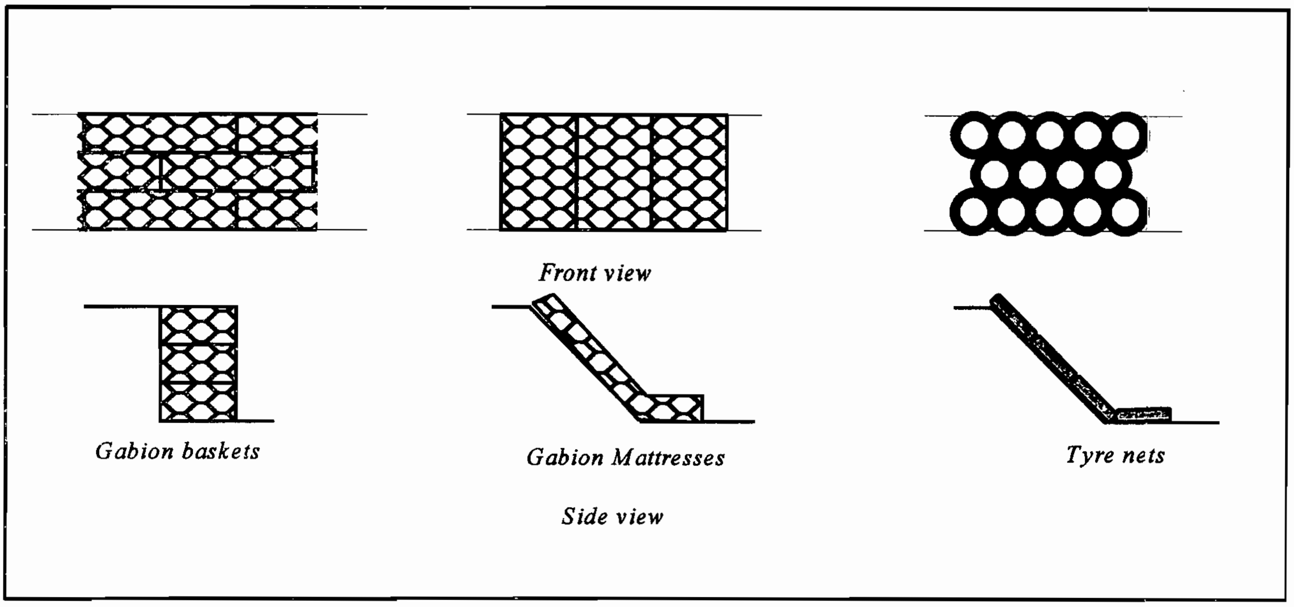

Figure 3. Protecting the outside bend of a stream from undermining

the streambank where sediment tends to be deposited and where suitable vegetation must be encouraged.

In all the instances mentioned, and because large sums of money could be involved, the interested land user is referred to his local Soil Conservation Officer for more site-specific advice and possible financial assistance from the Government.

3 Reclamation of artificially drained areas. In reclaiming drained land, *i.e.*, in order to reinstate a saturated soil profile, the drains which expedited the removal of excess water, must simply be blocked, thereby stopping the free movement of water out of the system. Unless there is some specific reason, it should not be necessary to flatten all the ridges and fill in all the furrows of a ridge-and-furrow (cambered bed) situation. The furrows are simply blocked with earthen banks at distances dependent on the gradient of the furrows, so that the throwback of the lower dam does not interfere with the foot of the neighbouring dam upslope. In a similar fashion, if tile drains were inserted underground, the piping would be blocked every fifty to one hundred metres. This is easily achieved using the heaviest clay on site.

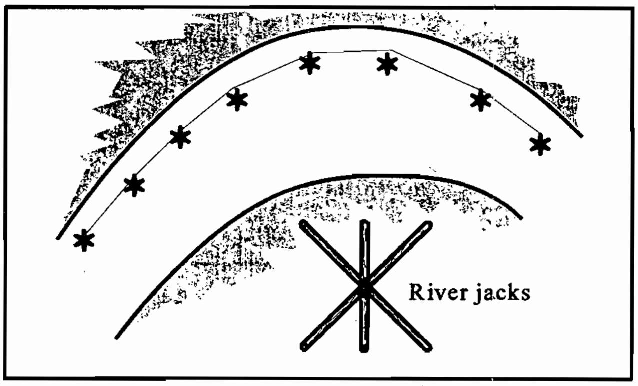

Figure 4. Using river jacks to stabilize eroding riverbanks

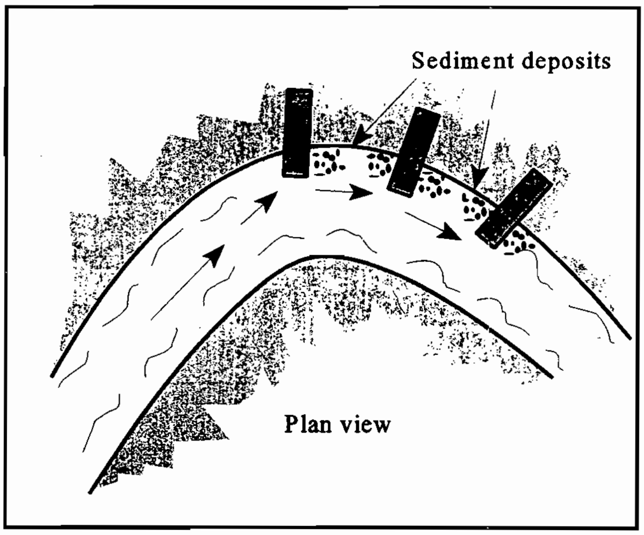

Figure 5. Using groynes to protect riverbanks

Table 1. Trees, shrubs and creepers suitable for planting along drainage lines in sugar growing areas (courtesy of S.A.S.A. Experiment Station at Mount Edgecombe).

LEGEND :

Plant form:	T tree	S shrub	
Cover:	D deciduous	E evergreen	
Growth:	F fast (> 1 m/yr)	I intermediate (± 0.6 m/yr)	S slow (± 0.3 m/yr)
Height:	T tall (> 5 m)	I intermediate (2 - 5 m)	L low (< 2 m)
Frost:	T tolerant	I intermediate	V vulnerable

TREE :

No.	Species	Common name	Plant form	Cover	Growth	Height	Frost	Coast/Inland	Comments
22	*Phoenix reclinata*	Wild date palm	T	E	S	T	V	C	Grows easily from seed
26	*Raphia australis*	Kosi palm	T	E	S	T	V	C	Grows easily from seed
34	*Strelitzia nicolai*	Wild banana	T	E	F	I	V	C/I	Transplants easily
39	*Celtis africana*	White stinkwood	T	D	F	T	I	C/I	Grows easily from seed. Drought resistant
42	*Trema orientalis*	Pigeonwood	T	E	F	T	I	C/I	Seeds prolifically
50	*Ficus sur*	Fig	T	E	F	T	I	C/I	Grows from truncheons. Seed difficult
57	*F. natalensis*	Natal fig	T	E	F	T	V	C	Grows from truncheons. Often a strangler
148	*Albizia adianthifolia*	Flat crown	T	D/E	I	T	V	C	
172	*Acacia karroo*	Sweet thorn	T	D	F	T	I	C/I	Soak seed in hot water prior to planting
183	*A. robusta*	Splendid acacia	T	D		T	I	C	
208	*Bauhinia galpinii*	Pride of the Cape	T/S	E	F	I	I	C	Seed germinates easily
245	*Erythrina lysistemon*	Common coral tree	T	D		T	I	C/I	Seed germinates easily
298	*Ekebergia capensis*	Cape ash	T	E	F	T	V	C	Seed germinates easily
300	*Trichilia dregeana*	Forest Natal mahogany	T	E		T	V	C	
324	*Bridelia micrantha*	Mitzeeri	T	D	F	T	I	C	Grows well from fresh seed
335	*Macaranga capensis*	Wild poplar	T	E	F	T	V		
364	*Protorhus longifolia*	Red beech	T	E	I	T	I		
380	*Rhus chiridensis*	Bostaaibos	T	D/E	F	I	I	C/I	
391	*R. peantheri*	Common crowberry	T/S		F	T/I	I	C/I	Often found along seasonal streams

Table 1. continued ....

Table 1. Continued ....

No.	Species	Common name	Plant form	Cover	Growth	Height	Frost	Coast/Inland	Comments
463	*Grewia occidentalis*	Cross berry	T/S	D/E	F	I	T	C/I	
447	*Ziziphus mucronata*	Buffalo-thorn	T	D/E	I	T	T	C/I	
464	*Hibiscus tileaceau*	Coast hibiscus	T/S	E	F	I	V	C	
468	*Dombeya burgessia*	Pink dombeya	S				V	C	
472	*D. tiliacea*	Forest dombeya	T/S	D		I	I	C/I	
524	*Barringtonia racemosa*	Freshwater mangrove	T	E	F	T	V	C	Needs permanent water
536	*Combretum erythrophylium*	River bushwillow	T	D	F	T	I	C/I	Seed germinates easily
540	*C. krausii*	Forest bushwillow	T	D/E	F	T	I	C/I	
555	*Syzygium cordatum*	Umdoni	T	E	F	T	V	C	Grows from truncheons
645	*Tabernaemontana ventricosa*	Forest bead tree	T	E		T	V	C	
646	*Voacanga thouarsii*	Wild frangipani	T	E	F	T	V	C	Can stand in water
647	*Rauvolfia caffra*	Quinine tree	T	D?E	F	T	I	C/I	Seed germinates easily. Transplants easily
670	*Halleria lucida*	Tree fuschia	S/T	E	F	I	T	C/I	
673	*Tecomaria capensis*	Cape honeysuckle	S/T	E	F	I	I	C/I	Grows from cuttings
708	*Canthium inerme*	Turkey berry	T	E		T	I	C/I	
724	*Brachyleana discolor*	Wild silver oak	T	E	F	I	V	C	Grows from cuttings
447	*Ziziphus reclinata*	Blinkblaar wag-'n-bietjie	T				T	I	Grows on dry stream shoulders
471	*Dombeya rotundifolia*	Wild pear	T				T	I	Grows on dry stream shoulders
361	*Harpephyllum caffrum*	Wild plum	T				T	I	Quick growing
617	*Olea africana*	Wild olive	T					C	Grows in wetter areas
318	*Antidesma venosum*	Tassel berry							Grows on dry stream shoulders

Table 2. Grasses suitable for the re-establishment of vegetation in watercourses and gulleys (courtesy of S.A.S.A. Experiment Station at Mount Edgecombe).

Botanical name	Common name	Growth	Drought	Frost	Dongas	Seed	Soils	Description	Miscellaneous
Acroceras macrum	Nile grass		*	*		*		Creeping perennial	Badly affected by cold
Andropogon appendiculatus		*							
Andropogon eucomus	Snowflake grass					*	Heavy clay (ouklip)	Densely tufted, upright, stemmy perennial	Indicator of poorly drained soils
Bothriochloa glabra	Purple-blumed grass							Robust perennial forming large tufts	Occurs where water accumulates
Brachiara serrata	Velvet signal grass		**					Loosely tufted perennial	
Bromus wildenowii	Rescue grass			*		*	Well drained soils	Winter growing perennial	
Chloris gayana	Rhodes grass					*	Loam	Tufted, stoloniferous perennial	Lacks persistence
Cymbopogon validus	Giant turpentine grass							Robust, tufted perennial	
Cynodon dactylon	Couch grass		*	**		*	Sandy	Variable, creeping perennial	
Digitaria eriantha	Smuts finger-grass		**			**		Robust, tufted perennial	
Digitaria swazilandensis	Richmond finger-grass		**	**			All soils	Perennial with creeping rhizomes	Easily affected by drought and cold
Echinochloa crusgalli	Barnyard millet		**				Moist, well-drained	Tufted annual	Fully grown in 6 - 8 weeks
Eragrostis capensis	Heartseed love grass		**				Shallow	Loosely tufted perennial	
Eragrostis lappula	Phakwane						Moist, sandy soils	Tufted, variable perennial	
Eragrostis plana	Fan love grass					*	Compact soils	Densely tufted perennial	Occurs on abandoned, arable lands
Hemarthria altissima	Red swamp grass						Wet soils	Perennial, underground rhizomes	Good soil binder, hardy
Imperata cylindrica	Cottonwool grass					*		Perennial, underground runners	
Ischaemum arcuatum	Hippo grass						All soils	Perennial with creeping rhizomes	
Leersia hexandra	Wild rice grass							Perennial, long underground stems	
Miscanthidium capense	Eastcoast broom grass		**					Robust perennial	Good firebreak

* **GOOD CHARACTERISTICS**
** **BAD CHARACTERISTICS**

Table 2 Continued......

Table 2 Continued.......

Botanical name	Common name	Growth	Drought	Frost	Dongas	Seed	Soils	Description	Miscellaneous
Monocymbium ceresiiforme	Wild oat grass						Leached soils	Loosely tufted perennial	Indicator of acid soils
Paspalum dilatatum	Common paspalum					**	Moist soils	Tufted perennial	Lack of consistently good seed
Paspalum notatum	Lawn paspalum			**			Moist, fertile soil	Sod-forming perennial	Aggressive invader
Paspalum urvillei	Giant paspalum			*			Wet soils	Tall, tufted, upright perennial	Invades naturally
Pennisetum clandestinum	Kikuyu grass		**			*		Creeping, robust perennial	
Poa annua	Annual bluegrass		**				Waterlogged soils	Small, bright green annual	
Setaria megaphylla	Broadleaf actaria					*	Waterlogged soils	Robust perennial	Found in shade
Stenotaphrum dimidiotum	St Augustive grass	*							
Stenotaphrum accundtum	Coastal buffalo grass					*	Sandy	Creeping perennial, extensive runners	Persisting under hard conditions

* **GOOD CHARACTERISTICS**

** **BAD CHARACTERISTICS**

GULLEY STABILIZATION WITH SMALL STRUCTURES

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INTRODUCTION

Gulley erosion is the visible manifestation of poor land use practices which have resulted in an increased volume and velocity of rainfall runoff water. When the energy of this runoff reaches the point where soil particles are detached and carried away, erosion is initiated and a gulley may be formed. This leaflet is adapted for KwaZulu-Natal conditions from one drawn up by the Döhne Agricultural Development Institute, and sets out to illustrate various fairly simple and cost-effective methods of stabilizing dongas.

CAUSES OF GULLEYS

Common causes of gulleys include one or more of the following:

* destruction of vegetation in watercourses and natural depressions caused by fires, overgrazing, and/or cultivation of soil within the flood limits of watercourses,
* failure of badly-designed soil conservation or water storage works,
* vulnerable outlets from earth dams, contour banks, diversion drains, waterways or road culverts,
* animal trails, footpaths, vehicle tracks, plough furrows, or ruts on sloping ground, and
* diversion of runoff into watercourses which were not adequately prepared and protected to take the additional runoff.

POSSIBLE EFFECTS OF GULLEYING

Possible effects of gulleying can be summed up as follows:

* fertile soil is lost,
* unproductive soil is deposited lower down on productive land,
* storage dams and/or irrigation canals fill with sediment,
* lands are cut up into smaller units which are more costly and more difficult to cultivate,
* gulleying may undermine farm facilities and roads, bridges and culverts,
* the water table in the vicinity of the gulley is lowered, thereby extending the effect of the gulley further than its edge, and
* unsightly gulleys decrease the value of the land.

STABILIZATION OF GULLEYS

Stabilization can only be properly realized through a programme of management of the catchment area as a whole, along with the treatment of the gulley itself. Various small structures for the treatment and rehabilitation of gulleys are described in this pamphlet. It should, however, be remembered that the ultimate objective of nearly all gulley control work is the stabilization of the gulley bottom and banks by vegetative means. The structures are simply a means towards an end; they are constructed at specified points in the gulley in order to catch up sediment and to anchor it at a depth great enough to provide suitable rooting space for plant growth to take hold. Without a structure, the sediment deposited in a gulley tends to be unstable, shifting with the higher flood peaks. A gulley stabilization structure, be it big or small (and provided it is properly designed and constructed) has an influence both upstream of its full supply level, and downstream of its apron. In the former case, depending upon the size of catchment in relation to the size of basin created behind the structure, the size of individual sediment particles, and the vegetation established in the sediment, the sediment deposition will build up a slope which can be as much as 2% to 3%. In other words, when contemplating the stabilization of a gulley, the structures are not spaced merely according to the height of a structure, but according to the expected effect of each structure in the gulley. The structure should also have an effect downstream through the source of seepage water that it provides.
There are three other aspects to be considered.

* Any structure contemplated must be durable and long-lasting, or else the good work started will be destroyed in a couple of years' time. This means that great care

must be taken with the choice of material, with the keying of the structure into the gulley, and with the creation of sufficient freeboard to cater for flood peaks.

* The narrowest part of a gulley is **NOT** usually the best place to site one of these structures. The whole idea is to slow down the speed of flow of flood-waters. This causes it to drop its load of sediment. The wider the spillway of the structure, the lower is the velocity of the water flowing through it, and the less damage that is likely to occur. Lower velocities will result in greater sediment deposition.
* Having created better conditions for vegetation to colonize the gulley, the plant growth will tend to attract grazing animals as much as the water which is now stored there. *The gulley must be fenced off,* and all grazing strictly controlled in order to promote stability.

Here follows various types of fairly inexpensive structures which could be tried out. They should not be attempted in gulleys with catchment areas greater than 10 hectares in extent. The local soil conservation officer will assist with more specific designs and information.

TYRE STRUCTURE

As with all gulley stabilization works, the success of the work depends largely on careful preparation of the site. Gulleys should preferably not be deeper than 3,0 m and overflow height should not exceed 1 m. Any size tyre may be used, but preferably size 14 and larger. Tyres should all be the same size to facilitate construction.

Site preparation

Sloping gulley banks, where present, must be excavated perpendicularly at the point where the structure is to meet the banks. A layer of tyres is then laid firmly against one another, in the form of an arc through the gulley, in order to mark out the trench for excavation. See Figure 1. The trench should be excavated to a depth of two tyres. Where hard, stable soil is present, however, one tyre depth will be sufficient.

The connection of the structure with the banks is in the shape of a V with at least one tyre recessed into the bank, because this section forms the shoulder and is built higher than the overflow. The freeboard must be a minimum of one metre, and preferably 1,2 m.

Construction

Place a row of tyres firmly against one another in the trench. Knock an iron standard into the opening of each tyre so that the upstream side of the tyre rests against the iron standard. The standards must be driven into the foundation to a minimum depth of 400 mm, and they must be long enough so that they will just stick out above the last layer of tyres on completion of construction. It is essential that all the holes in the standards are facing the same direction as the centreline of the structure. Fill the hollows and openings of the tyres with durable, hand-sized rock. Thread 3-mm wire (8 gauge) through the holes in the standards and as closely as possible to the layer of tyres. Repeat with every successive layer. The

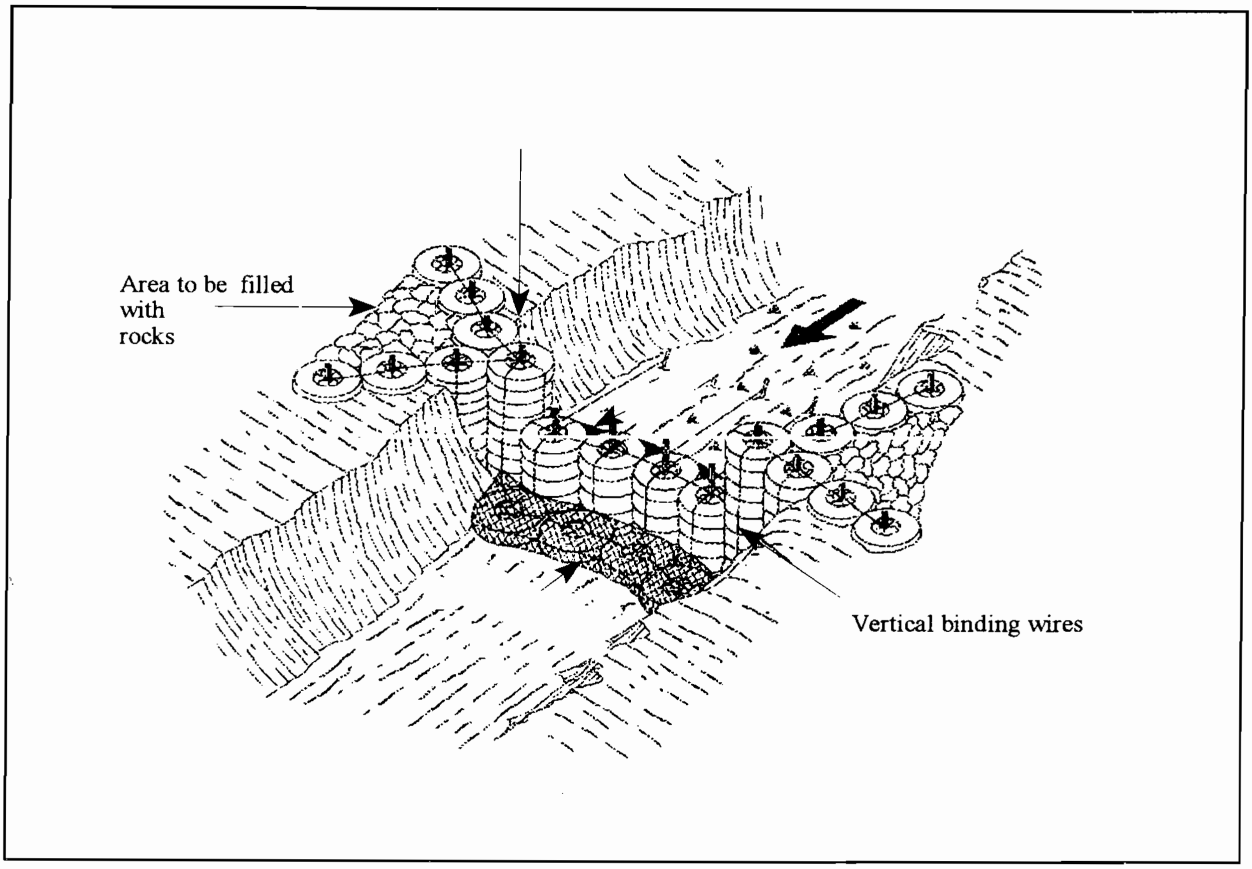

Figure 1. The tyre structure

wire must also be threaded through the standards in the shoulder section of the structure and pulled as tight as possible. This procedure is repeated until shoulder and overflow height are attained. Each tyre must be attached vertically to the tyre of the previous layer with the same type of building wire.
Once the structure has been erected to the required height, the standards are knocked in level with the top layer of tyres. Care should be taken, however, not to overstrain the horizontal wires when knocking in standards, as they will break. Rather cut off excess lengths of standards to neaten up the work. The opening formed by the V at the shoulder should be filled with rocks or stable soil.

Apron

A single layer of tyres is placed on the downstream side of the overflow, filled with rocks and attached firmly to the structure. Wire netting is placed over and attached to this layer to prevent the rocks from being washed out by stormwater. This layer is extremely important and serves as an apron to prevent scouring and undermining of the structure. In catchment areas larger than 10 ha a double row of tyres must be installed in order to increase the width of the apron. Short iron standards may be knocked into the opening of the tyres to further reinforce the structure.

Filtering out the sediment

The structure as it stands still has fairly large gaps through which sediment will move. It is necessary to provide a filter of geotextile which allows water to pass through but retains the fine aggregates. It must be attached to the upstream side of the work. The material must be anchored at least 300 mm deep below the bottom layer of tyres. It must also cover the top layer to prevent stones from being washed out during storm conditions. The geotextile must be attached to the vertical binding wires starting at the bottom layer and thereafter at every second layer. The material must be placed at least 500 mm directly into the gulley banks at the shoulders.

THE SEDIMENT FENCE (Figures 2 and 3)

This structure is limited to an overflow height of 500 mm and in gulleys with a degree of soil or soft rock in the bed, but with a catchment area no more than 10 ha in extent. Its function is to filter sediment out of flood flows.

Site preparation

A trench 300 mm deep by 300 mm wide, must be excavated through the gulley at right angles to the direction of flow and extended at least one metre into the gulley banks.

Construction

Iron standards are knocked in at an even spacing of 2 m from one another, to a depth of at least 300 mm into the foundation. They must be placed against the downstream side of the excavation. Iron standards must also be knocked in at both ends of the trench and anchored. Three-millimetre plain galvanised steel wire is then threaded horizontally through every second hole in the standards starting at the bottom, pulled as tightly as possible and secured to the anchors. Wire netting,

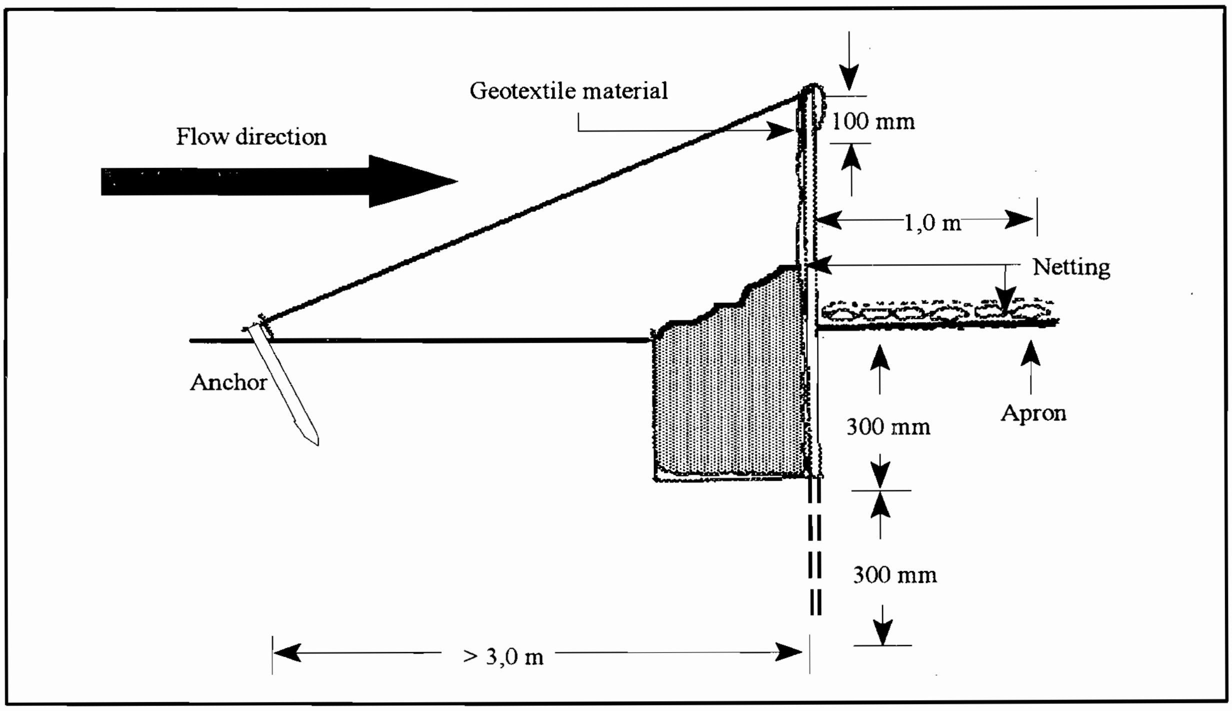

Figure 2. A sediment fence in section

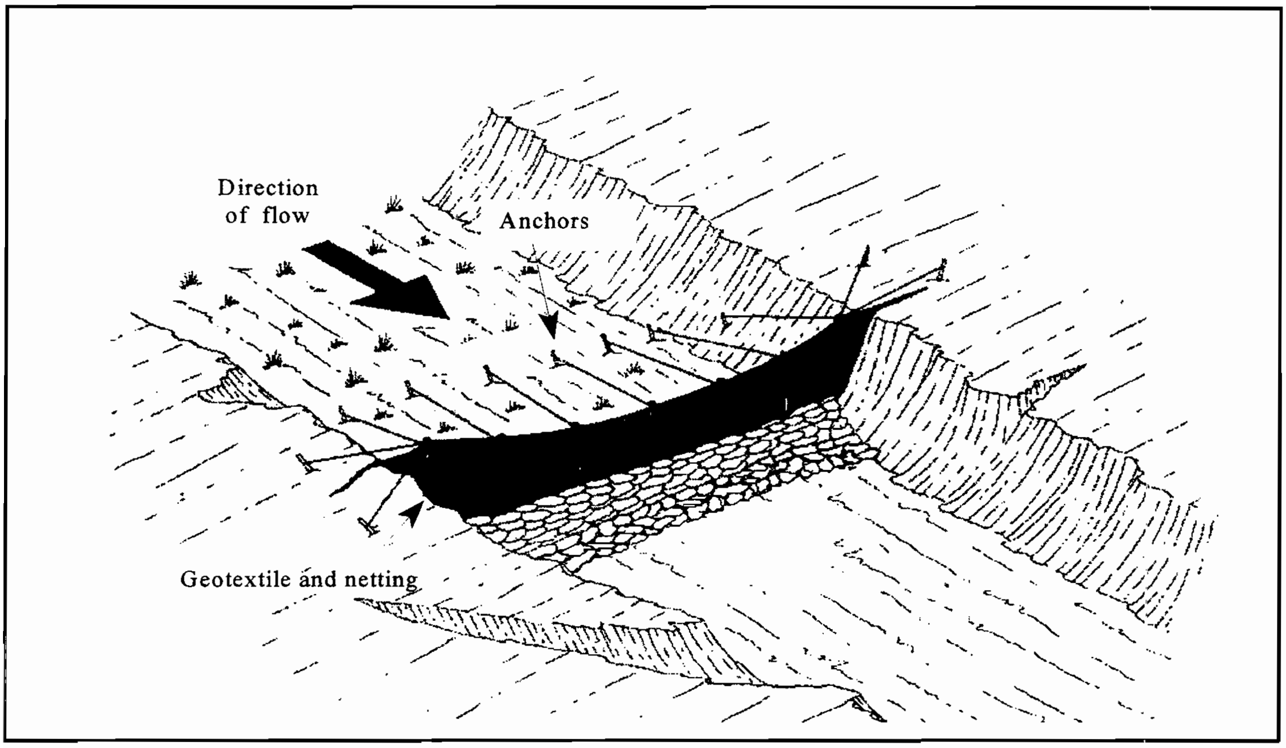

Figure 3. The sediment fence

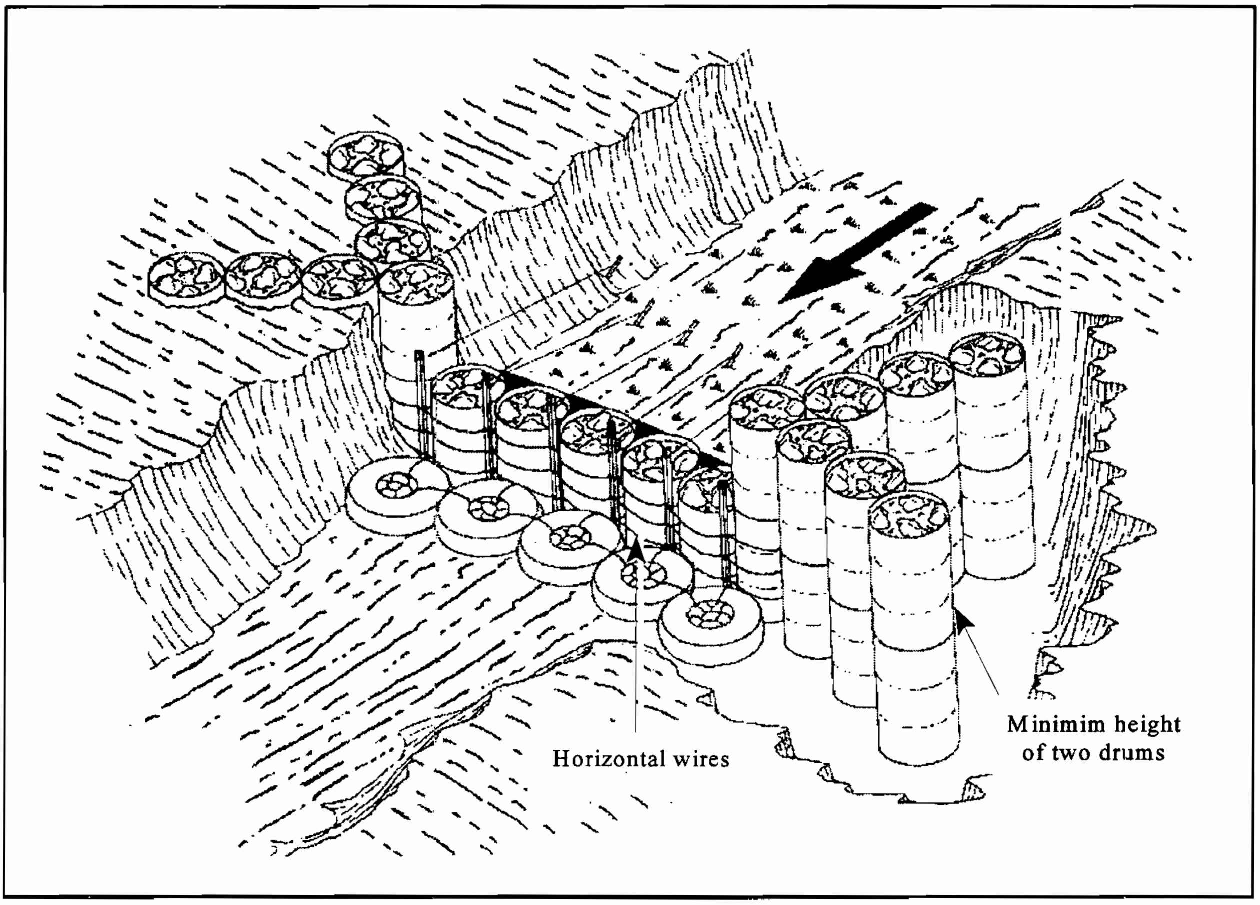

Figure 4. The barrel weir

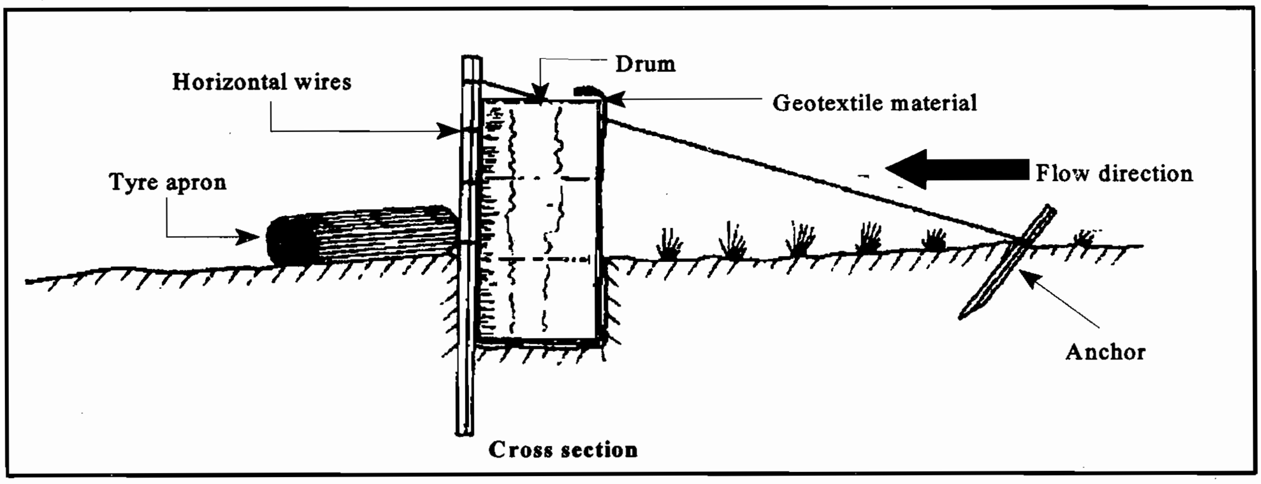

Figure 5. The barrel weir of home-made gabions

900 mm wide, is now firmly attached to the horizontal wires and standards. A flap, 100 mm wide, is folded over the top wire and secured along its length at the back of the structure. Geotextile filter material is now attached to the netting. Provision must be made for a strip broad enough to cover the width of the trench and for the fold in the netting at the top. The excavation is then filled with soil. Every iron standard in the structure must be anchored approximately 3 m away by another standard driven into the ground on the upstream side of the structure.

Apron

An apron of durable rock, not less than 1 m wide and enclosed in wire netting, must be constructed on the downstream side. The surface of the apron must be level with the gulley bed and should be securely attached to the main structure. The establishment of vegetation can be accelerated by planting fast-growing grasses or reeds which are adapted to local weather conditions into the sediment.

THE BARREL WEIR (Figures 4 and 5)

One of the problems with tyres and geotextile fabric is that they are both liable to damage by fire. An alternative is the use of discarded 200 litre drums which are filled with rocks and a sand-cement slurry.

Site preparation

Where sloped gulley banks are present they must be excavated perpendicularly at the point where the structure will meet the gulley banks. Excavate a trench one drum diameter in width in the shape of a shallow arch facing upstream. The trench should be at right angles to the direction of flow in the gulley.

The minimum depth of the trench is one third of the drum height. Figure 4 shows how the structure must be keyed into the banks of the gulley to provide shoulders.

Construction

Place the drums in the trench as close together as possible and ensure that the overflow section is level. Because of a need for freeboard, those drums used for the shoulders must be lengthened by placing a second one on top of the first. The top drums of the shoulder must have the base removed to form a unit with the bottom drums. Place durable rocks of varying sizes, but not larger than 150 mm diameter, into the drums in layers of approximately 250 mm thick, and add a 1:8 mixture of cement and sand in the form of a slurry. The slurry must be worked throughout the rock layer before adding the next. The slurry mixture can be prepared from any gravel, sand and small stone which is normally available on the site in the form of sediment. Insert iron standards on the downstream side of the trench after the slurry has been poured into the drums. Remember that the holes in the standards must face in the same direction, *i.e.* parallel to the centreline of the structure. Insert the iron standards in such a way that the horizontal wires fit tightly against the drums. Three-mm (No.8) wires are then threaded horizontally through the holes and pulled as tightly as possible. One strand must be just above ground level, the second one in the middle and the third one about 150 mm from the top of the drums. Geotextile fabric must then be attached to the upstream side of the entire structure and anchored between each drum to the horizontal wires with binding wire. Anchor the iron standards to one or more pegs on the upstream side. For the construction of the apron you are referred to that for the tyre structure.

A WEIR OF HOME-MADE GABIONS (Figure 6)

Site preparation

Sloping gulley banks, where present, must be excavated perpendicularly as for the previous structures. Excavate a trench 1 metre wide by 300 mm deep at right angles to the stream line and at least one metre into the bank on either side.

Construction

Insert iron standards on both sides of the trench as shown in Figure 6. Thread 3-mm plain wire through every third hole, starting at the bottom holes, up to the required overflow height (maximum 900 mm) and pull as tightly as possible. Attach wire netting to the horizontal strands up to overflow and shoulder wall height. Geotextile fabric is fitted to the waterside face of the structure, but on the inside of the netting.

Durable rocks and stones up to 150 mm in size must then be packed in the box formed by the netting after which the top of the structure is closed off with wire netting.

Every effort must be made to fill up even the smallest interstices with stone. The apron may be constructed of either a layer of rock in strong wire netting attached to the structure, or a layer of tyres, as previously described. The apron should be at least as wide as twice the overflow height and the top of the apron must be level with the donga bed. The size of stone must not be less than the mesh opening of the netting wire used. The gulley banks around the shoulders are sealed off with plastic sheeting to prevent the water from cutting around them.

This structure can also be built in the form of a sausage in small catchments up to 10 ha. The stones are enclosed in wire netting with geotextile material placed in the middle. This kind of structure is seldom built higher than 600 mm, although with time the overflow level can be lifted by adding an extra sausage to it. This is placed on deposited sediment, and just on the upstream side of the structure so that a stepped effect is obtained. The required freeboard must be maintained by lifting the shoulder walls simultaneously.

WEIRS OF TREATED POLES

An overflow height of 1,5 metres must not be exceeded on this type of structure.

Site preparation

Clear the site of all loose material down to the consolidated soil foundation. Excavate anchor pole positions to a minimum depth of 600 mm. All other poles must be buried a minimum of 500 mm and sealed with plastic sheeting to prevent water passing around the structure within the bank. (See Figure 7). Excavate 2 m into the gulley bank on either side of structure.

Construction

— Use treated poles of not less than 100 mm in diameter.
— Saw poles into the required lengths and paint the ends with creosote.

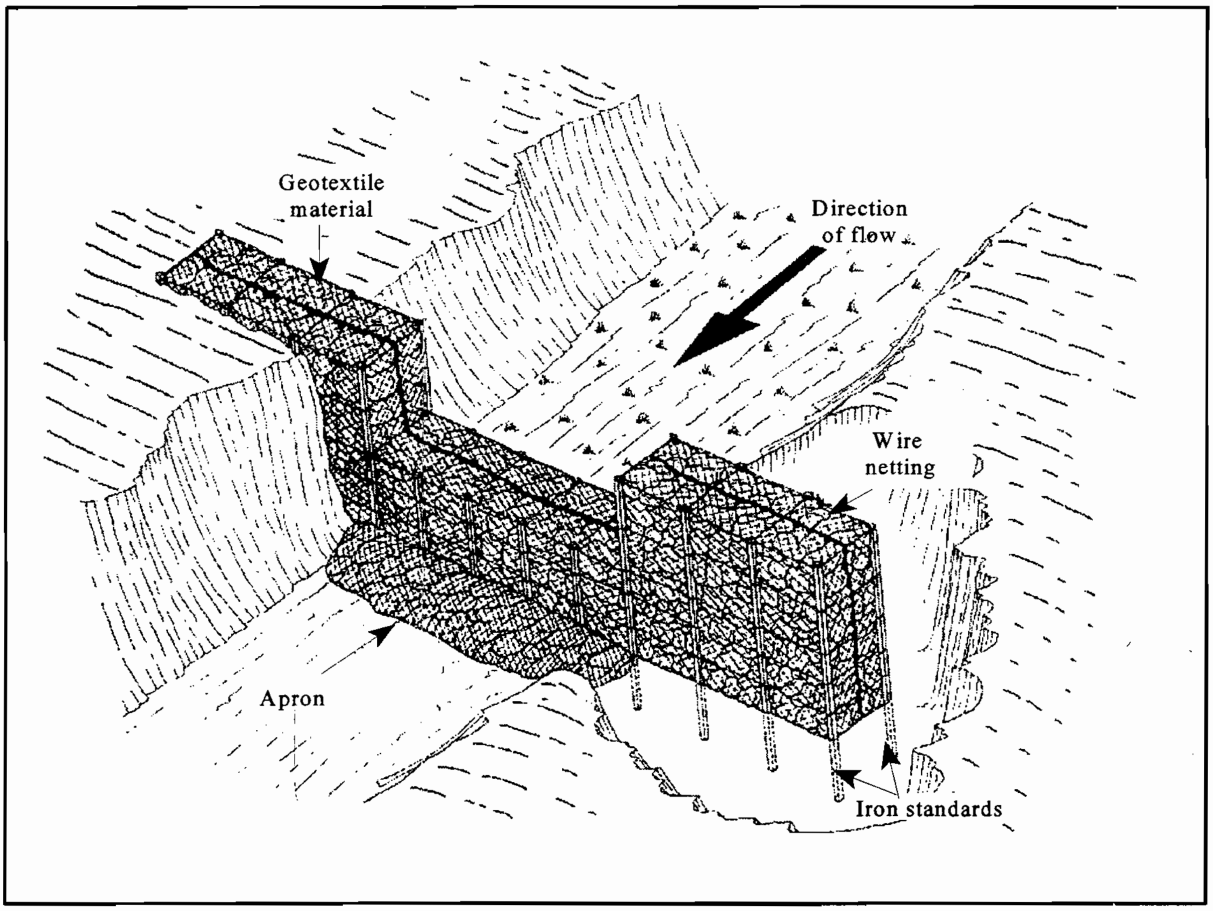

Figure 6. A weir of home-made gabions

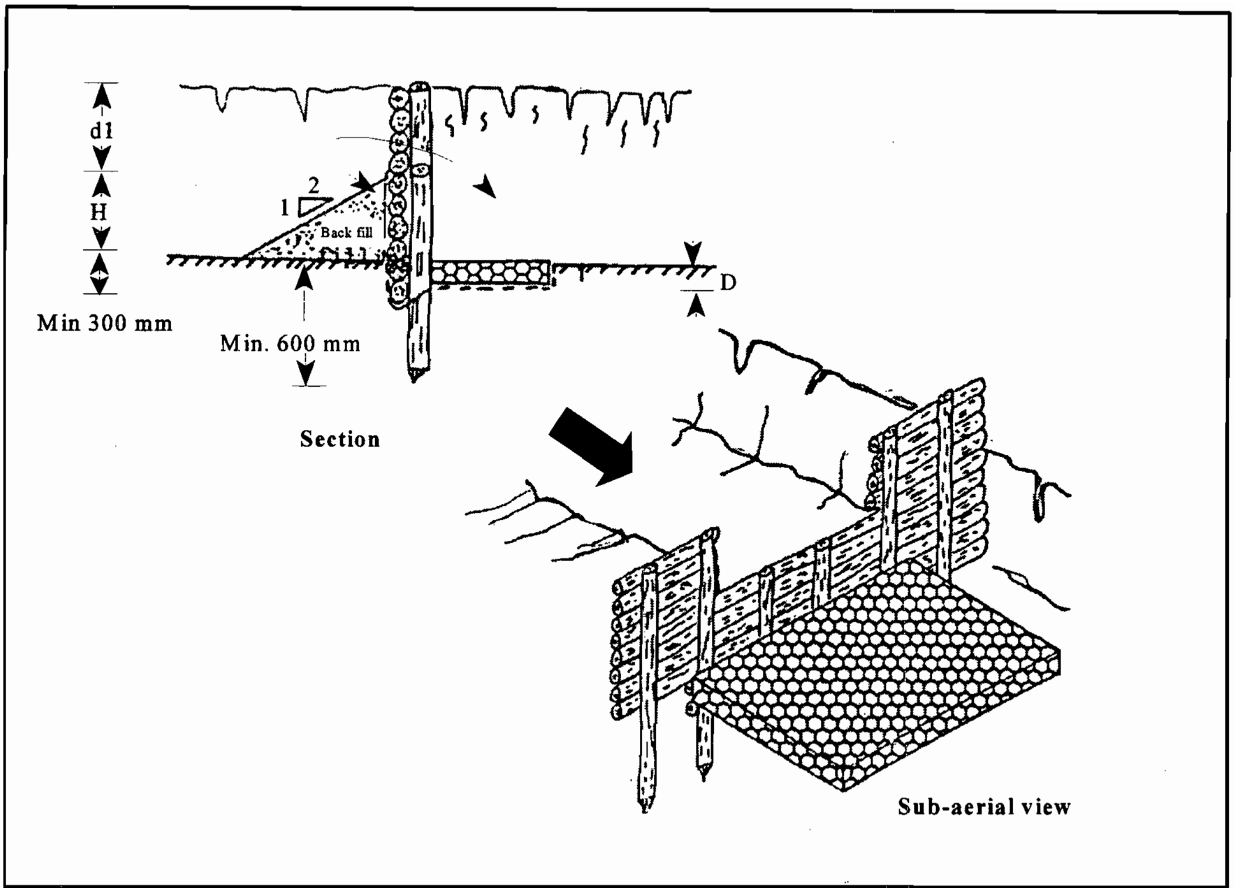

Figure 7. A weir of treated poles

- Plant the anchor poles not more than 3 m apart.
- Bind the horizontal poles onto the anchors on the upstream side, using 3-mm (No. 8) galvanised wire.
- Attach geotextile onto the upstream face of the structure and provide protection against ultra violet rays (*e.g.* with hay) until sediment covers the cloth.
- Construct an apron using durable rock overlaid with strong wire netting securely wired and fixed to the main body of the structure. The apron should be ≥ 0.5 m wider than the overflow width. The length of the apron should be twice the overflow height.
- Treat the site and immediate surrounds with ant poison.

ROCK PACKS (Figure 8)

Although these structures are the most widely used, their construction, generally, is very poor. Every effort must be made to lay them properly, and sufficient freeboard is imperative.

Site preparation
The foundation of the pack, including the apron, must be excavated to a minimum depth of 100 mm. This should be increased to 300 mm where the foundation material is unconsolidated. Excavations for the shoulders of the structure should extend a minimum of 900 mm, or equivalent to the height of the shoulders, into the gulley banks. All loose soil should be placed upstream of the structure. Where the base consists of rock, the first line of stones should be cemented into place. The height of unreinforced rock pack structures should not exceed 1,0 m at the overflow.

Construction
If required, geotextile material can be placed in position first. Choose flat rather than round stones if possible, especially for the overflow section, and pack them sloping back toward the upstream side of the structure.
Sizing of stones is important and a mixture of sizes should be used in order to achieve a dense pack. The shoulder walls must form one unit with the overflow section. Complete the pack by placing small stones and gravel on the upstream side to act as a filter.

GABION WEIRS

This structure can be built to heights up to 5 m, and on larger catchments, provided adequate design procedures are followed. Gabion baskets and mattresses are expensive to purchase and should only be used on any scale after a proper design has been prepared by a competent technician, and proper plans have been provided.

Site preparation
Excavate neatly so that the geotextile material/hyperliner is held against *in situ* material on the upstream side by the gabion basket before it is filled. This also assists in the control of water passing around the gabions where the structure is keyed into the gulley bank. Mark out the structure 10% larger than required to facilitate

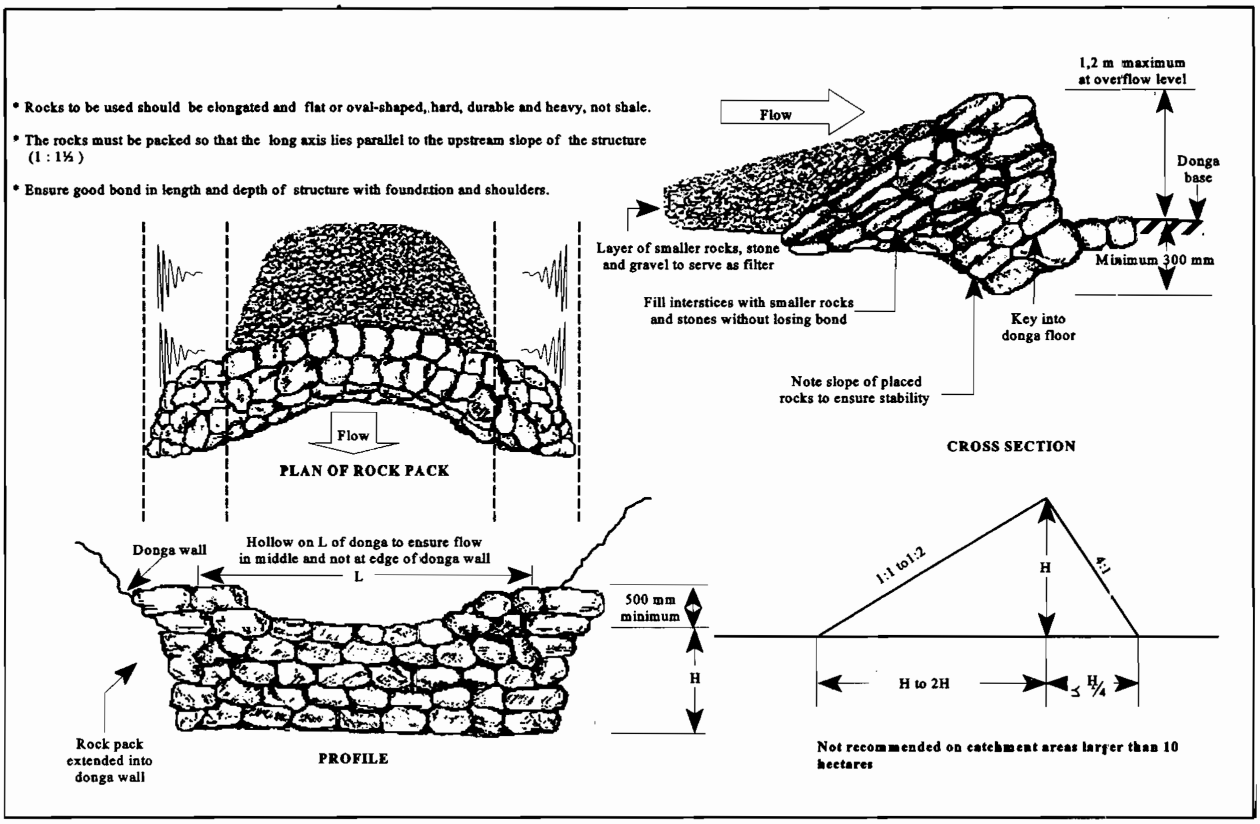

Figure 8. Specifications for rocks packs

construction, and excavate the foundation level down to consolidated material. All loose soil should be placed upstream of the structure.

Construction

- Line the foundation with geotextile before placing the gabion baskets in position.
- The baskets are purchased in a knock-down form. They should be erected outside the gulley and placed carefully in position along all adjacent edges.
- Wire together only with the binding wire supplied by the manufacturer, and strictly according to his instructions.

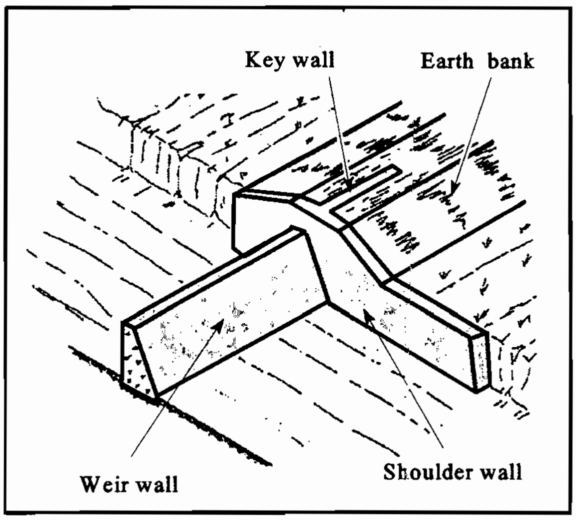

Figure 9. A mass gravity weir

- Fill the baskets with durable, hand-sized rock, filling in with smaller material. Placing is important, and the baskets must be carefully packed as densely as possible using different rock sizes - a minimum of 100 mm and a maximum of 300 mm diameter to facilitate handling and fitting.
- After every 300 mm layer of stones the baskets must be reinforced with wire cross-struts in order to maintain the correct basket shape.
- After filling , each basket must be securely wired.
- As with all the other structures described, an apron must be provided. Its size will be specified on the plan provided by the soil conservation officer. Attach securely to the main body of the structure. Minimum length should be at least twice the height of the overflow, but could be longer.
- Depending on the scale of the work, the stability of the foundation, and the size of the flood peak, a stilling pond and toe wall may have to be added.
- Finally, place loose soil material excavated from the foundation against the upstream side of the structure.

CONCRETE AND MASONRY STRUCTURES (Figures 9 to 11)

The structures previously described in this pamphlet can all be built at relatively low cost and with unskilled labour. It should be mentioned, however, that concrete and masonry works are the ultimate in terms of structural

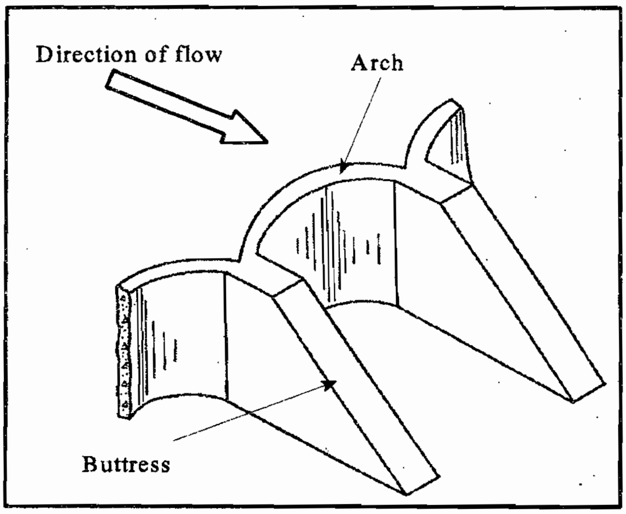

Figure 10. An arch weir

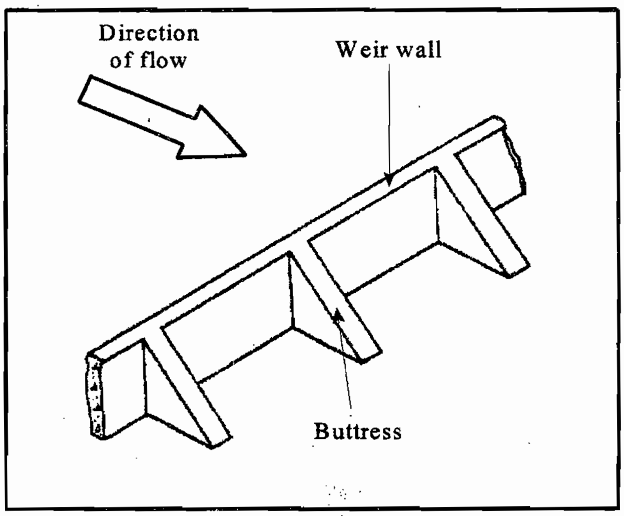

Figure 11. A buttress weir

strength, durability and low maintenance. Concrete and masonry can be used in place of, or to augment and strengthen, all the structures described in this guide. Almost all structures of a more sophisticated design, or where high strength is required, will have to be constructed of concrete. These structures are, however, beyond the scope of this guide, and sketches of them are only included for the sake of interest.

Conservation of Farmland in KwaZulu-Natal

FARM ROADS

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INTRODUCTION

The road systems serving most farms consist of the minimum of possible length of permanent road to the homestead, supplemented by temporary tracks used for exploitation purposes, probably due to the fact that roadmaking is regarded as a costly and difficult operation requiring heavy machinery, expensive equipment and a cash output beyond the owner's means. On the other hand, poorly designed and constructed roads:

* increase travelling time, which results in delays and an increase in fuel usage,
* increase vehicle wear and tear, which results in financial loss, and
* encourages usage of alternate routes, which results in poor farm management, soil erosion and poor security.

Farm road construction can constitute a very expensive part of property development, but is also an area which, with a little attention to detail in planning, will make farming that much easier. Time spent on planning is essential so that the road network will not only serve, but complement all enterprise operations. This guide sets out recommendations for road layouts on farms, and suggests the best methods for reducing maintenance costs.

THE PRINCIPLES OF ROAD LAYOUT ON A FARM

Roadway layout should be so designed that they not only form strategic fire-belts when placed along farm boundary lines, but they should also complement internal firebreaks. The basic principles of road layout include the following:

* runoff control planning principles must at all times be adhered to: see guideline no. 2.2 in this series,
* laden hauls should be on a downhill gradient, if at all possible,
* as transport is expensive, the backtracking of laden vehicles should be avoided,
* roads sited on watersheds have minimum interference from extraneous runoff, and rainwater is easily disposed of by mitre (side) drains,
* roads sited on crests (*i.e.*, placed at right angles to the natural contour) run parallel to the direction of runoff and may therefore cause problems at the lower end of long hillslopes, if runoff from the roads is not well re-distributed,
* the siting of diagonal roads is only considered on excessive land slopes, as they cause problems with runoff water disposal,
* link or tertiary roads that run across the land slope have to cope with all runoff water from the landslopes above them; where this type of road is considered necessary, therefore, they should be in the form of free spillover roads in the non-arable situation, and the infield contour structures should be used as roads in the cultivated land situation,
* where infield roads are necessarily parallel to artificial or constructed waterways, it is often possible to site the road in the middle of the waterway where the excavated material has been stockpiled from both sides. The road then runs above the surrounding land surface with the waterway on either side of it. Special precautions are necessary to allow for crossings of waterways. See Figure 5.

THE PRINCIPLES OF ROAD ROUTING

Farm roads are generally "dirt" roads, which when dry tend to powder, the dust causing damage to adjacent plant life through interference with the photosynthetic process. When subjected to storm rainfall they become a major source of watercourse pollution by sediment. Runoff also tends to damage these roads.
The basic principles of road routing are therefore:

* routes should be so selected as to minimise environmental impacts, and except for crossing purposes, should not be routed within 25 metres of watercourses or wetlands,
* wherever possible, "dead-end" roads should be

avoided, but when they are unavoidable, provision must be made for a suitable turning bay,

* soils high in organic matter, very sandy or wet, vertic topsoils, and other highly erodible soils should be avoided.

ROAD CLASSIFICATION AND LIMITATIONS

Definition: Road grade is the slope of a road, and is generally expressed as a percent, or as a direct ratio. For example, a road that climbs a slope by 10 metres in height for every 100 metres of length has a 10 % grade, or a 1:10 gradient.

Class A roads: For use by Hilo vehicles (in sugar cane parlance) and vehicles of 30 tonne gross vehicle mass and more. They are preferably sited along watershed lines. They should have a maximum gradient of 1:15 or 7 %, with a minimum carriageway width of 5 metres. The minimum curve radius of corners should not be shorter than 40 metres. See Figure 1 and Table 1. Stormwater disposal should be via pipe culverts under the road. Drainage of the surface and of the subsurface layers of the road is necessary to ensure stability, and the surface should be constructed of compactable material with good wearing qualities.

Class B roads: These are roads which are capable of accommodating up to 12 tonne vehicles, and should preferably be sited on crest lines as well. Their maximum gradient should be 1:10 (or 10 %), with a minimum carriage-way width of 4 metres. The minimum curve radius should not be less than 30 metres, and stormwater disposal is usually via berms across the road although underpass culverts would be preferable. Surface hardening of selected areas may be necessary to ensure stability and reduce maintenance.

Class C roads: These are roads for traffic comprising only light delivery vehicles, tractors and tractor/trailer combinations for firefighting and other lighter farm duties. Their maximum gradient should be no more than 1:5 (20 %) over short distances. Minimum carriageway width should be 3 metres, and their radius of curve may be as little as 15 metres. Adequate drainage must be provided, usually in the form of cross berms. The advantage of berms is that the water is discharged onto vegetation and not concentrated as in the case of an excavated side drain.

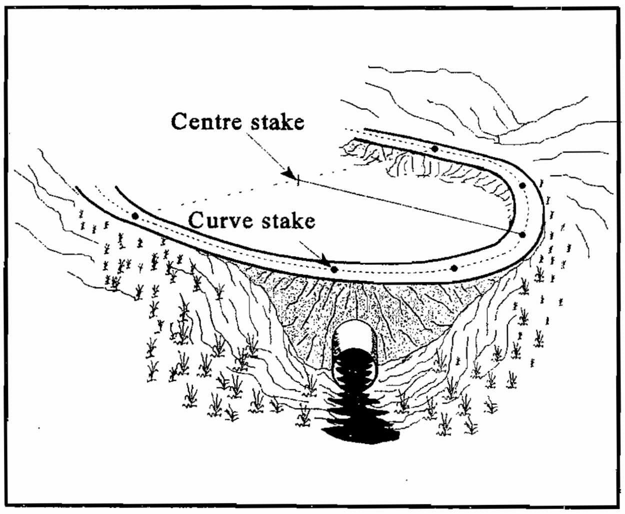

Figure 1. Pegging a curve of given radius

ROAD LAYOUT STANDARDS FOR ENVIRONMENTAL PROTECTION

Generally speaking, construction standards should be such as to minimise environmental degradation and to reduce maintenance requirements.

No road should be constructed at a gradient of less than 1:50 (2%), as roads that are level, and especially when not properly constructed, raised above ground level, or drained and sealed, tend to become water traps, resulting in the travelling surface collapsing. The exceptions to this general rule are:

* the cultivated land situation where class C roads are made alongside conservation structures,

* at stream and river crossings, in order to prevent sediment-runoff from the road from entering the watercourse.

No runoff should be led off roads directly into watercourses because of the sediment problem, but should flow through at least 10 metres of grass or close-growing vegetation before entering them. Roads should cross watercourses at right angles, and leave them on the contour, so as to avoid drainage water emptying directly into the watercourse. The 30 metres of roadway before a

Table 1. Offset lengths in metres for a given 15 metre interval along curves of different radii See Figure 2

Curve radius (m)	Offset length on 15 metres
10	10,5
15	9,0
20	7,5
25	5,5
30	4,0
45	2.5

watercourse must have a marked reduction of gradient, thereby promoting deposition of the sediment load, prior to the stormwater discharge entering the watercourse.

Drifts should be confined to sites of solid rock. If this is not possible, they should be constructed with suitable materials such as concrete, gabion work, *etc*. This aspect is dealt with in greater detail in a later section.

Cuts and fills should be balanced along the route to reduce the number of borrow pits and soil dumps to a minimum.

Artificial waterways, constructed in cultivated lands for runoff disposal, must not be used as roadways because of the erosion hazard occasioned by a high concentration of runoff in these areas during storm rainfall.

No road that is to be built to run parallel to a watercourse should be sited within 25 metres of such watercourse, depending upon the terrain and the flood hazard along it, unless the road is built up to stand above the floodlevel, and has suitable protection. Road layout should be so designed that they not only form strategic firebelts when placed along farm boundaries, but they should also complement internal firebelts.

Constructed fills and excavated cuttings should be stabilized by grassing with a suitable indigenous grass. Weed control should be practised along roadways. Unusually steep grade sections must receive special surface protection, such as concrete strips. On sharp cuves the road grade should be reduced by 1% on 45m curves and up to 4% on (tight) 15m curves.

Erosion is influenced or caused by:

* removal of vegetative cover,
* disturbance of a soil surface,
* steepness of slope, which determines velocity of runoff water,
* erodibility of substrate, and
* concentration of runoff water.

All of these factors must be considered when siting a road and when planning its construction.

PLANNING THE ROUTE

Using an orthophoto or aerial map, with formlines (contour lines) on it, mark off all the points of influence along the proposed route, *e.g.*, start, end, stream crossings, dip tanks, gates, cliffs, wetlands, *etc*. Using the aforementioned planning principles, complete a mapping traverse which will dictate the necessary road grades, and develop the road network plan.

MARKING THE ROUTE

Locate the road route on the ground using pegs that are easily visible. The actual gradient pegging is done using an Abney Level. An Abney (or hand) level is simple and quicker to use than a dumpy level, although not as accurate or versatile. Its use is fully explained in the

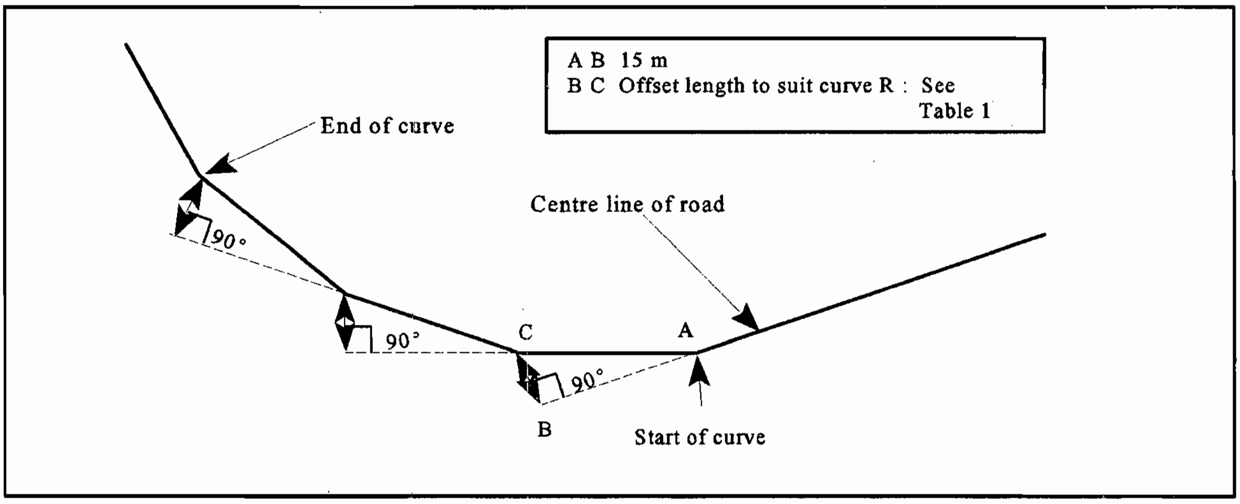

Figure 2. Laying out a curve by the offset method

guideline no. 2.3 entitled "A Farmer's Guide to Surveying Contour Banks". Where a simple curve or bend of minimum radius must be marked, the positions of the beginning of curve and the end of curve must be identified and marked. Figure 1 shows how the curve is marked out using a rope of desired radius length. On more difficult terrain, the curve may be marked by the offset method. Pegs are put in at regular, specified intervals along the curve circumference by offsetting by a given, equal distance each time. See Figure 2 and Table 1.

CONSTRUCTION OF FARM ROADS

Construction activities should generally be timed so as to minimise soil erosion, and the revegetation of disturbed areas must begin before the heavy rain season commences.

Keep cut-and-fill road benching sites to a minimum, as these are not only costly but are erosion hazards, with possible high maintenance costs. If they are necessary, 20% more volume of cut is needed on average for obtaining a compacted fill. Wherever possible a cut-and-fill situation should be such that two-thirds of the carriageway be on the cut and only one third on the fill area. All vegetation must be removed before the filling operation commences, otherwise the dead material along the interface could cause sliding of the fill during wet weather.

The side slopes of earth embankments should not exceed 1:2 (50%) and should be well grassed. A berm or ridge should be constructed at the top of the embankment if surface water will be an erosion hazard. The outlet of such a berm should be aligned to ensure safe disposal of runoff away from the embankment or into a well protected chute or pipe down the embankment slope.

The above information for embankments applies also for cuttings. In cuttings extra attention should be given to

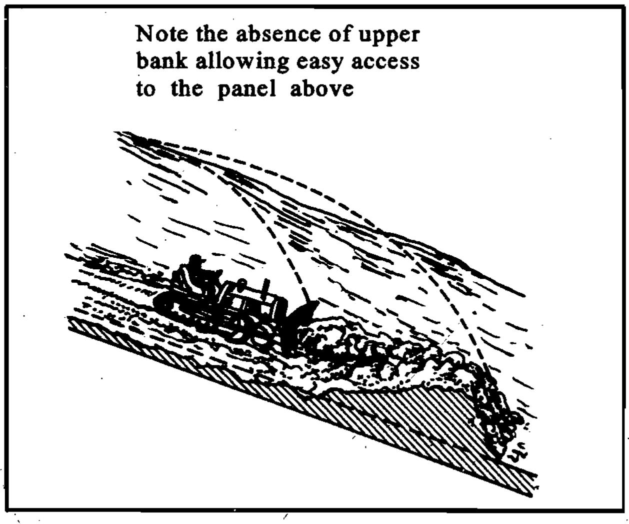

Figure 3. Road construction using soil being pushed down the slope to create a bench

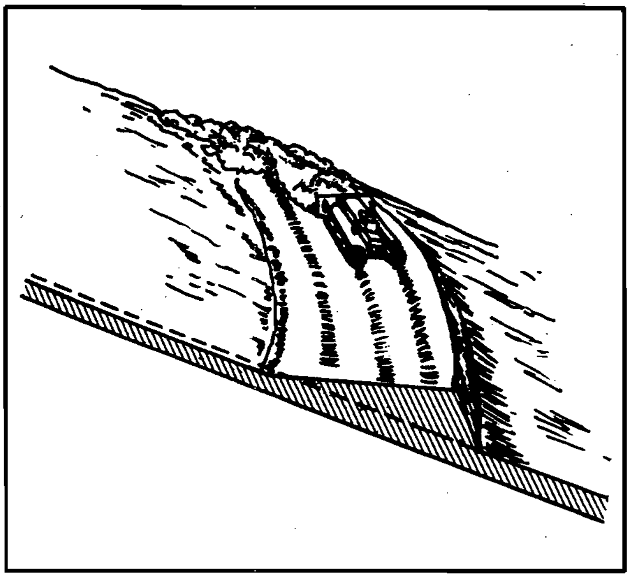

Figure 4. Shaping the road using soil pushed down the slope

ensure surface water does not flow down the cutting face. A stormwater drain should be constructed above the cutting to control any concentrated runoff threatening the side slopes. Where subsurface drainage is a problem, interceptor drains may be necessary.

A problem of cut-and-fill construction is that it creates a steep bank which can be an impedance to field access. An improved construction method is shown in Figures 3 and 4, where the bench is achieved with no cut face of any significance. A tracked vehicle would be a safety necessity in roadmaking on hillslopes of 30% and greater.

ROAD DRAINAGE

* **Subsurface Drainage**
  Water is held within the soil body, and if there is too much (poor drainage) it turns into mud with little form or texture. When water stands in puddles it seeps into the roadbed, saturating it and causing the collapse of the road surface. The material used and the construction methods adopted will dictate the extent to which the rainwater will infiltrate into the road surface.
  Some soils are naturally wet, *e.g.* those in depressions and vleis, and these areas should be avoided where possible by choosing an alternative route. If such areas need to be crossed, stabilization can be obtained by overlaying the route with a woven geotextile filter fabric which is covered with roadbuilding material and topped off with the surface material. Seepage water passes through the fabric, but does not allow the *in situ* material and the placed material to mix, thus preventing degradation of the roadbuilding material. The geotextile must be strong enough to withstand the stretching as it becomes embedded through the pressure of traffic. The company

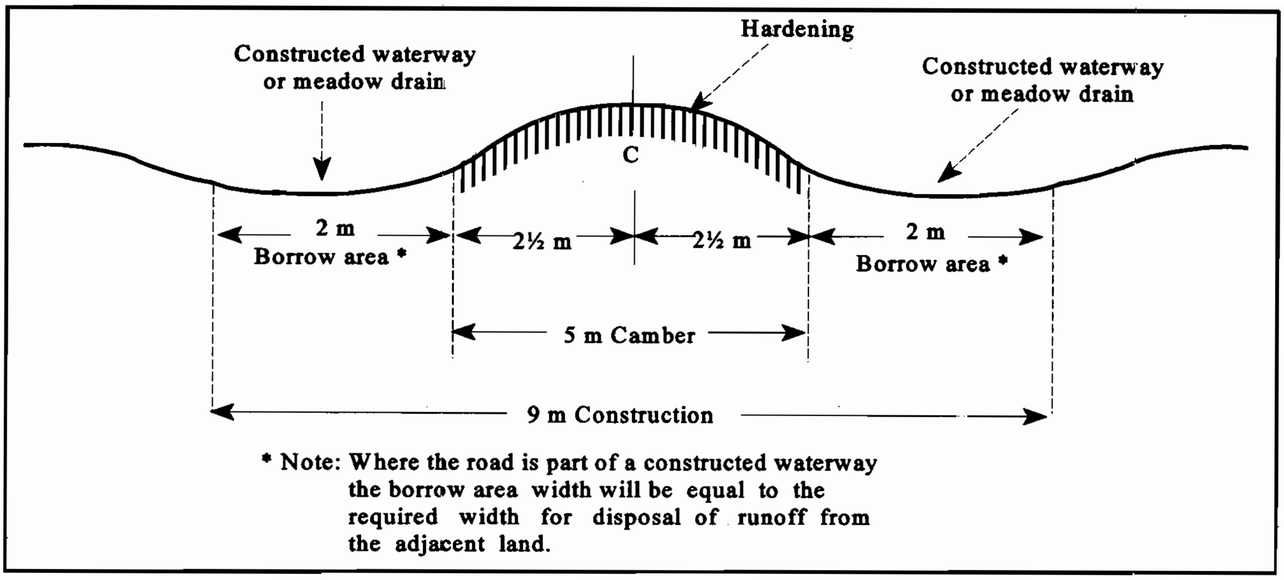

Figure 5. Shaping a road to promote drainage : an example

Industex in Port Elizabeth can weave a cloth suitable for most farm-type loads. Kaymat of Pinetown does the same. It should be noted, however, that non-woven geotextile does not have the same strength and should not be used for this purpose.

* **Surface Drainage**

Runoff water must leave the road surface and cut-and-fill slopes rapidly but in a non-erosive manner. This is accomplished by using a strong surface material and giving a cambered shape to the road so that it actively sheds water falling on it (Figure 5).

Excessive surface seepage into the roadbed must be minimized.

Free spillover roads across sloping ground can be satisfactorily surface drained by slanting the road surface towards the downhill side at an incline slightly greater than the road gradient. This degree of inclination or cross slope must obviously not be so great as to introduce the risk of vehicles sliding off the road. A road grade of 1:17 (6%), for example, using a 1:16 road surface cross slope, does not need special road hardening, and requires a minimum of cross drainage as well.

Roads with a reverse slope for surface drainage necessitate the construction of drainage ditches and culverts. These ditches and culverts must cater for all the runoff from the

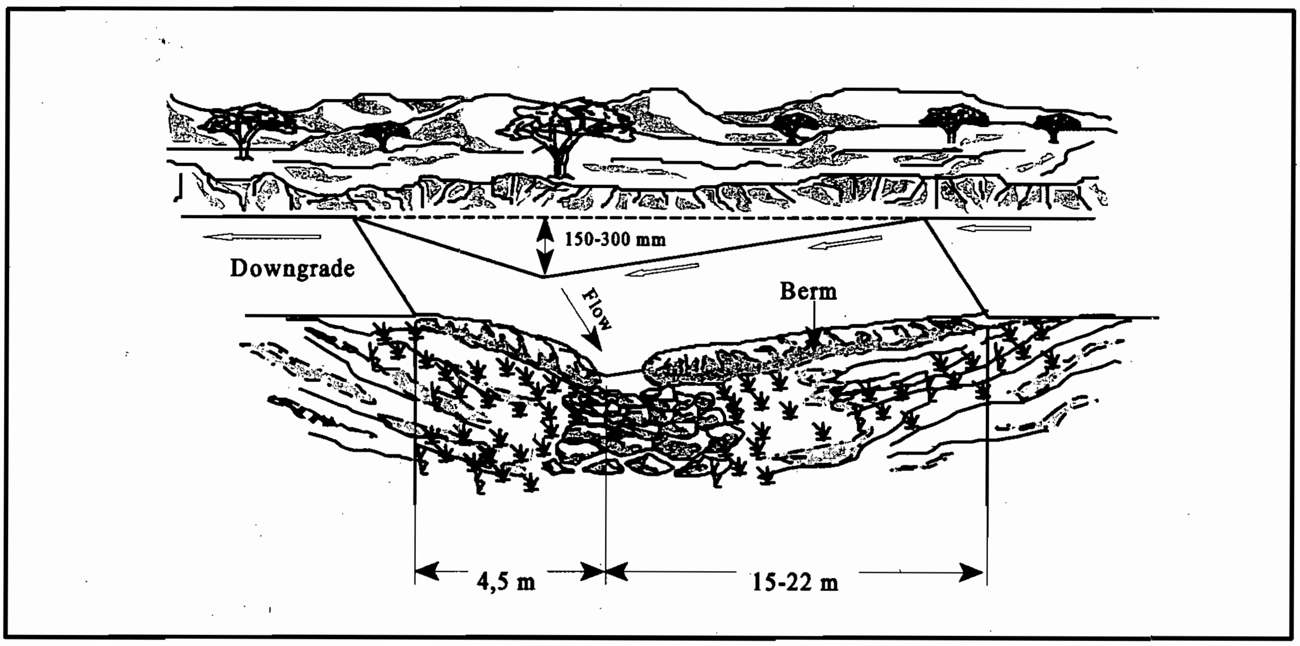

Figure 6. Cross drains for heavy vehicles

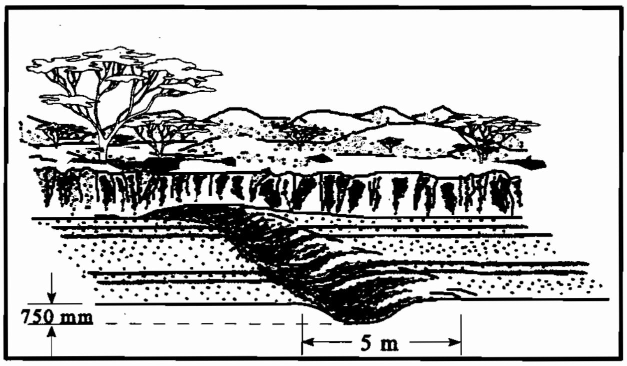

Figure 7. Cross drains for light vehicles

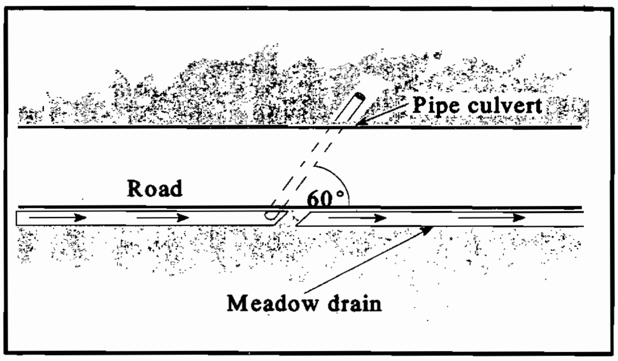

Figure 8. Alignment of culverts

landscape upslope of the road. In order to reduce stormwater build up, and to ensure its safe disposal, they must be spaced regularly along the road.

Cross drains are suitable for road grades up to 10% (1:10) and have fairly low maintenance needs. (See Figures 6 and 7 for dimensions). Figure 6 type cross drains are suitable for heavy vehicles, and due to the wide base, "bellying" of the vehicle is circumvented. Figure 7 type drains should only be used on low standard, C class roads, for they impede and slow traffic down. Proper spacing of cross drains is essential and, as with mitre drains, the general rule is to divide a constant of 300 by the road grade (%), to give the spacing in metres. For example, given a road grade of 1:20 (5%), the spacing will be 300 ÷ 5, which is 60 metres.

All outlets must be so aligned that they do not cause erosion, and must flow through at least 10 metres of vegetation before entering watercourses.

The road surface must be well compacted to form as impermeable a layer as possible.

ROAD CULVERTS

Piped culverts are generally used for major road links, but in the farm situation they tend to get neglected, blocked and become non-functional. Regular cleaning is important. When used in natural watercourses, the pipes must be placed in the natural channel and at the same gradient as the watercourse. Outside of the watercourse, alignment should be at 60° to the roadside drain direction. See Figure 8.

Pipe culverts should not be less than 600 mm in diameter but for ease of cleaning 900 mm is preferable. Placing them at a minimum of 600 mm below the road surface avoids damage to them by heavy vehicles, and sealing the pipe joints avoids seepage of water into the roadbed. If they can be placed at a 10% gradient, they are considered to be self-cleaning. Where drop inlets are necessary, either to avoid inlet erosion, or to create a pressure head for increased capacity, inlet diameter must be two to four times the culvert diameter. See Figure 9.

WATERCOURSE CROSSINGS

Where farm roads cross both natural watercourses and/or artificial waterways they must always do so at right angles to the streamline. Crossings should preferably be confined to sites where solid rock lies across the watercourse. Where this is not possible they should be constructed of suitable, durable material such as reinforced concrete, gabion work or grouted stone. Examples of these methods are shown in Figure 10.

Specifications for a farm-type bridge made of concrete are obtainable from the Portland Cement Institute, Westville.

ROAD CONSTRUCTION

In the farm situation it is necessary that costs be kept as low as possible. Local *in situ* material must be used wherever possible. Soils having a high clay percentage of 15 to 30% may be used in the construction of roads for use by traffic that is not heavy. Should these soils become slippery when wet, gravel material, low in clay must be imported as topping. Decomposed dolerite and laterite make good road surfaces for low maintenance roads. Should *in situ* soils be very sandy with less than 15% clay content, clay soil material should be imported and mixed to obtain an impermeable, compacted surface. Proper soil compaction is only obtained when the material is at optimum moisture content (OMC). Each soil type has its own OMC, which is determined in a laboratory. As a rule of thumb, the OMC varies with percentage clay in soils, as follows:

* up to 15% clay	=	approx.	10% OMC
* between 15% and 35%	=	"	15% OMC
* between 35% and 55%	=	"	20% OMC

A grader blade at high speed during construction assists in the mixing action and also helps compaction. When mixing aggregate or lime with the road material, use the highest speed compatible with power available and operator safety. An alternative method to expensive gravel importation is the new chemical treatment using

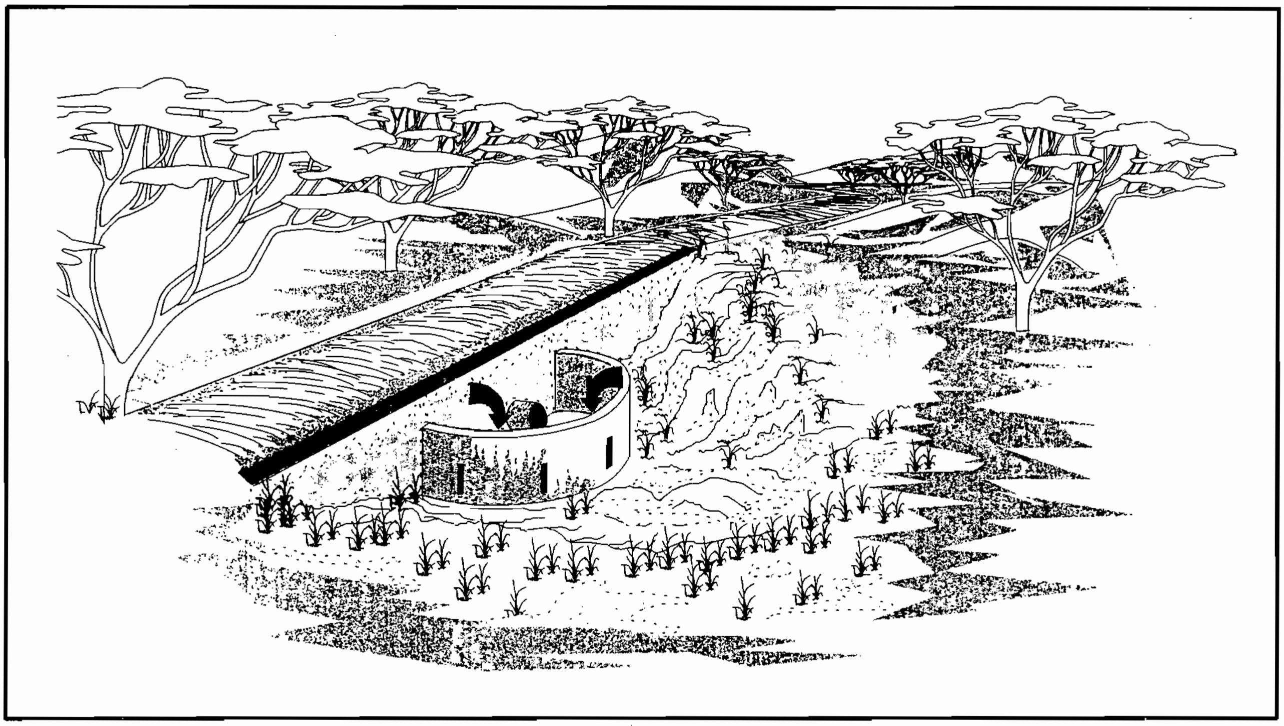

Figure 9. Building a drop inlet

one of the ionic soil stabilizers available on the market. The following is an excerpt from the distributor of the chemical which is reproduced without any guarantee by the author as to its validity : "Ionic soil stabilization allows for improved compaction, and increases the physical and mechanical characteristics of a wide range of soil types. Ionic soil stabilizer changes soil particles chemically so that they can no longer retain adsorbed water which normally renders high clay content soils unsuitable for road construction, housing developments, *etc.* The adsorbed water generally acts as a lubricant on soil particles and thus under heavy rainfall or heavy moisture conditions, compaction is lost and the roads become impassable.

After treatment with ionic soil stabilizer and the consequent release of adsorbed water, soil can generally be compacted to a density of 100% plus and will remain resistant to heavy rainfall or moisture penetration. This in turn leads to much better quality road surfaces, less pot-holing, rutting, deformation and corrugations (in some cases roads become too hard to be graded and this saves considerable costs in road maintenance!). Furthermore, as the adsorbed moisture has been removed from the treated roads, there is no longer expansion or contraction under freezing and thawing weather conditions, thus preventing one of the major causes of road deterioration.

Ionic soil stabilizer is an excellent and effective substitute for alternative stabilizers such as lime, with one drum of 210 litres of the chemical achieving the same objective as 40 - 60 metric tonnes of lime. The use of ionic soil stabilizer is a cost effective and permanent alternative treatment for gravel roads, resulting in higher densities for clay soils, considerable reduction in dust [up to 80%] and savings in vehicle maintenance costs due to improved riding surfaces in both wet and dry conditions. Ionic soil stabilization is highly recommended for all agricultural, forestry, secondary and primary road construction applications."

There are a number of different ionic stabilizers on the market, each better suited to particular soils than others. The CSIR Roads and Transport Technology division has perfected a technique for determining the best product for the soil type involved. Their telephone number is 012 - 8412939.

ROAD MAINTENANCE

This must take place regularly (at least annually) over the entire network. All blocked culverts and drains must be opened up and all invader weeds controlled. All minor roads taking only occasional traffic should be encouraged to grass over for stability and low maintenance.

Grading of roads should take place after a rain shower, when the surface is moist but not muddy. By avoiding using roads immediately after heavy downpours, and by first allowing a period of time for them to dry off, the need for grading will be greatly reduced. Road material generally washes across the road surface, so all grading or scraping must commence from the lower roadside edge, working the material across the surface towards the upper

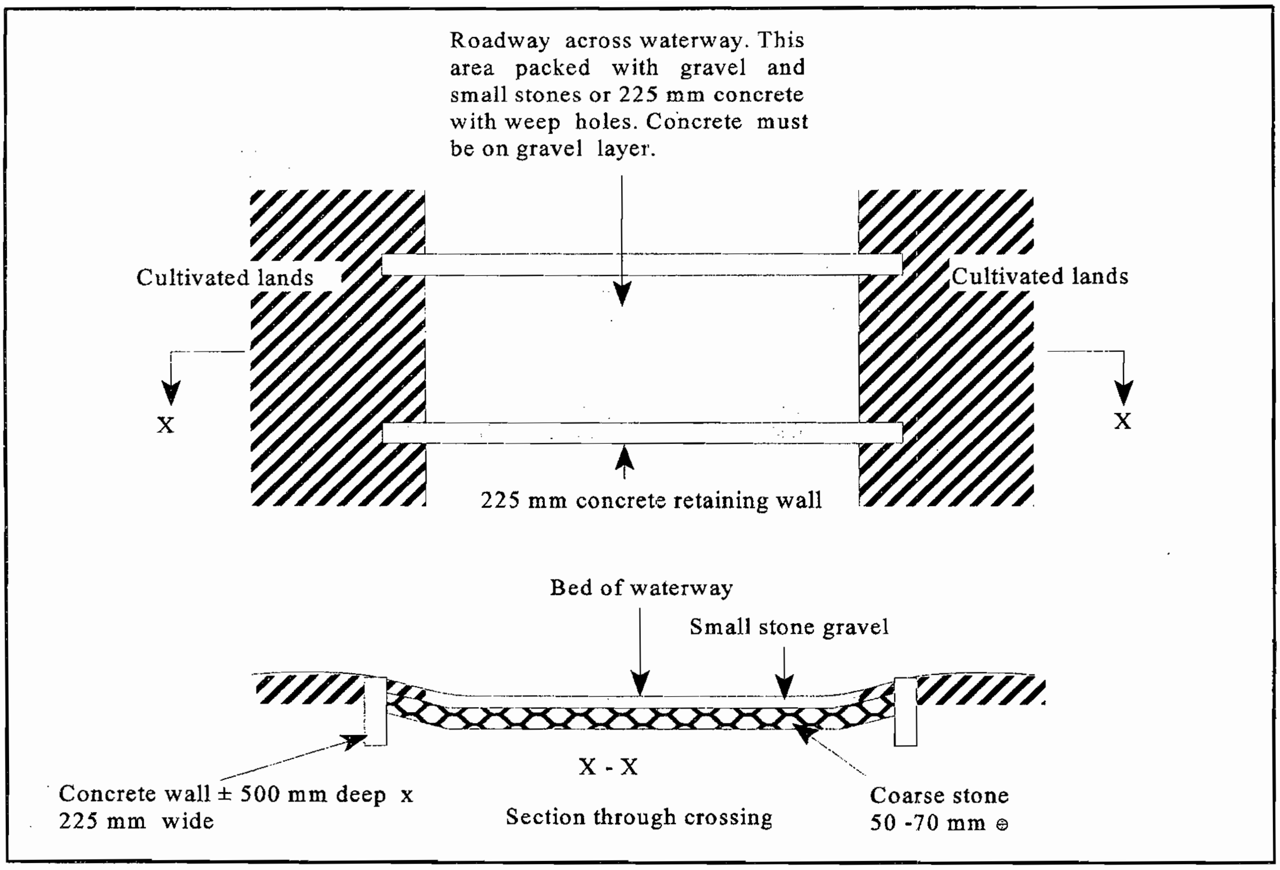

Figure 10. Crossing over a waterway

edge with the grader blade set at an angle of 20° - 30°. For ordinary maintenance work the blade is tilted forward until the top edge is ahead of the bottom edge. Extreme forward tilting is used for a trowelling action in order to smooth the material without moving it. Rough or pitted surfaces must be planed smooth by a cutting action and the surface material respread over the smooth base. This type of job is usually worked from the centre of the road to each side. Cut a smooth base, blading the surface material to each side, then respread this material evenly.

If the rough surface is too hard to cut with the blade, it should be torn up with a scarifier, then bladed to one side as the base is planed smooth. The scarified material is then spread over the smooth base. After the operation is complete, no ridges should be left across the surface, and especially not along the lower surface edge, as this will impede the flow of surface drainage across the road and create a rut. This will cause runoff to flow along and in the roadway, with all the accompanying problems.

It is not only important that conservation principles be implemented in the initial planning phase of the road networks, but where mistakes have occurred, these must be identified, and an ongoing process of correction must take place. Quarries and borrow pits should be rehabilitated or turned into permanent water bodies if no longer required.

All transhipments or stack sites along forest and cane roads must be so placed as to avoid the blocking of drains. If any infield machinery servicing takes place, oil, fuel or any other chemical substances and non-biodegradable materials must not be allowed to pollute the roadway runoff water disposal system.

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Conservation of Farmland in KwaZulu-Natal

GENERAL RIDGE TILLAGE PRACTICES

W B Russell
KwaZulu-Natal Department of Agriculture

INTRODUCTION

There are a number of valid reasons for ridging. When the ridges are constructed across the slope they improve water conservation, they assist in raising springtime soil temperatures, and in lifting roots out of a waterlogged situation when the plants are sited on the ridges. The problem, however, is the fact that ridging

* interferes with the hydrologic pattern of runoff water,
* increases the micro-topography of the field being cultivated, causing increased runoff locally,
* directs the flow of excess rainfall during a storm, and in doing so, causes overtopping of the ridges if flow direction changes as a result of poor layout. Damage by erosion is then caused downslope as well, and can cause waterlogging if the layout is incorrectly planned, thus leading to a result opposite to that which was expected.

The act of ridging increases the possibility of erosion on the ridge faces, and the V-shaped channel between adjacent ridges concentrates the runoff, increasing its velocity and, therefore, both its scouring action and its sediment-transporting capacity.

The danger to the landuser and the environment has never been better illustrated than in a series of runoff experiments carried out at Cedara. Soil losses in the 1990/91 season, from plots 22 metres long, on an Inanda clay, at 9% slope and subjected to natural rainfall, were in excess of 50 tonnes per hectare where tobacco was grown on ridges up and down the slope. Runoff amounted to 136 mm of the 272 mm of storm rainfall that caused the erosion, a massive 50% of the rain that fell. This was in spite of the fact that the Inanda clay is generally considered to be relatively erosion-resistant and to have good drainage. An additional problem encountered was that it was not noticeable that excessive soil loss had taken place. Great care is therefore needed in planning a system of ridges, as it is used traditionally in KwaZulu-Natal, for the production of potatoes, pineapples, tobacco, and latterly, sugarcane, timber, and maize. This leaflet offers suggestions as to how best to apply the principles of ridging in sustainable agriculture.

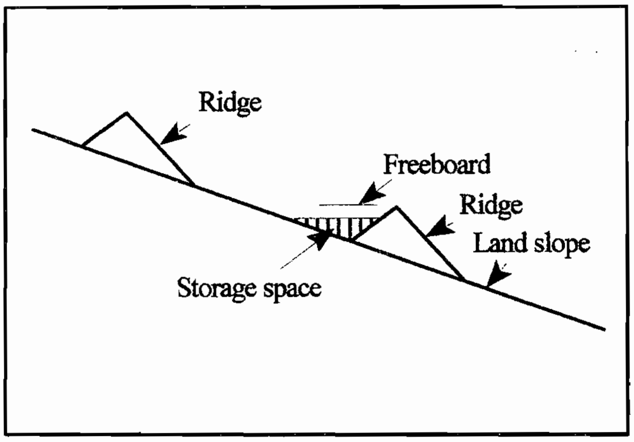

Figure 1. Cross section through two adjacent ridges

The following article is taken *verbatim* from 'The Link' a newsletter issued by the SASA Experiment Station at Mount Edgecombe:

RIDGING IMPROVES PROFIT
by Tony Tucker, Head, Extension Department, SASEX.

In the sugar industry it is estimated that at least 20% of the land (about 75 000 ha) consists of soils which fall into the poor, grey duplex group, such as those of the Longlands, Westleigh and Katspruit forms. The topsoil is light and sandy, but covers a subsoil which is heavy, impermeable and becomes waterlogged in times of good rainfall. The crops then decline rapidly and replanting is often necessary after only three crops.

To improve the yield potential of these soils, trials were started by SASEX in 1979, in which every line was planted to cane in the apex of an artificially created ridge drawn 300 mm in height and 400 mm wide at the apex. The ridges dispose of the excess water in the inter-row, while allowing the cane roots to develop in deeper soil above the water table. This enhances root development, conserves the soil, and improves water use. It also confines compaction from infield equipment to the inter-row, with minimum damage to the cane row.

Ridging improved yields by an average of two tons of sucrose per crop over three crops, when rainfall was at, or above, normal. At current prices this could amount to a benefit of R1 500 per hectare per crop.

The cost of making the ridge initially is estimated at R125 per hectare, with re-ridging desirable after each harvest. Although responses from ridging are unlikely in dry years, it is important to make ridges **before** the onset of wet periods to obtain the greatest benefits. **Now** is the time to identify areas likely to respond to ridging and to construct the ridges while the soil is relatively dry.'

WHERE TO RIDGE

There are two basic reasons for ridging. One is to lift plant roots out of a shallow water table, and the other is to improve the efficiency of rainfall, trapping excess water which would produce runoff, and allowing for a longer period for infiltration to take place into the profile.

RIDGING FOR TOTAL RAINFALL RETENTION (Contour ridges)

This technique has application for high moisture requirement crops such as sugarcane and timber. The ridges are built exactly on the contour and the crop is planted on the ridge. This not only has the advantage of creating surface storage to entrap all the rain that falls, but because the ridge is constructed largely of topsoil, the young growing plant has the benefit of an artificially-deepened and fertile medium. Its young roots are, however, kept clear of occasionally (or regularly) saturated conditions. Soil temperature on the ridge is also increased, to the benefit of early spring-planted crops.

Adjacent ridges must be constructed to be large enough and stable enough to provide sufficient storage between them to contain the maximum expected runoff. (See Figure 1.) If the land is flat or very gently sloping, this poses no problem, but as the slope increases, so the need arises for the proper design of ridges. The settled height of a ridge will be a function of:

* **the spacing between ridges :** for narrowly-spaced crops such as potatoes and tobacco (where the soil is sufficiently well drained for these crops) this poses no particular problem, as the storage capacity between even small ridges is generally sufficient to hold the results of heavy rainfall. The wider the spacing however, (mainly for timber and orchards), the larger must be the micro-catchment area which will contribute runoff to the little dam formed by the ridge on the lower side, and the greater must be the height of ridge, in order to dam all the runoff that is generated.
* **the slope of the land :** the steeper the slope, the taller the ridge must be, in order to entrap the runoff. Figure 2 gives the change in unit storage capacity for various heights of ridges as the land slope varies.
  Figure 3 gives an indication of the 1-in-10-year frequency, 24-hsour rainfall, which is recommended as the basis on which to work out the storage requirement of a ridge.

While infiltration will take place simultaneously with runoff, it is considered safer to ignore this loss, and to

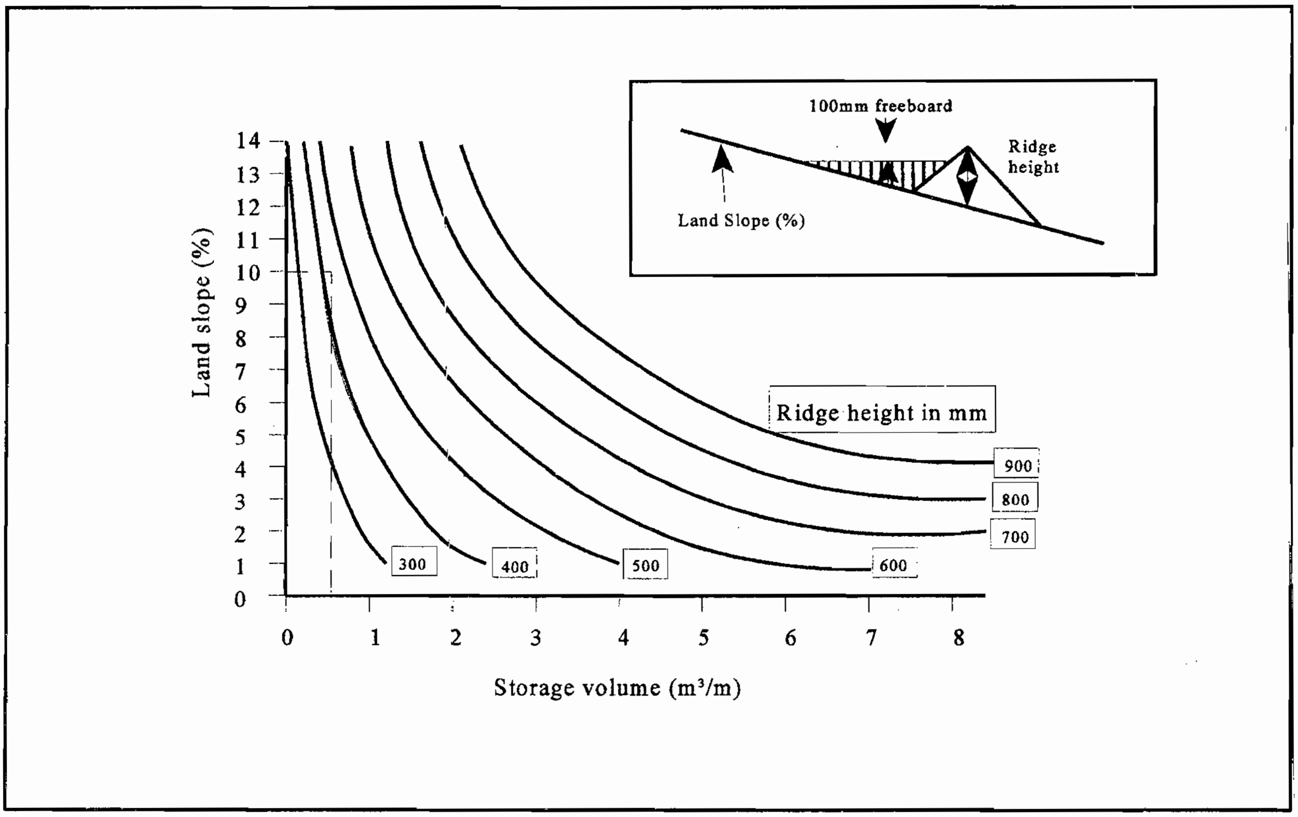

Figure 2. Volume of basin (m^3) per metre length of ridge. Ridge height makes allowance for a 100 m freeboard

design for 100% runoff. Calculating the volume of runoff, which must be catered for, is simple arithmetic. For example, consider a land slope of 10% with a 4 metre spacing of ridges required (*i.e.* row spacing) on which *Eucalyptus* is to be grown in the Babanango area of 125 mm.

Total runoff per metre length = design rainfall x row spacing = 0,125 x 4 = 0,5 m^3. Reference to Figure 2 indicates that a settled ridge height of 450 mm is required to safely store the expected runoff, allowing it time to infiltrate into the soil where it will be available to the crop. ***The one big problem with this technique is, of course, to keep the ridges exactly on the contour.*** If the ridge remains on the contour, runoff will move down the slope until it is trapped by a ridge, and there it will stay until the water infiltrates the profile. Any deviation from the contour however, will cause the runoff, trapped by the ridge, to move along the gradient so formed. Once the runoff reaches a section where the contour line is regained (*i.e.* there is no longer a gradient) the lateral movement of runoff will cease and water depth will build up. If the build-up is greater than the height of ridge provided, the runoff will overflow the ridge (and probably damage it) and move into the next compartment, resulting in an excess of water against the next ridge downslope. This could also break, leading to a succession of breaks and a gulley being eroded down the slope. Failure of the system would result. ***For this reason, level ridges on sloping land should be very carefully planned, very carefully constructed, and regularly maintained.*** They should also be restricted to land slopes no steeper than 10% to 15%, to deep and well-drained soils, and to high water-use crops and those that give a good ground cover or supply of surface litter.

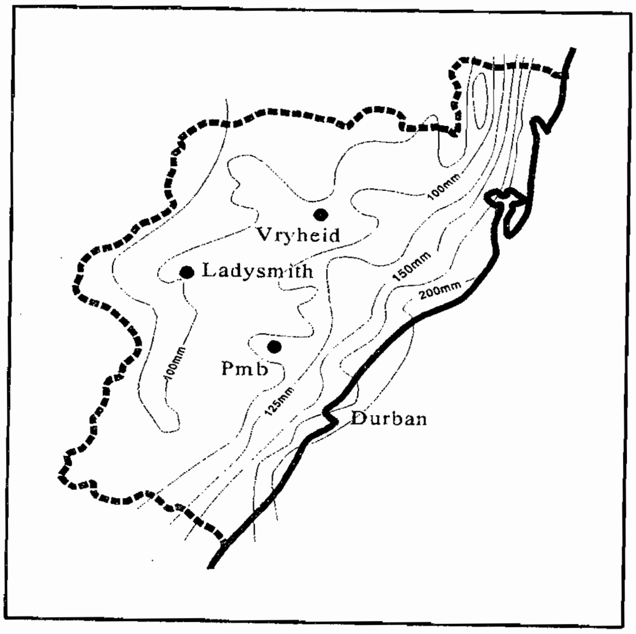

Figure 3. Expected maximum 24 hour rainfall in KwaZulu-Natal for a 10-year return period. (Schultz and Arnold (1979, modified

A method which can be used to improve the safety of the system is that which is called tie ridging. Adjacent ridges are tied one to another by a series of cross berms of the same height as the ridges, in order to prevent water moving more than five to ten metres along them. The cross-ties can be constructed manually or mechanically. In order to carry out the latter procedure, a tractor and dam scoop or grader blade will be needed. It is also necessary that the tractor and scoop can move across the slope between two adjacent ridges without damaging them. The operation is then one of shifting merely a thin layer of soil along a section five to ten metres in length and dumping it to form the cross-tie. (See Figure 4). Not much labour may be needed to complete the tie up, which is especially needed on the lower ridge. This action of scooping up soil in order to tie up the ridges will automatically increase the storage capacity behind them, by the volume of soil so removed and dumped.

RIDGING TO REDUCE WATERLOGGING: (Drainage ridges)

Under this heading is included the need to improve effective rooting depth on a duplex soil, not because of the possibility of waterlogging, but also in order to improve a site for cropping. The problem frequently arises that soils such as Avalon, Westleigh, *etc.*, which give acceptable crops in fairly dry years, become waterlogged in wet years, or for periods during a season. The waterlogging not only causes oxygen deficiency, but affects weed control which in turn causes a reduction in yield. In this situation the need is not only to construct a raised bed, but to construct one which is free-draining. Excess water in the field (*i.e.* both in the top part of the profile and on top of the land surface) must be removed from the field, but not to the extent that it will effect production in the drier seasons. The term for this technique in valley bottomlands is Ridge-and-Furrow, but the aims are exactly the same as on damp hillsides. The only real difference is that, in the case of bottomlands, a gradient to promote drainage has to be sought, while on the hillside, a gradient that will not promote soil erosion and excessive drainage, must be determined. A second

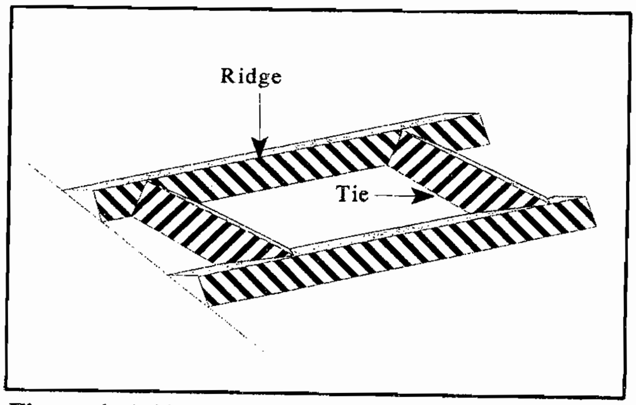

Figure 4. Ridges tied every 5 to 10 metres

difference is that the hillside ridges are generally of the order of only 1 metre in width, while in the flatter bottomland situation they can vary from 6 metres to as much as 20 metres. For a full explanation on the planning and construction of the latter, the reader is referred to leaflet No. 7.1 in this series. For direction on the specific requirements of a special crop like pineapples, the reader is referred to leaflet No. 2.11.

PLANNING THE LAYOUT OF RIDGES

Irrespective of whether the ridges are to be of the contour or the drainage type, the first principle to be recognized is that all natural waterways and watercourses must be retained as water disposal areas. The second is that the layout should preferably start on the crest of the hill. If this is not possible a stormwater drain must be constructed which will remove all extraneous runoff from the catchment area above. The design of this drain is best left to a person competent in hydraulic design, such as the local Soil Conservation Officer.

* **Marking out contour ridges** is very simple. Using either a hand level or a dumpy level, lines are marked on the ground surface with the chosen gradient (1:100 should be ideal), using a tractor-drawn subsoiler. If a fixed direction plough is used to mark the lines, marking should be carried out from one side of the land only. Pegs, 500 mm long (made of 4 mm wire with a flag attached) are inserted every 25 metres and the tractor operator follows each line in turn. The first line is marked as high up on the slope as possible. The second line is started, the requisite width away from the first one, at the steepest section of the slope. (See Figure 5.1.) If the land slope changes (*i.e.* decreases) across the width of the land, the line will veer away from the first line, in proportion to the change in slope. This is in order, and this second line can be completed. At the point where the deviation of the lines 1 and 2 is the greatest, a line should be started the requisite distance downslope from line 1 and continued in both directions until it reaches the end of the land, or meets line 2 (see lines 3 and 4 in Figure 5.1). The procedure should be repeated until the extra space between lines 1 and 2 is filled up, and the next major line should be started below line 2, *i.e.* line 5 in Figure 5.1 at the steepest point. The draw-in line 6 between lines 2 and 5. Figure 5.1 should be easily understood. Only after all the short rows between two full lines have been marked should construction commence, otherwise there will be problems in crossing completed ridges.

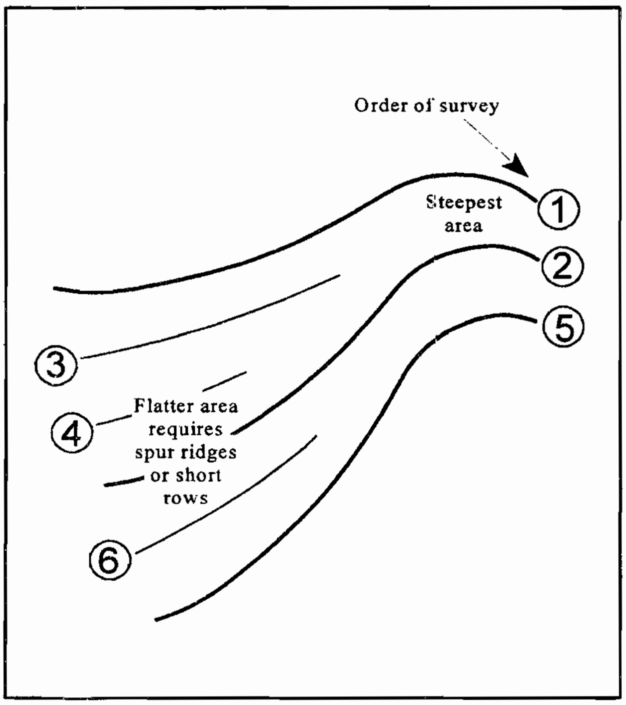

Figure 5.1 Layout of level or contour ridges on uneven ground

* **Marking out drainage ridges** is a little more difficult. In order to perform its function properly, without high and/or low spots to create wet spots, each line must be free-draining. The system of ridges is best superimposed on an existing contour bank system. See leaflets No's 2.2 to 2.6. Although each ridge acts as its own mini contour bank and will operate as one for most rainstorms, the major system provides a protection for the heavier rainstorms, especially where annual crops are planted. The major system also assists in planning the detail to ensure that each ridge is truly free-draining. Figure 5.2 explains the method which should be used.

There are, in fact, two methods which can be followed. The first one entails the actual survey of each individual ridge starting at the steepest section of the land, and making it the required distance away from the topmost contour bank. The required grade is marked out, and where land slope decreases the panel will widen in width. Only when the panel reaches double the required width will an extra spur ridge be possible. The problem with this method is that it is time-consuming and results in many short rows, especially if the land is fairly undulating. The master line method results in the minimum number of short rows while also making them all free-draining. The gradient is, however, allowed to

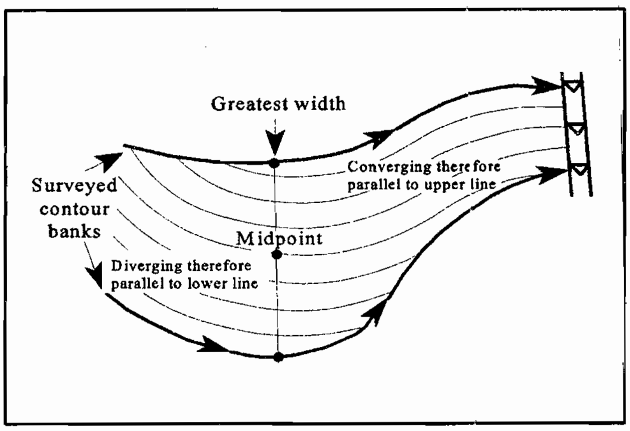

Figure 5.2. Layout of drainage ridges on uneven ground

increase as the slope change dictates. It is based on the principle of drawing the ridge lines parallel to the contour banks, but where the contour banks themselves are not parallel, the ridges are marked parallel to the upper contour bank if they are converging in the direction of flow, and parallel to the bottom one where they are diverging in the direction of flow. This procedure is achieved in practice by identifying the widest position of the field between two adjacent structures, and marking the midpoint between the two structures. From this point the ridge lines are marked as shown in Figure 5.2.

CONSTRUCTION OF THE RIDGES

The conventional method is to use the lines marked as centrelines, and, using either a mouldboard or a disc plough, to build the ridges up to the required height and width by repeated clockwise ploughing. Specialized implements are available in the trade.

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Conservation of Farmland in KwaZulu-Natal

THE LAYOUT OF PINEAPPLE PLANTATIONS

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Adapted for KwaZulu-Natal conditions from the original document entitled 'Run-off Control Planning on Pineapple Lands' and circulated as an unpublished internal document by the Döhne Agricultural Development Institute. Aspects pertinent to KwaZulu-Natal have been included by the editor and are indicated in italics.

INTRODUCTION

Runoff control planning on pineapple lands differs to a large extent from the systems adopted for other crops. This can be attributed to four basic factors:

* The cultivation of pineapples is largely mechanised. It relies on a boom spray for the application of herbicides and fertilizers, and where mechanisation has been developed, a conveyor belt boom for harvesting. A system of conservation structures is therefore necessary whereby it is possible to drive a tractor operating a boom spray along roadways which are so spaced as to ensure that the entire field is covered by the spray, while overspraying is avoided as far as possible. (The possibility of a boom spray with shut-off nozzles has not yet been fully investigated).
* Pineapples are sometimes cultivated on extremely steep slopes of up to *12 percent in KwaZulu-Natal* and often on fairly erodible soils.
* The accepted practice is to cultivate pineapples on ridges which are approximately 600 mm wide with a canal 250 mm wide by 200 mm deep on either side. See Figure 1. These ridges give rise to the following problems:
  - The further one moves away from the equator, the more necessary it is to run the ridges from north to south. This ensures that the plants receive adequate sunshine, and that one row is not subjected to shading by the other. It is also often in conflict with the requirements of runoff control planning.

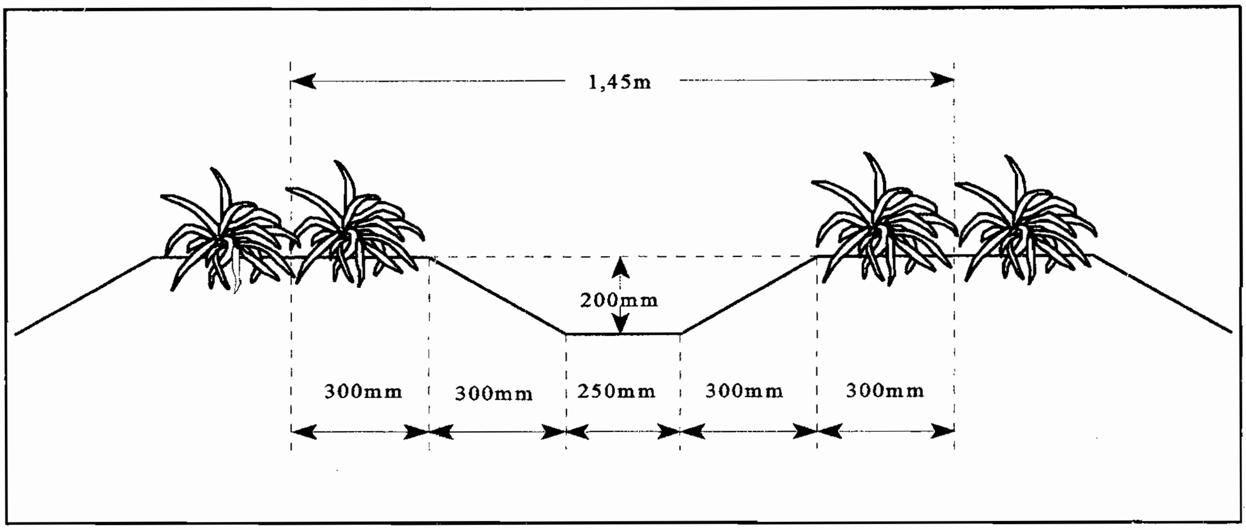

Figure 1. Dimensions of a typical ridge for pineapple production

- The ridges have steep micro-slopes and these are exposed to raindrop action and runoff erosion for 6 to 12 months after construction and planting and before canopy cover protects them. The practice of ridging results in a concentration of runoff water in the canals between the ridges, and the general practice of ridging up and down the slope leads to a greatly increased flow speed. As a result scouring in between the ridges becomes excessive.
- Without a surface mulch, erosion on and between ridges is excessive where contour banks are spaced as for conventional crops. Research regarding the effect of mulching on pineapple ridges has been carried out fairly extensively in the Eastern Cape Region. Pineapple lands are kept clear of all other vegetation for up to 3 years. The pineapple plant itself provides virtually no cover during the first *6 to 9 months in Zululand* and can be considered as providing reasonable resistance to raindrop action only from then on. Heavy rainstorms occurring during this period cause widespread damage.
- In an effort to reduce the movement of disease-carrying ants from one field to another, the roads between fields are often disced with a harrow. This also serves to control weeds, but when the roads are aligned downhill, erosion by runoff is excessive. Again, if the roads are aligned on the approximate contour, but without due regard to disposal of runoff in a controlled manner, erosion can also result.

This guide sets out the various methods of planning mechanical structures for the control of erosion, and explains the biological methods of mulching and minimum tillage developed in the Eastern Cape for even better control of soil and water loss on pineapple fields.

RUNOFF CONTROL PLANNING

The basic requirement for a runoff control plan of any farm is a good map. Use should be made of orthophoto maps, if available, but if they are not, an aerial photo map with a scale of 1:10 000 should be ordered through the local Agricultural Extension Office.

Because the ridging of soils downhill creates such a high erosion hazard it is recommended that great care be taken in determining both soil type and slope in the fields to be planted. Soils of high erodibility on steep slopes should be avoided. Table 1 gives cut-off limits for these two aspects. An important aspect of runoff control planning in pineapple lands therefore, is the determination of soil erodibility as explained in Leaflet No 2.3 entitled ' A Farmers Guide to Surveying Contour Banks.'

There are three recognized types of layouts, and both terrain suitability and the land users' preference will be

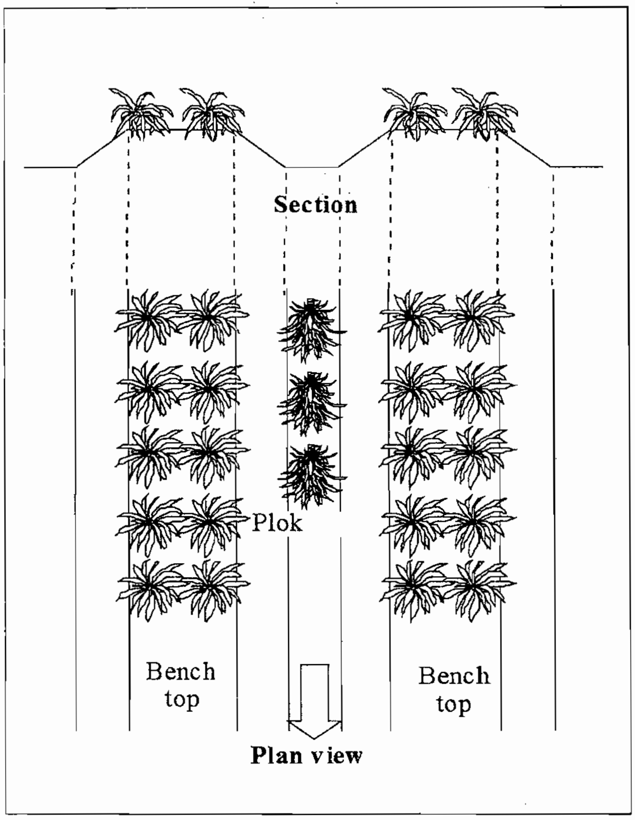

Figure 2. Layout of pineapple ridges with plock in-between

needed to decide upon the specific one to be adopted. Once the decision is made, all natural watercourses and unsuitable areas are marked on the map. The chosen layout is then marked on the map, to scale, in order to plan the field work needed. This will be explained after the principles of the various layouts have been discussed.

LAYOUT OPTIONS

There are three basic layouts which are acceptable to the Department of Agriculture and any one of these layouts may be used, depending on practical implications and the land user's preferences. They are described in increasing order of preference on the part of the authors.

1 THE BLOCK SYSTEM (Figure 3)

The block system comprises narrow artificial waterways, spaced double-boom-length-plus-road-width from edge to edge with service roads between

Table 1. Maximum slopes for pineapple ridges downhill and with spacing as specified, for KwaZulu-Natal conditions

SOIL ERODIBILITY	Maximum slope (%)	
	With mulch	Without mulch
High	10	5
Moderate	15	10
Low	20	15

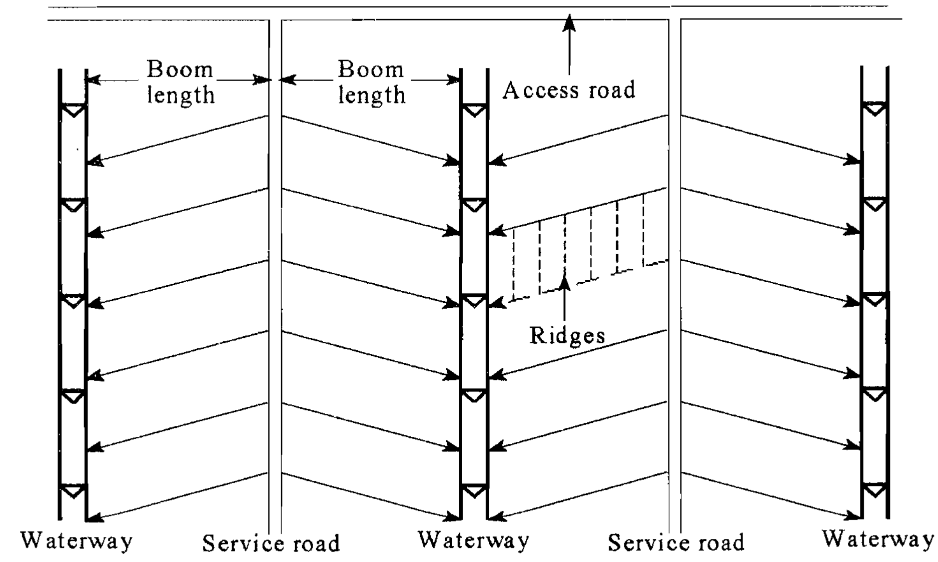

Figure 3. The Block System

them. The blocks run downslope from an access road which is ideally situated on the crest. In the event of the access road not being on the crest, and there being a catchment area and resulting runoff from above the land, provision must be made to protect the land by a system of storm water drains. This is a task for the local Soil Conservation Officer. The waterways must run as closely as possible at right angles to the true contour lines, so that natural flow lines can be maintained. They are kept as straight as possible and parallel to each other to facilitate the application of herbicide and fertilizer by boom spray. The exact distance of one boom length from the centre road to the edge of the waterway ensures that all plants are covered by the boom, and that no double applications are made. This spacing also facilitates mechanical harvesting. When the waterways start deviating from the natural direction of flow because of a change in terrain, the direction of the waterway must be corrected. A V-shaped block is established to correct the problem (See Figure 4). The maximum width between waterways may not exceed double boom length plus roadwidth. Contour banks are measured out and built with a gradient falling from the crest road to the waterway on each side as shown in Figure 3, and the pineapple ridges are constructed in the conventional manner, downhill between the contour banks, with the channels discharging into the contour bank canals.

* **Location of the waterways**
The basic requirement in setting out an artificial waterway is to select a safe discharge point. It must be established that the discharge point is capable of carrying the additional water which is to be discharged onto it, and that it is not prone to erosion. Then:

— A true contour should be set out approximately 100 m long, with pegs approximately 10 metres apart, at the position where the waterway is to discharge. A peg should be selected on the true contour line which is at the centre of the discharge point. If there is no contour line it should be set out at the centre of the discharge point, and in line with the contour lines already set out.

— From this peg, and at right angles to the contour line set out, a line should be marked running up the slope, and the next centre-line peg of the waterway inserted, approximately 25 m away. At this peg the procedure given above should be repeated until the crest or highest point of the land is reached. Each centre peg must be distinctly marked. All the unnecessary pegs should be removed, and it should be confirmed that the position of the waterway on the map is where it was originally planned to be. If not, it must be drawn in the correct position. Dimensions of the waterway are best left to calculation by the local Soil Conservation Officer. The centre line of the first waterway having been set out, the positions of the other waterways needed are set out by tape until the stage is reached where the

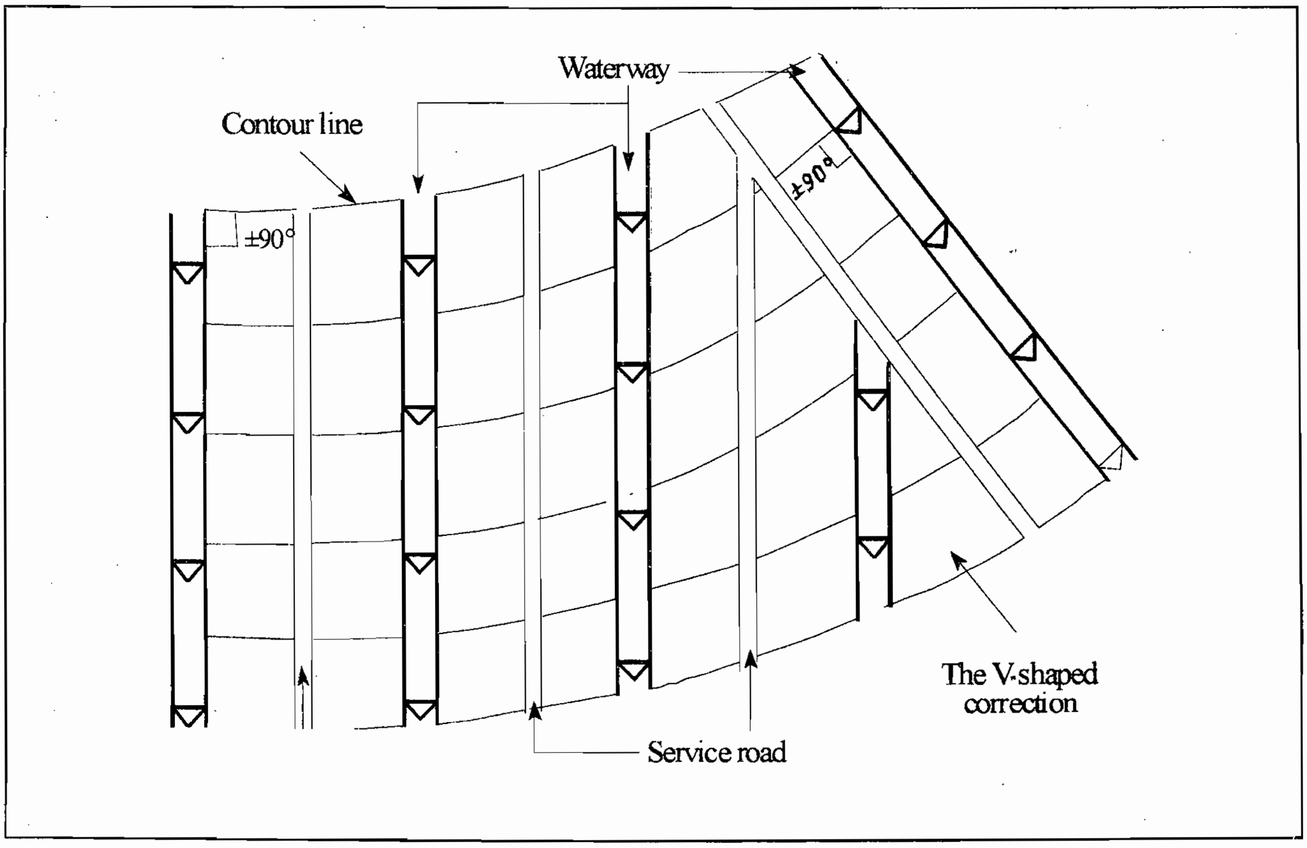

Figure 4. Correcting the Block System

position of the waterway deviates from the flow lines to such an extent that a V-shaped block is required. The distance between the centre line pegs is 2 x length of the actual boom plus the road width plus one waterway width.

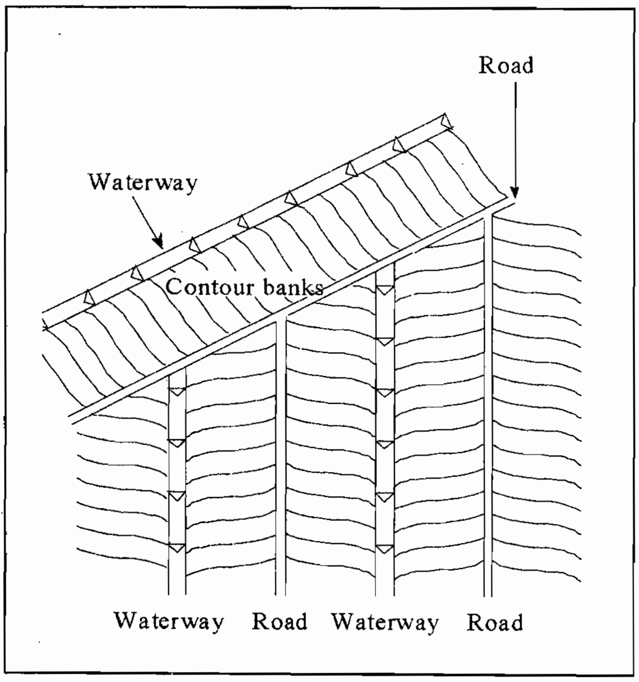

Figure 5. The Block System: another example

2 **THE CONTOUR SYSTEM (Figure 6)**
The contour system of layout is based on the use of the contour banks as service roads, with their spacing restricted to either boom length or multiples of boom length, with service roads parallel to the contour banks in between. The waterways for such a system may be placed at any practical distance apart, but should not exceed the maximum allowable flow length of contour canals for the specific soil series. See Table 2 for maximum flow lengths.

3 **THE CONTOUR BLOCK SYSTEM (Figure 7)**
The contour block system is a layout where the service roads are parallel to one another up and down the slope, with the contour banks spaced in accordance with the specified vertical interval, and with a minimum cross sectional flow space of 0,5 m^2. The maximum flow length of contour banks is as specified in Table 2. The planting ridges in this system form a

Table 2. Maximum flow lengths for contour banks in pineapple fields, for KwaZulu-Natal conditions

SOIL ERODIBILITY	MAXIMUM FLOW LENGTH (m)
Low	300
Moderate	200
High	100

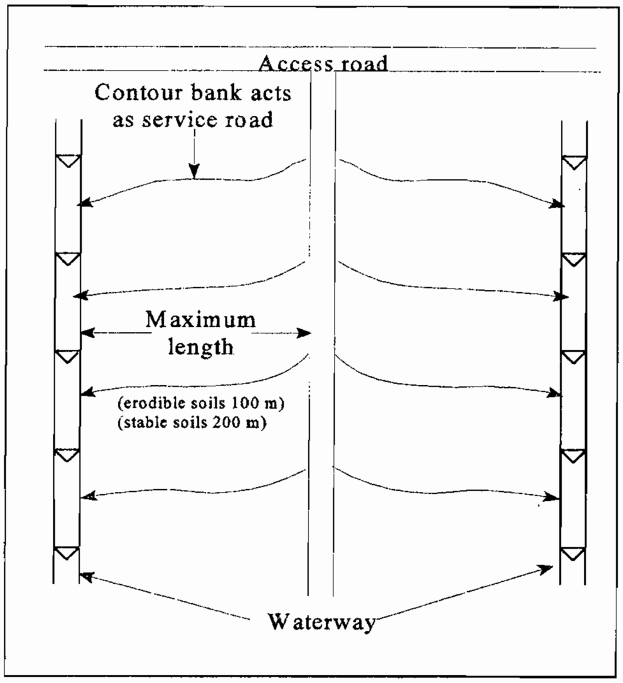

Figure 6. The Contour System

perfect block where the service roads act as a border to each block, as shown in Figure 7. The first action in setting out this system would be to identify and mark the natural watercourses, and then to place the artificial waterways where required. These waterways must be designed and constructed to Departmental specifications, and properly established to a permanent grass cover. This should take place at least one growing season before the rest of the layout is completed. The next step would then be to commence from the watercourse or waterway, and the first service road would be pegged one boom length from the first one and thereafter two boom lengths between each successive road. This eliminates the construction of a service road alongside the waterway, and the problem of poor junctions between contour banks and waterways as a result of damage by implements crossing them. The contour banks are pegged out as described above after the construction of the ridges, or in the case of flat plantings, after the plant markers are laid out. Where the contour banks cross the service roads they are shaped as indicated in Figure 8. What this does in effect is to `flatten' out the contour bank structure and make it more suitable for traffic, while not reducing the flow space in any way. An access road is usually constructed on the crest of the land. If necessary, additional access roads may be constructed according to the layout requirements.

SPACING OF CONTOUR BANKS

Due to the increased erosion hazard of ridging up and down the slope and high rainfall intensities, it is recommended that the spacing of contour banks for pineapple fields as indicated in Table 3 be used to calculate the spacing thereof.

GRADIENT OF CONTOUR BANKS

The gradient should be such that excess runoff is intercepted and discharged into the waterways in a non-erosive manner. The velocity of flow in the canal should not be so high that it erodes the canal lining, but it should also not be so slow that sediment deposition results. The values in Table 4 should be used in pineapple fields.

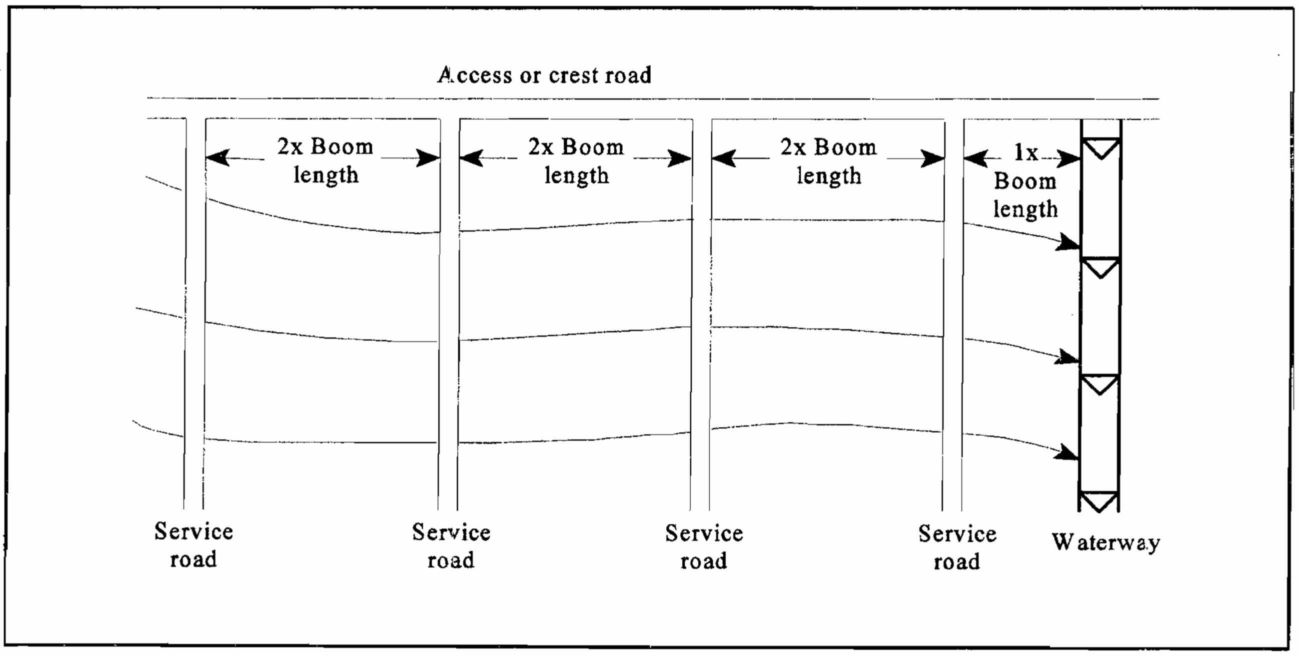

Figure 7.1. The Contour Block System

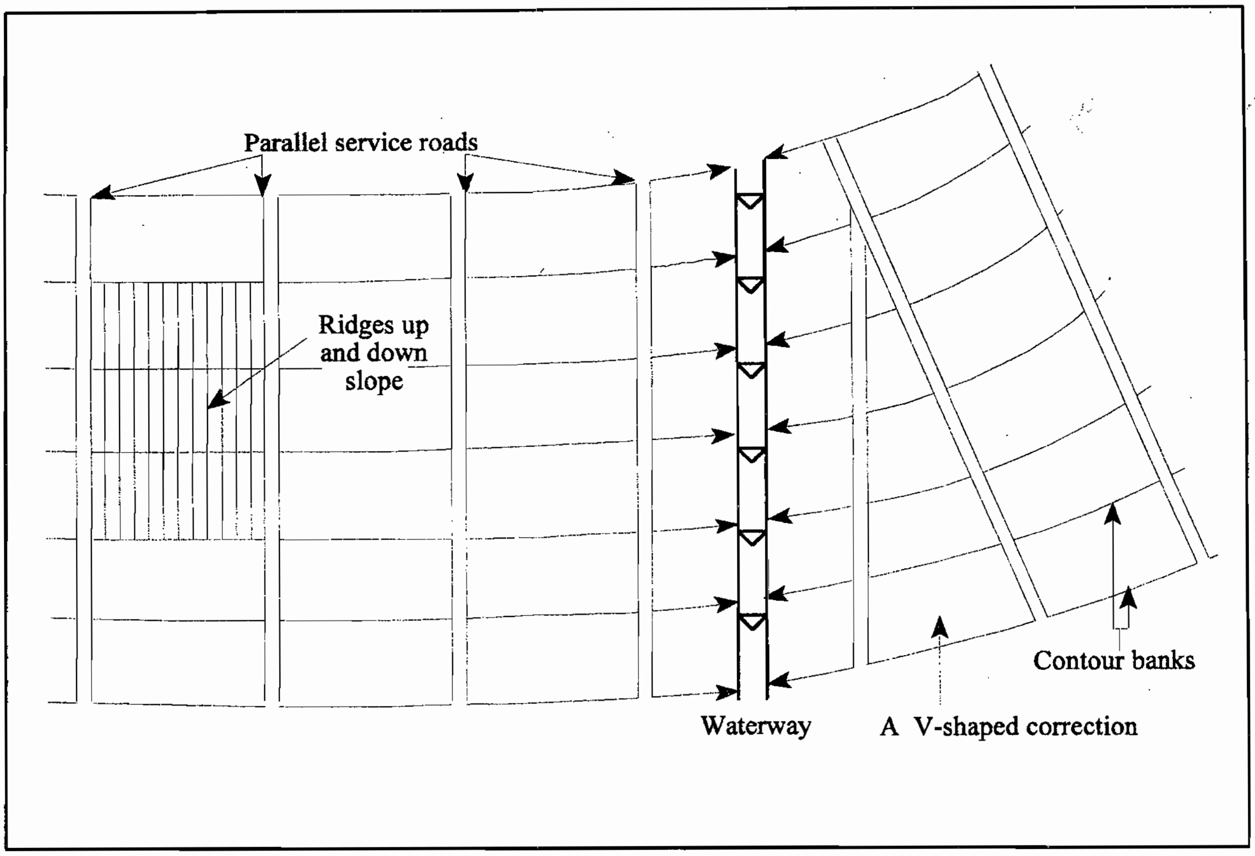

Figure 7.2. The Contour Block System

Table 3. Vertical Interval in metres between contour banks on pineapple lands, for KwaZulu-Natal conditions

SLOPE %	SOIL ERODIBILITY		
	Low	Moderate	High
2	1,30	1,05	0,80
3	1,45	1,20	0,95
4	1,60	1,35	1,10
5	1,75	1,50	1,25
6	1,90	1,65	1,40
7	2,05	1,80	1,55
8	2,20	1,95	1,70
9	2,35	2,10	1,85
10	2,50	2,25	2,00
11	2,65	2,40	2,15
12	2,80	2,55	2,30
13	2,95	2,70	2,45
14	3,10	2,85	2,60
15	3,25	3,00	2,75

Table 4. Maximum gradients (%) for contour banks in pineapple fields, for KwaZulu-Natal conditions

SOIL ERODIBILITY	FLOW LENGTH OF CONTOUR BANKS (m)	
	0 - 150	150 - 300
Low	2	1
Moderate	1,5	1
High	1	-

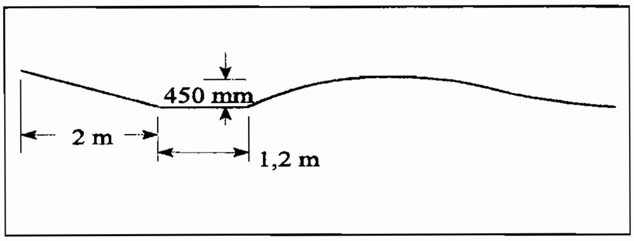

Figure 8.

DIMENSIONS OF CONTOUR BANK CANALS

Contour bank dimensions are determined by the requirements of the layout. The canal which will not be used as a service road must have a minimum cross sectional area of 0,5 m^2. The dimensions of such a contour canal are normally as shown in Figure 9. The contour canal which is used as a service road must make provision for the maximum vehicle width used on the farm. The width would normally be a minimum of 2,5 m. The flow depth will remain the same. Contour canals must be extended partially into service roads so as to divert any runoff water from these service roads into the grassed waterways. Figure 10 indicates the minimum requirements . *Finally it must be stated that the disc harrowing of service roads which are angled downhill should not be practised.*

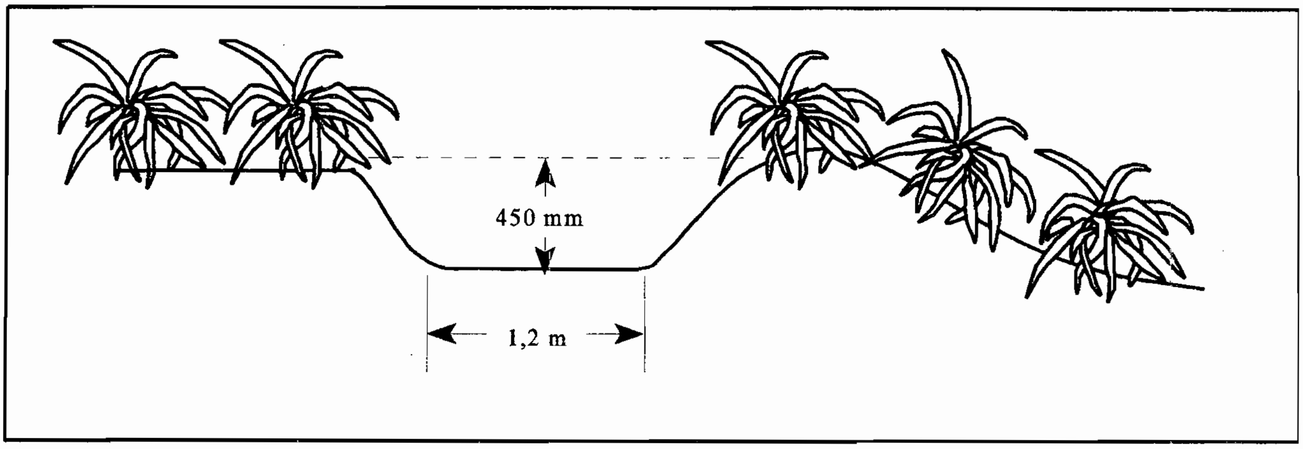

Figure 9. A typical contour bank planted up

BIOLOGICAL MEASURES

Systems of minimum tillage in conjunction with surface mulch, or simply the application of surface mulch in the form of old pineapple plants (called plok) have been developed in the eastern Cape, and have resulted in a dramatic reduction in soil losses. Minimum tillage with surface mulch is carried out as follows:
The old pineapple plants are cut down by means of a bush slasher. This operation is normally carried out in two stages. The slasher first cuts down the top ± 70% of the old plant and then the remainder is slashed.
To clear the existing ridge of old pineapple stumps and root material as well as to loosen the planting area, two systems may be used:

* The ridge is cultivated by means of a rotary cultivator to loosen the soil and at the same time remove old plant stumps and roots from the ridge crest, or else
* the ridge is cultivated by means of a small rotovator, to create a proper plant tilth on the ridge crest. If necessary the ridge may also be ripped before marking, planting and rolling.

On new layouts, the most practical means of providing the required plant material cover is to utilise old plants. Whole plants are removed and taken to the new layout and packed in the canals between the ridges with the stem (root section) pointing up slope. This method of placing old plants is recommended so as to ensure that the leaf section acts as an anchor. The rate of plok application is dependant on the erodibility of the soil and the slope of the land. Experimental work is at present being carried out on this aspect. It is recommended that on slopes of up to 10% and on fairly erodible soils, plants be packed in such a way that they just touch each other or overlap. It is advisable, although rather more labour intensive, to rest the stem or root section of one plant on the leaves of the adjacent plant to discourage volunteer growth as much as possible. Field trial results show that on steeply sloping erodible soils at East London, soil losses can be reduced by up to 30 times on fields packed with plok in the canals compared to those without it.

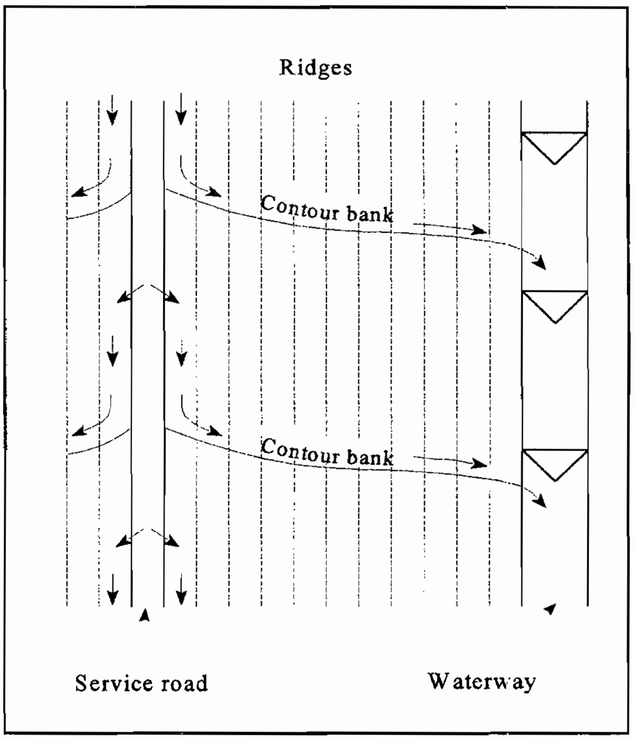

Figure 10. The tie-up between the service road and the contour bank

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Conservation of Farmland in KwaZulu-Natal

BENCH TERRACING

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INTRODUCTION

Contour banks, in conjunction with a properly designed system of grass leys and/or conservation tillage techniques on an annually cropped land, can contain soil losses within acceptable limits on many soil types up to a maximum slope of 12% to 15%, dependent upon soil erodibility, rainfall erosivity and the crop planted. On slopes in excess of this figure, however, and especially on the more erodible soils, it is virtually impossible to achieve this aim. Not only are contour banks of the necessary capacity difficult to construct and maintain on these slopes, but a real danger exists of rapid accumulation of sediment in the channel behind the structures due to soil movement between them. Crop residue left on the surface can also be washed into the channels, and generally the danger of breaching increases with an increase in slope. A further problem lies in the concentration of runoff from conventionally cultivated lands when contour banks discharge their load into the discharge areas on these steep slopes. Not only are the runoff velocities on these slopes then generally excessive and difficult to control, but the increased water loss from the cultivated land area means a low effective rainfall and, therefore, relatively lower crop yields. Where the techniques of no till and permanent cover crops are either unpractical or insufficient in themselves to to a tolerable level, or the competition for moisture rules out the use of a cover crop, the only long-term solution for cropping steep slopes is to reduce both the degree and the length of slope by means of bench terraces. See Figure 1. These structures may, in fact, also be considered on flatter slopes where flood irrigation is practised. There are certain problems encountered in the planning and design of bench terraces, however, and these are discussed on the following pages.

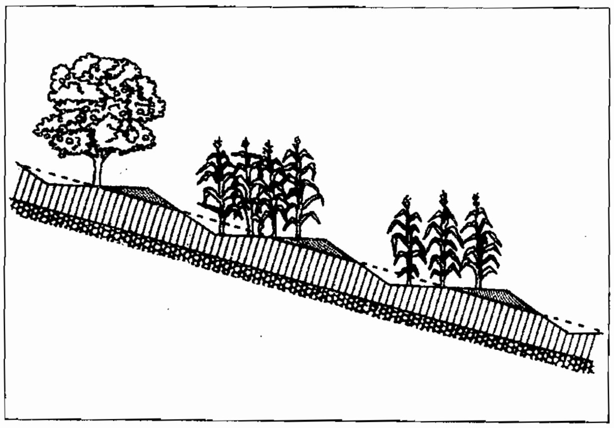

Figure 1. Cross section showing benched effect

TYPES OF BENCH TERRACES (See Figure 2)

Bench terraces can be divided into four types, and Figure 2 shows their various cross-sectional views.

* Absorption or Level Terraces. These are constructed exactly on the contour and provided with sufficient freeboard so that they can trap all the rain that falls. Their cross section may be level, with a small edge wall providing the freeboard, they may have a reverse slope to provide the freeboard, or they may have a combination of both. They are principally used in dry areas where rainfall is low and moisture for crop production is, therefore, at a premium. Latterly, they are also being constructed in some timber areas where rainfall, although high, is marginal for timber production. The precaution here is that their construction on hillslopes will result in periodic saturation of the soil profile, and if a smooth interface is present underground between the soil mantle and the underlying parent material, conditions are created for a landslide to occur. ***Absorption terraces should therefore only be constructed after a very detailed soil survey has indicated soil suitability, and that the parent material is highly weathered rock. Where they are built for the growing of high water-use crops like timber the danger of sliding is somewhat reduced because of the generally dry profile they cause. Trees also assist in anchoring the bench to***

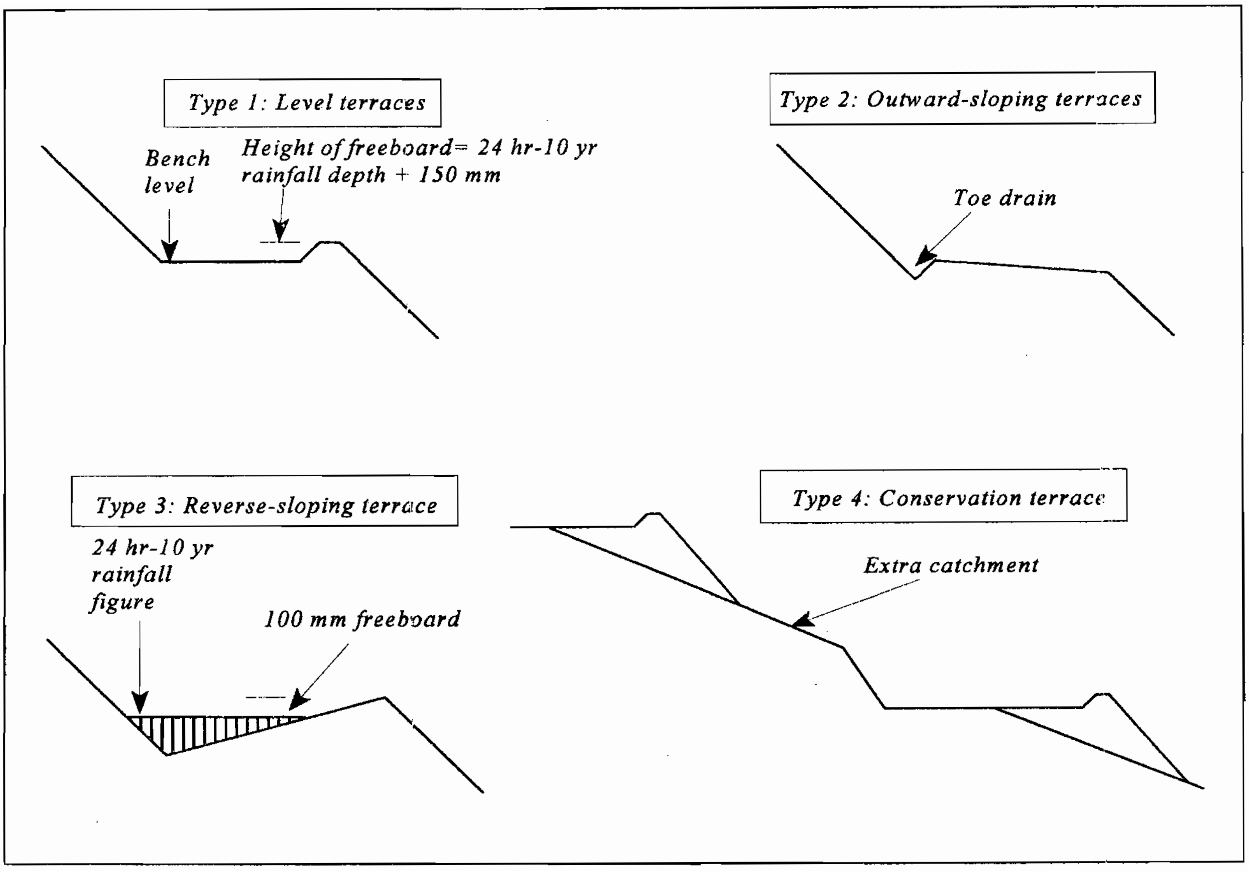

Figure 2. Types of bench terraces

the sub-soil. It may be necessary to install a system of drains at the toe of each fill in order to make the structures safe against sliding. This is discussed in more detail later.

* Outward-sloping terraces, also called spillover roads in the sugar industry, are possibly the most stable of structures ***if the idea is only to slow down the rate of overland flow by runoff, and a sod-forming grass or timber is to be cropped.*** They are, like the previous type, also set out on the level, although no harm should occur if they are given a gradient towards a suitable discharge area. They will also be suitable for framing the layout of orchards on steep slopes, and provide for effective erosion control if they are used for infield traffic routing. Great care must be taken to stabilize the back slope, as excess water from the platform necessarily flows down it into the toe drain on the next bench. The toe drain, if it is constructed on a slight gradient, will intercept the runoff and divert it to a safe disposal point.
* Reverse-sloping terraces are probably the most widely-used of the four. As indicated in Figure 2, excessive rainfall can move to the toe drain, and because it is provided with a lateral gradient, the runoff can move along the toe drain to the discharge point. ***The chances of super-saturation of the profile are, therefore, reduced, although any instability of the back slope adjoining the toe drain which leads to slumping could lead to blockage of the drain and overtopping of the structure behind the blockage. It is once again emphasised, therefore, that wherever a gradient is given to a terrace, extra special care must be taken in stabilizing the back slope.*** Stabilization of the back slope is discussed later.
* Conservation bench terraces are, in fact, a modified form of level terrace, and constructed in areas where soil moisture is extremely limiting. In surveying them, an uncropped area immediately upslope of the structure is made available for contributing extra moisture to the bench by runoff. ***The design of the freeboard of the bench must take account of this extra water, as overtopping could result in large scale damage.***

SITE SUITABILITY FOR BENCH TERRACES

Special reference has been made to site suitability in the preceding paragraphs. The following are general considerations when planning a system of terraces.

Soil depth and land slope

The most important limitation to the construction of terraces is, naturally, lack of soil depth. Bearing in mind that the construction will be a cut-and-fill operation with a view to growing crops on the platform, the end product should have an effective soil depth of not less than 500 mm. The minimum effective soil depth for the site on which terraces are planned will, therefore, be a function of terrace width required and land slope, *i.e.*, the wider

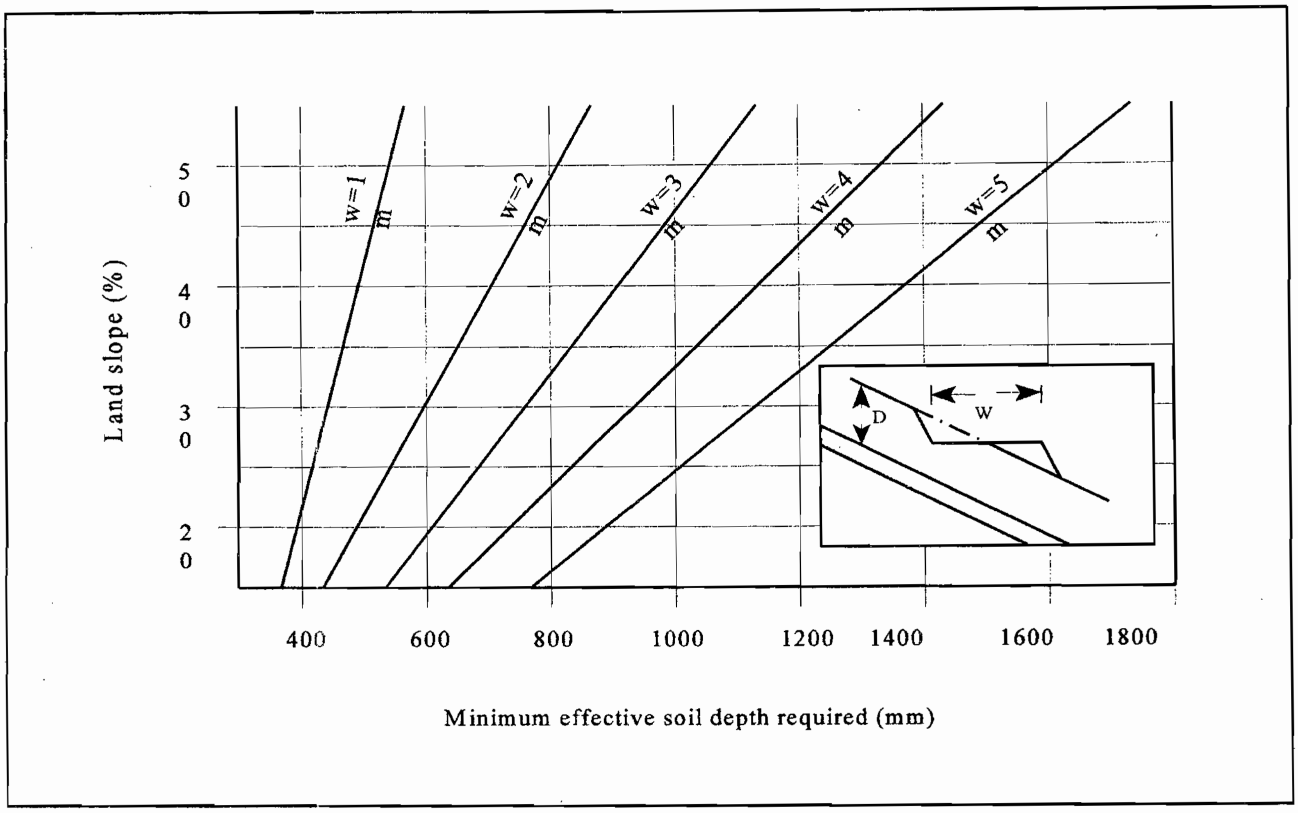

Figure 3. Soil depth necessary for a given bench terrace width

the terrace the deeper the soil will have to be and, similarly, the steeper the land slope, the deeper the required effective depth. The width of terrace is a function of type of crop to be grown and the type (width) of machinery to be used on the terraces.

The formula for determining the required minimum soil depth is based on the assumption that the width of the cut equals the width of fill. The formula is, therefore, expressed as:

$$D = (\frac{width}{2}) * (\frac{\% slope}{100}) + 0,5\ m$$

Figure 3 is provided to simplify the calculation. If the parent material is reasonably weathered, it may be possible, once the bench has been cut and shaped, to deep rip and so create a deeper effective rooting depth.

Implement widths

In choosing a width it is important to make allowance for mechanization. The width of a terrace should be chosen in multiples of implement width plus an extra width for the toe drain, if needed.

Maximum land slope

If soil depth is not limiting, the whole problem is an engineering one involving stabilization of the back slope, the safe disposal of excess runoff water and the economics of the project. The back slope may be stabilized with either vegetation, stone pitching or, taking it to the extreme, with a properly designed vertically-faced retaining wall of brick, stone masonry or concrete. The latter may prove to be too expensive for the normal agricultural situation, but if recourse should be made to this method the reader is referred to a qualified civil engineer for the design of retaining walls. The more near vertical the back slope is made, the less land area is lost to production, and the lower the runoff which must be catered for in graded terraces. Figure 4 shows the various methods of back slope stabilization, while Figure 5 examines the area lost to production on a range of land slopes when the back slope is varied.

Table 1. Recommended back slopes based on soil texture and method of stabilization

Soil type	Angle of repose in degrees	Vegetated slope	Stone pitched slope
		Vertical : horizontal	
Loam	65	1 : ⅔	1 : ½
Clay loam	70	1 : ½	1 : ⅓
Clay	45	1 : 1	1 : 1

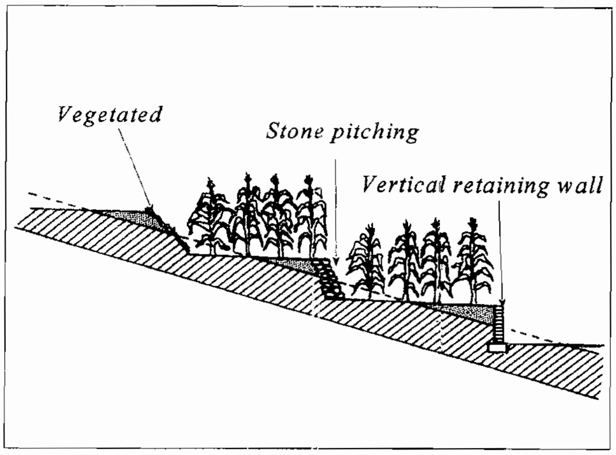

Figure 4. Types of backslope stabilization

Vegetated and stone-pitched back slopes

Depending on soil texture and degree of wetness, different soil types have different angles of repose, which in turn has a bearing on the maximum steepness to which the back slope may be constructed. Table 1 sets out the recommended angles for stable back slopes. These angles apply to cuts and fills that are properly compacted, a climatically suitable plant species used for stabilizing vegetated back slopes and, in the case of graded benches, satisfactory drainage ensured by smoothing out high and low spots.

Where vegetated back slopes are used, the species chosen will depend on soil type and climate, but preference should be given to low growing, sod-forming grasses. This will reduce maintenance costs and provide a modicum of protection should the terraces overtop during a heavy storm. Where stone pitching is used, it should be a minimum of 300 mm thick. ***It is once again emphasised that one of the major problems that can develop in a system of graded bench terraces is for the back slope to become unstable, collapse, and block the toe drain of the terrace below. Correct decisions on stabilizing the back slopes, the proper construction thereof and the need to drain the fill are therefore vital considerations in the design of terrace systems.***

In trials on a clay loam where terraces have been constructed for timber planting, a standard 1 : $^1/_2$ (vertical to horizontal) has been found adequate, provided weed control was carried out with a view to maintaining a plant or trash cover on the back slope until the establishment of the tree canopy and build-up of litter takes over the task of soil protection.

Slope measurement

Finally, when land slopes are determined ***en situ*** instead of from a topographical map, height difference is normally measured over ***slope distance*** and not, as it should be, over ***horizontal distance***. On slopes in excess of 20% this can lead to an appreciable error. Figure 6 enables the determination, over a range of slopes, of the correct percentage slope when height difference is measured over a standard twenty metres slope distance.

RUNOFF DISPOSAL

On well drained sites and in low rainfall areas, the structures can be planned and designed to capture and store all precipitation, thus improving rainfall efficiency. In this case the terraces would be constructed level in both directions with an emergency spillway to protect the system during periods of abnormally high precipitation rates. The need for a well protected disposal point is then not so great and may, therefore, not be a limiting factor. In high rainfall areas, however, and/or in areas of restricted drainage, the design must make allowance for removing excess rainwater to a suitable discharge point. The steeper the terrain and the more unstable the soil type, the greater will be the problem in coping with storm

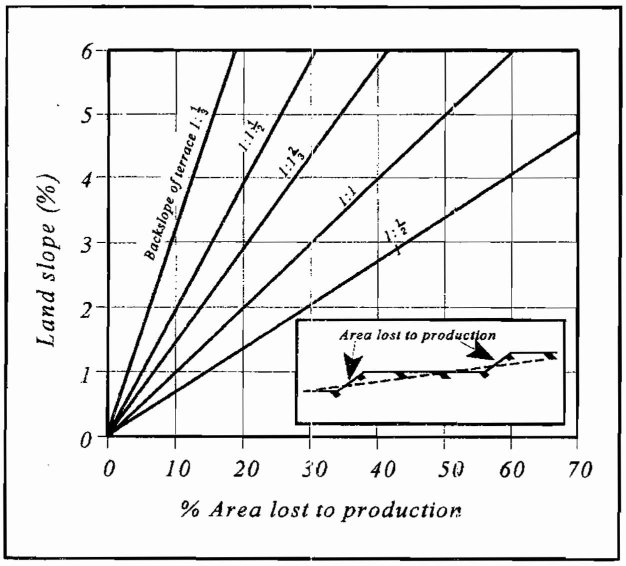

Figure 5. Relationship between terrace and back-slope and the area lost to production on different land slopes

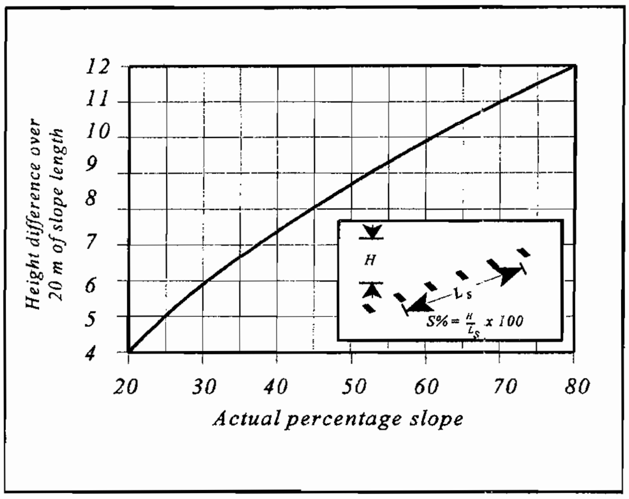

Figure 6. Determination of land slope on steep slopes

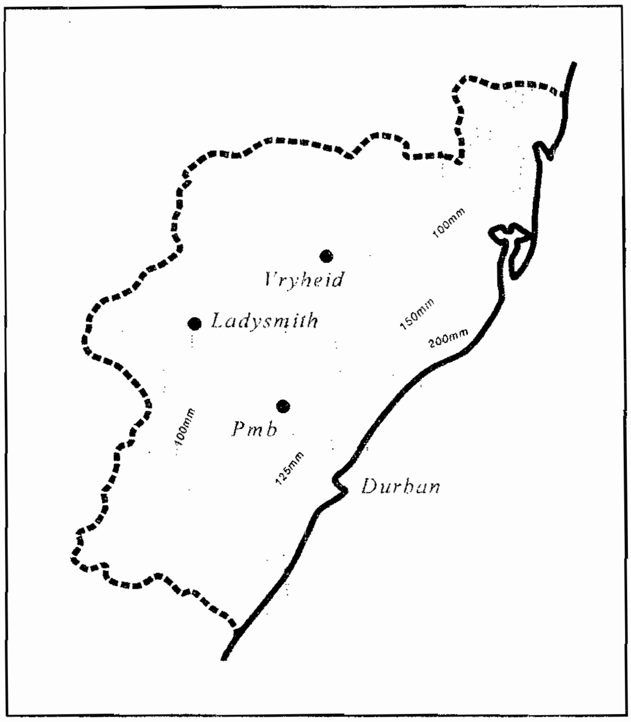

Figure 7. 24 hr-10 year rainfall frequency zones of KwaZulu-Natal for a 10 year return period. (Schulze and Arnold 1979, modified)

runoff. Grassed waterways can only be used on steeper slopes under very favourable conditions. Under less favourable conditions and in areas of low and/or winter rainfall, waterways lined with concrete or masonry may be required. Another possibility which is dealt with in the next section is the use of piped drainage or the so-called tile outlets. This will, of course, increase the cost of the system over that of conventional systems, but they have been used to good effect in many countries. The value of the crop to be planted will determine whether an expensive but foolproof disposal system is feasible or not.

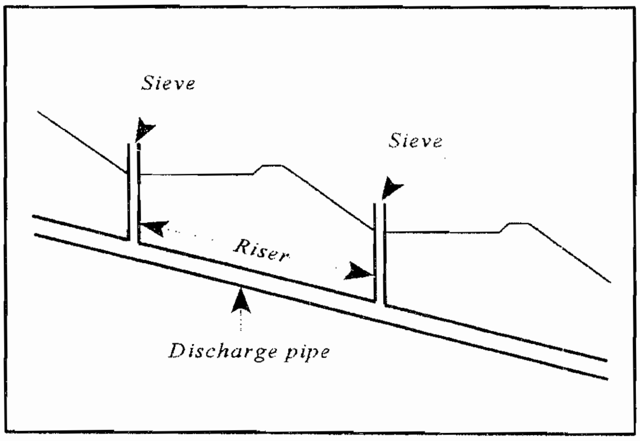

Figure 8. Bench terrace with tile outlets

HYDRAULIC DESIGN

Level or absorption terraces: Level terraces are constructed in low rainfall areas in order to trap as much precipitation as possible, and to store it in the subsoil in order to make it available to plants after the rains have ceased. Level terraces are, therefore, designed as small shallow dams built on the contour in order to store precipitation on the surface until it can infiltrate into the soil profile. The depth of surface storage is, therefore, a function of maximum expected rainfall and the infiltration rate of the soil. ***It is suggested that the maximum 24-hour rainfall for a ten year frequency occurrence be used as a basis for determining the capacity of level terraces.*** The rainfall depth which should be used for any specific region in KwaZulu-Natal is shown in Figure 7. The height of the retaining bank (see Figure 2) should be the 24-hour rainfall depth plus 150 mm freeboard. The emergency discharge point is then built up to a rainfall storage depth only. Any rainfall event greater than that designed for will overflow into the emergency waterway.

Graded terraces : The method of design for a gradient is complicated and needs the expertise of a trained engineer or technician. In view of the damage that could be caused if the structures overtop, the reader is earnestly referred to a competent designer such as the local Soil Conservation Officer. Design must take cognisance of rainfall intensity and frequency, of soil type, length of terrace, and crop grown. The slope of the terrace can vary between 0,5% and 2%, and the gradient chosen can in fact also be varied in an effort to make the benches parallel.

Tile outlets: Where for various reasons a normal grassed or otherwise lined waterway is not feasible, a tile outlet may be suitable. In this instance the terrace is constructed on the contour, as for a level terrace. The bench acts as a temporary storage dam and the discharge

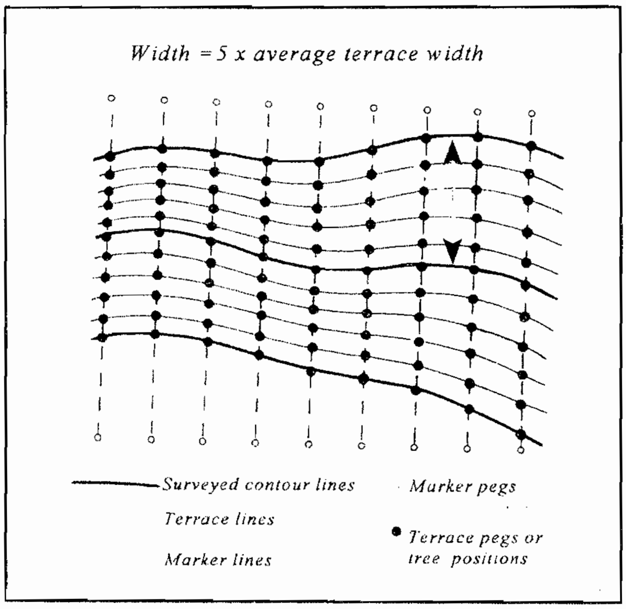

Figure 9. Laying out irregular terraces

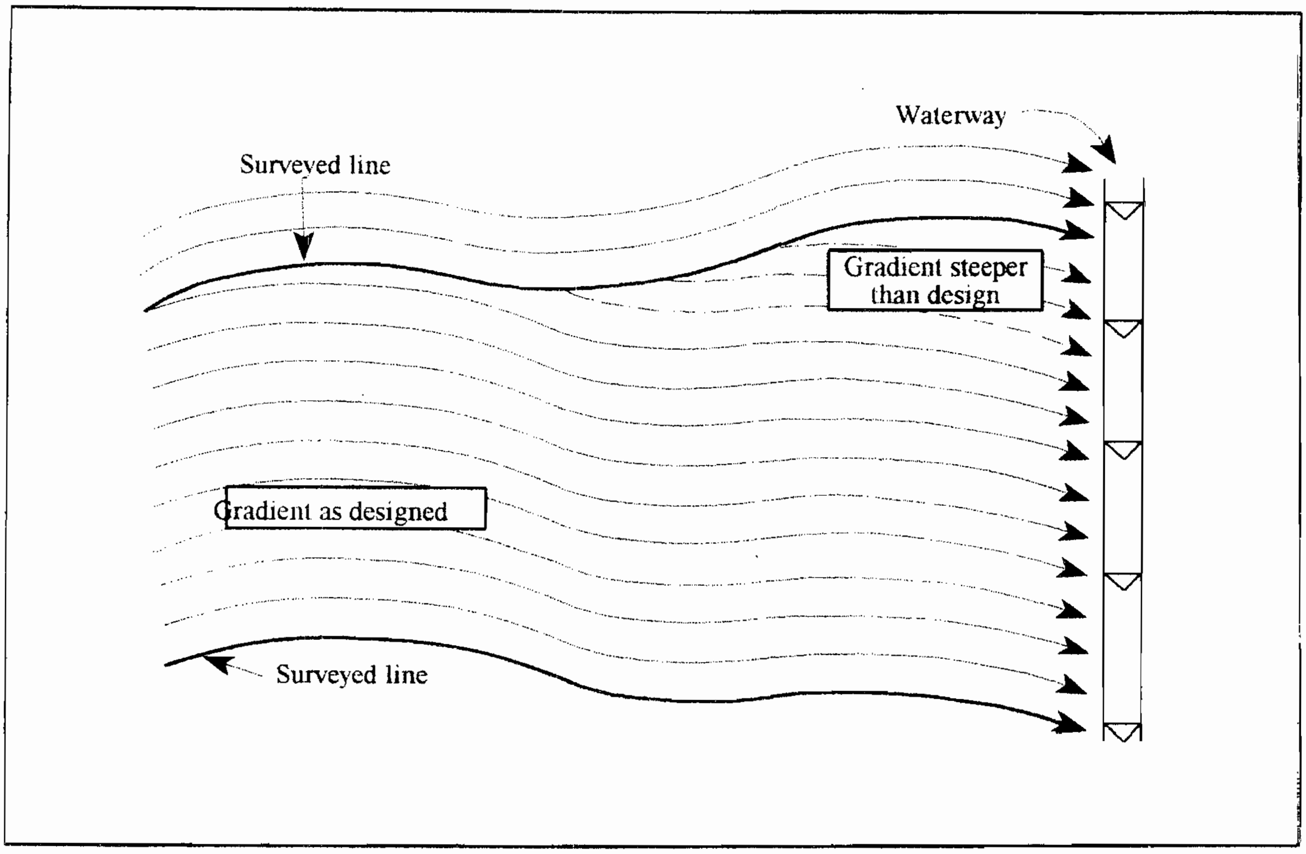

Figure 10. Laying out parallel terraces

point is an underground pipe (plastic, concrete, clay or asbestos). Runoff enters it by way of a riser at each bench. Design procedure is the same as that for a gravity pipeline which will draw off all stored runoff within 12 hours (see Figure 8). Design considerations will require that the underground pipe increases in diameter as the catchment area (*i.e.* area of terraces) increases down the slope. The pipe must be buried below cultivation depth. Further economy can be realized by reducing the total 24-hour rainfall depth according to the expected infiltration rate of the soil profile involved, as illustrated in the following example:

If the bench is 300 metres long by 4 metres wide and the expected 24-hour rainfall is 150 mm, the total rainfall to be catered for is therefore 180 cubic metres. If the final (minimum) infiltration rate is 5 mm per hour, this constitutes a volume of water over 12 hours of 72 cubic metres. The adjusted runoff to be catered for is, therefore, 108 cubic metres over 12 hours, or 2,5 litres per second in respect of each terrace, instead of 4,2 litres per second. This will constitute a considerable saving in the cost of piping.

Draining the toe : Where saturation of the benches could result in the possibility of a slip circle forming on the back slope, an engineer must be called in to design a suitable drainage system.

THE PLANNING AND SURVEY OF BENCH TERRACES

The purpose of this leaflet is to make the reader aware of the pros and cons of benching steep land. Considering the erosion hazard which is created when large amounts of runoff are either entrapped or intercepted and concentrated on steep slopes, the reader is referred to a suitably trained person to assist in the overall planning and design of the bench terrace system. Figures 9 and 10 merely show how a final layout will look. The latter figure indicates how land area can be saved from wastage when gradients are allowed to vary in order to make the benches parallel.

BENCH TERRACE COSTS

The costs that will be incurred in constructing terraces is largely a function of:

* width of terrace,
* slope of land,
* type of protection required for the back slope, and
* construction machinery.

If no expensive retaining walls are required, the width of terrace is the overruling aspect influencing cost. The work required for moving earth is a function of the volume and the distance to be moved. Thus, the cost varies with the third power of the width per unit ***length*** of terrace and with the second power of the width per unit ***area*** of land. See Figure 11. ***From an economic point of view, therefore, the width of terrace should be made as narrow as possible.*** This will have the added benefit of

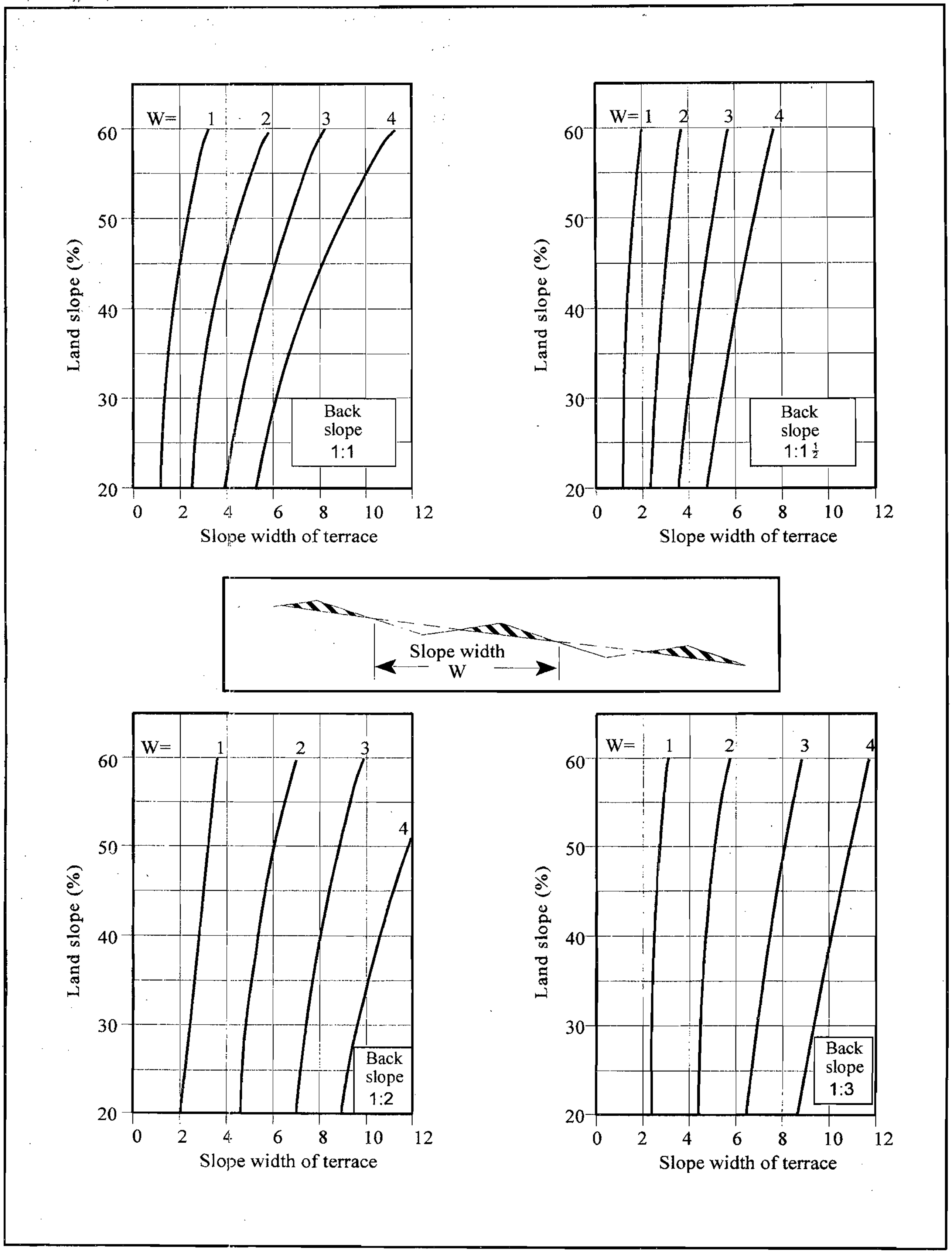

Figure 11. Slope width of bench terraces (dimensions in metres)

making the runoff intensity, which has to be accounted for in graded terraces, the absolute minimum as well. Implements for the construction of benches are dealt with below.

CONSTRUCTION OF BENCH TERRACES

Terraces can be built with either a plough or a bulldozer (see Figure 12). The latter can be very expensive if a contractor has to be hired. If the former is used in conjunction with a tractor, the steeper the slope of the land, the more dangerous it becomes in terms of vehicle overturning. On slopes in excess of 30% it is preferable to use a bulldozer, but if finances are limiting, then the initial work could be carried out with animal power in order to create an initial platform on which a tractor can work more safely. In the construction process one starts at the upper end of the field and moves downslope from one bench to another.

The plough: One has the choice of animal or tractor power, with the precautions mentioned above. The plough however should be a reversible type, otherwise the job becomes too costly, as all work entails moving soil downslope. A fixed-direction plough would therefore require that the return trip is made without working. With animal power, preference should be given to a mule or donkey instead of oxen. Whichever is used, the size of plough must be suited to the motive power and must be in proper adjustment. In surveying the terraces, two lines per terrace will have been marked: the top of the cut (the C line) and the bottom of the fill line (the F line). A start is made by ploughing along the F line, turning the sod downslope. With the return journey the plough has been reversed and the cut of the ploughshare still turns the sod downslope. This process is continued until the C line is reached. The procedure is repeated from just above the F line to just below the C line, and repeated again, and as often as is needed in order to create a bench of the desired width, with a cut-face upslope of the bench and a fill-face downslope of the bench. Construction continues to move soil outwards until the platform has the required reverse slope back into the hillside if this is a design requirement. Repeated traffic over the fill has, in the meantime, helped to compact the platform, and the freeboard depth at the heel makes allowance for flow depth when runoff moves off it. Where level terraces are constructed, the bench should be finished off level in both length and width. Both graded and level terraces must be protected from overtopping by building a small bank on the edge of the bench. In the case of the reverse sloped terrace, it is a bank 150 mm high to provide dry freeboard, the depth caused by the reverse slope on the platform having provided the wet freeboard. In the case of the level terrace, the bank should be expected to take the maximum 24-hour rainfall plus 150 mm dry freeboard (see Figure 7).

The back slope is trimmed by hand to the required slope and stabilized either by spot planting vegetation or by packing stone, as decided upon during the design stage. In the event of upright retaining walls, these will have been constructed prior to earthmoving. Regular maintenance of both the freeboard bank at the edge of the bench and the back slopes are very important. If the latter is stabilized with grass it must be kept in good condition by regular slashing, or the very judicious use of a contact herbicide. Should ponding occur at the heel of the bench, a furrow must be ploughed along it in order to assist drainage.

The following bench downslope is then constructed with the previous F line being the new C line, and with a new F line marked parallel, the necessary construction width downslope.

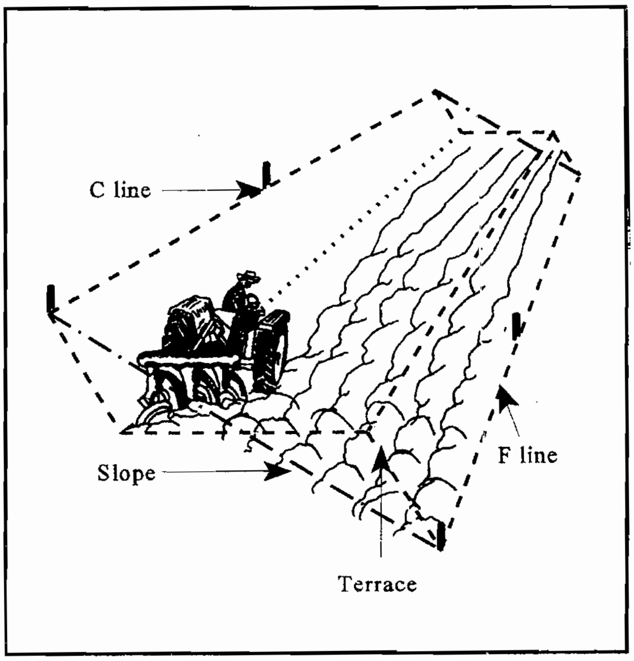

Figure 12. Construction using a disc plough

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WETLAND DEVELOPMENT: THE RIDGE-AND-FURROW SYSTEM

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INTRODUCTION

This leaflet is compiled from the original guide drawn up by the authors in 1977. Sections of the original have been omitted as being superfluous to the aims of this leaflet, while retaining sufficient information in order to assist the land user in implementing a ridge-and-furrow system on his farm. Sufficient background information to planning criteria is given, however, in order to acquaint the land user with the basic requirements. Where the problem area lies in or near a flood plain, and where an increased erosion hazard will result from the drainage, the services of the local soil conservation officer should be sought. *In this context too, the attention of the reader is urgently drawn to the need for anyone contemplating the drainage and development of a true wetland or vlei to approach his local government extension office for a permit to do so.* Regulation 7 of the Conservation of Agricultural Resources Act (No. 43/1983) controls the development of all forms of wetland. It is an offence in terms of the said Act to carry out any modification of existing wetlands without the necessary permission to do so. This guideline will be issued along with any permit granted by the Director of Resource Conservation. An application for permission to drain a wetland may be made either to the local agricultural extension officer or to the Chairman, Wetlands Advisory Committee, c/o the KwaZulu-Natal Department of Agriculture, P/Bag X9059, Pietermaritzburg 3200. A thorough investigation of the site and its catchment area will then be made in order to determine what environmental impact development of the wetland will have. All those public authorities having an interest in water and environmental conservation are given the opportunity to comment on the application. Their comments are collated and passed to the Director, Resource Conservation, who is the final arbiter and the permit authority appointed in terms of Act 43/1983 to decide on such matters.

ADVANTAGES OF THE RIDGE-AND-FURROW SYSTEM

To be successful, any soil conservation system must enjoy unreserved farmer co-operation. Any system requiring special skills and equipment for its maintenance, and even its construction, is unlikely to receive the support it should have. With this in mind, the following advantages of ridge-and-furrow are significant:

* within specified limits of length and gradient, ridge-and-furrow is a self-contained soil protection and drainage work whose construction and maintenance are entirely farmer type operations, thus obliging the farmer to participate fully in a permanent, effective system for soil and water conservation and drainage, simply because the system is an essential part of farming practice;
* the layout is fixed, and thus protection is permanent. There is no stage at which land is vulnerable because design criteria are based on bare soil, and ridges are permanent. All agricultural operations are facilitated because land is in units or blocks which do not vary in width;
* the furrow is the drainage unit (Figure 1). Not only does it shed surface runoff when this occurs, but it also prevents the water table from rising too high, adversely affecting crop growth. The furrow capacity is such that even a slight furrow gradient will discharge a large volume of water. Depending on the soil type, therefore, a variable furrow gradient with wide limits may often be permissible. This will enable considerable straightening and paralleling to be achieved, thus reducing the disadvantages that occur with traditional contour bank systems;
* although crops grown on ridges will benefit from land smoothing, <u>ponding</u>, a severe limiting factor under normal field conditions where impeded drainage occurs, will be eliminated;

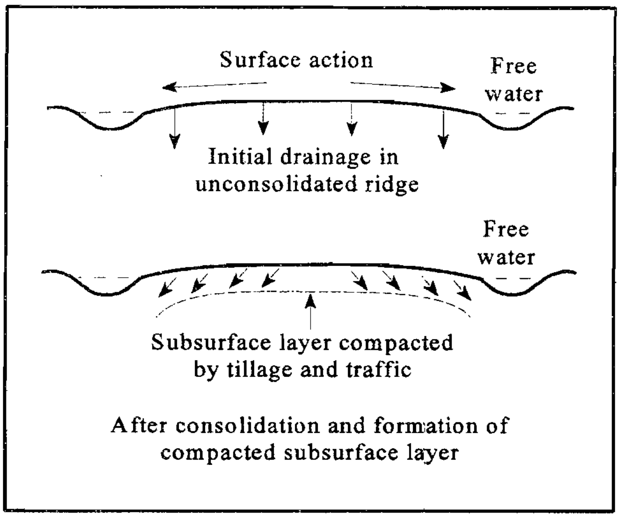


Figure 1. The drainage action in a ridge

* more rapid surface drying after rain permits earlier and more effective agricultural operations, and in particular the cheaper mechanical control of weeds and vital plant protection spraying. It also ensures more uniform (and higher) soil temperatures.
* *The water table is lowered and controlled in a ridge-and-furrow system,* yet plants can make use of the subsurface moisture during dry periods.
* A subsurface cambered base is induced at a depth of approximately 500 mm through tillage . This assists in drainage when the land is saturated by prolonged rains.
* A cheap, simple method of flood irrigation entails the construction of a furrow along the crest of the ridge. Blocking the flow of water will allow simultaneous flooding of both shoulders of the ridge if the job is done properly.

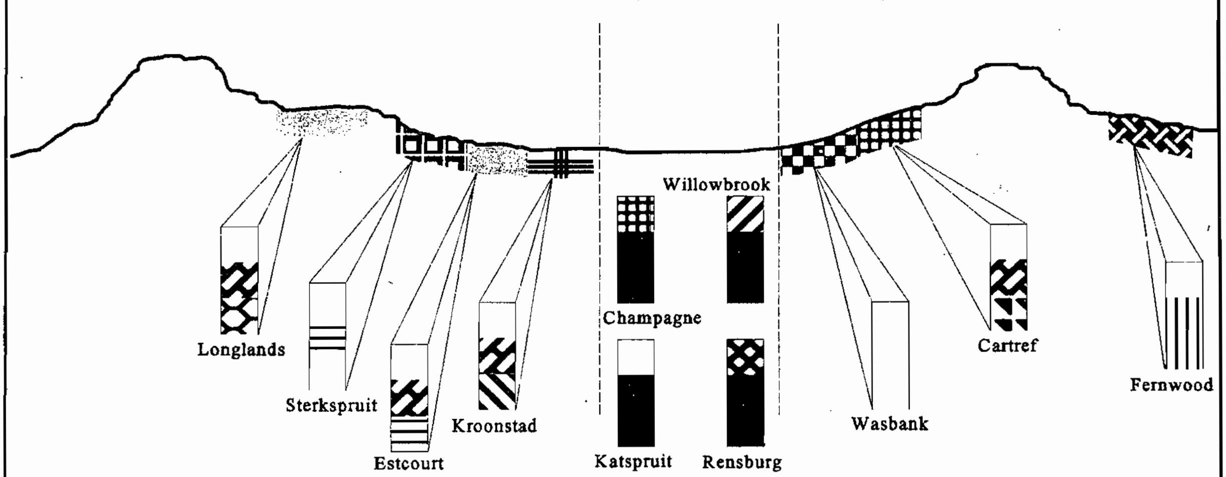
In addition to these specified advantages, the following benefits of a general nature may be anticipated:-

* so-called marginal land is transformed into land of fairly high production potential,
* higher yields and nett profit margins can be expected,
* flood damage is reduced or may be eliminated if the layout is designed correctly,
* access is improved and maintenance cost is low, and
* where conditions favour development of saline conditions, it is likely that this hazard will be curtailed, if not prevented, with ridge-and-furrow.

PLANNING RIDGE-AND-FURROW DEVELOPMENT

Important basic principles include:-

* **The need for a thorough survey and assessment.** The meaningful development of any particular or problem area cannot be planned without first making a thorough assessment of *all factors*. These include soils, topography, climate, rainfall, runoff potential, flooding hazard, vegetation, current and future land use and the requirements of capital and management. For this a careful inspection of all available records, maps and aerial photographs should be made and a close inspection of field conditions undertaken. The farmer himself is likely to have valuable information of the extent of the drainage problem and the benefits of his experience should also be used. Rarely is there a precise boundary between poorly-drained and well-drained land. Usually there is an intermediate zone, of varying width, with drainage changing from one extreme to the other on either side. For this reason, and because soil protection and drainage measures applicable to poorly-drained and well-drained land must be merged to form a workable whole, studies should extend well beyond the problem boundary.
* **Consider the catchment as a whole.** *The development of wet agricultural land should be seen as part of an overall catchment plan.* This is especially important when considering bottomlands. From the hydrological point of view the catchment, or sub-catchment, is a logical unit for providing a master plan. *Wetland development that fails to consider land use practices, the state of conservation, and the scope for water storage projects throughout the entire catchment area, albeit on one farm or many farms, is likely to engender problems.* It is imperative therefore that the planner look beyond the boundaries of the wetland itself and consider the catchment in its entirety.
* **Treat each wetland on its own merit.** Wetlands are unique entities in a landscape, each of which has very different characteristics, agricultural potential, problems and management needs. Thus no standard plan may ever be formulated to meet all contingencies. It should be appreciated therefore that each development project will pose its own problems and necessary solutions. The scope for development could vary considerably on one and the same farm. It should be remembered that factors other than natural characteristics, including economic considerations, pollution hazard, the need for conservation of wildlife and the attitude of the owner, will also influence the final choice of development strategies. There should be a rational approach in the selection of alternate uses for each wetland.
* **Wetland development is an integral part of the farm plan.** Wetland development, as for any development work, will have an impact upon other farm enterprises. It will require additional inputs of capital, labour, machinery and management, all of which must be viewed in relation to the needs of the other enterprises. It must be appreciated, however, that once the initial development operations are completed, costs are as for normal arable production. In fact the total development effort will be similar to breaking up a heavy turf.



Diagnostic topsoil horizons

Organic	Deep black horizon of over 10% organic carbon
Melanic	Dark, well structured, with high base status
Vertic	Black, strongly structured and expansive topsoil
Orthic	Normal topsoil. Does not qualify as any other diagnostic horizon

Diagnostic subsoil horizons

E-Horizon	Grey, gleyed horizon, second in vertical sequence
G-Horizon	Dense, strongly gleyed horizon with permanent water table
Gleycutanic	Cutanic character with marked gleying directly underlying an E-horizon
Soft Plinthite	Strongly mottled with maximum accumulation of Fe and Mn oxides and hydrates periodically saturated
Hard Plinthite	Indurated iron pans second or third in vertical sequence
Lithocutanic	Illuvial B-horizon weakly developed in weathered rock
Prismacutanic	Dense structured (prismatic or columnar) horizon under an abrupt transition
Regic sand	Coarse textured 'grey' horizon, showing little or no profile development

Figure 2. Diagrammatic representation of soil form common to wetlands

* **Wetland development must ensure safe use of the land.**
  The most important principle concerns the need for optimum conservation of natural resources, especially soil and water. The plan must make provision for the safe disposal of all runoff by providing, where necessary, well-designed flood control structures, established waterways and stable outlets. In the case of bottomlands it is essential that the `key area', usually comprising rock, remains in its natural state and is afforded complete protection. Interference with the natural outlet will not be tolerated under any circumstances.
* **Control of the water table should be maintained.**
  In promoting wetland development emphasis should be given to **land improvement,** and this means more than simply the removal of free water from the surface and root zone. Rather, it is the control of the elevation of the ground water table within the root zone (Hill, 1968, Scotney,1970). Control in the case of bottomlands means that the moisture status could be returned to its original state at any time. Ironically enough, most wetlands are best farmed under a system of carefully applied irrigation. The moisture status can also be controlled in this manner.
* **Vulnerable points should be protected.**
  Sections that are liable to regular flooding should be shaped and established to permanent vegetation. Other danger points such as runoff disposal structures must be monitored carefully. If any erosion is present, remedial measures must be taken immediately.
* **Implement the plan in accordance with a priority sequence.**
  The development plan as a whole should follow five logical steps, viz. survey, assessment, planning, implementation and evaluation. The farmer is vitally involved with the implementation phase and it is here that he and the planner must have mutual and complete understanding of the plan. The need for the development must first have been fully appreciated before this phase is entered. Furthermore, the plan should be implemented according to a pre-determined sequence. It is important that the simplest operations are tackled first, and in most instances it is unwise to develop the entire wetland in one season, since it is likely to overtax available resources of capital, labour and management, and could lead to serious erosion. It is preferable, particularly in the case of large areas vulnerable to erosion, to develop the area section by section so that only 20 to 25 percent of the total area

is developed at any one time. The priority sequence should also take account of the construction or establishment of storage dams, waterways, cut-off drains and access roads.

* **Layout of normal conservation works and wetland structures to be integrated.**
  In most instances it is necessary to marry the wetland structures (*e.g.* waterways) to those of the conservation layout of the arable land on the upland adjoining the wetland. For this reason, it may be necessary to extend the wetland layout beyond its defined boundary. In both cases care should be taken to prevent aggravating the problem of poor drainage or erosion. Where a ditch has to be dug, excavated material must be spread evenly to avoid local ponding.
* **Wetland development must meet the requirements of existing legislation.**
  As has already been stated, a plan for development should take account of all relevant legislation, especially that of the Conservation of Agricultural Resources Act, No. 43/1983. Regulations concerning the breaking of new land, drainage of 'vlei' areas, cultivation of watercourses, burning of natural vegetation and prevention of erosion are particularly relevant. The Water Act (Act 54 of 1956), Forest Act (122 of 1984) and Mountain Catchment Areas Act (Act 63 of 1970) can all have a bearing on the development plan.

CRITERIA FOR PLANNING RIDGE-AND-FURROW SYSTEMS

The ridge-and-furrow system is well suited for any flat land requiring drainage and protection against erosion. Essential design criteria and factors influencing planning of a layout are as follows:

* **Waterways or discharge areas.**
  These may form an essential part of the system and they should be developed before other works are undertaken. Particular attention should be given to stabilising the point of final discharge of such waterways and the furrows themselves where waterways are not required.
* **Direction of flow** is important and is determined by the lay of the land and permissable flow velocities in the furrow. The latter are dependent on soil texture and are set at :

sandy loam	0.8 m/s	clay loam	1.0 m/s
loam	0.9 m/s	clay	1.2 m/s

* **Ridge dimensions** are influenced by a number of important factors :-

  — Depth of soil: The deeper the soil, the wider the furrow espacement may be. It is recommended that 20 m in width should not be exceeded, so that the volume of soil to be moved will not be excessive.

  — Gradient: The steeper the grade, the narrower the furrow espacement should be.

  — Availability of implements: Powerful tractors with large implements move soil more easily than smaller units, and thus facilitate wider espacement of furrows and/or higher ridges. However, even a furrow espacement of 10 m can be worked satisfactorily with a combine harvester with a 5 m cutter bar. Because crop husbandry may change, however, ridge dimensions are based on soil depth and furrow slope only.

* **Length of furrow.** This is governed by the soil texture and the gradient in the furrows. Provided the safe velocity of flow in the furrow is not exceeded, the furrow may be up to 500 m long in bottomlands, and up to 250 m on upland sites. The calculation of grade and length of structures is best left to a competent person such as the local soil conservation officer.

RIDGE-AND-FURROW CONSTRUCTION

* **Preliminary preparation.**
  The land to be treated should be free of dongas, old terraces, trees (other than those being left for shade purposes), fences, termitaria, artificial levees, old watercourses and so on. Moreover, land-levelling will facilitate ridge building and will result in better quality, more uniform ridges. Tall grass or other vegetation should be slashed or burned off, because it impedes marking out and also because buried trash will make subsequent ploughing difficult.
* **When to build.**
  Wetlands are subject to erosion and flooding. As a rule, therefore, the safest time to build is in the dry season, though moist (not wet) soil conditions improve construction efficiency. Where the risk of flooding and erosion is slight, construction may take place at any time.
* **Construction equipment.**
  Although land improvement and cultivation of this land are operations which, to a varying extent, are separated in time, the methods and implements should preferably be common to both operations. The implements are those used for farming, be they spade, blade terracer, earth scoop, light land-leveller, subsoiler, plough (one-way or reversible), disc harrow or roller. It is important to emphasise the function of the roller here.
* **Construction considerations.**
  The planned details must now be transferred onto the land for execution. The line and gradient of the furrows are therefore pegged and the positions of the ridges indicated. See Figure 3. The local Soil Conservation Officer can be called upon for assistance if required. The required slope from ridge to furrow over the designed width is achieved by ploughing, preferably with a disc plough for increased efficiency,

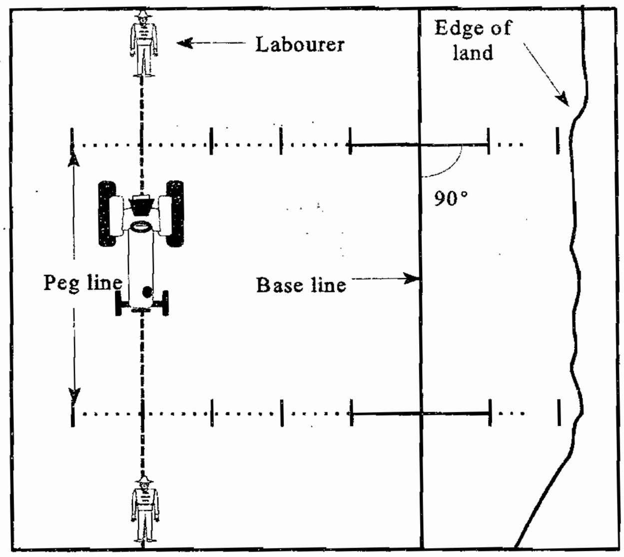


Figure 3. Setting out furrows

onto the ridge, thus ensuring that the dead furrows correspond with the position of the furrows required in the design. To construct higher ridges the process of clockwise ploughing is merely repeated, several times if required. Extra height must be provided to allow for settlement. If permanent pasture is to be established, shaping of the finished surface is vital because of the relative permanence of the surface and the likelihood of mowing, etc. Where annual cropping is to be practised, disc harrowing can be used to ensure that the slopes are uniform and that drainage is in fact not impeded by the cropping procedures.

Because these areas are low-lying and relatively flat, it follows that construction must take place during the drier periods when the likelihood of flooding is diminished. The moisture content of the soil must however be sufficient to allow soil movement and compaction without the formation of large and heavy clods.

* **Management pointers**
  Grazing of pastures should be avoided when animal trampling could damage the land profile.
  The timing of cropping operations must be carefully monitored to ensure that the soils are not so wet that tracks destroy the effect of the constructed ridges and furrows.

* **Maintenance tillage**
  Complete maintenance is achieved by normal tillage, by ploughing clockwise around the ridge in the traditional manner. Under normal circumstances for annual crops, ridges are gathered by ploughing for primary tillage. Secondary tillage, transport and other agricultural operations will generally prevent the ridge crest from exceeding its height limit. However, should this occur, ridges can be ploughed out or harrowed flatter. The efficiency, productivity and ease of management of the ridge improves progressively for several seasons until the requisite camber is induced at the surface and the base respectively. The actual time taken for this to occur will depend on many factors, such as cropping frequency, soil type and farmer interest, but for average conditions it may be three years before peak productivity is reached. Here it is important to stress that where permanent pasture is the preferred land-use, this should not be considered until the ridge shape is satisfactory, and for this the time period referred to will be required. In the interim, annual fodder crops and grasses should be grown to enable ridge development to take place until 'maturity' is reached. It must also be borne in mind that permanent pasture does need periodic rejuvenation, and ridges may settle somewhat, particularly where rapid growth has made heavy stocking or mechanised surplus grass extraction obligatory. The timing of this operation and the break crop to be grown will depend on local circumstances such as flooding hazard, irrigation availability, and management. The importance of this time period cannot be over-emphasized, and this is the appropriate place to refer back to ridge width selection. Modern agricultural thinking will recommend that the broader the ridge, the easier the management, ***but this is not necessarily true.*** The system, in any of its forms, does not hamper mechanised farming. A combine harvester can be operated without difficulty on a 10 m ridge. The point to remember in any case is that without the ridge, crops will not grow, and no mechanical work will be possible when these are required most. Thus, for ridge width selection, err rather on the narrow side and reap the benefit of more rapid development..

* **Cropping**
  It will have been seen that, once planning and development procedures have been implemented, farming takes over. Thus, there are no special cropping requirements because from that point on it is business as usual. The rate of reclamation and improvement will be found to increase markedly as soon as agricultural operations are undertaken. Soil in the furrow will be 'raw' for a time, but with subsoiling, fertilising and soil drift it will improve. Grass pastures should be planted into the furrow, but an unplanted strip should be left athwart the furrow in the case of annual plants.

* **Irrigation**
  Most wetlands are best farmed under a system of irrigation because once the water table has been lowered the water requirement for crops is normal and, in the absence of rain, soil moisture deficit must be made good. *The first task, however, is to control the water table and to remove excess water from the surface and from within the soil, before adding more.* In wetland situations the overhead irrigation layout should always be superimposed on the drainage plan, and not vice-versa. If correct planning procedure is followed, then permanent irrigation pipes can usually

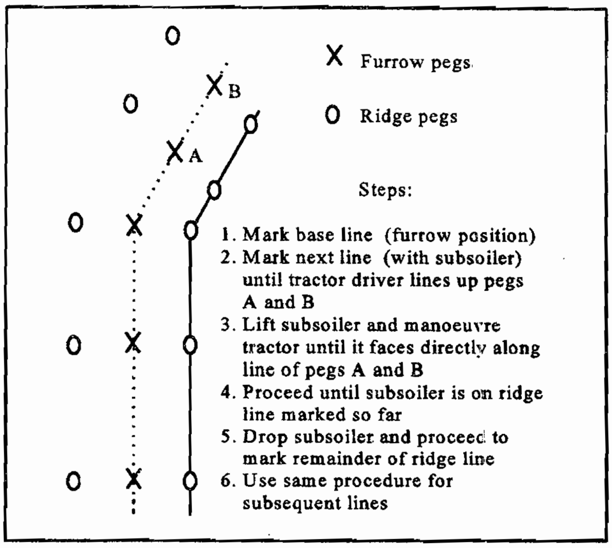


Figure 4. Steps in marking out furrows

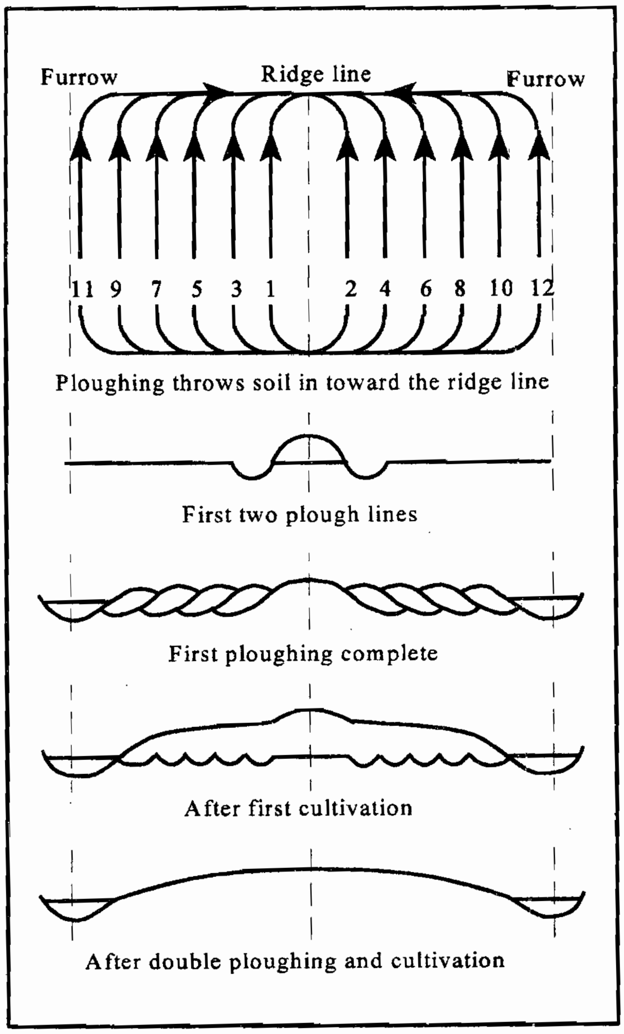


Figure 5. Development of the ridge

be laid along access roads or ridge crests, thus removing the risk of damage by deep cultivation. Where crossing ridges with a permanent main is unavoidable however, this must be laid at least 600 mm below the ultimate furrow level. It may be thought that ridge-and-furrow itself imposes physical obstacles for spray lines and laterals. This is not so because deflection of a portable pipe is sufficient to accommodate the ridge profile. Ridge-and-furrow will also accommodate drip and microjet irrigation with no more inconvenience than is experienced with cropping itself. During the first year or two of wetland development, irrigation may be of considerable benefit, but the cost of overhead irrigation may prevent this system being used. With proximity and low lift of water often available however, simple, reasonably efficient, economic irrigation may sometimes be achieved by applying water down a small groove furrow drawn along the ridge crest. The flow rate will depend on ridge width, slope length and soil type and condition, but flow is easy to regulate via plastic pipes from a furrow flanking the access road, or from gated pipe, for example. Although it may take time to bring soil up to field capacity with this method, once this stage has been reached it is easily and cheaply maintained; moreover, excess water is removed safely. Under certain soil conditions and during the early stages of ridge development when the soil is 'raw' and the base camber has not developed evenly, water distribution will be uneven and there will be wet and dry patches. There may well be leaching too, and in some soils lateral water movement is unacceptably slow. The benefits will be found to justify the small effort and low costs involved, however.

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Conservation of Farmland in KwaZulu-Natal

SUBSURFACE DRAINAGE

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INTRODUCTION

The land user wishing to drain a piece of land is cautioned against carrying out this operation on a wetland or vlei without having first been granted a permit in terms of the Conservation of Agricultural Resources Act (No.43/83) to do so. Consult your local Extension Office if in doubt.

Subsurface drainage in the agricultural sector means the removal of excess water from the soil profile by means of constructed, underground, or open site drains. The potential yield of a particular soil is determined by a number of factors, of which soil depth is certainly the most important. This limiting factor can be caused not only by the presence of an impermeable rock or clay layer, but also by a high water table, which, particularly in the growing season, can rise into the root zone, causing a drastic reduction in the rate of plant growth. By draining the profile the watertable is lowered and the required effective soil depth is attained in which optimum root development can take place. Where excess soluble salts are present within the root zone or on the surface, these salts can be leached out with the help of subsurface drainage as well.

The benefits of subsurface drainage on waterlogged soils and on soils that have become salinized by poor irrigation methods can be summarized as follows:

* Optimum crop yields will be increased because free air circulation in the root zone is promoted, and therefore bacterial activity.
* The risk of plant diseases is reduced.
* Rainfall efficiency is improved, surface runoff is reduced, and the erosion hazard decreased.
* Improved drainage means better root development which in turn means better drought resistance.
* Improved drainage means that soils warm up quicker in springtime, dry off quicker after a rain, and are therefore ready for cultivation that much sooner.

TYPES OF SUBSURFACE DRAINAGE

There are three basic types of drains, namely open site, enclosed and mole drains. The first two are more or less permanent (see Figure 1), while the mole drain is a temporary measure lasting 2 to 3 years only, depending on soil type. Irrespective of the type of drain, however, they are all spaced a calculated distance

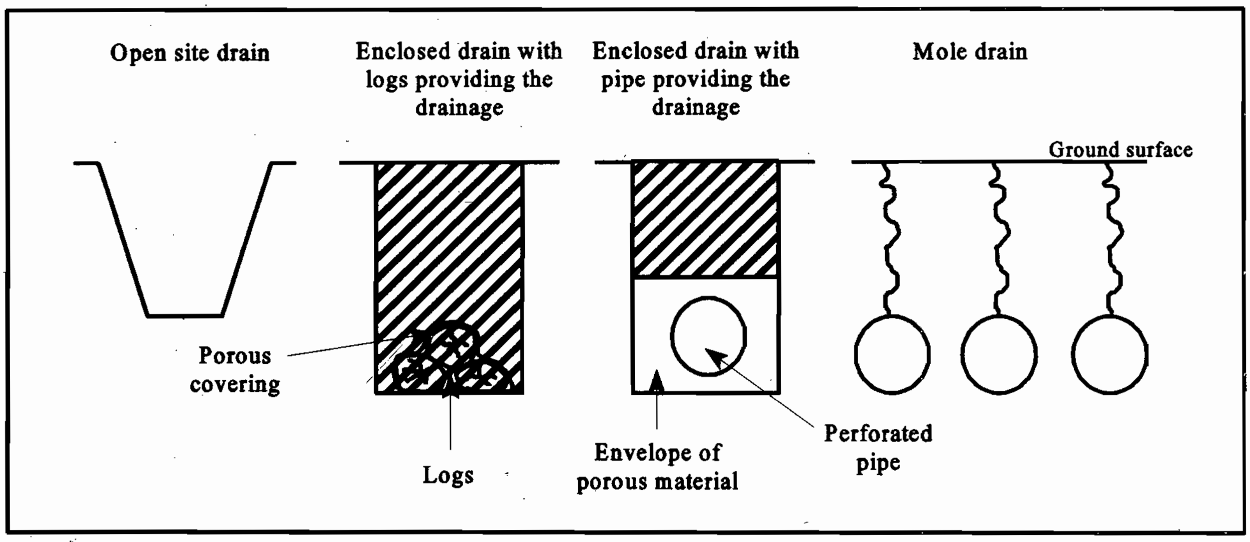

Figure 1. Various types of drains (in section)

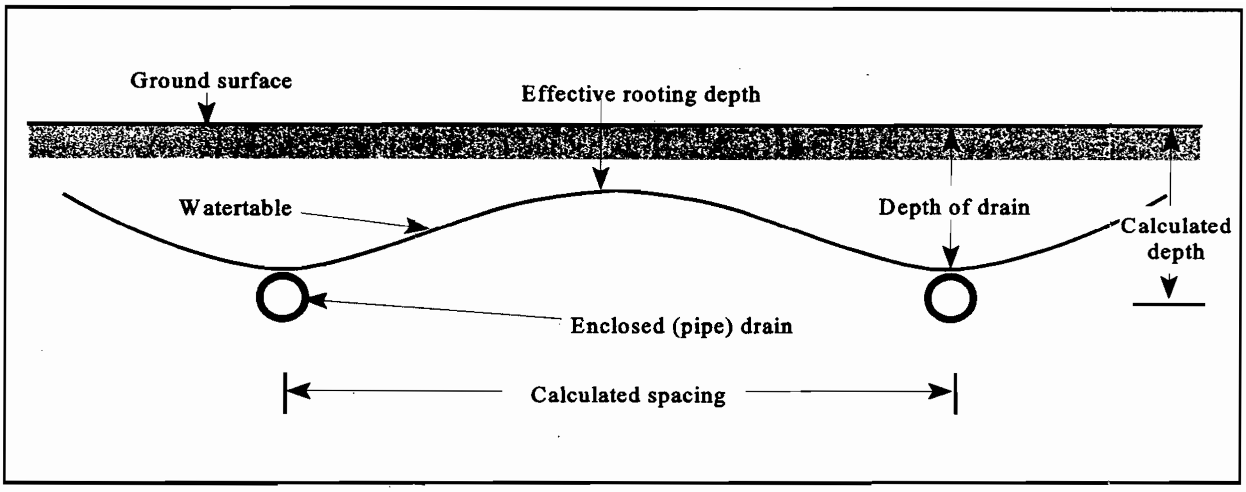

Figure 2. The effect of subsurface drains is to lower the watertable in order to improve effective rooting depth

apart, and at a predetermined depth, in order to cause a draw down in the watertable (See Figure 2).

ADVANTAGES AND DISADVANTAGES OF THE DIFFERENT FORMS OF DRAINS

All forms of drains need regular maintenance in order to keep them functioning, and some forms need more maintenance than others. As a basic principle, the enclosed type of drain should be placed below rooting depth, otherwise roots will find their way into the drainage spaces and block the system. Failure to place them deep enough will result in severe maintenance problems.

* **Open site drains** will not only have to be cleaned out regularly, but extreme care should be taken in their initial choice. Because they are open, surface runoff will find its way into them, and if the soil is erodible and the runoff of any great quantity, the danger of erosion causing real damage is possible. Soils having E horizons should not be drained by this method. The E horizon material tends to get washed out by seepage, leading to the collapse of the drain. Again, because they are open, they are not easily traversable and cause a break-up of the land into a number of smaller fields. They require a headland on either side of them and this combined width, together with their own top width, can result in the withdrawal of a sizable piece of land from production for every open site drain excavated. Their redeeming features are the fact that they are fairly inexpensive compared to the other forms, and the positions of blockages are easily identified and usually easily cleared. They also offer refuge to wildlife on the farm, which should be an important consideration.
* **Mole drains** (Figure 1) are underground tunnels formed in the soil by pulling a bullet-shaped mole to which an expander has been attached (Figure 4) through fairly damp clay soil. A tunnel is formed underground with a "leg slit" connecting it to the soil surface, and with cracks in the soil, formed by the shank to which the mole has been welded. Both the slit and the cracks expedite the movement of excess water into the mole drain. Mole drains are the least expensive to install, but pipe formation and stability is dependent upon the physical properties of the soil to be drained. It would appear that mole drains can be formed in soils where the clay content is 30% or greater, and a measurable degree of calcium carbonate in the soil will act to improve the physical stability of the drain. These drains are normally used on heavy soils to improve the efficiency of enclosed drains already installed, rather than as a system all on its own. The main problem with them is that their discharge ends tend to collapse, blocking and reducing their action. It is possible, however, to insert sections of piping, of the same diameter as the mole drains, into their discharge ends to overcome this problem. Traditionally, however, they are drawn through a field which already has pipe drains, at about 400mm depth, and at 2,5 to 3,0 metre spacing, at whatever slope is available, in order for them to cross, underground, the backfilled filter envelope of the drain pipes previously installed. See the following section on Enclosed Drains. They therefore discharge their drainage water into the permanent drainage system. The diameter of the drain is normally 75 mm.
* **Enclosed drains** are those which have some sort of conduit installed at or near the bottom of the ditch so that drainage water can move along it, and the upper part is filled in by replacing the *in situ* material (Figure 3). Many farmers excavate trenches and partly fill them either with durable rock or with logs, in order to provide passages along which the drainage water can move. Plastic film is then placed over the rocks/logs and the trench backfilled with *in situ* material. No proper investigation has ever been made (to the writer's knowledge) as to the long-term efficiency of

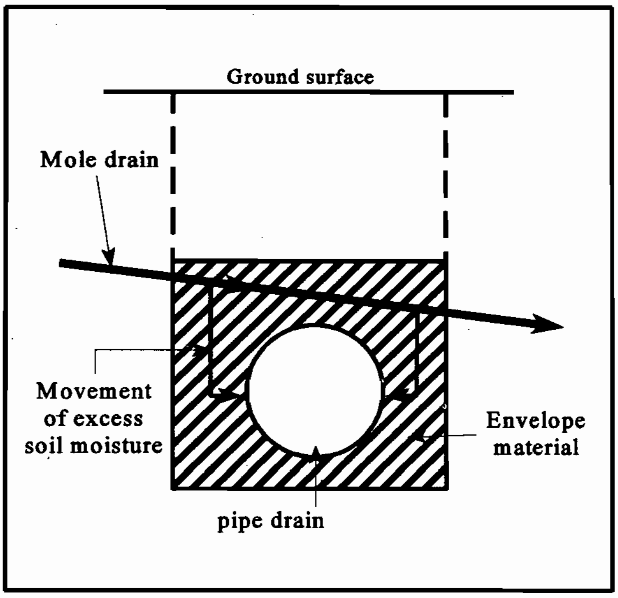

Figure 3. A mole drain can be used to improve movement of water towards a pipe drain

this method, but the one big problem that could arise as a result of this method is the internal collapse at some point in the tunnel created. This will have the effect of stopping the drainage action along the drain as far as the point of blockage, but the actual point of collapse will not easily be evident aboveground. Large-scale excavation is therefore required in order to locate the blockage, let alone repair it. Another problem is that, once installed, the drainage action is uncontrollable. The passages may not be large enough, so that the rate of drainage is not optimum, or it may be so swift that internal erosion takes place, with the ultimate collapse of the entire system. If the drain works, it will carry on draining through flood and drought, whereas, in the type described below, drainage can be slowed down (if not halted entirely) during times of drought.

The most expensive, but at the same time most trustworthy of drains, is the one which has a perforated pipe placed near the bottom of the ditch, with an envelope of filter material (in the form of stone, gravel and/or coarse sand) around it in order to allow the drainage water to filter through it, carrying with it the finest particles which would otherwise clog the filter. These solids (clay, silt and very fine sand) will then

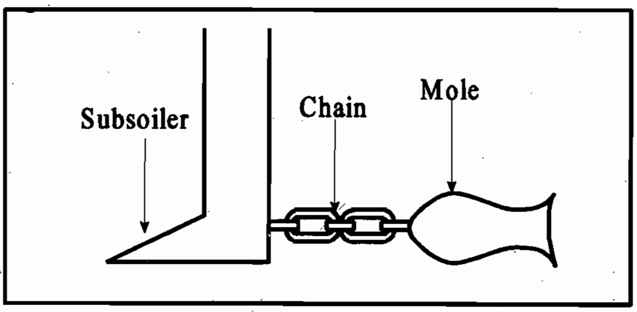

Figure 4. A mole drain attached to a subsoiler for pulling mole drains

deposit in the pipe, so that along with selection of the filter material, a system of manholes or inspection pits (see Figure 5) is included in the system to enable the cleaning out of the drain pipes until such time as the fine material that was disturbed during excavation of the trench has all been removed. *The use of filter fabric or geotextile as a filter material around a drainage pipe is not recommended.* Clay particles and hydroxides in the seepage water tend to block the cloth and the system becomes inoperative.

THE LAYOUT DESIGN

The planning and design of a subsurface drainage system entails an investigation into both the surface topography and the presence, nature and undulations of any impervious strata below ground. It requires knowledge of

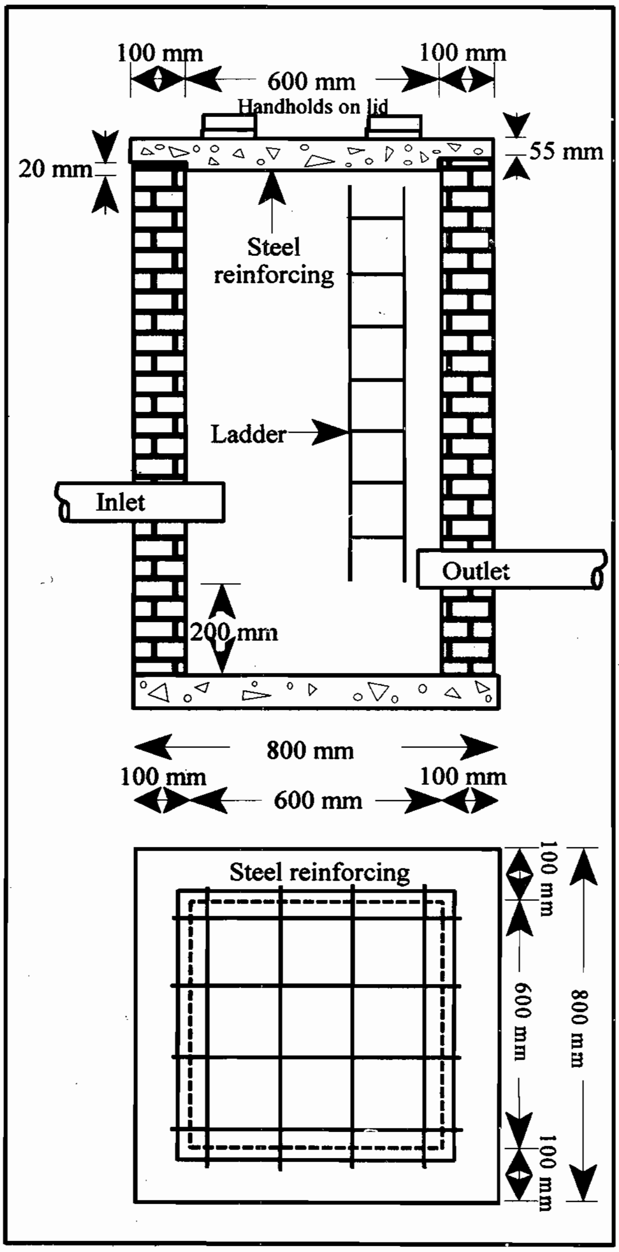

Figure 5. Cross section of a typical manhole. They can also be constructed circular in plan

the depth of the water table throughout the affected area, the source of the water table, the hydraulic conductivity of the soil, and the crops to be grown. *Leaking dams or over-irrigation could be causes which, when rectified, could cancel the need for drainage, or at least reduce the intensity thereof,* and this aspect must be fully explored before deciding to implement a drainage system. It must be well planned in order to optimise effectiveness over cost, for subsurface drainage properly done can be very expensive, albeit worthwhile. It behoves the land user with a problem of this nature to consult an expert on the subject before implementing a drainage system. In cases where it is established that the waterlogged condition is as a result of water permeating laterally into the area, then a single cut-off drain may be the solution. (See Figure 6).

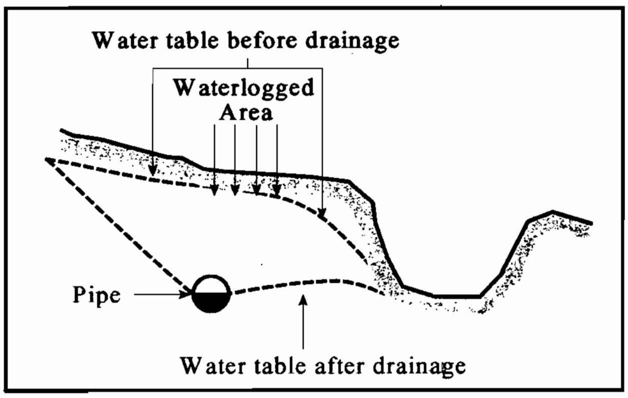

Figure 6. An interceptor drain

Where only occasional, isolated wet areas exist within a field, then a local system tailored to the specific needs can be used. (See Figure 7).
If the specific area is very flat, and waterlogging occurs continuously, while infiltration from the surrounding area cannot be detected, then an extensive drainage system will generally be necessary. Depending on the topography, either a grid or herringbone system can be used. (See Figures 8 and 9.)

The most economical layout in a grid system is to have longer laterals and shorter main lines. This also avoids a lot of T joints and there is less chance of obstruction taking place. In the case of brackish soils, extensive drainage is necessary to effectively leach out the salts.

DESIGN OF SUBSURFACE DRAINAGE

Once the type of drain and the type of layout to be used has been decided upon, the next step is to design the system. This means that the spacing, gradient, and, in respect of piped drains, the size of pipe to be used, must be determined.
The depth of the drain is determined by:

* The required root depth of the planned crop;
* The presence and depth of an impermeable layer;
* The available discharge point.

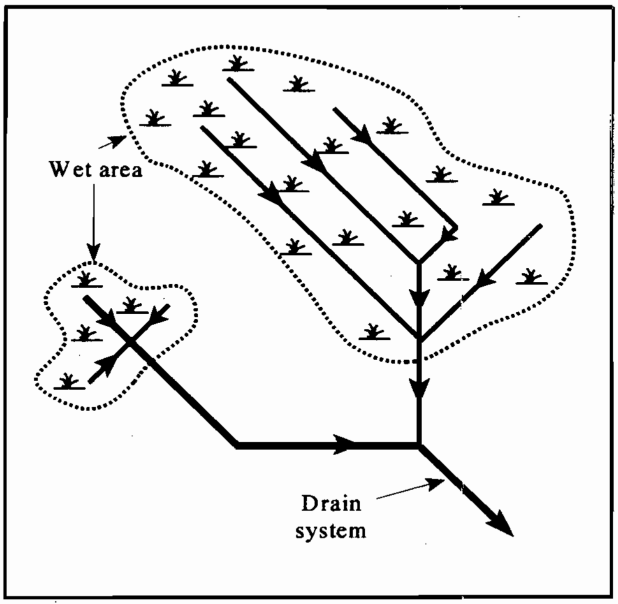

Figure 7. A drainage system tailored to meet local requirements

Unless there is an impermeable layer, the pipes must be laid at the maximum practical depth which allows for widest spacing of drains and consequent maximum cost saving.

Drain spacing is determined by:

* Permeability of the soil (rate at which water can pass through the soil);
* Depth of drainage system;
* Depth of impermeable layer underneath the drainage pipe.

Where practical, drainage pipes should run parallel to the contours (*i.e.* perpendicular to the slope). See Table 1 for rule of thumb spacings.

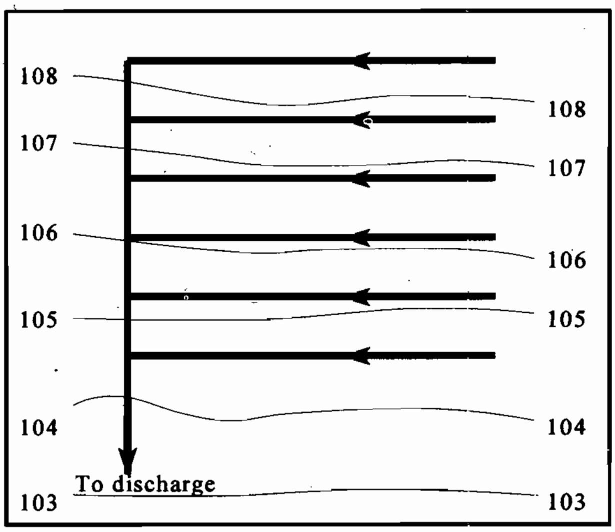

Figure 8. The grid system

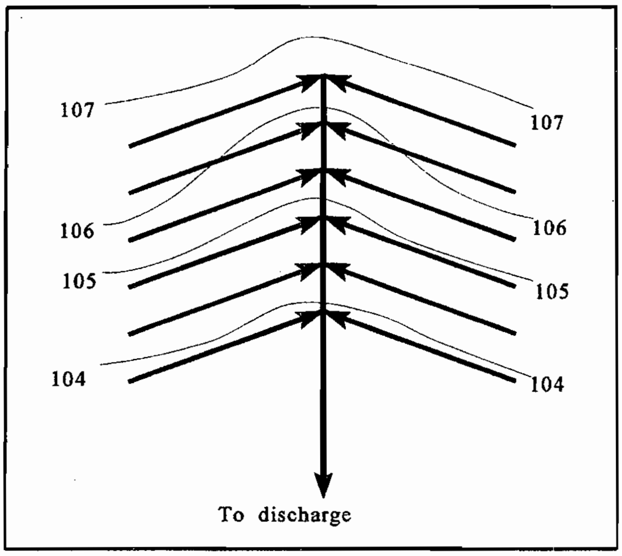

Figure 9. A herringbone system of drainage

Pipe size is determined by:

* Quantity of water which is to be removed from the soil profile;
* Gradient of the pipeline;
* Flow characteristics of the pipe.

As should be evident by now, Table 1 can only be an approximation, and considering the cost of installation of a scheme covering a hectare or more, the services of an expert is considered essential wherever the cost is going to be high. Table 1 should only be used for the smallest areas.

Table 1. Guide for spacing of drainage pipes

Soil Type	Drain depth in metres			
	0,9	1,2	1,8	2,7
Sandy	40	45	60	90
Loam	22	25	33	50
Clay Loam	13	15	20	30

GRADIENT OF DRAINS

Open site drains are normally given the same gradient as the fall of the land. It is therefore essential that all extraneous surface water be diverted from the field so that it does not interfere with the functioning of the drains. If an interceptor drain (Figure 6) is an open ditch it should also be protected by a stormwater drain upslope of it to avoid runoff entering it. The gradient of an open site interceptor drain should be of the order of 1% (1:100). The gradient of pipe drains is very closely linked to both spacing and diameter of pipe, and, once again, only a competent technician will be able to assist in this respect. Suffice to say that maximum slope of these drains should be 4% and minimum 0,2%

MANHOLES FOR PIPED DRAINS

The specifications for manholes are given in Figure 5. They should be constructed at intervals along pipes no greater than 125 metres, and also at every junction, change of gradient of the pipe, and/or change in direction.

CONSTRUCTION OF PIPE DRAINS

Most of what needs to be said about the construction of open site, mole and non-piped enclosed drains has already been done under the various preceding sections. The rest of this section will deal with the construction of pipe drains, but certain principles enumerated below will apply to the installation of all the other types of drains discussed as well.

* Excavation and installation should be carried out when the soil is at its driest - this will save on costs;
* Excavation and installation must be commenced at the discharge point and worked back to the start of the drain;
* The width of the trench should be limited to save costs, but without increasing the difficulty of the working conditions;
* Do not over-excavate: if using a machine, get the final bed gradient manually. If by chance over-excavation does take place, back-fill with the filter material rather than with the *in situ* material.
* Regularly control the gradient of the excavation as well as the pipe, using a profile and a boning rod (see Figure 10);
* The perforated/slotted piping must be laid with the perforations/slots on the *underside* (see Figure 11).
* Place filter material carefully, with a minimum thickness of 75 mm - 100 mm around the pipe. A shutterbox can be used for this and will save on filter material (see Figure 12). The material may comprise crushed stone 5mm - 15 mm, riverbed gravel, coarse sand, or coal ash. When in doubt the suppliers of drainage piping will carry out a test of the material available and advise on its suitability. After placing the filter material inside the shutter, backfill outside the shutter with *in situ* material and then lift the shutter out, thus keeping the filter material where it is required.
* A solid walled pipe must be used for the last three metres at the discharge end, and the outflow must be unimpeded, although the discharge end itself should be fitted with a one-way action rodent excluder gate to stop small animals from entering the system.
* It is good practice to install standpipes at the end of a branch line. The maintenance of a drainage system is made easier, and it also indicates the position of the

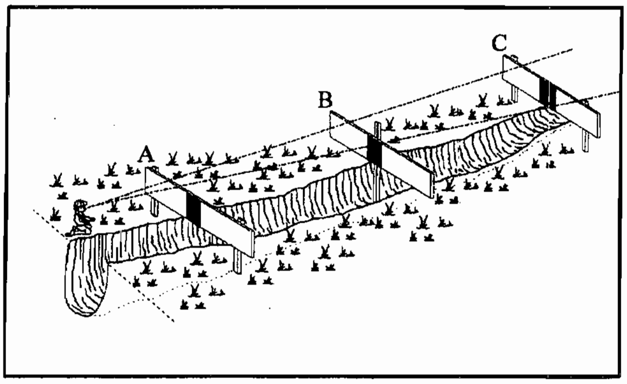

Figure 10. Gradient control using boning rods. A and C are gradient control points, and B is the boning rod

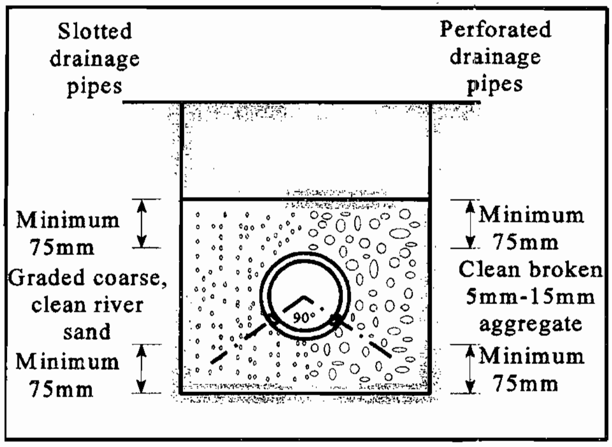

Figure 11. The filter envelope material depends on the type of pipe used

underground pipes. Rodding eyes are coupled to the drainage pipe by means of a 90° or 45° bend. Rodding length should not exceed 125 m.

* The trench must be carefully backfilled to prevent the pipe being damaged. Clay or soil of low permeability must not be used for backfill.
* The sediment that **will** enter the system must be regularly cleaned out to ensure proper long-term functioning of the drains. Cleaning the sediment out of these pipes proceeds as follows:
  As the pipe is laid from one manhole to another, so a nylon rope is drawn through each section of pipe until the rope, anchored in the first manhole, lies inside the full length of the pipe to the adjacent one, where it is also tied fast to the protruding pipe. The rope is left there as a permanent facility. The cleaning operation involves tying another rope of similar length, which has a ball of rags attached to it, to either end of the rope in the pipe. The rope is then pulled through the pipe so that the bundle of rags (which just fits the bore of the pipe) moves with the gradient of the pipe, pushing any sediment before it. This sediment empties into the lower manhole, whence it can be removed manually. The ropes are untied and the next sections are swept in succession until the whole system is clean. *This cleaning operation must be repeated once a month until the sediment removed is negligible. A six-month cleaning thereafter should suffice.*

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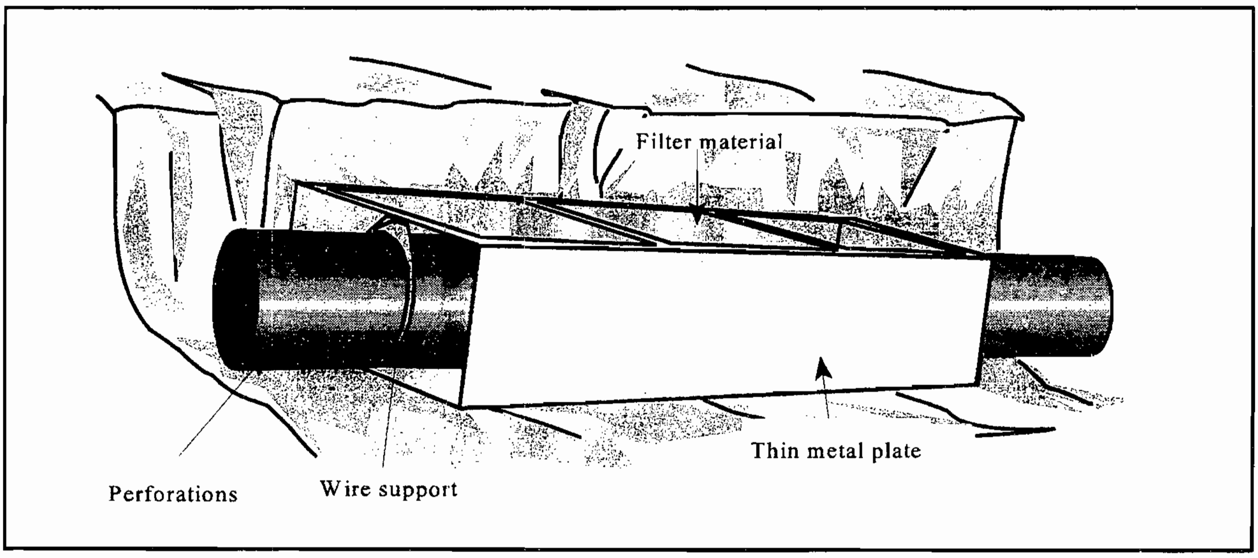

Figure 12. The use of a shutterbox to place filter material around the drainage pipe

Conservation of Farmland in KwaZulu-Natal

IMPORTANT ASPECTS REGARDING THE ESTABLISHMENT OF TIMBER PLANTATIONS

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Forestry Development : Department of Water Affairs and Forestry
and
R G Mattison
KwaZulu-Natal Department of Agriculture

The Forest Act (No. 122 of 1984) and its regulations controls afforestation, fire protection and other matters of silvicultural concern to farmers. This leaflet summarizes the most important points of concern to the farmer who is considering planting timber on his farm.

THE PLANTING PERMIT SYSTEM

No virgin land, or land which has been clear-felled for more than 5 years, may be planted to commercial plantations without a permit. Application must be made to the Forestry Extensionist in either Pietermaritzburg (0331-428101) or Eshowe (0354 - 42087), depending upon the location in which timber is to be planted. The Zululand office (at Eshowe) covers the area north of the Tugela River and east of the Buffalo River, while the KwaZulu-Natal office (at Pietermaritzburg) covers the remainder of KwaZulu-Natal. See Figure 1.

Exotic, evergreen trees use more water than natural veld, and unplanned large-scale plantings will affect the availability of water. The primary objective of this permit system is the conservation of water supplies. A limit to the area which may be planted in a sub-catchment has been calculated in order that downstream users will not be completely deprived of water.

Permit application forms for any commercial afforestation are available from the above-mentioned offices and must be completed and submitted together with a certified copy of the title deeds of that property. The applicant must also identify the property boundaries on a 1:50 000 locality map. A photo-based farm map is then produced by the Department of Agriculture for use in identifying the areas suitable for tree planting on that farm.

Comments on the application are invited from agricultural extension and soil conservation staff (and through them also conservation committees), the Natal Parks Board and the Department of Water Affairs.

The property is inspected by Forestry, Natal Parks Board and agricultural staff. The following details must be shown on the map:

* streams, wetlands and other sponge areas,
* areas which may be afforested,
* areas which are currently afforested, and
* areas which are totally unsuitable for afforestation.

A minimum of 30 m must normally be left open on either side of the edges of streams and wetlands. This may be increased to 50 m or more, based on circumstances such as the importance of the site as a watersource for downstream users. As a general rule of thumb, only about 75% of a property will be allowed to be planted to trees, but under special circumstances this can be exceeded.

The Department of Water Affairs & Forestry has determined a maximum area which may be planted to trees on a sub-catchment basis. If a permit is refused due to the catchment allocation having been filled, the application is placed on a waiting list and may later be approved if a previously issued permit lapses and the area involved is returned to the pool. Areas of timber converted to agricultural crops may also be returned to the pool.

Permits are valid for 3 years, after which the area is inspected to determine :

* whether permit conditions have been met,
* the area is actually planted, and
* whether an extension of time is required.

If trees were planted too close to streams and wetlands prior to the introduction of the permit system the landowner is requested to remove such trees and re-establish grass on the cleared area. The open strips must be kept free of all invader plants, and weeds must be removed.

Applications for small woodlots are inspected by a forestry extensionist who issues authorization. A permit in terms of the Conservation of Agricultural Resources Act (No. 43/1983) is necessary if virgin land is to be used in establishing this woodlot. This permit must be obtained through the local government agricultural extension office.

LAND PREPARATION REQUIREMENTS IN TERMS OF THE CONSERVATION OF AGRICULTURAL RESOURCES ACT NO. 43/1983

Act 43/1983 applies to the forester whenever the natural resources are at risk. The following regulations must be adhered to in terms of this Act:

regulation No. 3. A further permit is required to cultivate land in excess of 20% slope,

regulation No. 4. Every land user must protect his land against excessive soil loss by the use of one or more specified measures, and

regulation No.7(3). No one may cultivate within 10 m of the one-in-ten-year flood line of a stream or wetland without a permit, <u>unless</u> the area was under cultivation at the inception of this Act, and the agricultural resources are not presently at risk of degradation.

Permits under regulations 2, 3 & 7 may be obtained by applying to the local agricultural extension office of the Department of Agriculture. Where permits are granted, these will be made conditional on certain conservation measures being implemented. They are summarised below.

In all instances where full primary cultivation is to be practised, compartments should be established in panels across the slope. Panels should be a maximum of 250 metres wide on erodible soils and 500 metres wide on erosion-resistant soils. Adjacent panels situated one below the other should be planted and harvested at least one year apart.

The minimum standards for land preparation are based on good silvicultural practices and the need to conserve rainfall. One of the best ways of doing this is to maintain a cover of mulch on the soil surface. Plantation slash should therefore be conserved and not burnt if at all possible. An overall mulch blanket will give the best result. See Table 1 for the recommended conservation norms for land preparation on land being planted to timber.

SOIL CONSERVATION PRACTICES IN TIMBER PLANTATIONS

The following practices are essential to ensure that soil erosion is kept at acceptable limits:

* control of the runoff from roads/tracks to ensure that no erosion occurs because of the concentration of that runoff,
* land preparation on the contour wherever possible, *i.e.*, ripping, discing, *etc.*,
* extraction routes planned on the contour or crestline wherever possible,
* plantlines on the contour,
* brushwood stacked on the contour. The use of a slash chopper on dry brushwood should be considered in order to reduce it to manageable size and to facilitate its spreading over the land surface. This will decrease the fire hazard considerably and improve rainfall efficacy,
* fire belts. Vulnerable areas such as fire belts must receive special treatment to ensure that vegetational cover is maintained, and the length of the slope must be controlled by the construction of spreader berms across the slope at regular intervals. Unless such precautions are taken, concentration of storm runoff will result in severe erosion damage,
* ensure that all watercourses have good vegetational cover but remove all invader/alien plants.

PLANTATION ROADS

A fair proportion of any plantation area is made up of roads. By their very nature, roads tend to intercept runoff and to concentrate it. If they are not correctly sited they can cause both maintenance and erosion problems. The reader is referred to Agricultural Production Guideline number 6 (Farm Roads) in this series for a fuller dissertation on the siting and construction of roads.

FIRE CONTROL AREAS

Under the Forestry Act a farming community may approach the Minister via its Farmers' Association to declare a specified area to be a Fire Control Area. If approved, the declaration is published in the Government Gazette, and the Minister appoints a fire control committee for that Area. This committee is responsible for the formulation of fire protection plans and for the implementation of these compulsory plans. A Fire Warden is appointed and he assumes the responsibility of directing the fire fighting operation when the need arises.

Whereas, outside of a Fire Control Area, the negligence of the land user on whose property a fire originates is presumed , negligence in respect of veld, forest, or mountain catchment area fires occurring within a Fire Control Area has too be proven. This aspect of the Act, therefore, encourages farmers to form such areas for their own benefit and protection.

Table 1. Conservation norms for land preparation

% LAND SLOPE (degrees) * Soil Erodibility High	 Low		MINIMUM STANDARDS
1 - 8 (0,5° - 4,5°)	1 - 12 (0,5° - 7,0°)	**	Full preparation with any implement, but preferably leaving as rough a surface as possible. Weed control should be aimed at leaving a mulch on the surface.
9 - 15 (4,5° - 8,5°)		**	1. Full cultivation with tined implements only. 2. Strip cultivation with any implement, with an area of at least one metre width between strips which may only be ripped or treated with herbicides. Weed control should be aimed at leaving a mulch on the surface.
	13 - 20 (7,0° - 11,0°)	**	Full primary cultivation with any implement followed by secondary cultivation in a restricted strip one metre wide along the tree line. Weed control should be aimed at leaving a mulch on the soil surface.
16 - 25 (8,5° - 14°)	21 - 30 (11° - 17°)	**	Full primary cultivation with tined implements only. Planting must take place within two months of land preparation. No mechanical weed control may take place. Spray treelines with herbicides or hand hoe around the individual trees a maximum of 1,5 m in diameter.
26 - 30 (14° - 17°) Maximum	31 - 40 (17° - 22°)	A single tined rip along the tree line. No mechanical weed control may take place. Spray tree lines with herbicides or hand hoe around the individual trees a maximum of 1,5 m in diameter.	
	41 -50 (22°-27°) Maximum	In grassveld, a swath 1 m wide should be sprayed along the tree line prior to pitting. Pitting only, with a maximum of 1,5 m diameter pits. Weeds to be controlled by herbicides (full cover) or hand hoeing of the pit area only.	

* High soil erodibility for these norms is simplified as being any one of the following:

- ° Less than 500 mm effective soil depth. Soil depth is considered as being restricted by strongly-structured, gleyed or hard plinthic horizons.
- ° Less than 15% clay in the topsoil on a slope greater than 8% (4,5°).
- ° All soils having E horizons.

All other situations are regarded as having a low erodibility.

** **All cultivation across the slope.**

FIRE BELTS

In terms of the Forest Act:

* within a fire control area, every landowner must enter into a written agreement with each of his neighbours as to the width, method of clearing, sharing of cost, *etc.*, for their mutual boundary fire belts,
* outside fire control areas, a landowner must serve a notice on his neighbour of his intention to clear a fire belt by burning, either on his side of the boundary only, or communally on both sides of the boundary, and
* a fire belt must be cleared of inflammable material, and be of sufficient width so as to reasonably be expected to prevent a fire crossing it. In this respect, the following are the methods of clearing in descending order of acceptability:
  - mow and remove vegetation before the fire season, although the grower might have difficulty in this respect regarding fire insurance,
  - plant a summer crop for soil protection during the wet season and harvest it before the fire season, leaving the soil bare for that period with the soil surface and roots remaining undisturbed,
  - plant a crop that will be green during the fire season,
  - spray a desiccant (*e.g.*, Gramoxone) and burn when dry, but before the fire season,
  - hoe to remove surface growth only, leaving the roots intact, and
  - on slopes of less than 20%, shallow plough or harrow and construct crossdrains no further than 25 metres apart.
* a boundary fire belt may, by agreement, be located away from the true boundary line because of difficult terrain. This might, however, lead to legal problems in the event of a fire occurring on the land between the fire belt and the true boundary.
* as the burning of fire belts is dangerous, with many such fires escaping and causing damage, such burning may be prohibited at the most dangerous time of the year. In KwaZulu-Natal this is generally from 1 August to 30 September, although it may change, by Ministerial decree, from one year to another.

GENERAL BURNING PROHIBITIONS

Due to the danger of carrying out burning operations over weekends when most labour is away from the farm, there is a prohibition against lighting fires over weekends throughout most of the year in many areas of KwaZulu-Natal. Details will be published each year by the Directorate of Forestry Development.

This prohibition extends from 18:00 Fridays to 06:00 Mondays, but certain types of fires are exempted viz:

* domestic fires for cooking food,
* fires in fireplaces at recognised camp and picnic sites, and
* burning cane prior to harvesting may be done up to 08:00 on Saturdays and after 17:00 on Sundays.

SPECIFIC BURNING PROHIBITIONS

KwaZulu-Natal has been divided into six sub-regions for which specific burning regulations are enforceable under the Forestry Act. These regulations specify such periods as: when plantation slash may not be burnt, when fire belts may not be burnt, *etc.* The dates are reviewed each year based on weather conditions. For current prohibitions the reader is referred to the Forestry Extensionist in Pietermaritzburg (0331 428101) or Eshowe (0354 42087) from whom a leaflet giving details may be obtained.

BURNING OF CROP RESIDUE/PLANTATION SLASH

The residue left after harvesting of timber, maize or any other crop may be burnt in order to leave the land clear for replanting. This is, however, generally not desirable from a soil conservation and fertility point of view and landowners should be motivated to avoid burning if at all possible. It should by now be clear to foresters that a surface mulch not only reduces the risk of soil erosion in the plantation, but also vastly increases rainfall efficacy, especially on steep slopes. For best effect the residue/slash should be scattered over the entire surface. The best alternative to scattering it is to windrow the slash on the contour. If this is unpractical, spot dumping between rows will help to maintain a level of organic matter in the plantation, while having easy access through it as well.

The burning of residue usually takes place during the dry months and might be very hazardous - particularly with plantation slash which might smoulder for days, or burn underground for days or even weeks. For this reason there is, in some areas, a prohibition on the burning of crop residue between 1st August and 30th September. If burning is carried out in contravention of this prohibition prosecution could be instigated.

REFERENCES

Anon. 1984. The Forest Act No. 122/84. Government Printer.

Anon. 1983. The Conservation of Agricultural Resources Act No. 43/83. Government Printer.

SOME ASPECTS OF SILVICULTURE PRACTICES FOR MAINTAINING AND IMPROVING SITE PRODUCTIVITY

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(Adapted from a paper read at the Long Term Site Productivity Seminar held at Sezela on 26 May 1989).

INTRODUCTION

The recent upsurge in soil conservation sentiment and legislation has served to focus attention on the ability of the ever-expanding forest industry to adequately manage its most precious resource, the plantation site. Timber is one of the few renewable resources of the world, provided that the inherent productivity of the site is maintained. Should the forest manager be found wanting on this issue, then he must be compared with the miner of gold or coal who can never replace the substance wrung from the earth.

The importance of maintaining or improving the long term site productivity is paramount in the forest industry. Large scale expensive manipulations of the site such as irrigation and regular fertilizing are difficult to justify when such cost must be compounded over the rotation period. As plantation yields are largely bound to inherent site productivity, it is important that all aspects of the site should be investigated and understood. Only then can they be managed to the best advantage. Yet such investigations have received scant attention in this country as, fortunately, our forestry sites and climate are relatively favourable by world standards. Fortunately, our plantations have never suffered from the low growth rates experienced on the impoverished and waterlogged sands of Australia and south-eastern U.S.A.

Unfortunately, however, this has lead to a great complacency in our forest industry with little attempt being made to understand the fundamentals of the site. The first areas to be afforested in this country were located in the moist pockets frequently having deep and fertile soils. These sites are relatively stable and can tolerate a reasonable amount of mismanagement without suffering a noticeable decrease in yields. The need for more plantation land which has arisen during the last decade has forced the industry to afforest more marginal land where site conditions are relatively unfavourable.

Typically, these marginal sites comprise dry, shallow soils and are sufficiently fragile to be intolerant of poor management. Such sites increase the demand for knowledge of the site and the silvicultural operations available to best utilize and protect this resource. Some of these operations are discussed below.

SILVICULTURAL OPERATIONS INFLUENCING SITE PRODUCTIVITY

Site Preparation

The 1980's have seen a sudden intensification of establishment practices. Thus, the pitting mattock gave way to the plough and vast tracts of virgin grassland were prepared, sometimes on steep slopes and erosion-prone soils. Companies which had previously balked at spending R300/ha on site preparation are currently spending up to R1 500 to remove old tree stumps before recultivating and replanting. Unfortunately, while it is difficult to mismanage a pitting operation, complete preparation is a far more sophisticated operation which can result in substantial degradation of the site. Complete preparation requires a knowledge of the soils and their potential erodibility. This knowledge is frequently lacking or absent and under the usual budgetary or production pressures, mistakes on a large scale are made in the field.

The tragedy of these errors is that they may markedly reduce future yields. The topsoil, and in particular the organic matter component, is an extremely important contributor to site productivity. Organic matter has the ability to absorb and retain relatively large amounts of water, is an important source and reservoir of nutrients and improves soil tilth. Site preparation should aim to produce rapid initial tree growth in order to effect early canopy closures, thus also reducing the risk of soil erosion. At the same time these operations should to the greatest extent possible attempt to leave the topsoil undisturbed. The use of heavy machinery which scrapes or rakes the surface layers tends to collect the topsoil, leaving other sections barren. Deep ploughing to depths greater than 400 mm simply inverts the soil profile and puts much of the topsoil beyond reach of the tree's developing root system. The answer is not to stop intensive preparation completely, but to carry out such operations judiciously and with due regard for the required end result.

Site preparation on previously forested sites has undergone a radical change in recent years. With management's desire for complete cultivation on these sites being complicated by the old tree stumps, vast amounts of money are being spent on chipping or shearing the offending stumps. In the latter case the debris is burnt and the site ripped and/or disced. *Yet current research evidence would appear to indicate that the response to intensive preparation on such sites is minimal compared to the dramatic difference realized on grassveld sites.* It is probable that soil tilth is no longer a crucial issue when replanting as the original tree root systems have penetrated the profile. With the death of these roots, channels are left through the soil for the subsequent crop to colonize. Current evidence suggests that, provided weed growth is kept under control, regeneration should be effected by planting in a simple pit or rip line. The major justification for removing the old stumps is to provide easier access to machinery during subsequent in-field tending and harvesting operations. It would certainly appear that a number of the intensive and costly regeneration operations are not only cost ineffective, but through their adverse impact on the topsoil, probably lead to a decrease in the long term site productivity.

In an attempt to halt the indiscriminate site preparation being practised by some forestry organizations in KwaZulu-Natal, norms to govern future operations have recently been agreed upon by representatives from all sections of the local forest industry and the Department of Agriculture. These norms take into account the need for thorough site preparation to increase yields, and the need to keep soil erosion to a minimum. The concept of panels, which are designed to limit the length of any one slope which is exposed to possible soil erosion, is introduced into forest operations. Soils are also classified into categories of high and low erodibility although most of the former soils are not recommended for commercial afforestation. Details are given in Table 1.

It is perhaps fortunate that site preparation practices have received so much initial attention from the conservationists. Many silviculturists now feel that the harvesting and road making operations, which are perhaps the major culprits of site degradation in the forest industry, should also be put on a firmer conservation footing.

Slash disposal

Management of the slash and debris remaining from the harvesting operations offers the silviculturist one of the few opportunities of actually increasing long term site productivity. By conserving this material and allowing it to be incorporated into the site, the organic matter component can be increased. Yet the vast majority of slash is burnt simply because it facilitates the forthcoming planting operations. This is a classic example of the short term benefits, accruing from the reduction of costs by a few rand per ha, being held more important than the long term improvements of the site potential.

The advantages of slash conservation are numerous:

* it provides a mulch: the soil is protected against erosion and evaporation
  — soil temperatures are moderated
  — weed infestation can be reduced
* it contributes to the levels of soil calcium, the nutrient which has recently been shown to be important for vigorous growth of many tree species in southern Africa.
* it can improve the water holding capacity of the soil by increasing the organic matter status.
  The final point was demonstrated when a rainfall simulator was tested on a recently planted stand of *Acacia mearnsii* (Black Wattle) at Bloemendal Field Experiment Station near Pietermaritzburg. While runoff was observed both in the hoed tree line and in the rotovated between-row swath, there was no runoff from a between row swath where a former brush pile had been incorporated into the soil by the rotovator.

There are at present only a few options available to reduce the slash bulk other than by burning. The most viable option is the use of the roller-chopper to smash and cut the debris. This operation is successfully used in some of the southern Australia *Pinus radiata* plantations and has helped to improve the nutrient status of their chronically impoverished soils. In South Australia, an initial chopping takes place soon after harvesting in order to reduce the fire hazard. The site is left fallow for a year, whereafter the remaining slash is again rolled prior to planting in order to assist its incorporation into the soil. The possibility of chipping excessive quantities of debris using a mobile chipper has been tested by one of the more far-sighted forestry companies in this country. Furthermore, the amount of slash in crops such as *Acacia mearnsii* can be kept to a minimum by maintaining stocking close to the optimum 1 500 trees/ha, thereby limiting unwanted branch development. Alternatively, the experience of the Usutu Forestry Company which was forced to suspend slash burning owing to *Rhizina* infestation, suggests that even with a high slash-producing species such as *Pinus patula* planting costs can actually be reduced by not burning.

There are good reasons why slash and litter should be actively managed to improve its decomposition and incorporation into the soil. Evidence from the pine

Table 1. Norms for site preparation in the forest industry

Slope Soil Erodibilty High	Low *	Type of cultivation	Tillage direction	Remarks
0-8% (4,5°)	0-12% (7°)	Full conventional	Across slope	Leave surface as rough as possible
9-15% (8,5°)	-	1. Full primary cultivation with a tined implement only 2. Strip cultivation with any implement leaving a minimum of 1 m between strips which may be ripped or sprayed	Across slope Across slope	Weed control should be aimed at leaving a mulch on the surface
-	13-20% (11°)	Full unrestricted primary cultivation followed by secondary cultivation along plant line only	Across slope	Weed control should be aimed at leaving a mulch on the surface
16-25% (14°)	21-30% (17°)	Full primary cultivation with tined implement only	Across slope	Plant within one month. Weed control via herbicide (strip 1-2 m wide or complete) or hand hoe around the tree, no mechanical control
26-30% (17°)	31-40% (22°)	Single rip / subsoiler tine along tree line	Across slope	Crawler tractor recommended. Weed control as above, spray prior to planting
-	41-50% (27°)	Single rip / subsoiler tine along tree line, interrupt every 50 m.	Down slope	Crawler tractor recommended. Plant within one month. Weed control as above.
>30%	>50%	Pit	-	Maximum diameter 1 m. Weed control as above, restrict hand hoeing to pitted area

* *i.e.* those soils having a topsoil with clay > 15% and an effective soil depth (excluding gleyed and plinthic horizons) > 500 mm and where slope > 8%. Excludes all soft E horizons.

N.B. In all cases compartments to be laid out in panels across the slope. Maximum panel width 250 m (high erodibility soils) and 500 m (low erodibility soils). Adjacent panels situated one below the other should be planted and harvested at least one year apart.

plantations at Usutu suggests that nutrients are trapped in the litter layer. Ideally, a gradual breakdown of this litter should be induced, thus releasing the nutrients to best effect. Burning is not the answer as most of the nitrogen volatilizes and is lost, while potassium is rapidly leached

Furthermore, it destroys organic matter and results in a drastic reduction in the biological activity in the topsoil as the responsible organisms are killed.

The option of not burning may still be ignored on some of our better forestry sites boasting a healthy topsoil. However, on many of our marginal, drier sites which have already lost much of their topsoil, retention of the slash should be regarded as obligatory. The chance to put something back into the site from which we so ruthlessly take, should not be lightly passed over.

Weed control.

Based on experimental evidence, the Institute for Commercial Forestry Research (ICFR) has for years advocated a policy of complete weed control for hardwoods until canopy closure. This evidence supported the concept that, as soil water is the single most important factor influencing tree growth in southern Africa, water taken up by competing vegetation would be lost to the trees and thus limit their growth. However, having shown the considerable benefits of complete over minimal weed control, are we not at the stage where we can perhaps modify this 'scorched earth' policy? It has been shown in Australia and elsewhere that the retention of limited or selected vegetation as cover crops or as a mulch between the plantation rows can actually enhance tree growth. Although such crops will consume water, selection of the correct species and correctly timing their establishment will keep moisture loss to a minimum. The crops in return will increase the organic matter level and on occasions act as a reservoir for nutrients which, when incorporated into the soil, could benefit tree growth.

Two examples from Australasia illustrate the use of selected inter-row vegetation. Plantations of Hoop pine *(Araucaria cunninghamii)* in Queensland are interplanted with a succession of cover crops commencing with millet and followed by oats, couch and kikuyu during the establishment period. The former crops limit soil erosion, otherwise a problem on the steep slopes, while the latter crops provide a cost-effective method of controlling woody vegetation. The grasses are also grazed by cattle where agro-forestry is practised. On some of the sandy podzolized soils of Australia and New Zealand, lupins *(Lupinus angustifolius)* are used as a cover crop in *Pinus radiata* plantations primarily to supply nitrogen. Indications are that this crop could represent a more effective and less costly means of supplying nitrogen than the use of conventional inorganic fertilizers. This evidence supports the contention that lupins might well be used in the plantations on the Zululand sands.

The possible advantages accruing from the use of a cover crop should, however, not be used as an excuse for leaving the voracious grasses and weeds commonly found in our plantations uncontrolled. The use of suitable cover crops could be seen as a possible step forward towards complete weed control, which in itself is a giant step ahead of minimal or no control. Cover crops would have to be tested, comparing the performance of a variety of species under various site conditions. *Eucalyptus grandis* which has rapid early growth and a dense canopy would shade out any inter-row vegetation at an early stage. At the other extreme, species such as *Pinus elliottii* and *Pinus taeda* may only close canopy after 7 years, thus allowing ample opportunity for a variety of cover crops. Groundnuts are sometimes planted between *Eucalyptus grandis* at establishment in the Northern Transvaal. Farm workers who control the groundnuts in effect keep the stand weed-free at minimal cost while the cover crop produces an income and also adds nitrogen to the soil.

ABSOLUTE LIMITS TO THE PRODUCTIVITY OF A SITE

If one accepts the premise that tree growth is largely dependant on the inherent site productivity, then it must be considered that on the more marginal sites it will ultimately be the site that determines the yield, no matter how thorough the silviculture may be. This is particularly applicable to the drier sites in southern Africa where soil water rather than nutrient availability is the chief factor limiting tree growth.

Trees are known to be heavy consumers of water. A single *Eucalyptus grandis* tree in the Sabie area has been measured transpiring 140 litre per hour during mid-day. Thus, if the trees transpire more water than is replenished via rainfall, the soil water reserves must eventually be depleted, and tree growth will suffer accordingly. There are many foresters in the field who are convinced that current yields are markedly less than those of previous rotations. While the reasons for this decline are often due to poor management and sometimes due to the serious drought of the 1980's, many of our marginal sites must be drying out. If we continue planting thirsty species like *Eucalyptus grandis* such sites can only deteriorate further.

How does intensive silviculture, with its aim of maximising tree growth, relate to the above concept? It is assumed that tree growth during the first 2 to 3 years is largely dependent on the silviculture applied. Thereafter, once the tree roots have fully colonized the site, growth is more dependent on the site itself and more specifically on available soil water. Intensive silviculture is producing trees with large root systems and healthy crowns which in turn pump out more soil water. On marginal sites, handicapped by limited available soil water, such silviculture introduces stress conditions at an earlier rather than a later stage. On such sites we cannot escape the fundamental fact that eventually it will be the site and not the silviculture which determines future yields, although this scenario may still lie ahead in southern Africa. Had compartment yields been measured over successive rotations, this could have been ascertained. Perhaps the very low standard of silviculture applied to many of the short rotation crops has helped to hide the unpleasant truth. The recent swing to intensive silviculture, however, may force managers to face reality - a reality that could be further aggravated by the afforestation of more marginal land. Perhaps even foresters will one day consider water more precious than gold!

It is possible that intensive silviculture should be limited to the better sites which do not suffer from significant periods of water stress, and that a more moderate approach be adopted on drier sites. The latter sites can be broadly identified by comparing the Potential Evapotranspiration (PET) with the prevailing rainfall. PET indicates the evaporative demand occurring on a site and is calculated by measuring climatic factors such as temperature, relative humidity and pan-evaporation. When the PET exceeds the prevailing rainfall, marginal conditions can be expected and a greater requirement exists for the practices to be tailored to the site.

OPTIONS IN MAINTAINING SITE PRODUCTIVITY

There is no quick and easy solution to the question of the maintenance of long term site productivity as the site itself is a complex interaction between many prevailing factors. The following are some of the options which could be considered by forest management.

Increasing the available soil water.

The obvious solution to this problem is to irrigate, a proposition which is no longer regarded as absurd as it was 10 years ago. If water can be used to produce, for example, surplus sugar which can only be exported at a loss, then it can certainly be used to produce timber which can be profitably exported. Overseas, research on this concept is being carried out on all continents using a variety of tree species and often using sewerage effluent as an irrigation medium. Detailed research is again a prerequisite for such a venture.

An alternative approach is to radically transform steep hillside slopes by creating terraces. As the 4 m-wide terraces are constructed along the contour, any excess water is stored where it falls and is not lost as runoff. Just as important is the movement of water within the soil profile. Theoretically this water in an unterraced situation would move down the hillside resulting in a water deficit on the upper and middle slopes and an excess on the lower slopes. After terracing, the water is presumably held on site as the flow pattern down the slope is broken. The use of terraces on such steep slopes is, however, fraught with danger. The method was developed in Portugal and Spain where the soft schist parent material and low intensity rainfall minimize the erosion potential. The soil water balance is favourable in these countries as the rain falls during winter and temperatures and evaporation are relatively low. The soil profile is thus recharged with water at the start of summer, the main growing season. In South Africa, the relatively infrequent but high intensity rain events have a high erosion potential. Our local soil water balance is less favourable as much of the summer rainfall is lost through evapotranspiration which can result in a soil water deficit at the start of, let alone the end of, the dry winter period. Furthermore, should there be an impervious layer below the surface then terracing may initiate mass soil movement on the slope. If the terraces are not constructed exactly along the contour any runoff is simply concentrated which increases the erosion hazard. The benches should also be provided with sufficient freeboard to enable the storage of at least 100 mm of rain, otherwise overtopping and damage can result. The construction of terraces is an extremely site specific operation which, in addition to expert planning skills, requires detailed knowledge of soils, underlying parent material and rainfall patterns. It is imperative that terracing be applied only by those who have sufficient expertise, as in the hands of amateurs it is courting disaster.

Maintenance of the organic matter.

The importance of this soil component has been stressed throughout. During the crucial period between clearfelling and canopy closure of the following crop, every effort should be made to conserve the existing organic matter. Ideally, the use of heavy machinery and the burning of slash should be limited, soil erosion prevented and a mulch used to protect the soil surface after planting. Existing levels of organic matter can be supplemented initially by actively managing the slash as a blanket over the entire soil surface. Wattle litter becomes hydrophobic, presumably owing to its tannin content. Pine litter can build up to dense layers, over a metre thick at high altitudes in some places, while the dry, brittle eucalypt leaves are not easily broken down. By the addition of moisture and/or nutrients it may be feasible to facilitate the breakdown of some of the litter. The use of selected cover crops can also be considered as an option to increase the organic material.

Manipulation of species and rotation period.

Field experience would appear to indicate that different tree species consume varying amounts of water. In addition, it is considered that the point at which stress commences and the tree begins to shut down or transpire at a reduced rate, will also vary between species. Figure 1 illustrates this hypothetical situation.

While there is sufficient available soil water, i.e., at field capacity, all species will transpire according to atmospheric demand. However, as the soil moisture falls and approaches wilting point, the supply of water from the soil becomes less than is demanded by the atmosphere. In order to protect the tree, the stomata will close and the rate of transpiration will be reduced accordingly. A demanding species such as *Eucalyptus grandis* appears to continue transpiring at maximum capacity until the available soil water is nearly depleted, whereupon there is a sudden reduction in transpiration. By contrast, a more robust species such as *Acacia mearnsii* may, by closing its leaflets, reduce the rate of transpiration at a much earlier stage, thus conserving the increasingly limited reserves of soil water more efficiently than does *Eucalyptus grandis*.

If this point is valid then it may be feasible to rotate different species on a single site, especially the marginal dry sites, in order to best utilize the limited water resources. Thus, a high consuming species like *Eucalyptus grandis* could be followed by *Acacia mearnsii* which is better able to tolerate the `pumped-out' soil profile and which rations the soil water more efficiently. Furthermore, wattle will add nitrogen to the site, and with deft management of the litter, could meaningfully contribute to the organic matter status. After the relatively harmful consequences of two short rotations and the associated clearfelling and site preparation operations, it may be prudent to opt for a longer rotation with a pine species in order to stabilize the site.

Such thinking could be carried a step further by contemplating a fallow period on marginal dry sites in order to allow the soil water reserves to replenish, not only for the following crop but also for the agriculturalists downstream who may be reliant on a steady supply of water. Such a policy is used to good effect in the cultivation of grain crops in the Orange Free State. In this case research has indicated the advantages of accurately monitoring soil water in relation to the oncoming season before deciding whether to plant. If this is feasible for crops such as wheat and maize, surely it should be considered in forestry. Forest plantations do not give the site a respite afforded by an annual agricultural crop which utilizes mainly the topsoil, as trees are perennial and also use the entire soil profile.

Increased monitoring of vital site factors.

If we are to manage the site efficiently, the factors responsible for the development of that particular site must be identified and monitored. The two most important categories are climate, particularly rainfall and temperature, and soil. It is a sad indictment of the priorities of the forest management of today that there is probably less rainfall information from plantation areas available at present than there was 20 years ago. Completing budget forms and labour allocation sheets is today regarded as more important than the factors really responsible for tree growth. Even worse, some companies have disposed of the earlier records as '20 years of records is sufficient'. Today our models require decades of rainfall readings on a daily basis, not weekly or monthly. Only then can effective rainfall be determined by considering the intensity of each event and the water lost through runoff or interception. Rainfall must also be compared with temperature which influences the rate of evaporation and evapotranspiration. Thus 800 mm in Piet Retief is worth much more than 800 mm in KwaMbonambi. There are probably not more than two dozen temperature recording stations on the 1,2 million ha of plantations in Southern Africa!

Information on the soil, particularly its depth, texture and structure, must complement the climatic data in order to ascertain the amount of soil water available to the trees. Fortunately, we have a soil classification system in South Africa which is simple and easily adapted to forestry conditions. There are few forestry companies in the country today who operate without obtaining prior knowledge of their soils. Those that fail to obtain or use this information, will almost invariably pay the price in reduced yields in the future. The effect of different tree species on different soil types also requires investigation As the trees dry out the profile, some soils develop large cracks which are easily visible on the surface. Reports of compacted zones in the upper subsoil of sandstone-derived soils under *Eucalyptus grandis* have been tentatively attributed to the soil drying out in the area of largest root concentration. Even deep well-drained soils in the moister areas appear susceptible to intense drying out under trees. These observations confirm that it is not only important to monitor the soil before planting, but to continue to do so after planting as well.

CONCLUSION

It should be accepted that we cannot continue to take out of the site without replenishing, and expect the site productivity to remain constant. The forest industry must be aware of the shortcomings of the marginal dry sites which are increasingly being afforested. It is possible that these high risk sites could suffer from long term water deficit problems if they are continually and intensively managed for trees. The industry should be aware of the forest decline among the European monoculture forests and be prepared to subsidise long term research to prevent similar problems arising in southern Africa.

The forest industry must actively manage its most precious resource, the site, in an ecologically balanced manner. The rationale behind the maintenance, or even improvement, of site productivity in the long term should be addressed first and foremost for the benefit of the industry itself. By doing so, the industry will ensure that it remains both successful and profitable in the long term.