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WETLAND DEVELOPMENT

RIDGE and FURROW SYSTEM

REVISED

1981

NATAL REGION

WETLAND DEVELOPMENT

RIDGE and FURROW SYSTEM

REVISED

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RIDGE AND FURROW SYSTEM

INTRODUCTION

WHAT IS WETLAND?

Wetland is described as a soil that is limited in its agricultural productivity by impeded drainage. The inherent or induced soil characteristics determining agricultural potential with which we are principally concerned are impeded drainage either alone or coupled with erosion hazard.

Impeded drainage may occur at any physiographic point; erosion hazard, however, increases with slope. Because of this two broad Wetland classes are needed since development design criteria to control and rectify these conditions differ. Within the overall Wetland condition, therefore, valley bottoms, river flood plains, pans and the like, with their level to near level conditions are separated from all other physiographic features. We call the former Bottomlands and the latter Uplands.

Wetland occurs in many forms and is caused by a variety of factors. Some of these may be classified as natural, whilst others as man-induced. Examples of these forms will be found in Chapter 1.

WHY WETLAND DEVELOPMENT?

A wide range of Wetland occurs in Natal and East Griqualand and indeed, elsewhere in Africa and beyond. The water - table in these soils is too high either throughout the year or during a part of it, for optimum production of crops, pasture or timber (Plate 1)

Plate 1 Unproductive Wetland

According to the description in the first chapter of this guide, it will be seen that certain forms of Wetland possess their maximum national value as they are. The Wetland development, or land improvement, recommendations made herein exclude such forms. The authors are fully aware of this and wish to emphasize this point at the outset.

It is evident that Wetland development poses problems. These are manyfold and in order to assess their diversity and extent, and to evaluate their real effect on the farmer (and thus on the nation), it is necessary to list the major ones. Problems fall into two categories - at farmer and national (and international) level.

Farmer level

- Extensive or even patchy Wetland prevents timely tillage. One wet patch can cause a tractor to become bogged down (Plate 2), thus holding up subsequent operations. Surface ponding or too high a watertable can drown a crop. Uneven ripening is one of the worst enemies of mechanical harvesting and crop storage. In general, tillage quality is poor and uneven; planting is delayed; plant growth is uneven and retarded; weed control is uncertain; and harvest delays cause large losses.
- Wet conditions favour diseases such as footrot and fluke which cause heavy livestock losses.
- Crop extraction and transportation are difficult and thus costly.
- Farming blocks are separated making access difficult and services such as irrigation buried mains more expensive.
- All these factors make unnecessary demand on the farmer's time and result in lower yields at higher cost.

Plate 2 Wetlands may hinder farming operations

National level

- Soil and water are national assets and it is of vital importance to the national well-being that these resources are safe-guarded.
- Soil eroded and carried into dams and the sea is an irretrievable loss.
- Water-logged soils can become brak and are then reclaimable only at great cost.
- World population expansion is making ever increasing demands on agriculture. Governments of all countries are aware of this and thus of the urgency of developing arable land to its maximum productivity. The extent of Wetland here and throughout the world is almost certainly large, as is typified in the table for Natal and East Griqualand. Moreover the World Food Conference held in Rome in November 1974 drew attention inter alia to the urgent need for improvement of water management and in particular the limiting factors impeded drainage and flooding. (U.N. ECOSOC : 1974)

WETLAND USAGE, PAST AND PRESENT

There is ample evidence, on the ground and from the excellent airphoto cover now available for the whole of South Africa, that pioneer farmers recognized that certain forms of Wetland, particularly bottomland, possessed considerable agricultural potential and that they tackled this class of land in their own way. It is likely that their efforts met with a fair measure of success, especially at the outset. However, because of intensification of catchment land-use bringing increased run-off, flooding and silting; lack of full understanding of the problem and thus incorrect design of drainage structures; and inadequate maintenance of these works, much of this success was short -lived. Unfortunately, too, severe erosion occurred in many bottomlands, particularly when farmers attempted flood control with levees. The net result was that it became widely known that reclamation was not so easy as it had appeared to be and now, 25 to 75 years later, in most instances land is decidedly wetter, and in worse shape, than at the outset.

In a country as large as South Africa and with a wide range of bioclimatic regions, the Government is almost certainly faced with a drought somewhere all the time and has to bear the brunt of relief measures. It is understandable, therefore, that drainage has almost became a dirty word. Thus, as availability of land has never been a factor limiting development, Wetland reclamation of this kind tended to be discouraged until recently, and justifiably so, too.

At present, bottomland usage is restricted to short, seasonal grazing, and some cropping where impede drainage is mild. Several thousand hectares of bottomland are now under ridge and furrow, the Wetland development treatment described in this guide. This development has so far been of a pilot nature to assess the feasibility of the system. The results to date have been highly encouraging.

Of uplands, they have been, and are, farmed extensively and are protected in the traditional manner with channel and broad-based terraces. Productivity is extremely variable. In average and wet years, summer crop yields can be medium to very poor. In a dry year, good response is sometimes obtained. Yields from winter cereals also vary. If, for example, early rains are light, good to excellent results are often achieved. If, on the other hand, these rains are copious, crops can suffer from wet feet and tillage and harvesting are adversely affected.

FUTURE PROSPECTS

Agricultural productivity of bottomlands and uplands is depressed because of impeded drainage and the intractability of many of their soils. Moreover, when they form part of a cultivated landscape, they upset many agricultural operations. Once the technique of 'taming' them is known, they can be transformed from being a liability to a positive asset. Climatic hazards of all bioclimatic sub-regions of Natal and East Griqualand include not only ecologically dry months (25mm rain and less) when soil moisture deficiency is a severe limiting factor for optimum plant growth, but also dry spells during the rainy season. This hazard is especially true of crops grown on free-draining soils. Crops grown on soils with impervious claypan and hard plinthic horizons, however, will not be so susceptible, provided that steps are taken to control the level of the water table.

By so doing, water table water, and water seeping over hard pans and the like, may be used to supplement water supplies during temporary shortages. Thus, once 'tamed', soils with inherent impede drainage may not only approach the productivity of their well-drained associates, but often at lower crop production cost. Furthermore, the very principle responsible for achieveing effective, controlled drainage - a compacted cambered subsurface layer induced by tillage - will also ensure reasonable efficient irrigation, and this at low water application cost. The dimension of this potential and how it may be realised, is described in the chapters that follow.

During the past 25 years extensive experience of Wetland development has been gained in Tanzania (Hill& Van Keulen, 1949), Senegal (Hill & Coleno, 1951), the Sudan (Bunting, 1952), Ghana (Hill, Kowal & Smuts, 1960, 1961), Rhodesia (Cormack, 1953) and South Africa (Hill & Frean, 1968; Hill, 1970; Hill & Frean, 1973), using the basic ridge and furrow principle. From the promising results achieved during the past 5 years in Natal and East Griqualand, it can be said with certainty that there is a great future for the development of certain froms of Wetland, the more so because an extensive area of land falls into this category.

DRAINAGE SYSTEMS

Broadly speaking there are two systems of drainage. First the enclosed type, stone filled, pipe or mole. Second, the open type, with ditch or open furrow. This guide is confined to to a study of the open type because this alone is capable of controlling the two basic interrelated problems common to so many areas of the world - the safe disposal of large volumes of surface run-off that occur during a relatively short period of time, followed by the efficient removal of excess soil water to a predetermined level.

During the past two hundred years much has been written on systems of soil protection, water conservation and underground drainage. All too often these have been dealt with as entirely different subjects. The result of this approach is reflected, for example, in a soil and water conservation system that induces waterlogging, whereas what is needed is a self-contained unit system, the construction, maintenance and cropping of which oblige the farmer to participate fully in an effective system for soil conservation and drainage for the crop of his choice, be this annual or perennial, permitting him to change his crop to suit the socio-economic order of the day.

NEED FOR PLANNING

The ensuing chapters provide the kind of information that must be obtained about Wetland before development may proceed; emphasize the importance of sound planning and detail procedures; and describe the system preferred by the authors and how to farm with it - FOR IT IS A FARMING SYSTEM LINKED TO A DEVELOPMENT SYSTEM - THIS MUST BE CLEARLY UNDERSTOOD. The system does not require investment in expensive, specialised equipment, used for a few hours per annum; no more than tillage equipment is called for, perhaps together with simple tools for smoothing and moving small quantities of soil here and there.

Here it is merely necessary to emphasize the need for sound planning. Even if the land to be developed is little used and yields poorly this does not confer the right of abuse or exploitation. There is an expanding Agricultural Service together with a network of Conservation Committees and it is from these that planning must and will issue. And although there are basic principles and procedures to follow, each area must be individually planned, for it will be different from others.

CHAPTER 1

DESCRIPTION OF WETLANDS

1.1 DEFINITION

Wetlands, as the name implies, include all lands that are either permanently saturated or temporarily waterlogged. A wide range in wetness is encountered; this may result from natural features or may be induced by man himself. All wetlands are characterised by soils showing evidence of impeded drainage and poor aeration. (Plate 3)

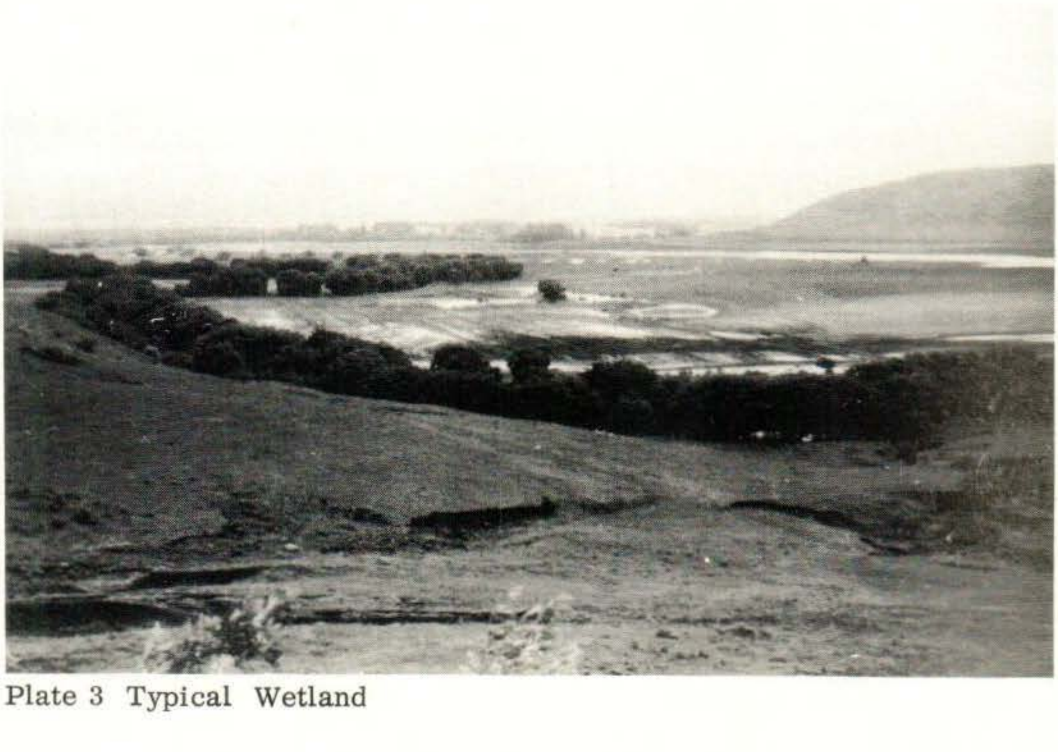

Plate 3 Typical Wetland

There is a clear distinction between wetlands in a bottomland or upland position. Bottomlands comprise level or near level areas along, and on a level with, the local drainage ways receiving runoff and seepage water from the adjacent uplands. These include all 'vleis' as defined by Scotney (1970), alluvial deposits subject to periodic flooding and pans without a natural outlet. Wetlands in the bottomland position are easily identified and usually remain wet for long periods.

Upland areas include the gently sloping land stretching away from, and rising well above the local drainage ways, as well as undulating, rolling or even hilly terrain. Wetlands may thus occur on relatively steep slopes but are most common in a lower slope position or on crests where slope is slight. Waterlogging is generally of shorter duration than in bottomlands but may nevertheless cause serious damage and financial loss by disrupting essential farm operations, such as harvesting. The presence of a springline can also give rise to permanent wetness in upland areas.

Many natural features give rise to wetlands. These include geological formations, such as dykes or sills, that arrest valley incision and create the so-called 'vlei' areas, backtilting of the landscape, reversal of the master drainage system, natural levees along rivers and streams and natural springlines from which water may seep to lower-lying areas.

Induced wetlands result from poor farm management or faulty construction of conservation and other works. Leakage from earth dams and irrigation furrows; mal aligned and poorly maintained drainage ditches; over-irrigation, incorrect primary tillage and land preparation leading to excessive soil compaction are but a few of the main causes.

Wetlands are frequently indicated by the natural vegetation. While certain species in themselves may serve as indicators, plant communities such as reedswamp, sedge meadow and hygrophilous grassland usually demarcate the area more clearly. These areas require special treatment and in some instances deserve careful protection. Without a well-planned development scheme they are generally farmed with difficulty and at great cost to the farmer. On many farms they occur as wasteland.

1.2 EXTENT AND DISTRIBUTION

Wetlands are widely distributed throughout Southern Africa yet few people realise just how extensive they are and their high potential for agricultural use. At farm level their development can have far-reaching economic implication.

The extent and distribution of wetlands is influenced by natural features such as landform, local relief, soil type, geology and rainfall. In areas of high rainfall with dystrophic soils, wetlands are generally confined to the bottomland position. In areas of lower rainfall however, they also occur in upland sites. Experience has shown that in gently undulating terrain up to 40 percent of the upland area may comprise poorly drained wetland soils.

As estimate of the extent and distribution of wetlands in Natal and East Griqualand has been made on the basis of the bioclimatic groups defined by Phillips (1969). For the purpose of this exercise bioclimatic groups 7,9,10 and 11, all comprising thornveld, were grouped. The estimates were made using all available soil survey data together with many individual farm investigations. The results are shown in Table 1.

Table 1 - Estimated extent and distribution of wetlands in Natal and East Griqualand

Bioclimatic group	Wetlands				Total area of Wetlands	
	Uplands		Bottomlands			
	%	km^2	%	km^2	%	km^2
1	25	2 213	5	443	30	2 656
2	20	1 708	3	256	23	1 964
3	12	760	3	190	15	950
4	18	3 294	8	1 463	26	4 757
5	-	-	1	20	1	20
6	15	1 543	10	1 029	25	2 572
8	30	4 850	12	1 940	42	6 790
7 9 10 11	5	920	15	2 760	20	3 680
Total		15 288		8 101		23 389

This wide extent is indeed significant if the loss in crop yield and severe erosion normally associated with unimproved wetlands is taken into account. Although the estimate for bioclimatic group 1 (Coast lowlands) is possibly excessive, the large amount of tile drainage currently being undertaken in the sugar belt suggests that wetlands are extensive along the Natal coast.

A detailed soil survey of portion of East Griqualand has revealed that up to 55 percent of the arable land comprises wetlands in both the bottomland (16%) and upland (39%) positions (Scotney, Jeffrey and Dekker, 1975). On many farms in this area it was found that between 20 and 40 percent of the arable land was associated with a wetness problem.

It has not been possible to estimate the extent of man-induced wetlands though it is likely that these areas are considerable. A survey of one particular irrigation scheme comprising 16 farms has however, showed that 11% of the irrigated land has become saline through over irrigation, leaking canals and inadequate surface drainage. (Department Agricultural Technical Services, 1975)

1.3 SOILS AND RELATED FEATURES

Wetland development requires that the planner is able to recognise and classify soils and assess their potential and limitations. Overall drainage condition and erosion hazard are two of the most important soil features affecting wetland development. Any plan for development must therefore not only improve drainage but also ensure adequate protection against erosion.

Soils common to the majority of wetlands are discussed in terms of the South African national system (Mac Vicar et al, 1975). Although there is often considerable variation in topsoil horizons, diagnostic subsoil horizons are limited to those displaying a marked degree of gleying i.e. clear signs of poor drainage. Horizons second in vertical sequence provide the best indication of the degree of wetness especially the G, E and Gleycutanic horizons. Prismacutanic and hard and soft plinthic horizons together with impervious rock are also common in wetland soils. Regic sand is of lesser importance. All diagnostic topsoil horizons may be found in bottomland sites while in the upland position orthic horizons, grey in colour and with a tendency to compact, are commonest.

The most common soils forms occuring in wetlands include the following:-

<u>Bottomlands</u>	<u>Uplands</u>
Champagne	Cartref
Katspruit	Estcourt*
Rensburg	Fernwood
Willowbrook	Kroonstad*
	Longlands*
	Sterkspruit
	Wasbank

* Soils frequently encountered in lower slope position

The Bonheim, Swartland and Valsrivier forms have not been listed, but are also occasionally encountered in Wetland areas. Diagramatic representation of the soil forms and an explanation of terms is given in Appendix 1.

A wide range in soil depth and texture is typical of many wetland areas. While bottomland soils tend to be clayey (over 35% clay) the clay content of the E-horizon in forms such as Kroonstad, Longlands and Cartref is frequently between 6 and 35 percent. Stonelines and narrow gravelly horizons that permit lateral movement of subsurface moisture are also common in many profiles. Calcareous soils and those tending to the formation of saline conditions under irrigation may also be found in wetlands.

Weak gradients typify most wetland areas and favour mechanisation. Slopes of less than 2 percent are usual in many bottomlands. However, it should be appreciated that wetlands can occur on slopes of up to 10 percent and more. Uneven land surfaces frequently give rise to small areas of wetland especially on near level sites.

Bottomland soils are inherently more fertile than associated upland soils. Base status, pH values and organic matter content are generally higher than in soils of the uplands and there is seldom a problem of aluminium toxicity. Requirements for lime and fertilisers (excluding nitrogen) are thus generally less for bottomland soils than for upland soils.

A characteristic feature of many bottomland sites is the so-called 'key' area, usually comprising a dolerite dyke or horizontal formation of hard rock which forms a nick point in the valley system. The importance of such a 'key' area and the need to recognise its role in any plan for development cannot be over-emphasised.

Wetlands differ markedly in size and shape. They may range from wide extensive floodplains to narrow, winding and often steep natural drainage ways. In the upland position they frequently occur as isolated patches surroundered by well-drained soils. Induced wetlands are generally of limited extent and are of more local significance.

1.4 UTILISATION

Current uses of wetlands are many and varied. Most wetlands in upland sites are cropped or are planted to pasture. Few attempts have been made to improve drainage conditions, however, or adjust crop selection, tillage or other cultural practices to overcome the wetness problem. Wetlands without improvement provide many problems for the farmer. The magnitude of these problems and their financial implications are seldom appreciated.

In early times the so-called 'vleis' were normally burned at the end of winter in order to provide early spring grazing for cattle or sheep. More recently, however, farmers have come to appreciate the high potential of these wetlands for intensive pasture production, crops such as sugar-cane, maize, wheat and vegetables and poplars. Intensive pastures of ryegrass (Lolium spp.), tall fescue (Festuca arundinacia) and clover, frequently under sprinkler irrigation, have been successfully established on many bottomlands and provide high quality grazing for dairy cattle and fat lambs. Optimum production is however, only achieved where drainage has been effectively improved. Poorly drained upland areas are usually protected from erosion in the traditional manner and, in many cases, the structures tend to aggravate the wetland problem.

It is unfortunate that, in many instances, development has not been planned on a scientific or rational basis. Inadequate attention has been given to the overall need for soil and water conservation. Many denuded wetlands, especially in the drier parts, bear witness to poor land-use decisions of the past and the failure to recognise the need for special treatment. Wetland development calls for planning of the highest order.

1.5 POTENTIAL, LIMITATIONS AND MANAGEMENT NEEDS

This guide stresse the value of wetland development. Despite this, there are bottomland areas that, for various reasons, may require total protection These may include areas of very high erosion hazard or with unique water yielding potential. Furthermore, there may be special reasons for total protection. The need to conserve key wetland areas for indigenous water fowl is an example given by Zaloumis (1975).

In such cases protection of the wetland is in the National interest and should be provided at all cost. Here the consequences of the project must be seen to extend beyond the boundaries of the individual farm. Ecological and aesthetic considerations may be equally as important as those with agricultural bias.

Recent experience has shown that the potential of wetlands for the intensive production of crops and pastures is extremely high. Optimum use of these areas however, requires first an improved moisture regime and second, management of the highest order. On farms where wetland development has been initiated it has been found the waste land can be made highly productive, flooding and erosion reduced and access over the farm greatly improved.

In their natural state wetlands have many problems. Poor internal drainage and unfavourable consistency of soils ensure that wetlands are difficult to work. Essential farm operations such as timely land preparation, weed control and harvesting are frequently impossible in undeveloped wetland areas. Bottomlands being low-lying, are also associated with excessive cold and the likelikhood of frosts. Reference has already been made to the high erosion hazard of these areas and there is the further hazard of internal parasites when wetlands are grazed by livestock.

Another problem associated with wetlands concerns land ownership. Frequently a wetland which is best planned as a single unit, will lie on either side of a boundary fence. In such cases development and implementation of a plan will demand the co-operation of both owners.

Farming wetland successfully demands careful decision-making and astute management. The plan for development should be finalised only after careful consideration has been given to all natural and other factors affecting the wetland itself and the necessary management. A cost-benefit analysis, though difficult, is also desirable. The plan should be formulated bearing in mind the need for both soil and water conservation on both the farm in question and others in the lower catchment area. It must also be appreciated that efficient maintenance of the many improvements effected in wetland development is essential if the benefits are to be of a longterm nature.

A 'sytems approach' in planning wetland development is necessary. Agricultural production systems at farm level, or larger scale, comprise many resource elements or components (e.g. soil, water) which in combination form subsystems. A wetland should be seen as such a subsystem and there should be careful understanding of the relationship it has to the overall and complex farming system.

Much of what has been learned about wetland development is the result of field experience. To date little, if any, local research has been undertaken. Until such time as this deficiency is made good much reliance will have to be placed on farmer experience and observation. The attitude towards agricultural production from marginal land is rapidly changing and there is a need to specify procedures to be followed in the intensification process. This guide is intended to meet this need and to provide information for those concerned with wetland development.

CHAPTER 2

PLANNING WETLAND DEVELOPMENT

2.1 PRINCIPLES OF WETLAND DEVELOPMENT

Wetland development requires that the planner bears in mind a number of basic principles. In presenting these, it is assumed that the need for development is beyond question and that all likely consequences have been considered. The development project must be justified and acceptable at local, regional and national levels.

Important basic principles include:-

- The need for a thorough survey and assessment.

  The development of any particular wetland cannot be planned without first making a thorough assessment of <u>all factors.</u> These include soils, slopes, climate, rainfall, run-off potential, flooding hazard, vegetation, current and future use of land and the requirements of capital and management. For this a careful study 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 obtained. Rarely is there a precise boundary between poorly-drained and well-drained land. Usually there is an intermediate zone or ecotone, 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 thereat to form a workable whole, studies should extent well beyond the wetland boundary.

- Consider the catchment as a whole

  Wetland development 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 entirely.

• Treat each wetland on its own merit

Wetland 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 contengencies. It should be appreciated therefore that each development project will pose its own problems and necessary solutions. The scope for development will 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 will have an impact upon other farm enterprises even as any development work has. It will require additional inputs of capital, labour machinery and management, all of which must be viewed in relation to the needs of other activities. It should be appreciated, however, than once the initial development operations are completed, cost is as for normal arable production. In fact total development effort will be of the same order as for breaking up a heavy turf.

• Wetland development must ensure safe use of the land

Perhaps 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 run-off 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 this natural outlet cannot be tolerated under any circumstances.

• Control of the water table should be maintained

In promoting wetland development emphasis should be given to <u>land improvement</u>, 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 (Roe and Ayres, 1954, Hill, 1968, Scotney, 1970). Control in the case of bottomlands assumes 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 flooding should be protected by cut-off drains, embankments or by being used only for pasture production where the heavy grass mat will lessen the erosion hazard. Other danger points such as disposal of run-off must be monitored carefully if any erosion hazard is present, and remedial measures taken immediately if erosion occurs.

- 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 or operator is vitally concerned 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 ploughed 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 should be integrated

  In many instances it is necessary to marry the wetland structures (e.g. waterways) to those of the conservation layout of adjoining arable land. 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, spoil must be spread evenly to avoid local ponding.

- Wetland development should meet the requirements of existing legislation

  A plan for development should take account of all relevant legislation especially that of the Soil Conservation Act. (Act 76 of 1969 as amended). Regulations concerning the breaking up of new land, drainage of 'vlei' areas, cultivation of water courses, burning of natural vegetation and prevention of erosion are particularly relevant. The Water Act (Act 54 of 1956), Forest Act (Act 72 of 1968) and Mountain Catchment Areas Act (Act 63 of 1970) could all have a bearing on the development plan.

2.2 CRITERIA FOR PLANNING RIDGE AND FURROW SYSTEMS

The ridge and furrow system is well suited for any land requiring drainage and protection against erosion. Essential design criteria and factors influencing planning of a layout are dealt with more fully elsewhere in this chapter and Appendix 2, but have been enumerated here for ease of reference.

- Waterways

  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 or the furrows themselves where waterways nor required.

- Direction of flow is important and is determined by the lay of the land and permissable flow velocities in the furrow.

- Ridge dimensions are influenced by a number of important factors:-

  a. Depth of soil. The deeper the soil, the wider the furrow espacement may be. It is recommended that 20m in width should not be exceeded so that the amount of soil to be moved will not be excessive.

  b. Slope. The steeper the slope, the narrower the furrow espacement should be. (Note. Siting of furrows across the slope to reduce the gradient of the furrows may lead to problems in soils with sandy E horizons - see Appendices 1 and 4)

  c. 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 10m can be worked satisfactorily with a combine harvester with a 5m cutter bar. Because crop husbandry may change, ridge dimensions are based on soil depth and furrow slope.

- Length of furrow. This is governed by the hazard of erosion. Erodibility depends on soil texture and the fall in the furrows. Provided the safe velocity of flow in the furrow is not exceeded, the furrow may be extended indefinitely. Details are presented in Appendix 2.

2.3 PLANNING PROCEDURE

Whether a very detailed investigation of the area is necessary or not is determined by the complexity of the problem. When only a small area is involved, the cause of water-logging can often be established quickly, a plan drawn up on the spot and put into immediate effect.

For detailed investigations two main phases are necessary - i.e. surveying and planning. The following steps are recommended:-

- Survey phase

  1. Obtain contour maps and aerial photographs (both enlargements and stereo pairs) of the area. Examine these for any factors mentioned below which might be of importance. The effect of the surrounding catchment, the cause of waterlogging, the area waterlogged, potential waterways and disposal points, etc., can often be pinpointed from a thorough examination of the aerial photos.

  2. Walk over the area noticing particularly the vegetation. Note changes on map or photograph - especially delineate areas which vegetation shows to be severely water-logged.

  3. Check soils and identify series (soil form at least). The location of each inspection site should be marked on map or photograph and a note made of the depth and texture of each horizon, and the nature of the limiting material if any. If salinity (brak) is suspected, samples must be taken for laboratory analysis later.

  4. Note the topography of the area. If it is at all complex, a topographic survey may be needed. Points to note are percentage slopes and any high or low spots or small pans.

  5. Check for perennial flow in the area. This involves both streams running through the wetland and springs which originate within it. If land is irrigated (or to be irrigated) make notes of maximum and minimum flow and periods at which they occur, and possible storage sites.

6. Check for seepage. This may be from springlines in the surrounding landscape or from furrows and dams.

7. If the land is irrigated, obtain details of irrigation methods and amount and frequency of water applied.

8. Ascertain what agricultural implements the farmer has available.

9. Find a suitable place for safe disposal of excess water.

10. Note the history of the land i.e. past usage, drainage practices, and when water-logging became a problem. Note also proposed usage.

At this stage the cause, or causes of the problem can be determined, and a solution postulated. It will be found usually that there are a combination of causes and very often a combination of solutions will have to be used. Some of these are listed in Table 2 and have been illustrated in Figure 1.

Table 2 - Causes of Wetland and some possible solutions.

Cause	Solution
• Natural flooding of a stream	Ensure run-off from catchment is controlled. Clear debris from bed and banks of stream. (Remove barriers to flow).
• Natural or artificial damming of a stream e.g. sills, dykes, oxbows, new channels, weirs, etc.	Design a ridge and furrow layout.
• Spring in land.	Small open ditch to lead off water - (Consider use of drainpipe if ditch impractical.)
• Seepage	Prevented by: a. Lining seepage source b. Diversion ditch
• Over-irrigation	Design a suitable irrigation system.
• Natural impervious layer close to surface.	Design a ridge and furrow layout according to recommended specifications.
• Artificially induced impervious layer. (hardpan)	Rip as deep as possible
• Localised low spots or small pans	Land levelling

- Planning Phase

  For the actual planning of the Wetland development the following steps are recommended:-

  1. Site major waterways on map or photograph. Include in this step waterways to control run-off from the adjoining catchment.

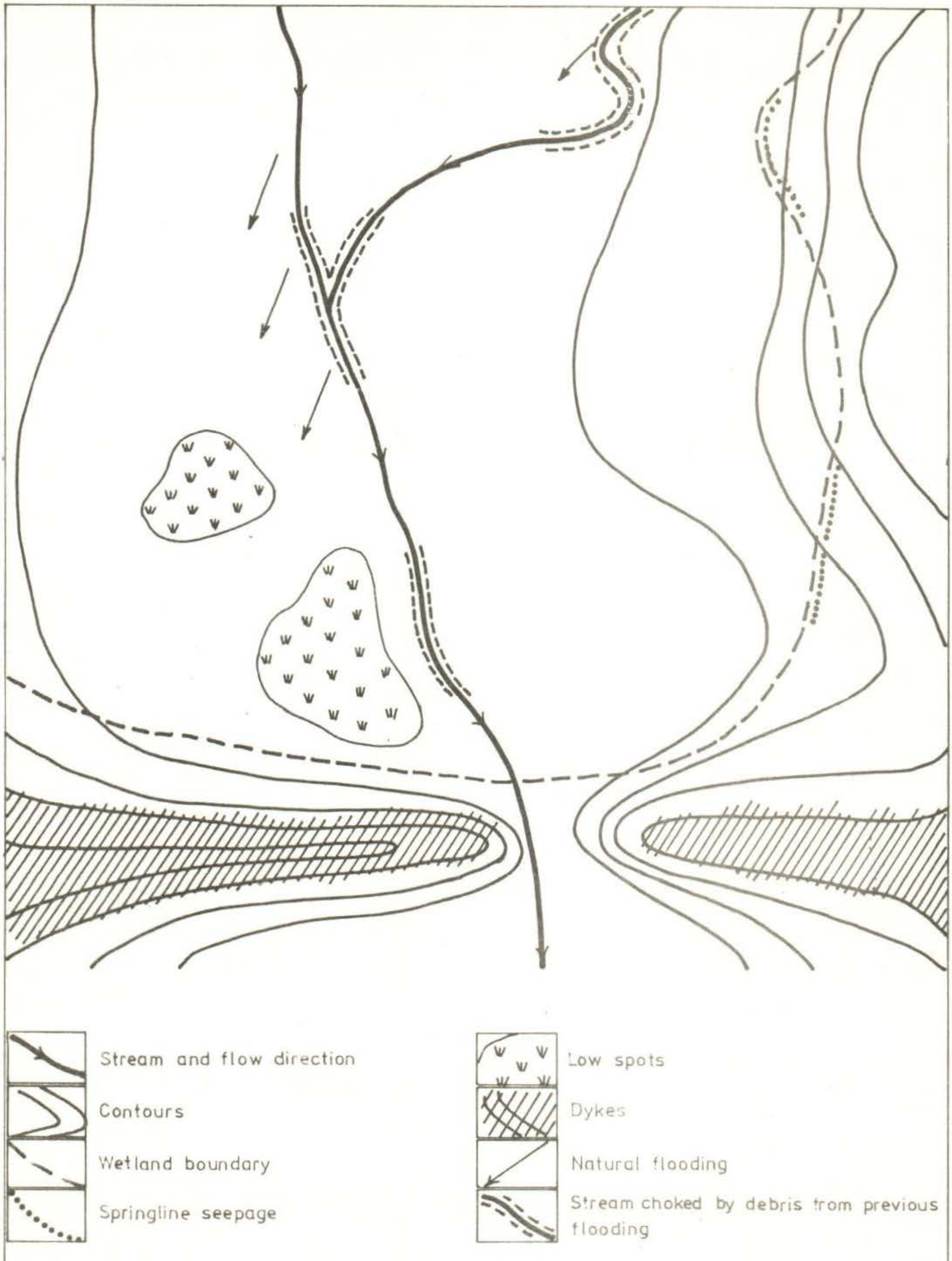

Figure 1. COMBINATION OF WETLAND CAUSES.

2. Site cut-off drains to divert water entering the area from the adjoining catchment if needed.

3. Note seepage control needed.
   N.B. In some cases the design of the ridge and furrow layout may serve to handle excess water from the adjoining catchment and/or springline, or other, seepage.

4. Determine direction of ridges and:-

   a. width of ridge base
   b. Height of ridge above furrow — See Appendix 2
   c. maximum length of flow permissible

5. Site necessary subsidiary waterways if required.

6. Consider access to and egress from the area.

7. Design waterways and access. These two items are combined as the soil removed to form the waterway can often be banked up alongside it to form a roadway. In cases where a waterway is fed from both sides, a "W" drain can be designed with the central section being used for the road (see Fig. 2). Where the waterway has to be crossed by vehicles a gravel "splash" is an advantage (see Fig. 3).

   NB 1. Furrows in the layout will be 0,3 - 0,5m (12 - 18") below normal soil surface so bed of waterway must be able to accommodate this.

   NB 2. Special attention must be directed to the safe disposal of the water issuing from the major waterways.

8. Design cut-off drains sited in second step above.

9. Design seepage control sited in third step above, i.e. line source point of seepage or design a diversion ditch (see Fig. 4)

10. Where it is necessary design the layout so that it links up with the lowest conservation structure of any lands bordering the Wetland.

11. Produce a master plan showing the whole development.

12. Discuss the plan with the farmer and modify if needed. It is highly desireable that the farmer visit layouts already in use, accompanied by his tractor driver, to obtain an idea of the necessary operations and the final product.

13. Bearing in mind the agricultural equipment available, determine, with the farmer, priority sequence and rate at which development should take place. During the actual construction work, frequent visits will be necessary to check progress. On such occasions the person responsible for the development must be present.

2.4 PRIORITY SEQUENCE OF OPERATIONS

Ideally any levelling of hummocky ground should be completed before field operations commence. Thereafter the following sequence should be adhered to on whatever section of land has been selected for development.

1. Peg and construct all waterways connected with the wetland to be developed. Waterways may be either flat or parabolic in shape. They should be stabilised before any further development takes place. This initial step is most important, especially where slopes are steep. Special care should be taken to ensure safe disposal of water

issuing from waterway(s). If stability of the outlet is doubtful it should be inspected at regular intervals during the rainy season and, if necessary, remedial measures taken.

2. Where access roads are to be constructed with the spoil from waterways the work should be done concurrently with 1. Where this is not the case they should come second in sequence.

3. Peg and construct any storm water drains or seepage control ditches (or line seepage sources) and allow time for them to take effect.

4. When the storm water drains and/or seepage control measures have dried the area sufficiently, the furrow lines of the layout should be pegged and marked with a subsoiler as deeply as possible. (i.e. 60cm). This ensures that this location will not be lost and will effect initial drainage.

5. Peg out ridge lines and construct the ridges by ploughing along the lines throwing the soil towards the centre of the ridge, moving outwards to the furrows marked in step 4. It is desirable to get the ridge shape as quickly as possible. To this end the soil should be rolled or disc-harrowed and reploughed. The rolling or discing will give sufficient compaction to the soil to allow reploughing.

   Note: The use of a grader will help obtain ridge shape very rapidly. However, compaction by rain and machinery is likely to be high, resulting in the need for further tillage operations.

6. Subsequent operations should be designed to achieve and maintain the desired ridge shape. All operations should take place parallel to the furrows of the layout.

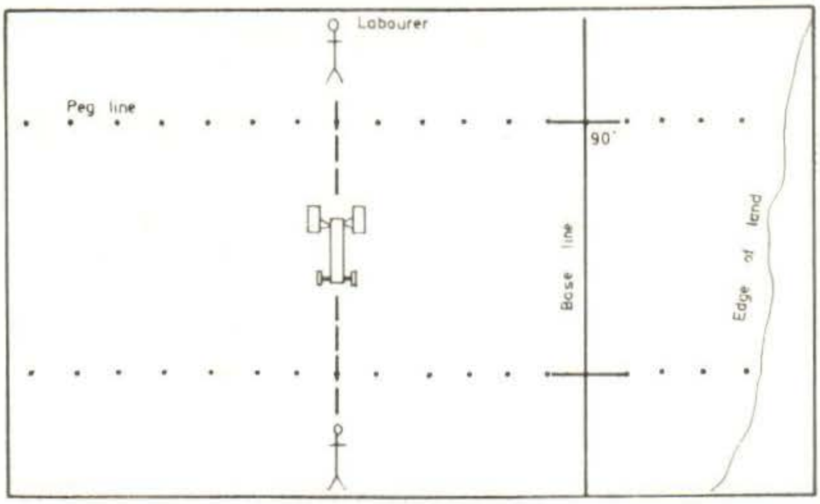

Figure 6. SETTING OUT FURROWS

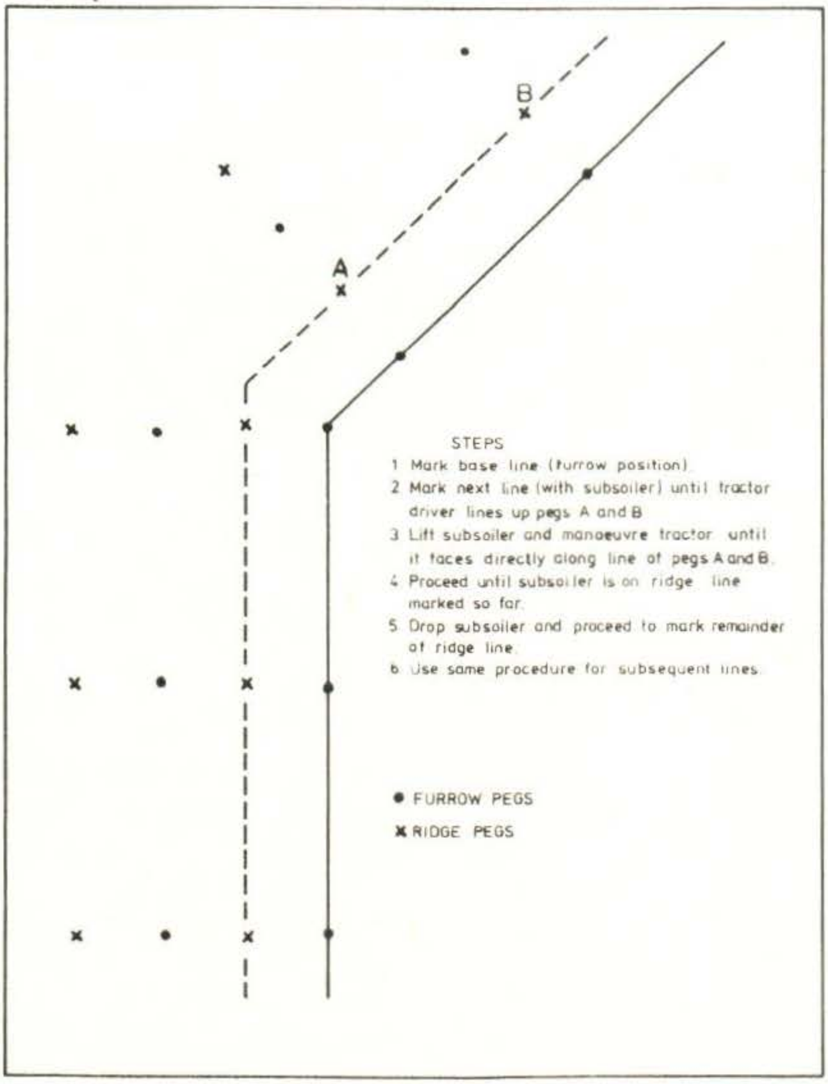

Figure 7. STEPS IN MARKING OUT BENDS.

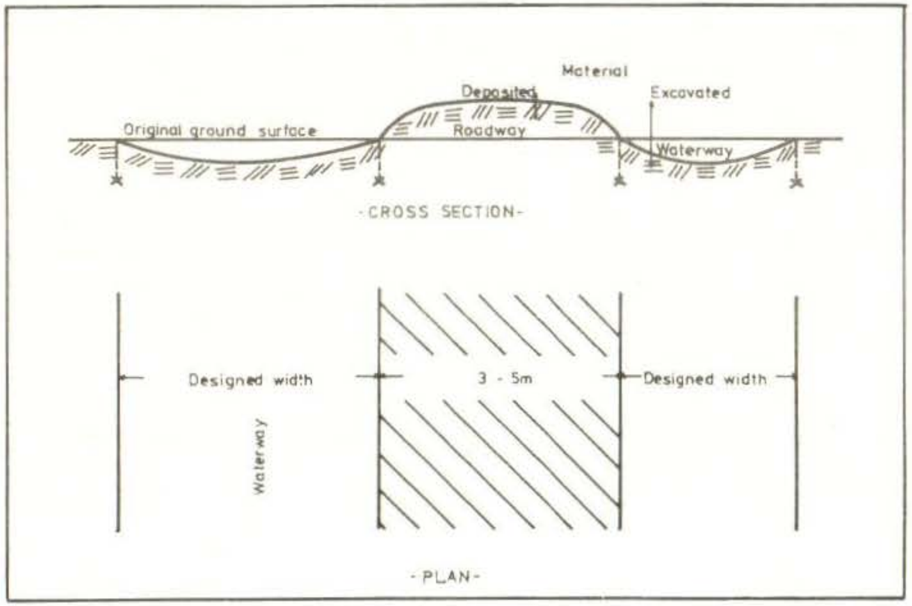

Figure 2. "W" DRAIN

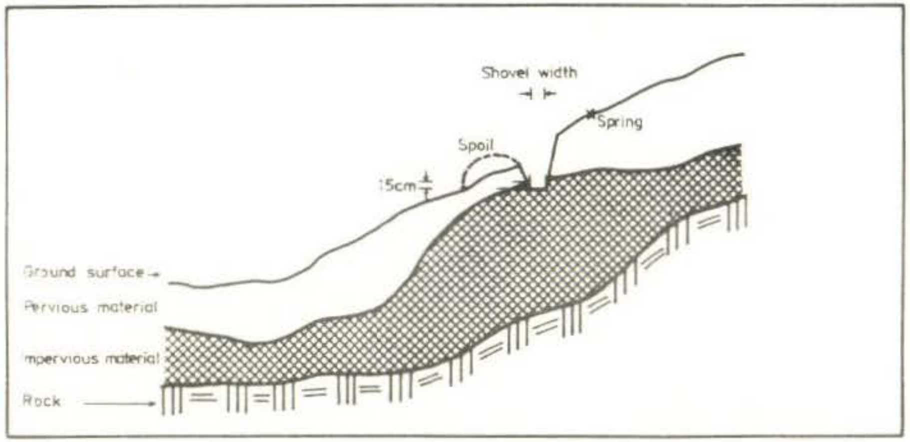

Figure 4. DITCH FOR DIVERSION OF SPRINGLINE SEEPAGE.

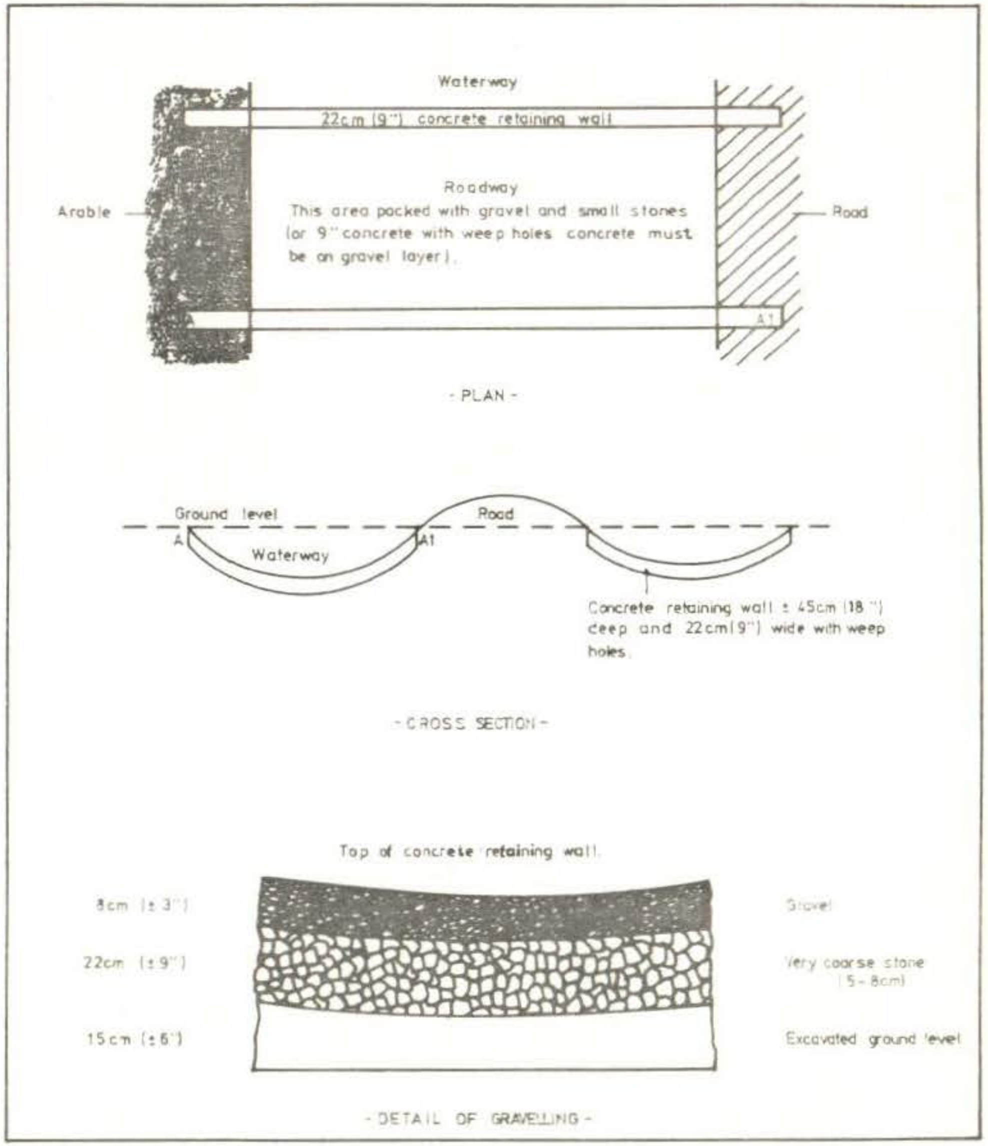

Figure 3. GRAVEL SPLASH.

CHAPTER 3

THE RIDGE AND FURROW SYSTEM

3.1 BACKGROUND HISTORY OF RIDGE TILLAGE

Long before recorded time man learned that the best way to keep himself dry was to build himself a roof capable of shedding rain water. The same principle was applied to roads and Roman roads were always surface cambered with drainage ditches on either side. When that great road engineer John Louden MacAdam developed his surface sealing technique (called 'macadamizing' after him), he adopted the original Roman drainage specification.

Although the ridge has been used by cultivars right through recorded history for various reasons, including drainage, it was not until the end of the eighteenth century that a broad type of ridge was used extensively in Europe. In Britian this form of ploughing was called ridge and furrow and it was given equivalent names such as hump & hollow, laze beds and corrugated ploughing, wherever it was used. It may still be seen, usually as pasture but sometimes as arable, in Holland, Belgium, Germany, France and Italy. It was called the cambered bed when applied to the heavy black turf soils used for sugar cane in N. America, the West Indies, Australia and West Africa. It was named broadland or banquette (French) when used where a soil erosion and drainage problem were both present. (Hill, op. cit.)

In Europe the plough was developed as an animal drawn tillage tool, the horse being more widely used than the ox. At that time the minimum optimum size and shape of a single furrow slice was 9" wide and 6" deep, equivalent to a draught condition of about 300lb. The sustained tractive force exerted by a good horse is about 200lb when travelling at 1,5 mph*. Thus, two horses were needed to pull such a mouldboard plough.

The optimum length of land was arrived at by the staying power of the horse, hence the furlong (or furrow long) measurement of 220yd. This enabled 3/4 to 1 acre to be ploughed in a day with the minimum time taken by turning and headland travel. In this way a ploughed width of 50 to 66ft was achieved in a day. However, because too much time would have been used on headland travel if such a width had been ploughed in one block, this was usually subdivided into <u>stetches</u> or <u>lands</u> whose width varied according to custom and local circumstances, but seemed to range between 7 and 21ft.

Until the Industrial Revolution, which brought a more efficient plough, sheep husbandry in Europe, and in Britian in particular, was for the greater part confined to the freedraining soils such as the great chalk downlands because of the sheep's susceptibility to footrot and to parasites associated with waterlogged conditions. With the Industrial Revolution came the demand for more wool, and sheep husbandry spread perforce to heavier soils marginal for sheep because of poor drainage.

* See Appendix 3 for conversion to metric measurements.

For heavy soils the standard practice was to do all ploughing in the autumn to achieve as much soil weathering by frost as possible. Where drainage was a problem, especially where snow lying on frozen ground thawed fast, the frequency of open furrows was beneficial. Normal practice was to split stetches annually to keep land level, but once the benefits of a broad ridge became apparent, annual ploughing to the same ridge and furrow positions caught on.

The ridge and furrow system as found on the bottomlands of Europe was the result of ploughing, year after year, heading in or gathering on the same stetch or land ridge and finishing off in the same furrow. Stetches were often wider than the 21ft. referred to and ridges 40ft in width, with a vertical interval between crest and furrow of 4ft. still abound, especially on old heavy clay pastures, subject to flooding.

3.2 RIDGE AND FURROW HEREIN DESCRIBED

In this chapter the land treatment which will not only effect improvement of certain forms of Wetland, but also enable them to be farmed in a practical manner is described.

The construction method remains basically the same as for its counterpart in Europe; with ridges running parallel to one another. Thus the term ridge and furrow has been adhered to as a description of this system. It is best described as being the result of a prescribed system of ploughing, with lands being laid out according to soil, slope, flood and erosion hazard, in a specific pattern. Ridgecrest and furrow trough lines are drawn and each 'land' is gathered by the plough into lands of preselected 'wave-length' (Plate 4). Repetitive ploughings in the same direction cause soil to be thrown up into a cambered land, the height of which slowly increases. Ridge height and form may be easily controlled by tillage. Optimum cultivation results in subsurface consolidation at a depth of approximately 50 cm (20").

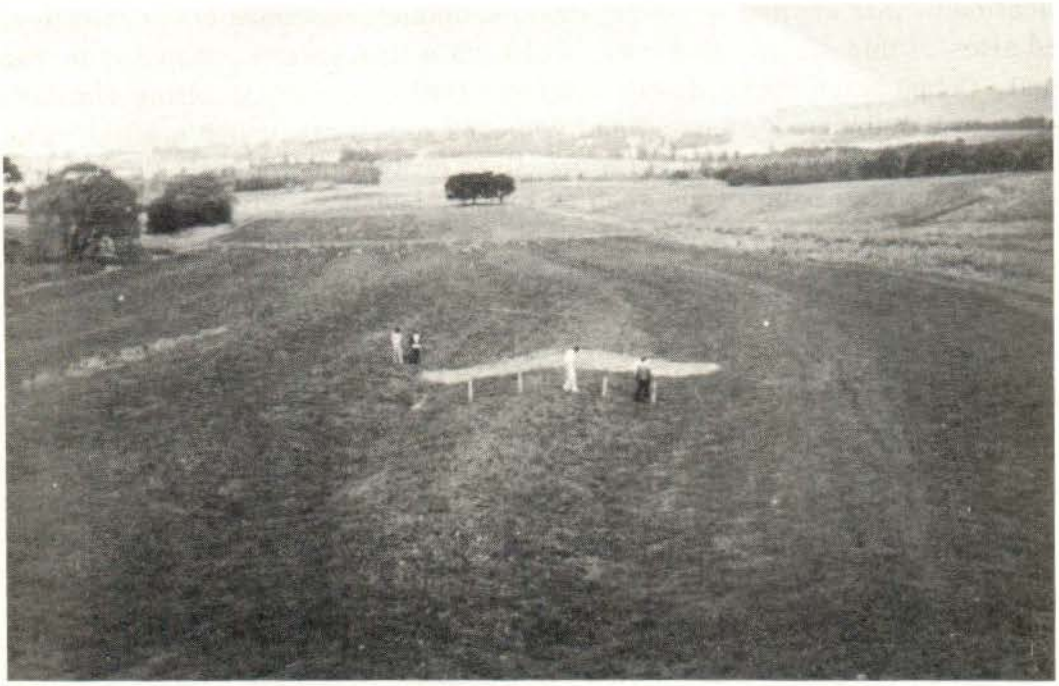

Plate 4 Ridge and furrow under pasture
Trench through ridge for soil inspection

3.3 THE RIDGE AND FURROW SYSTEM - OBSERVATIONS ON FIELD APPLICATION

- Bottomlands

These are often formed upstream of a rock sill or similar barrier highly resistant to erosion. In such instances gradients rarely exceed 2 percent and will often be as little as 0,2 or even 0,1 percent. It is emphasised that the ridge is a self-contained unit ensuring its own protection and drainage. Under alluvial conditions the layout is directed to conform to flooding pattern so that surface water is disposed of as the flood subsides. Control of the water table (i.e. drainage)is here assured by a narrow ridge of 10 to 12m raised high. Yearlong access for heavy infield crop extraction is essential for these conditions as it will be found that under planted pasture, (the wisest form of land-use under these conditions), livestock prefer upland pasturage during the summer months of December, January and February. At this time bottomland pastures will produce large valuable grass surpluses which must be easy to conserve.

The best access is often to be found on the river or stream bank for this is usually a well-drained location where coarse material is deposited during flooding. On the other hand, the bottomland may be flanked by a springline which remains permanently wet. This forms an unworkable zone physically separating bottomland from upland and preventing access between the two. Merging these two zones into a farmable unit is essential and, although springlines usually occur at change of slope, which may be from 3 to 6 to even 10 percent, the ridge may be extended, quite safely, through the springline and up the slope to the lowest conservation structure of the upland conservation system, for usually a short distance of 50 to 100m only is involved. In this way, springline water is disposed of and access assured.

- Uplands

Application of this system to poorly drained uplands has been restricted to a few selected sites of this stage. However, field scale trials were conducted in Tanzania, Senegal, Congo and Ghana between 1950 and 1961 on soils exhibiting similar characteristics to Rensburg, Kroonstad and Wasbank forms and under similar rainfall conditions. On these highly erodible soils excellent protection and water control were achieved and yields from crops such as maize, bananas, soya beans, sugar cane and millet far in excess of those attainable on land protected by grass strips, channel and bench terraces, were obtained. (Plate 5)

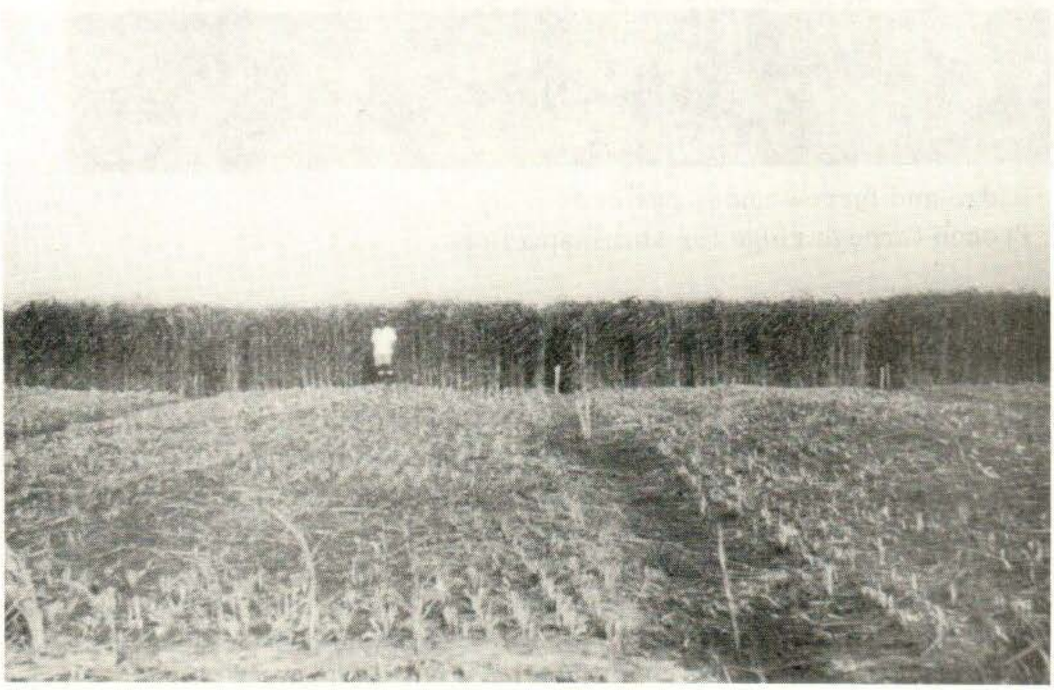

Plate 5 Millet in Ghana, 1953, on newly constructed ridges - note absence of fertility gradient

For these conditions, the late Mr. S. Smuts, the then Head of the Department of Conservation and Irrigation Engineering of the University of Ghana, selected a master gradient commencing at 1 : 150 and gradually flattening to 1 : 400. In practice, following critical field observation, he accepted steeper gradients over short distances for ridge lengths of about 300m.

Results from trials conducted in this country have been encouraging, as was to be expected and, in view of the extensive dimension of wetland in the upland position in Natal and East Griqualand alone, a very significant increase in agricultural productivity can be expected in time, provided that planning and implementation are sound. Appendix 4 should be consulted for treatment of Upland soils with E horizons.

- Man-induced Wetlands

The degree of wetness here varies with soil, slope and treatment. A fair to well-drained bottomland soil may easily be converted into a swamp condition by severe leakage from an ill-maintained, unlined irrigation canal or a large furrow for conveying water for a small hydro-electric plant, for example. In the majority of cases, however, an impeded soil drainage condition will be worsened by seepage from an earth furrow serving the area, or from a leaking dam, pipe-joint, lined canal, etc.

Topsoil horizon can be expected to be shallow and so ridge width will be limited to between 7,5 and 12m, depending on soil depth and whether the subsoil horizon is soft or hard.

3.4 ADVANTAGES OF THE RIDGE AND FURROW SYSTEM

To be successful, any soil conservation system must enjoy unreserved farmer cooperation. Any system requiring special skills and equipment for its maintenance, and even its construction, is unlikely to receive the support it must have. With this in mind, the following advantages 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 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;
- layout is fixed and thus protection is permanent. There is thus no stage at which land is vulnerable. When the land is bare, however, and the tilth fine, erosion may occur. A rough tilth till immediately before planting or the use of a nurse crop would lessen erosion hazard. All agricultural operations are facilitated because land is in units or blocks which do not vary in dimension;
- the ridge is the drainage unit, (fig. 5). Not only does it shed surface run-off when this occurs, but it also prevents the water table from rising too high and in this way adversely affecting crop growth. The furrow capacity is such that even a slight furrow gradient will discharge a large volume of water. Therefore, depending on the soil type, 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 contours;
- although crops grown on ridges will benefit from land smoothing, ponding, a severe limiting factor under normal field conditions where impeded drainage occurs, is eliminated;
- more rapid surface drying after rain permits earlier and more effective agricultural operations, and in particular the cheaper mechanical control of weeds and vital special plant protection spraying. It also ensured more uniform soil temperatures.

- There is no question of over-drainage. On the contrary, impeded drainage causes crop drowning and earlier onset of wilting in a dry spell. The water table is being controlled. If the topsoil horizon is provided with plant nutrients to the base of its profile, as it should be for phosphate at least, then rooting will extend and will have access to more water during stress periods because of its spread and depth;

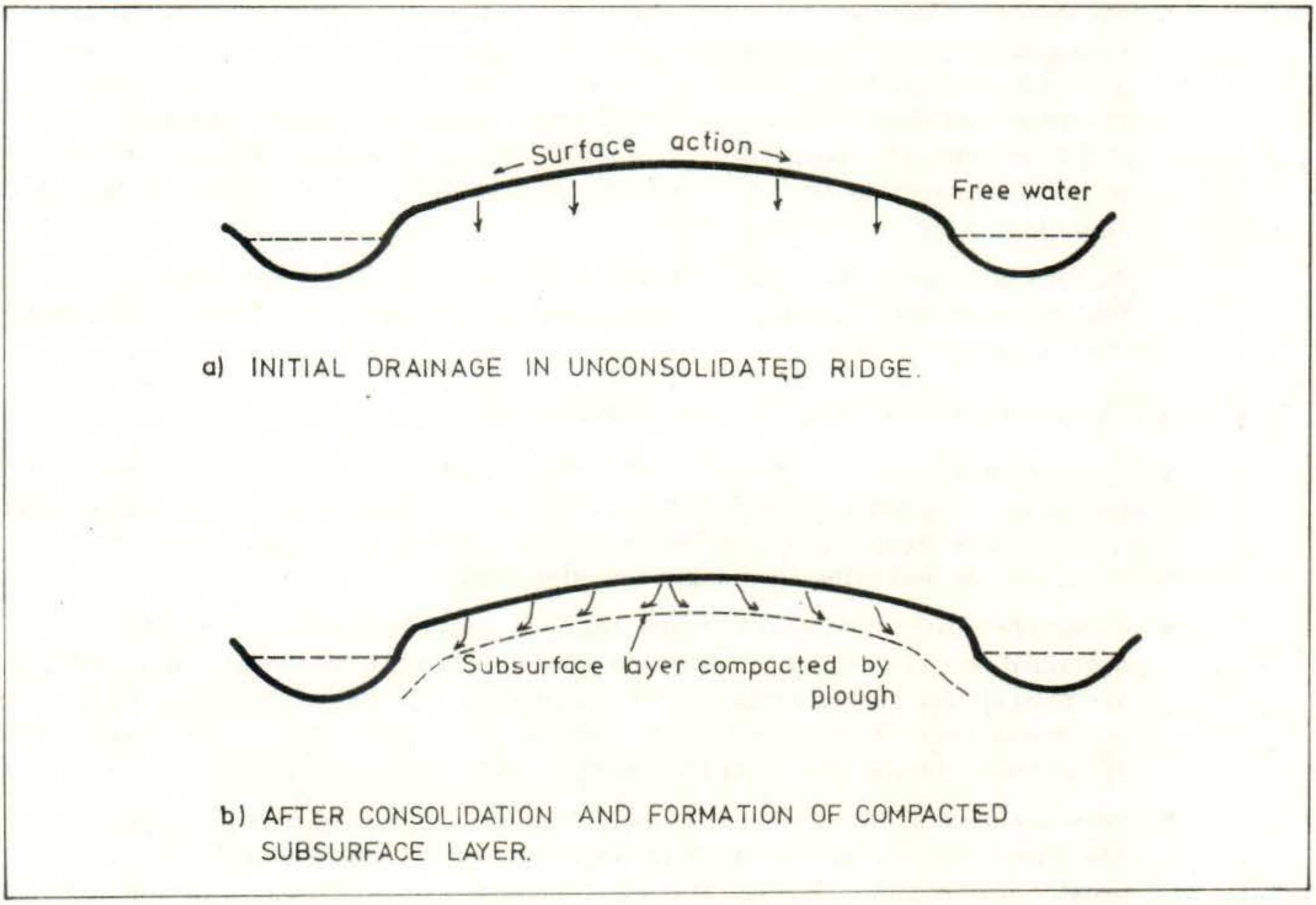

Figure 5. THE DRAINAGE ACTION IN A RIDGE.

- as has been stated, a subsurface cambered base can be induced in some soils through tillage at a depth of ±0,5m (fig. 5). When soil exceeds field capacity water moves out over this base and, at certain levels of rainfall, is also shed off the surface. This is how the drainage functions. Soil can be maintained at field capacity by a continuous trickle flow of water applied via a small furrow drawn along the ridge crest. This can be a cheap, simple method of irrigation efficient enough for the first one or two years of development under certain circumstances.

In the addition to these specific advantages, the following benefits of a general nature may be anticipated:-

- marginal land is transformed into land of high production potential;
- higher yields and net profit margins can be expected;
- flood damage is reduced or may be eliminated;
- access is improved and maintenance cost is low;
- where conditions favour development of salinity, it is likely that this hazard will be curtailed, if not prevented, with ridge and furrow.

3.5 DISADVANTAGES OF THE RIDGE AND FURROW SYSTEMS

When fully developed, according to correct design criteria, there are no significant disadvantages. It is obvious that if this system were used where no drainage problems existed, then dead furrows would present an unnecessary obstacle for combine harvester, for example. But where impeded drainage and erosion hazard are limiting factors to viable farming, this system disposes of these.

Some workers list disadvantages of the bedding system, as they term it (I L R I, 1974) as follows:-

- the slope of the furrows is not always sufficient, especially when made with a plough only;
- the topsoil is removed from the side of the beds to the middle, which may lessen crop yields near to the furrows;
- The furrows require regular maintenance, also to prevent weed problems;
- the system hampers mechanised farming;
- moreover that the bedding system does not provide a satisfactory solution for surface drainage when crops are grown in rows parallel to the dead furrows. The crop ridges prevent overland flow to the furrows, and consequently the rows have to drain into a field drain, or row drains have to be made and maintained. Therefore, the bedding system is only recommended for pasture or hay or any crop which allows the surface of the beds to be smoothed.

For the wide range of adverse conditions experienced and dealt with by this guide, it can be stated emphatically and without fear of contradiction in the field that the disadvantages given will not occur if design, tillage, and fertility are correct.

3.6 RIDGE AND FURROW CONSTRUCTION - METHODS AND MACHINERY

- Preliminary preparation

The block to be treated should be free from dongas, old terraces, trees (other than those being left for shade purposes), fences, termitaria, artificial levees, old water courses and so on. Moreover, where land is generally uneven, levelling will facilitate ridge building and will result in better quality, more uniform ridges. Where land is covered by tall grass or other vegetation, this should be slashed down or burned off, firstly because it impedes marking out and secondly because buried trash will make subsequent ploughing extremely difficult for some time.

A most important point to remember at this stage is that, under a very wide range of climatic conditions, a trickle flow of only 10 to 20 litres of water per minute can maintain one ha. (one or two gallons of water per minute per acre) of poorly-drained land permanently wet. Small spring and seepage flow of this kind is usually perennial and will prevent reclamation at any time of the year (except by means of specialised equipment), unless control measures are undertaken. All that is usually required is a small interceptor ditch which may be hand-dug or else pulled through with an ox plough. Water draining of this kind undertaken during the rainy season will ensure that dry season work can be carried out with the minimum of hindrance.

- When to build

  Wetland is subject to erosion or flooding. As a rule, therefore, the best time to build is in the dry season, though moist soil conditions will give the best results. Clearly where the risk of flooding and erosion is slight, development may take place at any time. This is especially true of alluvial bottomlands.

- Construction machinery and tools

  Although land improvement and farming this land are operations which, to a varying extent, are separated in time, the methods and tools must virtually be common to both stages.

  The reclamation tools are those used for farming, be they spade, blade terracer, earth scoop, light land-leveller, subsoiler, plough (one way or reversible), harrow or roller. It is important to emphasise the function of the roller here, or indeed, any operation effecting consolidation - harrowing or sheepsfoot roller and the like. The objective is to induce the consolidated combered subsurface layer referred to in 3.2.

  It is important to note that simple techniques are effective and that ridges can be constructed with animal drawn implements. One extensive piece of development on a heavily tussocked, strong clay soil in a perennial soggy condition, was achieved by plough, harrow and spade alone.

  Often the time separating construction from farming is short. The right treatment at the right time can transform, sometimes within a few weeks, land that is marginal, or unsuitable for crop production; and, although in that season it will yield far less than its potential, it will yield, and thus help to pay for the cost of improvement. The crop itself, with its root action alone, is an important part of the improvement process.

- Construction steps

  1. Marking

     It is assumed that the gradient has been selected by the planner and the basic furrow direction has been pegged. This furrow base line should be marked in either with a single tine subsoiler or a single Lister bottom. Marking falls into two categories and these should be treated differently, as follows:-

     For most layouts it will be found that ridges can be kept straight due to the range of furrow slope that the system permits. When this is the case it is only necessary to peg out two lines of pegs at right angles to the base line at the width interval selected (Fig. 6). When demarcation takes place labourers can be used for intermediate markers and lined by their foreman or the tractor driver. Suffice it to say that for this class of ridge the driver must be able to plough a straight furrow.

Where changes in land slope prevent the complete ridge from being set out in a straight line, it is preferable to have straight sections linked by tight bends rather than the whole ridge being a continuous bend (Fig 7). With ploughing it will be found that the 'sharpness' of the ridge 'joints' soon become less acute, with the bend.

Land should be marked on both sides of the base line and simultaneously with pegging, firstly because of the risk of pegs being knocked down by livestock and secondly because, as lines are parallelled off, furrow gradient checks should be made to ensure that permitted limits are not exceeded. Should this occur (i.e. level, back slope or too steep), then a new base line must be set out to the master gradient and the procedure repeated. The area lying between these two blocks will be a correction strip and may be used in a number of ways such as tree shade/wind breaks, silage pits, hay stacks, fertilizer dumps and so on. It may also be farmed on its own.

Once the permanent furrow positions have been marked, then the ridge positions may be likewise treated, though accuracy of marking is not quite so critical as it is for furrows. Where crest marking is done by plough, always throw the first furrow uphill so that the heading-in furrow slice(s) fall on top of it.

N.B. Great care must be exercised in clearly differentiating between furrow and crest position. It is easy to make a mistake and this can be extremely difficult and time consuming to rectify.

2. Ridge forming

In time gathering-in by any plough will produce a ridge. The quickest and best results, however, are always obtained by using the right plough. Although the usual criteria for plough selection apply, generally speaking the disc plough is superior to the mouldboard because the former casts soils further and higher than the latter and the larger the disc diameter, the better the cast. (Plate 6).

Plate 6 Ridge construction - heading in with disc plough

For the offset crest ridge the reversible plough takes its rightful place as being one of the finest and most effective soil conservation tools at our disposal but which, unfortunately, is scarcely recognised as such. Unless a reversible plough is used, there will be much idle travel.

Development ploughing commences at the crest position and the stetch 'gathered' until it is completed at the furrow. The importance of maintaining the precise location of the furrow is again stressed. The number of ploughings required to form the ridge depends on factors such as soil type, its condition, the type of plough used and the interval between ploughings. However, two ploughings should be given initially, with some form of secondary tillage and consolidation between them such as disc and roll, by which time the ridge will be permanently marked.

If procedure has been followed correctly, the man who is going to form the ridge, be it with ox, horse or tractor, has been shown completed work in order that the obtain a clear picture of what is required of him. At this stage, therefore he will be able to continue with the minimum of supervision, his skill increasing with experience.

The height and shape of the newly formed ridge, especially when this exceeds 10m in breadth, is usually deceptive as it will tend to settle considerably, the sides remaining concave rather than convex, the shape they will assume, with ploughing, after a few years. (fig. 8).

Several further points are of considerable importance at this stage. These are:-

a. any high spots in the furrow must be removed by spade or machine;
b. furrows must be extended into the waterway which should have been formed 0,3 - 0,5m (12" - 18") below normal soil surface;
c. furrows should be subsoiled well into the gleyed or plinthic horizons with depths of 0,5 - 0,75m (18" - 30") being aimed at.

Where circumstances have prevented pre-ploughing levelling, this may be sandwiched between development ploughings and although levelling at this stage is more difficult and less effective, it is better than not at all.

- Maintenance tillage

Complete maintenance is achieved by customary tillage, that is assuming the plough is used in the traditional manner. Under normal circumstances for annual crops, ridges are gathered by plough. Secondary tillage, transport and other agricultural operations will prevent the ridge crest from exceeding its height limit. However, should this occur, ridges can be ploughed out or disced down.

The efficiency, productivity and ease of management of the ridge improves progressively for several seasons until the requisite camber is induced at surface and base respectively. The actual time for this to take place 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 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 used to enable ridge development to take place until 'maturity' is reached.

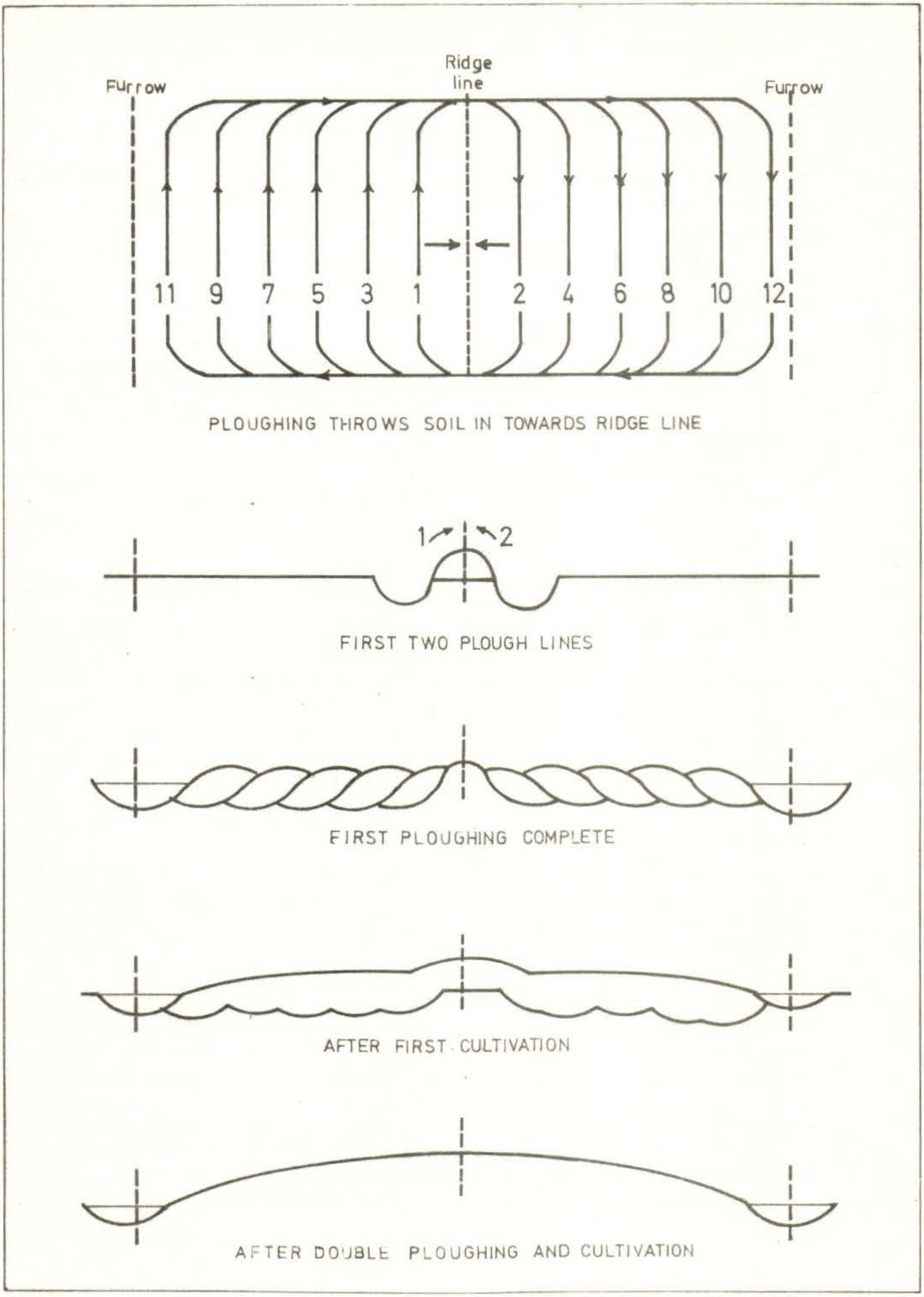

Figure 8. DEVELOPMENT OF RIDGE.

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 true. The system, in any of its forms, does not hamper mechanised farming. A combine harvester can be operated without difficulty on a 10m ridge. The point to remember in any case is that without the ridge crops won't grow and no mechanical work will be possible, when these are required most. Thus, for ridge width selection, rather err on the narrow side and reap the benefit of more rapid development.

3.7 CROPPING

It will have been seen that, once planning and development procedure 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 for other annuals an unplanted strip should be left in the furrow. However, this should not exceed the normal row width for maize, for example.

3.8 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 surface and within the soil, before adding more. More often than not, though, the irrigator, be he planner or user, is so concerned with matters such as evaporation rate, droplet size, rate of infiltration, rainer espacement, application cycle and the like that vital matters such as water table and disposal of excess water are not adequately considered, or do not feature where they should in planning criteria - FIRST.

In Wetland situations the overhead irrigation layout should always be superimposed on the drainage plan, and not vice-versa as is customary! If correct planning procedure is followed, then permanent irrigation pipes can usually be laid along access roads or ridge crests thus removing the risk of damage by deep cultivation. Where traversing ridges with a permanent main is unavoidable however, this must be laid at least 60cm. 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 portable pipe permissable deflection is sufficient to accommodate ridge profile (Plate 7). Ridge and furrow will also accommodate the more recently developed system of 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 overhead irrigation cost may prevent this system being used. With proximity and low lift of water often available, however, simple, reasonable 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 soil is 'raw' and 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.

No precise work has yet been undertaken to assess the effect, if any, of ridge and furrow on saline soils. This should be undertaken. As impeded drainage is one of the prime causes of saline development, however, it is likely that ridge and furrow has an important role here. The whole of this matter demands critical investigation.

Plate 7 Sprinkler line over ridges

CHAPTER 4

FARMING WETLAND

In Natal and East Griqualand several thousand hectares of Wetland on more than 70 farms, embracing widely differing conditions, are in various stages of development. Wherever planning has been sound, and husbandry good, high pasture and crop yields are being achieved and sustained.

A statement such as this, however, is, quite understandably, not substantial enough for any person or body responsible for long-term land care. Nor, in fact, is the mere substance of this guide. The good farmer, the sound land-use administrator, the well-experienced hydraulic engineer or the wise soil conservation committee will ask such terse questions as - is the practice safe? Does it work? Is it over-complicated? Is it practicable ? Does it pay? In answering such justifiable questions, an example of wetland development is presented.

It is a large livestock enterprise far removed from markets, the emphasis being on the production of wool, fat lamb and now, milk. Between 25 and 30% of the arable soils are poorly drained. The unit is managed by a good farmer able to integrate not only the complex biological and husbandry factors, but also the physical and mechanical and the human and commercial dimensions of agriculture.

4.1 THE FARM "ROODEBERG"

- Historical background

The Blore family settled in East Griqualand in 1886 on farms in the Weza and Franklin districts. Land usage was generally extensive with sheep and some speculation in cattle. The Franklin farm was used for summer grazing and the Weza property for winter.

At the southern foot of the Three Sisters mountains (2 000 m.a.s.l.) a 60 ha bottomland has been formed upstream of a dolerite dyke through both silt deposit from a strong flowing perennial stream which floods periodically, and accumulation of organic matter. 35ha of this bottomland lies on the Blore property and is fed and maintained by seepage water issuing from the surrounding upland. The total area of this bottomland and its adjacent poorly drained upland on the Blore property is 115ha.

The potential of this area was certainly recognised at a very early stage of the farm's history, but periodic, unpredictable flooding made usage difficult. Between 1910 and 1920 the stream was diverted to a hand-dug furrow in an attempt to obtain better control. Whilst the original dimensions of this furrow are not known, it would probably have been sufficient to cope with the summer flow of 0,15 - 0,30 cumecs. Straightening this streambed shortened the flow distance, thus increasing velocity, however, and according to accounts handed down the furrow quickly broadened and eroded down to its present bed which is now deep, but wide and stable.

Between that date and 1970, various attempts were made to effect further water control by ditching and flood irrigation. Although these met with limited success, the potential of the land for pasture production was established, particularly where coarse silt deposits occured. These island-type areas produced excellent high-yielding quality clover pasture. In spite of this, production from the bottomland was unreliable for the reasons given. Farming the upland wetland was largely unsuccessful except in "dry" summers. Farming the other upland was rewarding but due to the landscape setting of upland wetland and bottomland, access was always a limiting factor.

Although the main line of farming was sheep and beef, Mr. Blore recognised that the potential of this block lay in its capacity for milk production from a combination of intensive grass pastures and silage crops but, at the same time, he realised the problems to be resolved before this could become a reality. Accordingly he requested an examination of the situation. This was undertaken in August, 1971.

- Farm description

1. Situation extent

   The farm lies about longitude 29^{0} 20' E and latitude 30^{0} 10' S some 12 km westward of the village of Franklin, East Griqualnd in the Cape Province of the Republic of South Africa. It is 850ha in extent of which veld comprises 625ha and arable 225ha. Of the arable, 110ha is well-drained and 115ha some form of wetland.

2. Natural features.

   The farm Roodeberg lies accross the boundary between bioclimatic groups 4e and 4f as defined by Phillips (1969). The altitude varies between 11 00m and 1700m above sea level. According to the criteria for these bioclimatic groups the mean annual rainfall is between 700mm and 1100mm distributed over four to five wet months (over 100mm per month), four medium wet months (between 25mm and 100mm per month), and three to four ecologically dry months (less than 25mm per month). Occasional mist may occur. The mean annual temperature is between $13^{o}C$ and $17^{o}C$. The range of mean daily maximum and minimum temperatures is between $20^{o}C$ and $23^{o}C$ and $5^{o}C$ and $10^{o}C$ respectively. Frost expectation is from moderate to severe over long periods for several months.

   The topography of the farm varies from mountanious terrain with sheer to very steep slopes to gently undulating land of less than 15% slope.

   No records have been kept of the winter flow of the main stream. It was measured in August, 1973 as 0, 013 cumecs. Water available from perennial springs and seepage in the bottomland catchment amounts to about 0, 0026 cumecs. Some of this is stored in one dam holding 10 000 cubic metres and several other small dams. This water is used for stock watering and for gravity sprinkler irrigation.

   All bottomland and low lying areas are subject to occasional heavy flooding of short duration. These areas would be under water varying in depth from a few cm to 2m, on an approximate frequency of once in two years. One such flood has occured since development commenced, but water dispersal was completed within 24 hours.

3. Soil resources - Roodeberg

   The bottomlands on Roodeberg are dominated by soils of the Katspruit and Willowbrook forms. Areas adjacent to the bottomlands are generally associated with poorly drained fine textured soils of the Kroonstad form (Bluebank series). Longlands and Wasbank forms also occur in some isolated areas. Poor drainage is the major limitation of all these soils.

   The uplands proper are dominated almost entirely by deep, red, well-drained soils of the Hutton form (Doveton series) although small patches of the Mispah series are associated with outcrops of shale. The freely drained upland soils are eminently suited to the production of pastures.

While an integrated programme of crop and pasture production to meet livestock needs is facilitated by the soil resources, the success of the cropping system will depend on the degree of improved drainage achieved in the bottomlands and other wet areas.

- The Plan for Development

a. The Wetland project (Plate 8)

Plate 8 Aerial view of the Roodeberg Wetland project

This comprises an area of 115ha of which some 30ha is well-drained but has immediate bearing on the layout of the remaining 85ha of poorly drained soil. (Fig. 9a). (For table 3, see below)

b. Factors limiting agricultural production in areas under consideration

<u>Bottomland</u>. Basic fertility problems are minimal, but crop production is severely restricted by waterlogged conditions. Access even for livestock is difficult.

<u>Well-drained upland</u>. Fertility problems are those associated with low pH and aluminium toxicity. This applies to all upland dryland arable soils of the area. Effective correction is by liming and by taking regular soil tests followed by the application of recommended fertilizers.

<u>Poorly-drained upland</u>. Fertility problems are similar to those referred to above. In additions these are very poorly-drained soils of high erosion hazard, and unfavourable physical conditions, changing from a slurry to a concrete hardness within a very short space of time. They occur mainly in the lower slope position and it is for this reason that a safe use technique had to be determined.

TABLE 3 - The use and development of the Wetland project - Roodeberg

		Bottomland	Upland	
Soil Forms		Katspruit Willowbrook	Poorly drained Longlands Wasbank	Well drained Hutton (Doveton)
Area (ha)		35	50	30
LAND USE	Previous	Early spring burn Summer hay cut	Fodder crop prodn. severely limited by wetland conditions	Fodder crops
	Immediate Pre-development	As above. 10ha of isolated areas under flood irrigated clover pasture	As above	As above
	Planned	Complete ridge and furrow development overhead irrigated. Clover/grass pastures utilised by dairy herd and for ensilage. Every fourth year field crops for fodder production in rotation to rejuvenate pasture.	Ridge and furrow development as for bottomland with overhead irrigation	Overhead irrigation Fodder crops. Mainly maize silage to balance expanded milk production from wetland.

TOTAL AREA - 115ha

c. Choice of system

For the owner, the main problem to be resolved was the reclamation of the bottomland. Due to the incidence and severity of flooding, the uncontrollable fluctuating water table, the old silt banks and the oxbows, and the widespread wetness caused by perennial water issuing from former watercourses, it was decided that carefully planned ridge and furrow would be the only system for solving these complex problems in a practicable and economic manner.

Reclamation of the bottomland alone, however, would have been unacceptable because of the springline itself and wetness of the lower slope belt flanking the bottomland and denying ease of access. Provision was made in the plan, therefore, for including these wet upland soils of the influent surrounds and applying the ridge and furrow system in a slightly modified form to this important zone in order to link the bottomland to well-drained upland further up slope. By this method alone the whole block could be farmed as a single unit.

d. Implementation phases

As reliable, albeit circuitous access routes existed linking the dairy and sheep buildings with veld, hay production land and winter feed, and because the ridge and furrow system when applied to upland wetland was new to South Africa (although it had been well-tried and proven in many parts of tropical Africa 20 years previously - Hill, 1961), the bottomland was tackled first. For this block the sequence of operations was as follows:

1. The best existing planted pasture areas were left for production purposes during the development phases.
2. General access within the bottomland was established by controlling perennial water in hand-dug drains along planned positions.
3. Excess vegetation was removed by slashing and burning in early spring.
4. As soon as conditions permitted furrow positions were demarcated by tractor-mounted subsoiler. Subsequent to this, land was ploughed into ridge and furrow.
5. Annual crops, such as maize, barley and rye, were planted as soon as a fair ridge camber was achieved.

TABLE 4 - Stages of Wetland Development - Roodeberg (Fig. 9 b)

Stage	Period	Development	Area (ha)
1	August 1971	Master plan developed and agreed upon	85
	1971 - 1972	Section A pegged	20
		Master ditches hand-dug to dry out area sufficiently to permit ploughing. Section A ploughed to ridge and furrow and established to pasture when desired ridge shape obtained.	20
2	1973 - 1974	Section B pegged	15
		Master ditches hand-dug	
		Section B ploughed to ridge and furrow and established to pasture when desired ridge shape obtained.	15
		Section C pegged, ploughed to ridge and furrow and planted to maize.	15
		Overhead irrigation installed:	
		Pump operated (area bounded 'P')	35
		Gravity " " " 'Q'	15
3	1975 - 1976	Section E (part) pegged, ploughed to ridge and furrow and plante to maize	15
		Section C reploughed and planted to maize	15
		Section D pegged, ploughed to ridge and furrow and established to pasture when desired ridge shape obtained.	10
		Further overhead irrigation planned and installed (both pump and gravity operated.)	35
		Section E (remainder) pegged ploughed to ridge and furrow and planted to maize.	10

- Results

This farm is purely a livestock enterprise. The development described was implemented together with rapid expansion of the dairy enterprise without prejudice to the existing sheep and beef enterprises. At each stage careful economic appraisals were conducted to predetermine the economic viability of the development prior to implementation.

Herd size (including cows in calf and heifers mated) and milk production have been increased from 60 head and 360 litres/day in February 1971 to 325 head and 2 700 litres in August 1975. For the greater part these increases have been made possible by the additional high quality food from the bottomland and some of the upland now being reclaimed. (see plate 9.) It is anticipated that by October 1975 the production will be 3 500 litres/day from the same herd size as bought in cows come into production and that this level of production will be stabilized or even increased as a result of improved fodder flow resulting from the final stages of the development programme.

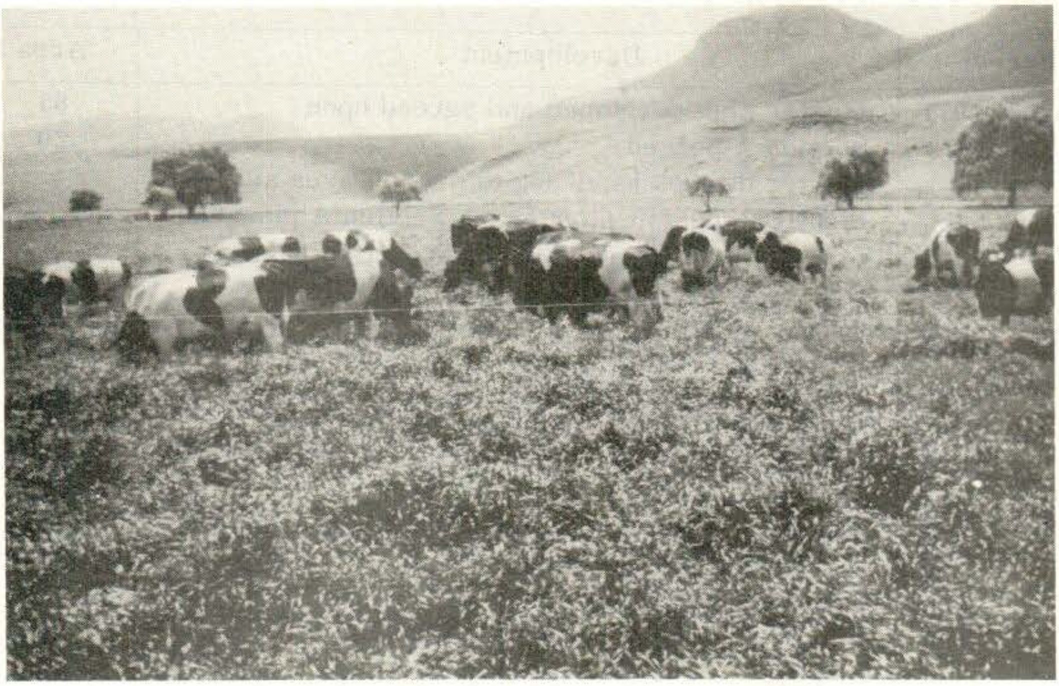

Plate 9 A fine pasture on ridge and furrow - Roodeberg

a. Benefits

The principal benefits are as follows:-

1. There has been a dramatic increase in fodder flow. This has been due, for the greater part, to the bringing into production of land of hitherto poor to mediocre productivity. In a developing situation such as this it is difficult to determine grass and fodder dry matter productivity increases. These will be measured in due course but herd increase and milk production are an adequate yardstick for the time being.

   One very significant improvement was achieved in 1974 when 10ha of poorly-drained upland yielded 4 500kg maize/ha (20 x 200 lb bags/acre). This was the first crop with ridge and furrow treatment. Rainfall was 932mm for the year of which 555mm (60%) fell during the main growing period of January to March.

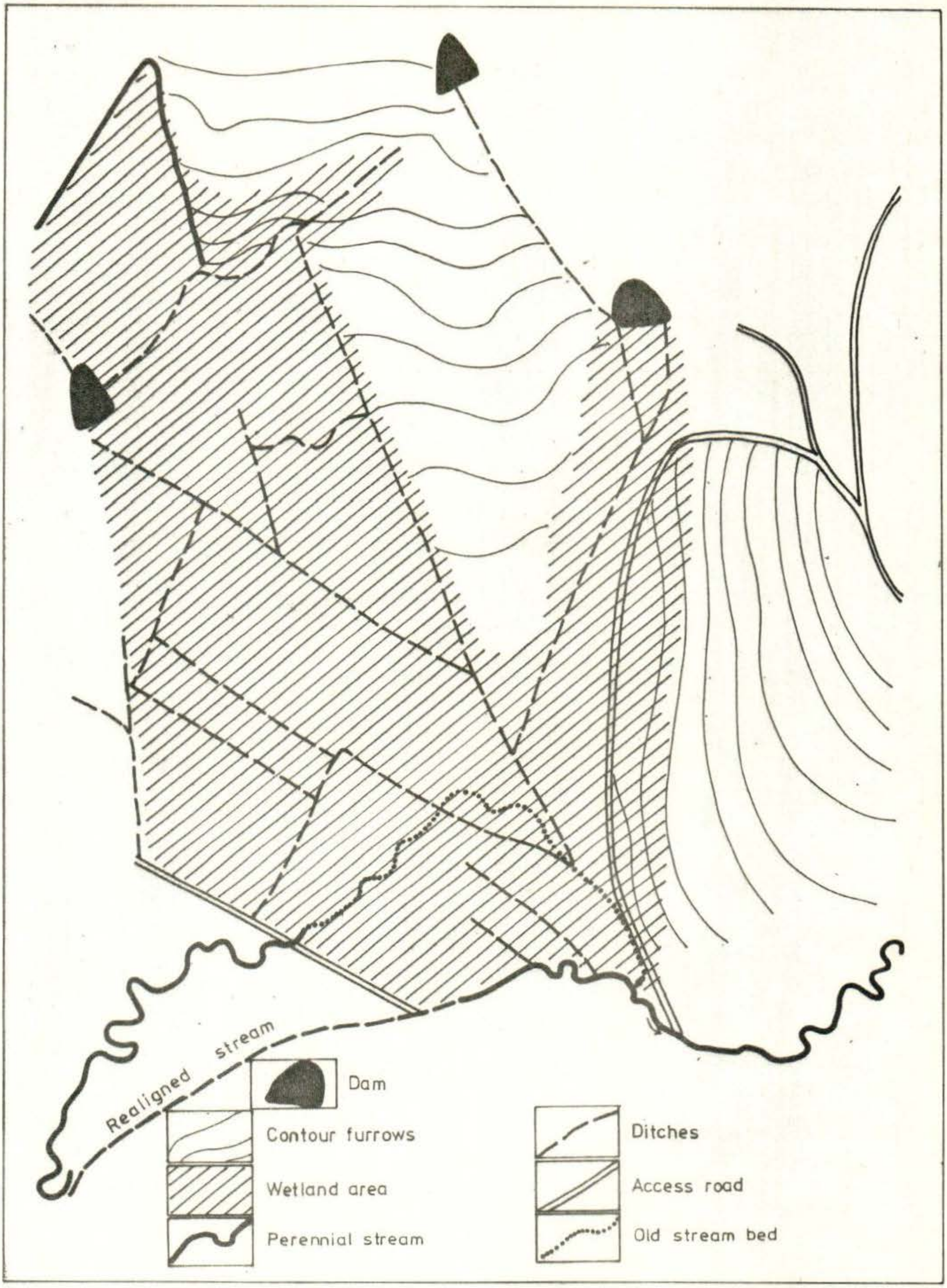

Figure 9a. J.R. BLORE ROODEBERG
PRIOR TO DEVELOPMENT 1971

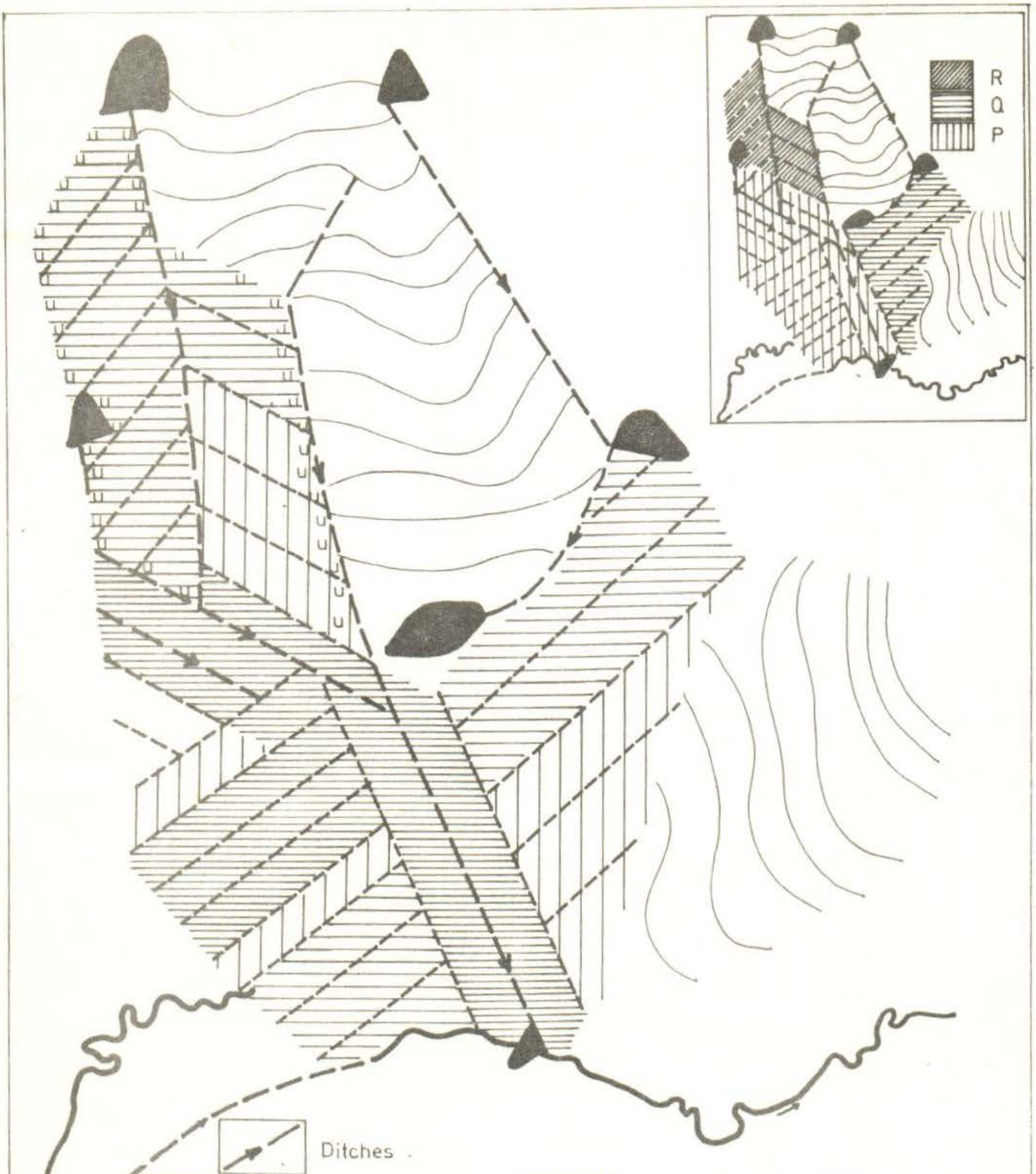

Figure 9b. SCHEMATIC DIAGRAM OF WETLAND DEVELOPMENT.

This land was usually planted to winter feed and productivity has never been much more than mediocre.

2. Greatly improved access has been achieved.

3. The effect of wild flooding has been reduced markedly and flood water dispersal has been accelerated.

4. A significant overall improvement in livestock health has been noticed. In particular <u>foot-rot</u> and <u>liver-fluke</u>, hitherto major problems, have been brought well under control.

5. The economic progress of the dairy enterprise has been most satisfactory. This is reflected in the results tabulated below.

TABLE 5 - Economic results of dairy enterprise on Roodeberg

Item	Oct. '71-Sept. '72 R	Oct. '74-Sept. '75 R	Projected to Sept. '76
a. Gross milk sales	16,560	91,240	120,000
b. Gross output from mild and livestock	22,288	115,946	150,000
c. Gross margin	5,972	43,237	50,000
d. Gross margin/cow	81.81	191	190
e. Average no. of cows	73	230	325
f. % of gross margin contribution by dairy to total farm gross margin.	17.17	52.79	65

b. Problems

1. Considerable capital finance has been required over and above that used for ridge and furrow development and irrigation to cope with the greatly enlarged dairy herd and increased milk production.

2. Access still remains a problem in terms of cow walking distance.

3. Zero grazing has been tried but found to be not entirely satisfactory. Silage appears to be a better system as it contributes to a more sustained fodder flow during dormancy. However, during the summer period (November to mid-February), although ryegrass pasture productivity is falling, cows do look for a change of diet and prefer well-managed veld and summer pasture such as kikuyu at this time. Moreover risk of flooding is high and it is advisable to move stock to higher ground. Excess fodder from the bottomland should be conserved preferably above flood level. For this a near-site rapid, inexpensive system of conserving this valuable forage is needed. Mr. Blore has estimated that this was ammounted to 40% or possibly more of annual production. No effort should be spared to perfect this operation.

4. The tremendous increase of high protein fodder produced from the bottomland and wet influent surrounds has necessitated the devotion of high-lying, well-drained arable land for hay and maize silage and the buying in of high energy concentrates. These formerly were produced on the farm.

5. When viewing this development programme it was not appreciated that management would become a limiting factor. A full-time, well-qualified manager has had to be appointed. (His costs are not reflected in the above gross margin figures.)

- Farmer's conclusions

1. The ridge and furrow system places no significant restriction on agricultural machinery or on irrigation. The layout facilities operations such as planting and fertilizing and is well suited to strip grazing or regular cutting because of the land sub-division it establishes.

2. Observation suggests that great economies in water utilisation are being achieved by efficient drainage of applied irrigation water, on account of the siting of the main pumping station at the dolerite dyke. In times of water shortage, this results in re-cycling of water which would otherwise be lost - a most important feature.

3. In my opinion, ridge and furrow and irrigation planning go hand in hand.

4. By the time the block is in production and irrigation has been developed to its economic limit, this "heart" of the farm will easily be capable of sustaining the quantity of milk anticipated for October 1975.

5. The ridge and furrow system, together with a sound development plan is, in this situation, the key to the development of Wetland.

SUMMARY

Wetlands describe conditions of impeded drainage limiting agricultural productivity. Development of such areas holds much promise for the astute farmer although some forms of wetlands could be of maximum value to the nation in their natural state.

The high potential of wetlands for a variety of uses, including pasture and crop production, has long been recognised. However, many of the early attempts at development failed through lack of knowledge, inadequate planning and faulty management. Procedures for land improvement of this kind are essentially simple but planning the development requires skill and adherence to conservation principles.

The occurence of poorly drained sites in Natal and East Griqualand is particularly widespread and constitutes an increasingly important challenge to the agricultural industry. Up to 40 percent of the potential arable land in some areas may comprise wetlands. Soils most common to wetlands in the bottomland position include those of the Katspruit, Rensburg and Willowbrook forms, and in upland sites, those of the Cartref, Estcourt, Kroonstad and Longlands forms. Difficulties in carrying out essential farm operations and the danger of erosion are among many problems associated with wetland use.

The need for careful planning is great and basic principles should be applied. These include the need for thorough initial survey, consideration of the entire catchment area, treatment of each wetland according to merit, integration of the wetland plan with that of the whole farm, emphasis being given to safe-use of the land, complete control of the water table, implementation in accordance with a priority sequence and consideration of applicable legislation. Criteria and procedures, including both survey and planning phases, have been formulated and serve as a guide to those interested in wetland development.

Ridge and furrow is strongly advocated as a simple, yet highly effective, means of wetland improvement. Historically, the system has been extensively used, especially in European countries. Ridge and furrow is the result of a prescribed system of repetitive ploughings which cause soil to be thrown into a series of parallel cambered beds to acceptable gradients. Each ridge (bed) is a self contained unit that ensures its own controlled drainage and protection. Advantages of the system are many and far outweigh the limitations.

The method of construction is simple and requires the farmer to follow a number of logical steps. Ridges are constructed by the use of normal farm machinery and at costs that approximate those of ordinary land preparation. Wetlands developed in this manner are easily farmed and require no special cultural practices. The system lends itself to intensive irrigation.

Many examples of wetland development are to be found in Natal and East Griqualand. These include successful ridge and furrow layouts on the farm "Roodeberg" in East Griqualand and on many other farms in Natal. Although the wetlands on such farms differ widely in terms of soil, slope and land use, careful planning and implementation have, in all instances, converted existing wasteland into productive fields. Financial and management benefits to the farmers have been considerable. These farmers consider this form of land development to be highly desirable.

All who contemplate wetland development would be well advised to follow the principles and procedures presented in this report and to seek appropriate advice and guidance.

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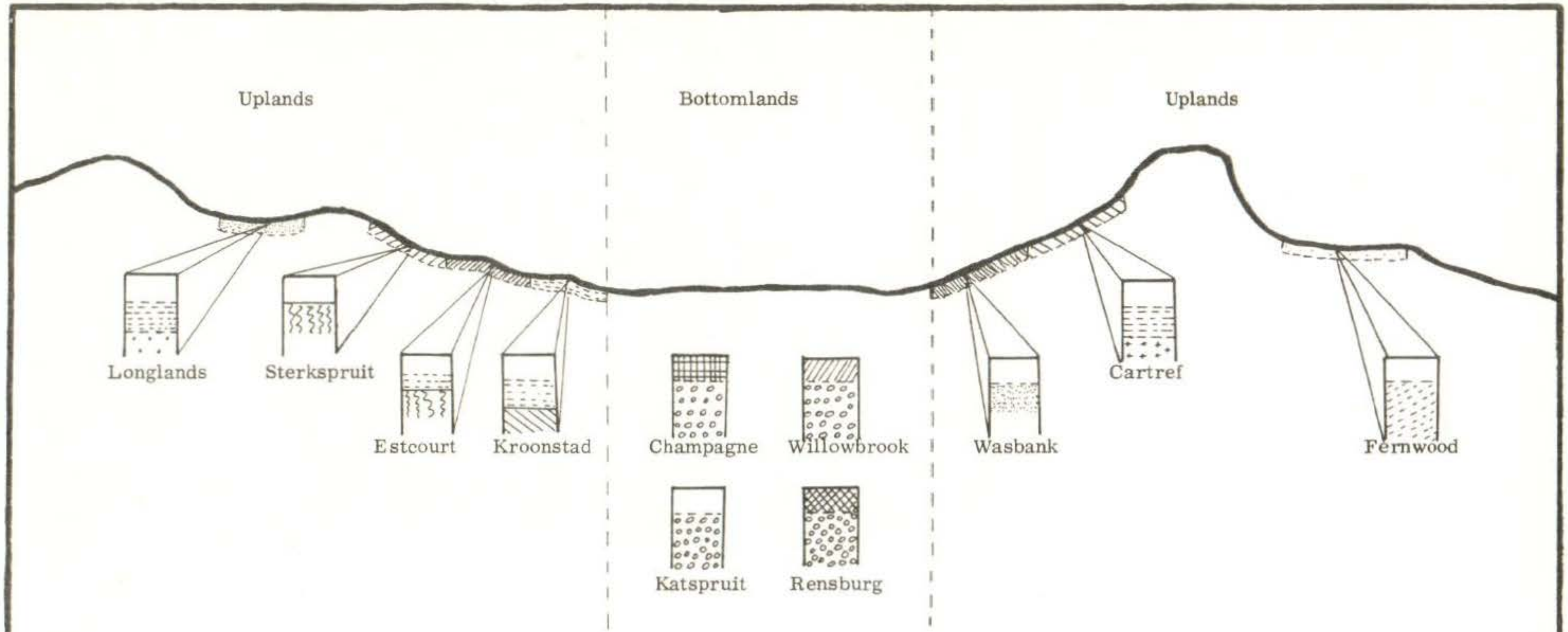


DIAGNOSTIC TOPSOIL HORIZONS

	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 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 E-horizon
	SOFT PLINTHITIC	Strongly mottled with maximum accumulation of Fe & Mn oxides and hydrates periodically saturated
	HARD PLINTHITE	Indurated iron pan 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

APPENDIX 1

DIAGRAMMATIC REPRESENTATION OF SOIL FORMS COMMON TO WETLANDS

APPENDIX 2

SOME DESIGN CONSIDERATIONS RELATING TO PLANNING RIDGE AND FURROW LAYOUTS FOR THE DEVELOPMENT OF WETLANDS

In this Appendix an attempt is made to answer 3 basic questions:-

- To what height above the furrow should the crest of the ridge be raised?
- What base width should be chosen?
- To what length may the furrows be extended safely?

Height of ridge above furrow

There is much controversy concerning the maximum slope across which a tractor and implements may operate with safety. A very conservative estimate of 15% has been given for clay soils. Much depends on the skill of the operator and it is felt that a 20% slope should be the maximum for design purposes. However, in table 7 below, slopes somewhat in excess of this figure have been included so that the designer will be given some degree of latitude. Of course ox or horse drawn implements can be worked on considerably steeper slopes.

Table 7 gives the relationship of the side slopes of the ridges (x and y) to the height of the crest (H) above the upper furrow. Ground slopes are given from 2% to 15%. Level and nearly level ground slopes have been omitted as the calculation involved can easily be done mentally. (Slopes of 1,5% and less can be taken as level ground, for all practical purposes). It should be noted that figures quoted are approximate.

When steeply sloping ground is encountered in Wetland development, the lower slope (y) becomes excessive if the crest of the ridge is central between furrows. Therefore a section of the table is devoted to ridges with the crest offset so that the upper slope covers about 1/3 of the base.

A further consideration is that the heavier the texture of the soil, the higher the crest should be, within reason, to promote rapid surface drainage. Much work remains to be done to determine the stability of various types of soils on differing slopes, and under differing cropping and cultivation systems.

Base width

Ridge slopes, the effective depth of the soil, machinery to be used to construct the ridges all play a part in deciding what base width to use.

With shallow soils the ridges will, perforce, have to be narrow as there will not be sufficient earth to build a ridge with a broad base, and get adequate drainage.

The narrower the base width the easier it is to move earth to the desired height especially on steeper slopes. However, a glance at table 7 will show that narrow bases are not always practicable. The designer must make his own compromise and decide which factors are of overriding importance.

With deep soils virtually any base width can be used successfully but here the machinery available for construction can be a factor to consider. Notwithstanding the fact that ridges can be built up over a period of time at little additional cost, as shown in the history of Wetland Development (Chap. 3), large implements and powerful tractors facilitate the rapid erection of broad based ridges. Thus it can be seen that there is a relationship between the width of the base, the height of the crest, and the machinery for construction.

Maximum safe length of furrow

By "safe" is meant "without incurring danger of erosion". Since erosion in furrows depends mainly on speed of flow of water and the nature of the soil, safe velocities for bare soil according to the latest available data were used to calculate the attached Table 8. These are 0.8m/sec for sandy loams (Sa Lm), 0,9m/sec for loams and silts, ans 1,2m/sec for heavy clays. Corresponding imperial measures are 2,75 ft/sec; 3,0 ft/sec and 4,0 ft/sec.

Mannings formula (1), with an 'n' value of 0,0225 was used with varying flow depths to determine what combination of side slopes (x and y from Table 7), and furrow slopes would permit maximum safe velocities, on different soil types. The depth of flow permitting the maximum safe velocity allowed the cross-sectional flow area to be calculated and thus (Q = AV) the maximum allowable run-off intensity in cumecs. This is reflected in Table 8. In many instances interpolation will be necessary and the figures must be treated as approximate.

Using the 'Rational' formula, (2), a maximum area which a furrow may be permitted to drain can be established. Other formuli including an area could also be used and would be perfectly valid.

Example: C is taken as 0,35; I is found to be 150mm/hr and A is unknown

∴ Q = 0,0146 A. Assume further that furrow slope is 2%, soil is loam and the average side slope of the ridges is 10%. From table 2 it is seen that the maximum permissable run-off intensity is 0,142 cumecs. The equation then becomes 0,142 = 0,146A

Therefore $A = \dfrac{0,142}{0,146}$ ha = 0,97 ha Having calculated the permissable area it is simple to calculate the maximum permissable lenght of flow i.e.

$$\text{length} = \frac{\text{area}}{\text{width drained by furrow}}$$

Assume the width drained by the furrow (crest to crest) is 20m - then maximum

$$\text{perm. length} = \frac{0,97 \times 10\,000\text{sq. m}}{20\text{m}} = 485\text{m}$$

It is quite practical to have higher furrow slopes than the 5% in Table 2 but the allowable run-off intensity will be very low, thus allowing only very short furrows.

---

(1) Manning's Formula

$$V = \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}} \text{ m/s}$$

where
V = velocity in metres per second
n = roughness coefficient
R = hydraulic radius
= $\dfrac{\text{cross sectional area of flow}}{\text{wetted perimeter}}$

and
S = slope in metres per metre

(2) Rational Formula

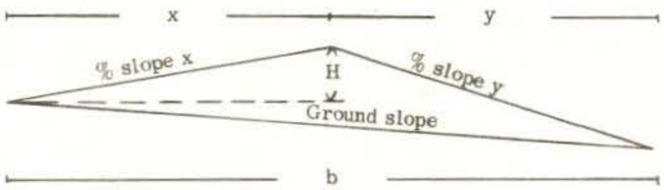
$$Q = \frac{CIA}{360} \text{ cumecs}$$

where
Q = run-off intensity in cumecs
C = constant
I = rainfall intensity during time of concentration in a defined catchment in mm/hr
A = area of defined catchment in ha

TABLE 7 RIDGE SLOPES FOR CENTRE AND OFFSET CRESTS

AT DIFFERENT GROUND SLOPES

RIDGE PROFILE



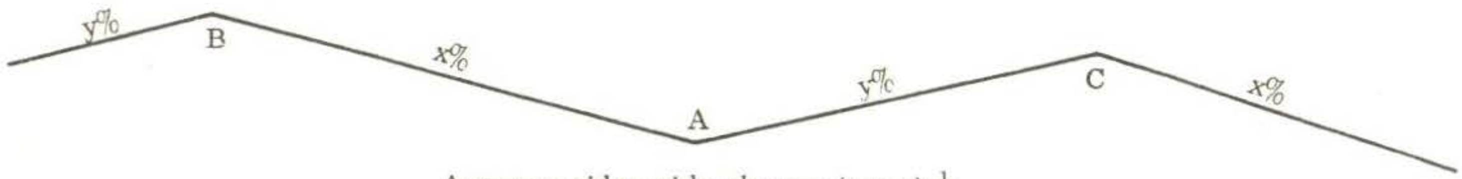
% GROUND SLOPE	H m	BASE 20 m (65,6 ft)				BASE 18 m (59 ft)				BASE 16 m (52,5 ft)				BASE 14 m (46 ft)			
		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3	
		% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y
2 %	0,3	3	7	4	5½	3½	7½	5	5½	3½	8	5½	6	4	8	6½	6
	0,6	6	10	8½	8	6½	10½	10	8	7½	11½	11½	8½	8½	12½	13	9½
	1,0	10	14	14	11	11	15	17	11½	12½	16½	18½	12½	14	18	21½	13½
	1,3	13	17	18	13½	14½	18½	21½	14	16	20	24½	15	18½	22½	-	-
	1,6	16	20	22½	16	18	22	-	-	20	24	-	-	-	-	-	-
3 %	0,3	3	9	4	7	3½	9½	5	7	3½	10	5½	7½	4	10	6½	7½
	0,6	6	12	8½	9½	6½	12½	10	9½	7½	13½	11½	10	8	14½	13	11
	1,0	10	16	14	13	11	17	17	13	12½	18½	18½	14	14	20	21½	15
	1,3	13	19	18	15	14½	20½	21½	15½	16	22	24½	16½	18½	24½	-	-
	1,6	16	22	22½	17½	18	24	-	-	-	-	-	-	-	-	-	-
4 %	0,3	3	11	4	9	3½	11½	5	8½	3½	12	5½	9	4	12	6½	9
	0,6	6	14	8½	11	6½	14½	10	11	7½	15½	11½	11½	8½	16½	13	12½
	1,0	10	18	14	14½	11	19	17	14½	12½	20½	18½	15½	14	22	21½	16½
	1,3	13	21	18	17	14½	22½	21½	17	16	24	24½	18	-	-	-	-
	1,6	16	24	22½	19	-	-	-	-	-	-	-	-	-	-	-	-
5 %	0,3	3	13	4	10½	3½	13½	5	10	3½	14	5½	10½	4	14	6½	10½
	0,6	6	16	8½	13	6½	16½	10	12½	7½	17½	11½	13	8½	18½	13	14
	1,0	10	20	14	16	11	21	17	16	12½	22½	18½	17	14	24	21½	18
	1,3	13	23	18	18½	-	-	21½	18½	-	-	24½	19½	-	-	-	-
	1,6	16	26	22½	21	-	-	-	-	-	-	-	-	-	-	-	-

% GROUND SLOPE	H m	BASE 12 m (39,4 ft)				BASE 10 m (32,8 ft)				BASE 8 m (26,2 ft)				BASE 6 m (19,5 ft)			
		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3	
		% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y
2 %	0,3	5	9	7½	6½	6	10	10	7½	7½	11½	11	8½	10	14	15	10½
	0,6	10	14	15	10½	12	16	20	12	15	19	22½	14	-	-	25	18
	1,0	16½	20½	25	15½	20	24	-	-	-	-	-	-	-	-	-	-
	1,3	21½	25½	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 %	0,3	5	11	7½	8	6	12	10	9	7½	13½	11	10	10	16	15	12
	0,6	10	16	15	12	12	18	20	13½	15	21	22½	15½	-	-	25	19½
	1,0	16½	22½	25	17	20	26	-	-	-	-	-	-	-	-	-	-
	1,3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4 %	0,3	5	13	7½	9½	6	14	10	10½	7½	15½	11	11½	10	18	15	13½
	0,6	10	18	15	13½	12	20	20	15	15	23	22½	17	-	-	25	21
	1,0	16½	24½	25	18½	-	-	-	-	-	-	-	-	-	-	-	-
	1,3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5 %	0,3	5	15	7½	11	6	16	10	12	7½	17½	11	13	10	20	15	15
	0,6	10	20	15	15	12	22	20	16½	15	25	22½	18½	-	-	25	22½
	1,0	-	-	25	20	-	-	-	-	-	-	-	-	-	-	-	-
	1,3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		BASE 20 m (65,6 ft)				BASE 18 m (59 ft)				BASE 16 m (52,5 ft)				BASE 14 m (46 ft)				BASE 12 m (39,4 ft)				BASE 10 m (32,8 ft)				BASE 8m (26,2 ft)				BASE 6 m (19,5 ft)			
% GROUND SLOPE		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3		x = y = b/2		x = y/2 = b/3	
	H m	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y	% x	% y
6 %	0,3	3	15	4	12	3½	15½	5	11½	3½	16	5½	12	4	16	6½	12	5	17	7½	12½	6	18	10	13½	7½	19½	11	14½	10	22	15	16½
	0,6	6	18	8½	14½	6½	18½	10	14	7½	19½	11½	14½	8½	20½	13	15½	10	22	15	16½	12	24	20	18	-	-	22½	20	-	-	25	24
	1,0	10	22	14	17½	11	23	17	17½	12½	24½	18½	18½	-	-	21½	19½	-	-	25	21½	-	-	-	-	-	-	-	-	-	-	-	-
	1,3	13	25	18	20	-	-	21½	20	-	-	24½	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1,6	-	-	22½	22½	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7 %	0,3	3	17	4	13½	3½	17½	5	13	3½	18	5½	13½	4	18	6½	13½	5	19	7½	14	6	20	10	15	7½	21½	11	16	10	24	15	18
	0,6	6	20	8½	16	6½	20½	10	15½	7½	21½	11½	16	8½	22½	13	17	10	24	15	18	12	26	20	19½	-	-	22½	21½	-	-	25	25½
	1,0	10	24	14	19	11	25	17	19	-	-	18½	20	-	-	21½	21	-	-	25	23	-	-	-	-	-	-	-	-	-	-	-	-
	1,3	-	-	18	21½	-	-	21½	21½	-	-	24½	22½	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8 %	0,3	3	19	4	15	3½	19½	5	14½	3½	20	5½	15	4	20	6½	15	5	21	7½	15½	6	22	10	16½	7½	23½	11	17½	-	-	15	19½
	0,6	6	22	8½	17½	6½	22½	10	17	7½	23½	11½	17½	8½	24½	13	18½	-	-	15	19½	-	-	20	21	-	-	22½	23	-	-	-	-
	1,0	-	-	14	21	-	-	17	20½	-	-	18½	21½	-	-	21½	23½	-	-	25	24½	-	-	-	-	-	-	-	-	-	-	-	-
	1,3	-	-	18	23	-	-	21½	23	-	-	24½	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9 %	0,3	3	21	4	17	3½	21½	5	16	3½	22	5½	16½	4	22	6½	16½	5	23	7½	17	6	24	10	18	7½	25½	11	19	-	-	15	21
	0,6	6	24	8½	19	6½	24½	10	18½	7½	25½	11½	19	-	-	13	20	-	-	15	21	-	-	20	22½	-	-	22½	24½	-	-	-	-
	1,0	-	-	14	22½	-	-	17	22	-	-	18½	23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1,3	-	-	18	24½	-	-	-	-	-	-	24½	25½	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10 %	0,3	3	23	4	19	3½	23½	5	17½	3½	24	5½	18	4	24	6½	18	5	25	7½	18½	6	26	10	19½	-	-	11	21½	-	-	15	22½
	0,6	6	26	8½	21	-	-	10	20	-	-	11½	20½	-	-	13	21½	-	-	15	22½	-	-	20	24	-	-	-	-	-	-	-	-
	1,0	-	-	14	24	-	-	17	23½	-	-	18½	24½	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11 %	0,3	3	25	4	20	3½	25½	5	19	-	-	5½	19½	-	-	6½	19½	-	-	7½	20	-	-	10	21	-	-	11	23	-	-	15	24
	0,6	-	-	8½	22½		-	10	21½	-	-	11½	22	-	-	13	23	-	-	15	24	-	-	20	25½	-	-	-	-	-	-	-	-
12 %	0,3	3	27	4	21½	-	-	5	20½	-	-	5½	21	-	-	6½	21	-	-	7½	21½	-	-	10	22½	-	-	11	24½	-	-	15	25½
	0,6	-	-	8½	24	-	-	10	23	-	-	11½	23½	-	-	-	-	-	-	15	25½	-	-	-	-	-	-	-	-	-	-	-	-
13 %	0,3	-		4	23	-	-	5	22	-	-	5½	22½	-	-	6½	22½	-	-	7½	23	-	-	10	24	-	-	-	-	-	-	-	-
	0,6	-	-	8½	25½	-	-	10	24½	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14 %	0,3	-	-	4	25	-	-	5	23½	-	-	-	24	-	-	6½	24	-	-	7½	24½	-	-	10	25½	-	-	-	-	-	-	-	-
15 %	0,3	-	-	4	26½	-	-	5	25	-	-	-	25½	-	-	6½	25½	-	-	7½	26	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 8 MAXIMUM PERMISSIBLE DISCHARGE (cusecs and cumecs)

FOR FURROW SLOPES TO 5% AND RIDGE SLOPES 5% - 25%



Average ridge side slope = $(x + y)\ \frac{1}{2}$

Furrow slope = % Slope from A to A'

Average ridge side slope		5%		10%		15%		20%		25%	
Furrow slope	Soil type	Cus	Cum	C's	Cum	Cus	Cum	Cus	Cum	Cus	Cum
1%	Sa Lm	13,2	,373	[illegible],5	,184	5,3	,150	3,3	,093	2,6	,074
	Loam	21,4	,606	10,3	,292	10,3	,292	7,9	,224	6,3	,178
	H. Clay	63,0	1,81	31,0	,878	22,0	,623	20,0	,566	16,3	,462
2%	Sa Lm	4,75	,134	2,4	,068	1,3	,045	1,2	,034	0,9	,025
	Loam	7,7	,213	5,0	,142	3,4	,096	2,5	,071	0,9	,025
	H. Clay	17,7	,501	14,4	,408	7,7	,218	7,5	,212	5,9	,167
3%	Sa Lm	3,3	,093	1,0	,028	0,7	,020	0,5	,014	0,4	,011
	Loam	5,7	,161	2,9	,082	1,9	,054	1,5	,042	1,1	,031
	H. Clay	12,5	,354	6,2	,176	4,2	,119	3,0	,085	2,6	.074
4%	Sa Lm	2,25	,064	1,1	,031	0,8	,023	0,6	,017	0,4	,011
	Loam	2,9	,082	1,1	,031	0,8	,023	0,6	,017	0,4	,011
	H. Clay	6,8	,193	3,3	,093	2,2	,062	1,7	,048	1,3	,037
5%	Sa Lm	1,4	,040	0,7	,020	0,5	,014	0,1	,003	0,08	,042
	H. Clay	4,9	,139	3,7	,105	2,5	,071	1,9	,054	1,5	,042
	Loam	1,9	,051	1,3	,037	0,7	,020	0,6	,017	0,5	,014

APPENDIX 3

Conversion of imperial measures referred to in chapter 3, to metric measures

6"	=	approx.	15cm
9"	=	"	22,5cm
300lb.	=	"	136,36kg
200lb.	=	"	90,91kg
1,5 m.p.h.	=	"	2,4 k.p.h.
220yds.	=	"	200m
3/4ac	=	"	0,34ha
1ac	=	"	0,405ha
50ft	=	"	15,3m
66ft	=	"	20,1m
7ft	=	"	2,14m
21ft	=	"	6,4m
40ft	=	"	12,2m
4ft	=	"	1,22m

APPENDIX 4

TREATMENT OF POORLY DRAINED UPLAND SOILS WITH E HORIZONS

A basic problem has become evident from field experience. Unless water moving through the E horizon is completely cut off and diverted it will continue and for various reasons will frequently emerge at the surface and cause localised waterlogging. This problem is particularly serious where the E horizon comprises coarse sand. Such horizons should never be exposed.

Field trials with narrow ridges of 6m base width (i.e. furrow to furrow) and constructed with a single ploughing have proved successful on these soils. However, much depends on the depth of the A horizon, since exposure of the E horizon will almost certainly cause waterlogging at that point. The purpose of the narrow ridge is to avoid exposure of the E horizon either by cultivation or construction.

Regic sands also tend to show the same characteristics as sandy E horizons and should be treated with caution in the same manner.

Estcourt farm soils, in addition to the E horizon problem, have a highly erodible prismacutanic B horizon. As a general recommendation these soils should not be cultivated.