LAND CAPABILITY ANALYSIS USING COMPUTERISED OVERLAY TECHNIQUES

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A Dissertation Submitted to the Faculty of Science
University of the Witwatersrand, Johannesburg
for the Degree of Master of Science

Johannesburg 1980

DECLARATION BY CANDIDATE

I hereby declare that this dissertation is my own work and that it has not been submitted to any other University

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'We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.'

Aldo Leopold 1948

ABSTRACT

A versatile computerised overlay technique to analyse relatively constant, objectively measured, land characteristics for their capability to sustain any defined land use was developed. The mapped form of each land characteristic, be it of a polygonal, network or discrete point distribution is stored in a data base system for subsequent retrieval and overlay by a grid of selected cell size. The capability rating of each measured land characteristic value is derived from a capability graph or table which relates this value to a capability scale according to existing information. A foreclosure of options in land use is also performed. The influence of each characteristic upon the overall capability for a defined land use is included by user defined weighting values. The overall capability of an overlaid grid cell is the weighted mean of the individual capability values for each land characteristic analysed. The result is mapped by overprinting on a line printer.

Information to select the land characteristics analysed for a land use, to develop the capability graphs and tables, to quantitatively analyse interrelationships between land characteristics and to define weighting values was gathered from the literature and various people. This information which controlled the analysis of the land for a land use and default sets of weighting values used if the user makes no choice, are stored in the data base system. The capability analysis program is composed of a suite of

interactive and non-interactive FORTRAN programs.

A trial run of the procedure was compared with a manual land capability analysis for an agricultural land use in Northern Lebowa, South Africa. The results illustrated the influence on the overall capability of both the weighting value and the selected overlay grid cell size. The value of a versatile capability analysis tool which can analyse any defined land use, using selected weighting values and grid cell sizes, was seen. The procedure is also not restricted by the study area size, the scale at which the land is surveyed, the choice of land characteristics used in the analysis, the shape of the capability graphs and the values contained in the capability tables.

ACKNOWLEDGEMENTS

I wish to thank Professor B H Walker of the Centre of Resource Ecology, Department of Botany and Microbiology of this University, for his supervision of the study; Professor C F Cresswell, Head of the Department of Botany and Microbiology for the use of facilities in the Department; the University of the Witwatersrand for the use of the computer and Dr F H Swart of the Department of Co-operation and Development, Pretoria, for the use of the Northern Lebowa data.

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CHAPTER 1

1. INTRODUCTION

All forms of land use involve the manipulation of the ecological processes present. If these processes are manipulated without an understanding of them, the land will be degraded and its potential for use constantly reduced. Land planning is 'the understanding of a system where action is contemplated, with some assurance of the predictable consequences of the alternative courses of action being contemplated' (McHarg, 1974). This will prevent the tying up of future resources in non-critical uses, the impairment of the quality of the resource by pollution and the over-extension of the land's capabilities (Grove and McCart, 1976).

Land is a system of several interrelated components which together produce the final observed condition of the land. In order to understand this system, each component must be studied. This is the basis of the holistic approach to land analysis which assumes that the 'land constitutes an integrated system with geological, hydrological, vegetational and other aspects, influenced by human factors' (Mohrmann, 1973). The following definition of land embraces this concept.

> Land is a specific area of the earth's surface; its characteristics embrace all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and the underlying geology, the hydrology, the plant and animal populations and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man (Brinkman and Smyth, 1973).

This definition describes an attribute as that which exerts an influence on man's use of the land. However, an attribute need not necessarily do so. Young (1976) uses this definition for a land mapping unit, which is a more appropriate term for land planning purposes.

The initial stage in a land use plan is an evaluation of the land using data collected by land surveys. Field measurements, aerial photography, satellite imagery (Earth's Resource Technical Satellite (ERTS) and LANDSAT)and other remote sensory techniques are used, the first two being the most common. A land evaluation is 'the process of estimating the potential of the land for one use or for several possible uses' (Young, 1976). Thus, no land evaluation is performed independent of a land use.

The land evaluation may be in terms of the land's suitability or of its capability. These are defined as

(a) Land capability is the fitness of a given tract of land to sustain a defined use; differences in the degree of capability are determined by the present state of the associated attributes of the area in question.

(b) Land suitability is the fitness of a given tract of land for a defined use; differences in the degree of suitability are determined by the relation, actual or anticipated, between the benefits and required inputs associated with the use on the tract in question (Vink, 1975).

A land capability analysis emphasises the inherent physical characteristics of the land, ie. the ecology, and their ability to sustain a land use. It 'establishes the limits within which a resource may be used for present and future societies' (Grove and McCart, 1976). Man's use of land is dependent upon both the natural and the human resources ie. technology, labour and finance. This latter resource which is included in a land suitability analysis is time-dependent. Thus the results will not be applicable for the same length of time as those of a land capability analysis. The final land use plan is a product of the ecological, social and economic elements of the land. It indicates how many uses there may be which is a function of the social and economic variables (Gilomee, 1976) and must be repeated when significant changes occur in these (Stewart, 1968). The ecological evaluation of the land (land capability) is the first step towards the social and economic development of the land (Whyte, 1976).

The evaluation of the land classifies it into homogenous units by analysing and synthesising the collected land data. A conversion table (or rating table) is generally employed in which the measured values of the land variables are awarded a numerical score depicting their suitability or capability. This classification simplifies the complexity and minimizes the volume of the data for further stages in the land planning process. It also allows for the comparison between the different land units and this aids in the formulation of the final land plan in which various policies, public opinions, etc. are considered.

A land evaluation may be carried out for the land in its present, existing condition without major changes, ie. those which can rarely be financed by an individual (Brinkman and Smyth, 1973) or for the land in a proposed, future condition after major changes have been implemented.

A land planner not only requires a knowledge of the land's ability to sustain a land use, but also the foreclosure in alternative land uses which may occur. It is very likely that a land use being studied will degrade some land resource necessary for another land use and thus exclude the latter's future implementation on the land.

All land use involves land management ie. the manipulation of the physical, social and economic elements of the environment. This manipulation means that no absolute or optimum values independent of the land use and its management system exist for a particular land variable. A change in this system will change a value previously specified. Good land management aims to obtain the maximum benefit from the land without unnecessary degradation. Land use without degradation of any kind or amount is impossible as all land use removes something from the land, be it only organic matter. Land management systems should involve the replacement and control of that which is removed wherever possible so as to limit the degradation. This will require that a description of the usage intensity and the management methods be given.

All land variables are of importance, being components of the ecosystem but the extent of their modification and manipulation depends on the variable and the finances available, eg. rainfall is modified by irrigation schemes which are more expensive to implement than the correction of an acid soil pH by a liming programme. Thus, their importance to man depends on the economic and social resources, the land use and the existing or proposed management system. A land evaluation should allow for the weighting of the land variables to reflect this difference in their importance.

A land evaluation is as accurate as the data used in the analysis. The greater the number of land variables measured in the land survey, the detail and the objectivity of their measurement, the greater is the accuracy of the results. However, until the advent of the computer, the time involved and the difficulties experienced in analysing and synthesising large amounts of data, rendered the collection of such amounts to be impractical. Flexibility is a useful and necessary feature in any land evaluation technique. The ability to change such variables as the management system, the land use, the weighting given to various land variables, the exclusion and inclusion of different land variables so as to highlight possible problems, hazards and successes, makes the technique generally applicable and useful. Such flexibility involves the land evaluation being repeated several times to examine different alternatives which was impractical before the advent of the computer. Also, since a land evaluation is dependent upon the land use, the land may only be evaluated for one land use at any one instance. The consideration of a number of possible land uses requires that the evaluation be repeated that number of times.

Within the last two decades, several different land evaluation procedures for both land suitability and land capability analyses have been developed. They range from the evaluation for one land use, eg. Scotney (1971) to a range of land uses, eg. Canada Land Inventory (McCormack, 1971); from utilizing data stored in a general purpose inventory, eg. Minnesota Land Management Information System (Craig, 1979) to that collected only for that land evaluation eg. A'Bear et al (1976), etc. These procedures may or may not be computerised.

South Africa has realised the necessity for land evaluation studies and several separate projects have been performed eg. A'Bear et al (1976), Beaumont et al (1975), Phillips (1973), Garland et al (1977), Schoeman and MacVicar (1978), etc. Each has been based on different assumptions, land variables, methods of analysis etc. There is a need for a general procedure applicable for land uses so that a comparison between studies is possible and manpower is not wasted in developing numerous separate procedures each time a land evaluation is required.

A central comprehensive inventory from which the data may be obtained for this and other purposes is an advantage as it will eliminate the development of many separate inventories for specific purposes. This decentralization raises problems in the transfer of the data between different systems unless there is a standard form of data storage and data units used. Unfortunately, this standardization is not yet present in the Republic. A central inventory will also overcome the problems and manpower hours involved in collecting together data from different sources. The data in a central inventory will need to be in a flexible form if it is to be used for different purposes. This requirement is satisfied by the storage of raw, uninterpreted data.

Land use and economics are inseparable and must be considered in any final land use plan. Many evaluation studies incorporate this factor, eg. Austin and Cocks (1977), Land Resource Division of the British Ministry of Overseas Development (1974), Food, and Agricultural Organisation of the United Nations (Young and Goldsmith, 1977) etc., often interpreting the land data immediately into such terms, eg. Beaumont et al (1975), Wagar (1976). The omission of an initial evaluation of the land itself without the economics being superimposed upon the ecosystem, is questionable.

The objective of this study was to develop a rapid, flexible, computerised land capability procedure for the analysis of all major land uses in the Transvaal. It is a tool in the development of a master plan for land use. Objective, ecological data measured at any land survey scale using field measurements, aerial photographs and ERTS are stored as digitised maps in an existing data base system. A grid of variable defined cell size is overlaid on the retrieved, digitised data. The evaluation of the gridded data depends on the land use and the foreclosure of alternative land uses is also considered. Various weights which may be assigned by the user, represent the relative importance of the land variables upon the overall capability of the land for the land use being studied. The results of the evaluation are displayed on a line printer using overprinting. Users of the procedure will require a rudimentary knowledge of the computer and FORTRAN. The procedure is flexible in its definition of the land use studied, the spatial distribution of the measured land data ie. they may have a polygonal, network or point distribution, the weighting values, the particular land variables weighted, the set of land variables evaluated for a land use and the selection of sections of the land measured. Provision for the addition of information, land variables and land uses other than those given in this study, is included.

CHAPTER 2

2. LITERATURE REVIEW

The literature available on the subject of land capability analysis may be reviewed in different ways eg. the historical development of land capability analysis, the description of studies in different countries eg. South Africa, America, Australia, etc. the description of studies to analyse different land uses, the methodology used eg. computerised and manual techniques, etc. Since this study is the development of a land capability analysis procedure, the literature is reviewed from the methodology aspect. This involves the measurement of the land and the subsequent evaluation of the data.

2.1 Land Capability and Land Suitability

The term 'land capability' is sometimes used to mean a land suitability analysis as defined by Vink (1975), eg. Murdoch (1970), Weitzman and Trimble (1955). However, these two terms are not synonymous. The latter includes social and economic variables which are excluded from the former. Certain land capability studies include biological productivity, eg. McCormack (1971). If this is measured in economic terms, these studies are land suitability analyses. Land capability is also used to refer to potential land use, eg. McCormack (1971) and Murdoch (1970), and indicates what the land may be used for with a particular degree of success. This is generally measured in economic terms. Land suitability would be the more appropriate term for potential land use analyses unless success is measured in non-economic terms, eg. the control of soil erosion.

A possible cause for this interchange in the usage of these two terms may be due to Jacks (1946) who defined five land classification types, depending upon the objectives of the planning procedure. Each classification was to be used to group land according to its suitability for producing plants of economic importance. The land was classified in terms of:-

(a) inherent characteristics
(b) present use
(c) use capabilities
(d) recommended use
(e) programme effectuation

Classification (a) is a land capability classification, yet it was referred to as land suitability.

The term land capability has been closely associated with the evaluation system used by the United States Conservation Service (Klingebiel and Montgommery, 1961). For this reason, in an attempt to distinguish between this and other evaluation studies, Young (1976) defines land suitability as the fitness of a given tract of land for a defined use. This is the same definition as that used by Vink (1975) for land capability. Young's distinction between the two terms is not thought to be useful or necessary and Vink's use of the term as land capability is preferred.

Young and Goldsmith (1977) evaluated an area in Malawi for its suitability for land use using the approach of the Food and Agricultural Organisation (F.A.O.) of the United Nations They evaluated the land using first qualitative and then quantitative data. They considered that the latter evaluation, in which the distinction between the suitability classes is defined in numerical terms, generally requires the use of economic variables when comparing different land uses. The disadvantage of the economic emphasis was not only the short-lived validity of the evaluation results due to the temporary nature of economic data, but also the sensitivity of the analysis to these factors was greater than its sensitivity to the variation in the land condition. Thus, the authors felt that the F.A.O. approach had confused land evaluation with an appraisal of the economics of the project. But it is not agreed that only economic variables may be quantified and used to compare different land uses. Quantified, non-economic variables can also be used, eg. different land uses require different slope gradients, etc.

2.2 The Measurement of the Land

The main problems in measuring the land are that the land is extremely complex, the land variables vary with regard to spatial heterogeneity and distribution (Mabbutt, 1968), and no land variable acts in isolation of other variables. Three basic approaches were developed to overcome these problems (Mabbutt, 1968):-

(a) Genetic approach. The land is repeatedly subdivided into units on the basis of those environmental variables governing morphogenesis. However, these units are large, heterogenic and complex and do not give the precision necessary for land evaluation.

(b) Landscape approach. This is an integrated approach in which the total physical environment is studied as a whole. The land is classified by aerial identification into landscape components (the fundamental descriptive land unit) and their patterns. These components are subjectively recognised by multiple land variables and it is assumed that each component is internally homogenous with reg. rd to these land variables. This means that the land may be quickly surveyed which is useful at the reconnaissance level. However, due to the complexity of the land, generalization is introduced when the land components are described. This means that it cannot be assumed that all the land variables are consistent within the same component unless the definitions of the land units are narrowed down to remove the generalization present. This will increase the survey time required, thus removing its main advantage, ie. the speed at which the land is measured.

This approach was developed independently by C.S.I.R.O. Australia and by South Africa (Young, 1968). The land compo ent was termed the land facet which is a geomorphological unit with a specified landform, soil profile and plant association (Partridge et al, 1973). It is the smallest homogenous land unit distinguishable (Young, 1968). A collection of recurring land facets form a land pattern and a collection of these form a land system defined as 'an area with a recurring pattern of genetically linked land facets' (Partridge, et al, 1973). However, Young (1968) states that it has 'failed to collect the type of information necessary for land use planning' due to its geomorphological basis.
Cook (1977) attempted to overcome this by mapping functional units which are 'mapped areas of land relatively homogenous in socio-economic status and the spatial patterns of their

biophysical properties and hence in their potential land use'. But these units were heterogenous which presented difficulties in their analysis.

Many land evaluation methods are based on this approach both overseas, eg. Natuıal Cultural and Environmental Resource Inventory of Puerto Rico (N.C.E.R.I.)(Dimock, 1973), the American project for the Regional Analysis and Management of Environmental Systems (Child et al, 1976), South Coast Project, Australia C.S.I.R.O. (Austin and Cocks, 1977), Land Resources Division of the British Ministry of Overseas Development (L.R.D. 1974) India (Whyte, 1963), General Ecological Model for the Netherlands (G.E.M.) National Phy Physical Planning Agency, 1977); in Africa, e.g. F.A.O. (Young and Goldsmith, 1977); and in South Africa, e.g. Schoeman and MacVicar (1978) and Phillips (1973). But, it is felt that the limitations due to its subjective basis overrides the advantage of its speed.

(c) Parametric Approach. Selected land variables are measured and assessed in an attempt to determine the connections rather than the differences (which is the aim of the landscape approach) between the land units. It allows for a comparison between different studies within which there is greater consistency, and it is readily computerised. The main difficulty involved is the choice of measurable land variables which are relevant to the land use. The interrelationships between the variables are not neglected but are dealt with quantitatively on the basis of the measured values. Unfortunately, much knowledge on the quantification of these relationships is missing but this is not insurmountable. With time and improved technology, it is expected that this approach will become more common as it is objective and is not limited by the spatial and descriptive definition of the mapping unit.

McHarg's (1974) Ecological Planning Method is based on this approach but the use of manual overlays cause it to be a very tedious and cumbersome method. Nehman et al (1975) attempted to overcome this by the analysis of planning resource units developed from the overlay of the different data elements. This reduction in the data volume and data sensitivity at the analysis stage was felt by the authors to be sufficiently compensated for by the improved flexibility and simplicity of the system.

Kiefer and Robbins' (1972) land suitability evaluation method, the Swaziland soil and land capability classification (Murdoch, 1968), the land use planning method used in South Africa by Loxton (1962), the land capability system used by the United States Conservation Service (Klingebiel and Montgommery, 1961) and that used by Zimbabwe (Ivy, 1977) are parametric in their approach but subjective data, measured in classes, are utilized. A'Bear et al (1976) and Beaumont et al (1975) also used this subjective, parametric approach in their South African studies. The main reason for doing so appeared to be the reduced data volume and greater simplicity of their analysis due to this reduced volume which is particularly important for manual procedures. Only that of Kiefer and Robbins (1972) was computerised.

A land survey is a procedure for measuring land. It may be a resource survoy in which separate studies of each land resource, eg. geology, relief, climate, hydrology, soil, vegetation, fauna and disease (Young, 1976) are made, or it may be an integrated survey. The former will be a parametric approach to the land and is preferred to the latter which is a landscape approach.

The spatial distribution of the land variables is of great importance in land planning and must be captured by the survey performed. This is generally done by mapping the data, which may be in three forms (Baxter, 19/6):-

(a) Point - the land feature has a location but no aerial extent eg. a borehole.

(b) Network - the land feature is composed of links (lines) which meet at nodes, eg. river system.

(c) Polygon - the land feature has an aerial extent in space, eg. a lake. The outline (boundary) is composed of lines meeting at nodes.

The land surveys for different land evaluation studies are conducted at various mapping scales (Young, 1976) depend depending upon the purpose of the exercise and the degree of detail required. Those conducted as a general guide to the resource potential and problems of a large region were conducted at smaller scales (1 : 100 000 is smaller than 1 : 10 000) than those conducted for a particular project. Examples of the former are McHarg (1974); Canada Land Resource Inventory (C.L.I.)(McCormack, 1971); Minnesota Land Management Information System (M.L.M.I.S.)(Craig, 1979); C.S.I.R.O. (Austin and Cocks, 1977); G.E.M.(National Physical Planning Agency, 1977); Environmental Decision Alignment Process (E.D.A.P.)(1973); Schoeman and MacVicar

(1978); etc. Examples of the latter are Kiefer and Robbins (1972); A'Bear et al (1976); Ivy (1977); Garland et al (1977); Beaumont et al (1975); Scotney (1971); etc.

2.2.1 Resource Inventory

A resource inventory stores the different features of all the resources collected by resource surveys, in an appropriate manner for future and present use. Young (1976) also defines it as data collected at survey scales of less than 1 : 100 000 to be used as a general guide to the resource potential and problems of a large region. However, this definition is inflexible; being dependent upon the survey scale and thus the former one is preferred.

The inventory is of greatest practical value if the data are collected in sufficient detail so that they are applicable for numerous purposes and are readily retrieved. This requirement must be balanced against the danger of storing data for their own sake if the inventory is not to become cumbersome and contain redundant information. A survey performed for a particular purpose, eg. land planning, is not ideal for creating a resource inventory to serve numerous purposes. A survey to specifically create a resource inventory should rather be performed from which the data required for land planning would be retrieved.

An inventory of this kind will be large and detailed. This type of inventory was developed by those studies which were not performed for a specific type of land use, e.g. C.L.I. (McCormack, 1971), Kiefer and Robbins (1972), N.C.E.R.I. (Dimock, 1973), Interstate '57 (Niemann and Miller, 1975), M.L.M.I.S. (Craig, 1979), etc. and is proposed for Zimbabwe (Ridler, 1979). At first, only data for a particular land use were collected and stored but more variables applicable to other uses were subsequently added eg. Kiefer (1972) collected urban land use data at first and later, variables for agriculture, transportation and open space land uses were added.

2.2.1 .1 Data Base Systems

A data base is a collection of interrelated data stored together without harmful or unnecessary redundancy to serve multiple applications (Martin, 1977). Its ultimate objective is to make application development easier, cheaper, faster and more flexible. A data base system is a set of separate data bases. The demand for a particular system is increased by the simplicity of its usage, the speed of data access and retrieval and the degree of variability allowed in the data input.

The volume of data for an objective land capability analysis is greater than that for a subjective analysis since there is a greater tendency to separate the land features into different data items. However a data base system is able to handle a large data set in a flexible manner. Reputable texts, eg. Martin (1977) and Baxter (1976) have dealt with data base systems in detail. A data base stores the fundamental data elements, ie. data items, in association with other items. A group of data items is called a data aggregate and these aggregates may also be associated with other aggregates. It is this association which increases the complexity of constructing a data base (Martin, 1977). Certain computer languages, eg. PL/1 and

COBOL (Martin, 1977) have the power to deal efficiently with data aggregates but FORTRAN programming language does not.

A data base system should be developed so that both foreseen and unforeseen future applications will be possible without requiring a fundamental restructuring of the base. This is not a simple task as it is not possible to accurately forecast all future applications. However, if the data are independent of the application programmes, ie. either may be changed without changing the other (Martin, 1977), the future requirements are more easily incorporated into the base.

'Data bases of wide applicability will not be built overnight; they will grow a step at a time' (Martin, 1977). This development is seen in the literature describing the M.L.M.I.S. System (Orning and Mak.. 1972; Hsu et al, 1973; Craig, 1979) and the N.C.E.R.I. inventory (Dimock, 1973) whose forerunner was the Land Use and Natural Resource Inventory of New York (L.U.N.R.)(Hardy and Shelton, 1970).

2.2.1 .2 The Storage of Geographical Information

The need to retain the spatial location of the data poses special coding problems and demands the use of a geocode which is a machine readable location. Geo-referencing is the giving of a geocode to the data (Van Demark, 1973). The geocode used is generally based on cartesian co-ordinates. Four methods of storing data items with their spatial location are (Tomlinson, 1970):-

(a) Geographic indexing system. Short standardized address records are created from the co-ordinates and are used as an index to them or to addresses on existing data sets. Morton sequencing which is a method of producing a unique sequence number from two indices, is used to create the address while hashing techniques retrieve and add information to the data sets using this sequencing method.(Gates and Van Demark, 1973). This is a slow method of data retrieval and access but it allows for easy line printer display.

(b) Simple grid location. A grid providing a course co-ordinate system is overlaid upon the mapped data which are then retrieved and accessed via the grid cell. The preparation of the data is slow and laborious but straightforward computer operations, simple data manipulations of complex data sets and simple graphic display is possible, e.g. M.L.M.I.S. (Hsu et al., 1973); N.C.E.R.I. (Dimock, 1973), L.U.N.R. (Hardy and Shelton, 1970); E-ZMAP (Child et al, 1976); E.D.A.P. (1973), Kiefer and Robbins (1972) and Austin and Cocks (1977).

The land variables within the grid cell are rarely homogenous (Van Demark, 1973). This heterogeneity may be captured by recording each value present, e.g. E.D.A.P. (1973), which greatly increases the complexity of processing and storing the data. Alternatively, one datum value only is processed, eg. Kiefer and Robbins (1972), E-ZMAP (Child et al, 1976) and L.U.N.R. (Hardy and Shelton, 1970). This necessitates that a choice is made, based upon a predetermined selection rule to ensure consistency in the decision. Such a rule may be a particular location, eg. the intersection of the grid lines, etc., or the modal (dominant value)(McDougall, 1976). This latter method is a better representation of the mapping unit, but the dominance of the value chosen is dependent upon the heterogeneity within the unit. More selection rules may be necessary to deal with these situations where a choice of 'dominance' exists.

The processing of one datum value per land variable premapping unit results in a loss of detail, the extent of which is a function of the heterogeneity present. This is dependent upon the survey scale and the grid cell size relative to the dominance of the modal value if this selection rule is used. The grid cell size should be fine enough to capture the level of detail required (MacDougall, 1976). However, such a requirement cannot be met for each land variable measured and thus the 'best' size is chosen. In making this choice, the grid cell size for both the most important and less detailed maps, as well as the errors resulting from using a cell size too close to the accuracy levels of the maps, must be considered (MacDougall, 1976). The level of detail processed in the land evaluation study may be altered by subdividing or combining the cells. For computerised procedures, search routines to determine the new value used to represent the new cell, are required. No literature was found in which the cell size was changed.

(c) Map compilation system. The mapped form is retained by the co-ordinates of the points or nodes of the polygons and networks. The use of the digitiser which is time consuming (Monmonier, 1971), simplifies this task as it records the co-ordinates and outputs them directly onto tape or disc, eg. C.L.I. (McCormack, 1971). The level of detail analysed may be changed by altering the old boundary lines and selection rules are used to determine which value of the old units represents the new unit created. Alternatively, grids of different cell sizes may be overlaid but no literature was found in which this latter technique was employed.

(d) Graphic data handling system This is very similar to the above except that the data are in a form amenable to measurement and analysis.

The map compilation system is preferred as the mapped form of the land survey data are directly retained with no loss of information and no prior selection of the scale at which the evaluation must be performed, and easily reproduced on the plotter or the line printer. Also, the possibility of greater variation in the detail used in the evaluation exists if grid overlays of various grid cell sizes are used.

2.3 The analysis of the Land Data

The sensitivity of the land capability analysis to differences and similarities in the land depends to some extent on the level of detail captured by the land survey. The detail captured depends not only on the scale at which the survey is conducted, but also upon the form in which the data are recorded.

Most studies measured the land in classes. Examples of those using capability classes are C.L.I. (McCormack, 1971), Ivy (1977), Murdoch (1968), G.E.M. (1977), Young and Goldsmith (1977). Examples of those using suitability classes are Kiefer and Robbins (1972), A'Beau et al (1976), Beaumont et al (1975). Examples of those using favourability classes are

Beaumont et al (1975), and Austin and Cocks (1977) used functional units. If a data base system was used, the data were stored in mapped form eg. C.L.I. or transformed into gridded maps before storage, e.g. Kiefer and Robbins (1972). These classes overcame the problems of measuring, storing and analysing heterogeneous mapping units as this heterogeneity was dealt with by the definition of the classes. Thus, the procedures were simplified. However, each classification used referred to a land use and thus the data were not in a form which could be used for other purposes or even for the evaluation of a different land use than that for which it was originally surveyed.

Austin and Cocks (1977) also included exclusion rules in their Australian land evaluation study to simplify the procedure. These subjective rules were used to eliminate unacceptable land uses in the project area depending upon the condition of the land. Only the remaining acceptable land uses were studied.

Certain land studies have incorporated weighting values for particular land variables to represent the effect and influence of different policies, eg. E.D.A.P. (1973); South Coast Project, Australia (Austin and Cocks, 1977); G.E.M. (National Physical Planning Agency, 1977); and McHarg's value system (Giliomee, 1976). Others used these values to represent the suitability (Keifer and Robbins, 1972) or compatibility (Child et al, 1976) of the land variables for the particular land use under study. These weights were all subjectively allocated and the need for research into the assessment and influence of social values was stressed (Giliomee, 1976). The weights used in a land capa ility analysis should reflect the importance of particular land variables to the land use being studied.

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CHAPTER 3

3. THE LAND EVALUATION PROCEDURE

3.1 The Approach

A land evaluation is only meaningful when related to a specific land use and thus its definition is important. Certain land conditions are required if the land is to sustain the land use. The land is evaluated for these conditions from a positive stance, ie. only these land conditions influencing the defined land use are considered. Other land conditions, which are not analysed may be vital for other land uses. These land conditions may be degraded, rendered unavailable or destroyed by the land use being evaluated. Since changes in these latter land conditions do not influence the land use being considered, the capability ratings given to the land are not affected. However, they will result in the foreclosure of options in land use. It is thus important that this foreclosure be considered in any land evaluation.

The land conditions are an expression of the land resources whose scientific measurement are generally impossible. Because of this, the 'land quality' has been defined which is an expression of a set of interacting single or compound land characteristics (Brinkman and Smyth, 1973).

The land evaluation for a land use requires that a set of land characteristics be combined to reflect the land conditions and their ability to sustain that land use. This combination must not neglect the concept that land is an ecological system of interrelated components. The evaluation results in a land capability map of different shades, each representing land of different capability to sustain the lard use being considered. These final mapped capability values are a weighted mean of the individual capability ratings given to each land characteristic, based upon their measured field values. The weightings given to each land characteristic reflect their relative importances, as judged by the user, in determining the overall capability of the land for the use being evaluated.

The land is surveyed at a selected survey scale and each land characteristic measured is stored in a digitised map form. These maps are overlaid in the computer by a grid of some selected size and transformed into grid maps.

The capability ratings for a land use are awarded by the following procedure:-

(a) A comparison of the measured values of those land characteristics defined as limiting with permissible values for the land use. If a value for a land characteristic is not permissible,the whole grid cell has zero capability. No further analysis of the cell occurs.

(b) A comparison of the measured values of the remaining land characteristics which are not limiti.. with their permissible values for the land use. If a value for a land characteristic is not permissible, the capability rating for it is zero and no further analysis of it occurs. This differs from point (a) in that only the land characteristic and not the whole cell is excluded.

(c) A consideration of the major interrelationships between pairs of land characteristics. This results in the modification of the measured field value of one member of the pair by the other. In certain cases, no further analysis of this latter member is required as its effect upon the overall capability of the land is reflected in the modification. In other cases, this member must be analysed further as it may have more than one effect upon the overall capability which is not considered in the interrelationship eg. the total rainfall value is modified by the total evaporation value. No further analysis of the evaportion is needed. The rooting depth is modified by the soil texture which is analysed still further since it affects the soil moisture capacity, the soil fertility, etc. which have not been considered in this relationship.

(d) The field values (modified as in (c) or unmodified) of each land characteristic are awarded a capability rating from relevant capability graphs and tables which relate the field values to a relative capability scale from 0 to 10. These graphs and tables are derived from the literature and all other available sources of information.

(e) The capability ratings are then weighted according to the relative importances of the land characteristics in determining the capability of the land for the land use being studied, before being summed together.

(f) The percentage weighted mean value is calculated.

The evaluation is computerised (Section 4) by storing the information required for these steps in default control data sets which may be changed by any user. These data sets, the digitised map data sets and the grid map data sets are all stored in a data base system. The last data set is retrieved and analysed for its capability to sustain a land use, according to the information stored in the control data sets.

The procedure, as just described, for this approach to land evaluation may be summarised as follows:-

(1) Define the land use.

(2) Based on the land qualities which express the land conditions required for the land use, determine the set of land characteristics to evaluate the overall capability of the land for this land use at the selected survey scale. Determine the values of the land characteristics which represent permissible field values for the land use.

(3) On the same basis, determine the set of land characteristics and their permissible field values to forecast the closure in other land uses.

(4) Determine and describe the major inter-relationships between any pairs of land characteristics chosen for the capability evaluation of this land use.

(5) Describe the capability graphs and tables for awarding a capability rating to each non-limiting land characteristic.

(6) Determine the weightings given to each land characteristic according to their importance upon the overall capability of the land for the land use.

(7) The individual weighted capability values of each non-limiting land characteristic are combined to give a final overall weighted mean capability value for the land for the land use defined.

3.2 The Land Resources

A first step in the development of a land use plan must be the analysis of the land resources themselves which are required for each particular land use.

A land resource includes all those features and processes of land which can be used in some way to fulfil a human need (Vink, 1975). Since their manner of utilization is dependent upon the land use, no land plan may be proposed or a land evaluation be performed without a clear definition of the land uses considered. A land capability analysis is an evaluation of the resources alone. Several texts, eg. Ehrlich, Ehrlich and Holdren (1977), Young (1976), etc, are available describing in detail facts and measurements of the different land resources. Thus, no description of this information is given.

3.3 The Land Use

Every land use is associated with a management system specifying the manner of utilizing the land resources. A basic management system may have several variations, eg. irrigation may or may not involve the artificial drainage of the land. These two variations of the basic irrigation management system are regarded as two separate land uses since the land resources will be managed in different ways. This concept of different levels of management constituting different types of land uses is an integral part of the land capability procedure being developed here.

Most procedures are devised for one or more defined land uses. To maintain the desired degree of flexibility within this procedure, it is necessary that any land use may be considered. It is impractical to define all possible land uses but without these definitions, a land capability analysis cannot be performed. A classification of the land uses into groups of similar activities will reduce the number and the following classificatory groups have been defined. The hierarchical relationship between them is depicted in Figure 1.

(a) Land use - This is the fundamental unit. It is a strictly defined use having specific optimum and permissible values for each land resource analysed.

(b) Land Use Type - This is a group of land uses less strictly defined. It has general optimum and values for each land resource analysed.

(c) Land Use System - This is a group of land use types of a similar activity having the same basic management system.

3.3.1 The Land Use Systems

The broad categories of land use mentioned in the literature are agriculture, which includes livestock farming, forestry, conservation, recreation, communications, urban and rural development, excavation of minerals and of construction materials. Additional land uses of importance to South Africa, where water is a limited resource, are dam construction and water catchment. These categories are classified as land use systems for this procedure and are defined as:-

(a) Agriculture - The mechanised cultivation of plants in homogeneous stands for man's ben fit and the grazing of indigenous or introduced grass species by

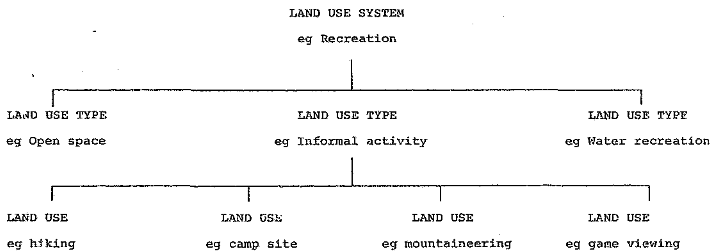

Fig.1 <u>The Hierarchical structure of the Land Use Classification System</u>

livestock. The land must be able to provide the conditions for plant growth, allow the use of mechanised tillage implements and be accessible to livestock. The land resources providing these conditions are climate, soil and relief (Vink, 1975).

(b) Forestry - The cultivation of tree species in homogeneous stands for commercial timber. The land resources providing the requirements for plant growth, ie. climate, soil and relief, are important.

(c) Conservation - The restoration and maintenance of the land in its natural state. This involves the management of the relief, soil, flora and fauna.

(d) Recreation - Any leisure activity which refreshes, entertains, agreeably occupies or amuses man. (Concise Oxford Dictionary) Land for this purpose must provide the resources necessary for the pursuit of a recreational activity, ie. flora, fauna, climate, water and relief.

(e) Urban and Rural Development - The construction of any permanent building for man's benefit, using mechanised construction implements. Land fit for this purpose must be able to support the load of the constructed structure without failure and allow the use of mechanised construction vehicles. The land resources providing these requirements are those of geology, soil, relief and flora, and fauna.

(f) Communications - The construction of any permanent right-of-way, using mechanised vehicles. The requirements and resources of the land are as for (e) above.

(g) Dam Construction - The construction of a permanent barrier in a river system using mechanised construction vehicles, behind which water is stored. The requirements and resources of the land are as for (e) above.

(h) Excavation of Minerals and Construction Materials - The dryland removal of rock material from the land, to be used for construction and industrial purposes. The land must process rock of industrial or constructional value. Also safe excavation, ie. avoidance of land slides, floc f of workings, etc. and the use of mechanised vehicles should be possible. The land resources meeting these requirements are those of geology and relief.

(i) Water Catchment - The terrain from which water is delivered to a stream, lake or reservoir below it. Land fit for this purpose should deliver relatively silt-free water to these water bodies. The land resources of relief, climate, geology and flora are important (Midgley and Pitman, 1969).

Power generation is a complex land use system involving the excavation of minerals eg. coal, water catchment, dam construction and communication networks eg. power transmission lines. A land capability analysis for power generation will require the separate analysis of each of these land use systems to produce a final integrated land capability analysis map.

3.3.2 The Land Conditions

Before a land use may be implemented, certain land conditions are required. A land evaluation procedure determines the fulfilment of these land conditions for the land uses being studied. These land conditions are an expression of the land resources whose individual scientific measurement and description is generally impossible. Owing to this, the land quality has been defined (Brinkman and Smyth, 1973) to indicate the direct relationship between the land as an ecological system and the biological and technological activities of land use. A land quality acts in a manner clearly distinct from the actions of most other land qualities in its influence on the capability of the land for a c[illegible] e and it may be used as a diagnostic criterion (B[illegible] nd Smyth, 1973). It is defined as an expression of a set of interacting single or compound land characteristics having different weights in different environments (Brinkman and Smyth, 1973). A land characteristic is a typical or distinctive feature of the land which may be seen or measured directly (Vink, 1975).

The main land conditions required by one or more of the land use systems are:-

(a) A particular land surface
(b) Accessibility and manouveribility over the land
(c) Resistance of the natural rock to weathering
(d) Safety to life
(e) Resistance to soil erosion
(f) Plant growth conditions
(g) Water catchment
(h) The presence of natural vegetation.
(i) The presence of higher forms of animal life.

Other land conditions may be important in certain situations. The flexible nature of the procedure (Section 4.7) allows for the consideration of such further land conditions provided that the land qualities expressing them are present or added. However, social and economic land conditions eg. conditions for water development, conditions for aesthetic appeal etc. are omitted as this is a land capability analysis procedure. The land conditions analysed and the land qualities used to indicate these conditions are given in Tables 1 and 2 respectively. These tables are based on a literature study and on discussions with various people from research institutions, government departments and universities (Appendix A).

3.3.3 The Definitions of the Land Qualities considered in the Procedure

Accessibility - the potential of reaching a point on or below the land surface with or without mechanised equipment.

Durability - the resistance of a natural rock to weathering.

Erodibility - the susceptibility of the site to soil loss by the action of wind and water.

Fauna - self-explanatory

Flooding hazard - the potential for a river, stream, reservoir or lake to overflow and flood the land surface.

Growth climate - the climatic conditions present to support productive plant growth.

Land surface - the presence of particular relief-forms and land surface cover.

Slope stability - the resistance of a slope to displacement.

Soil drainage - the movement of water into and through the soil profile.

Soil failure hazard - the potential of the soil profile to support a man-made structure without failure.

Soil fertility - the physical rooting conditions, aeration and nutrient status of the soil.

Flora - self-explanatory.

Water catchment - the potential runoff of precipitation from the land.

3.4 The Set of Land Characteristics Used to Express each Land Quality

A land quality is expressed by a set of land characteristics measuring the land. Two objectives of the procedure are that the data evaluated should be objectively measured and be independent of time. The set of land characteristics meeting these requirements were selected for each land quality. A brief description of the information used in making the choices with particular reference to the land conditions being expressed and not to the land use, follows for each land quality. The order of their description is from the more stable to the less stable land quality.

The measurement of certain land features is only practical at large scales eg. soil pH, soil joint structure. Other features may be measured at all survey scales but the degree of detail captured will depend upon the land characteristic used to measure them eg. topography may be measured as the percentage slope gradient or as a particular hillslope element. Thus the measurement of all the land characteristics chosen is not applicable to all survey scales. Rather than omit a land feature, if it is possible, a land characteristic, or set of such, is substituted to measure the same land feature at the scale at which the preferred land

Table 1 - The Main Land Conditions required for each Land Use System

	LAND CONDITIONS								
Land Use System	Land Surface	Accessibility and Manoeuverability	Weathering Resistance	Safety	Resistance to Soil Erosion	Plant Growth	Water Catchment	Natural Vegetation Presence	Wildlife Presence
Agriculture	*	*	-	*	*	*	-	*	*
Communications	*	*	-	*	*	-	-	-	-
Conservation	-	-	-	-	*	-	*	*	*
Dam Construction	*	-	-	*	*	-	-	-	-
Excavation	*	-	*	*	*	-	-	-	-
Forestry	*	*	-	-	*	*	-	-	-
Recreation	-	*	-	*	*	-	-	*	*
Urban and Rural Development	*	*	-	*	*	-	-	-	-
Water Catchment	-	-	-	-	*	-	-	-	*

Table 2 – The Land Qualities analysed for each Land Use System to Express the Required Land Conditions

Land Use System	LAND QUALITIES												
	Land Surface	Accessibility	Durability	Flooding Hazard	Slope Stability	Erodibility	Soil Drainage	Soil Failure Hazard	Soil Fertility	Growth Climate	Water Catchment	Flora	Fauna
Agriculture	*	*	–	*	–	*	*	–	*	*	–	*	*
Communications	*	*	–	*	*	*	*	*	–	–	–	*	–
Conservation	–	–	–	–	–	*	–	–	–	–	–	*	*
Dam Construction	*	–	*	–	*	*	*	*	–	–	–	–	–
Excavation	*	*	–	*	*	–	*	–	–	–	–	–	–
Forestry	*	*	–	*	–	*	*	–	*	*	–	*	–
Recreation	*	*	–	*	–	*	–	–	–	–	–	*	*
Urban and Rural Development	*	*	–	*	*	*	*	*	–	–	–	–	–
Water Catchment	–	–	–	–	–	*	*	–	–	–	*	*	–

characteristic is not measurable. Table 3 lists the land characteristics concerned. Those land characteristics measured at the small scale have a more general and broad level of measurement than those measured at the large survey scale which are thus preferred as they will indicate more similarity between sample sites. The land characteristics measured at the small survey scale are visible from air photographs or maps or are measured in the field. Those measured at the large survey scale may be laboratory measurements.

No numerical distinction is made between a large and a small scale survey scale deliberately so that the flexibility of the procedure is maintained. This procedure is developed to evaluate the land at any survey scale and thus level of measurement. Different surveyors using the same survey scale may measure different land characteristics depending upon the amount of time, the economics and the assistance available as well as the type and condition of the land. In listing the land characteristics used to express each land quality, all the land characteristics for all the survey scales are given. The definitions of all the land characteristics and their units of measurement are given in section 3.5.6. They are stored as digitised maps in a resource inventory so that their spatial distribution is retained (Section 4.3). Table 12 lists the land characteristics and the land qualities which they express. It is given at the end of the description of all of the qualities so that the definition of each land characteristic is known when the Table is studied. The land characteristics are ordered from the stable to the least stable land resource which they measure.

Table 3 - The Land Characteristics which may be used as Substitutes for each other

Land variable measured	Land Characteristic: Small scale (Broad level of measurement)	Large scale (Detailed level of measurement)
Rock	Natural rock group	Secondary mineral *Ten per cent fines* test
Slope stability	Geological discontinuities	Factor of safety
Relief	Hillslope element	Slope gradient Slope length
Soil permeability	Soil permeability index	Sub-soil texture Top-soil texture Soil horizon type
Soil strength	Stratigraphic Unit	Soil activity Soil joint structure
Soil strength	Transported soil origin	Soil activity Soil joint structure

3.4.1 Land Surface (The presence of particular relief forms and land surface cover)

Land surface features may be grouped into:-

(a) Rock surface cover - Most land uses require a soil surface which is free of rock cover. This cover may be due to boulders (greater than 25cm in size) or gravel (2 - 25cm in size) (Ivy, 1977). The amount of rocky cover and its distribution are both important but a measurement of the total surface area covered will not indicate the latter. Thus, an additional land characteristic of rocky cover distribution will be recorded where '1' indicates a single clumped distribution, '2' - a scattered clumped distribution and '3' - a scattered distribution. A continuous rock surface is considered to be distinct from rock cover since it is generally impossible to clear it and expose the soil surface beneath. This is because the rock surface is the exposed bedrock from which the soil has been eroded.

(b) Woody surface cover - This is dealt with under the land quality of flora.

(c) Landforms - The hillslope element and slope gradient measure the landform present. But, since the dominant value of these land characteristics is recorded, the presence of certain landforms would be omitted. To overcome this, certain landforms, eg. gullies and koppies, are recorded separately.

A gully (donga) is a water worn channel with a high erosion potential. A koppie is a boulder strewn hillock which is generally inaccessible to mechanised forms of transport and has little or no flattish areas. Both these landforms interrupt the landscape, the extent of their interruption being dependent upon the land area which they cover.

The aesthetic appeal of unusual or rare landforms depends upon the culture, background, previous experience, maturity, personality, etc., of the observer. Although no objective measurement is possible, such landforms are important to conservation and recreation. The presence of any landform considered to be of aesthetic or conservational value, will be recorded by the natural land feature land characteristic.

(d) Hydrological features - Water may be present in reservoirs, lakes, rivers and streams. The surface area of the first two types of water bodies is important since it represents unavailable land surface for certain land uses while it is the required surface for others. Rivers and streams, together with their tributaries, dissect the land into smaller land units which may be of an unproductive, uneconomic or non-usable size. These land features also present an obstacle to movement over the land.

The set of land characteristics expressing the land surface are the coverage of boulders, gravel, rock surfaces, natural land features, gullies,koppies, lakes, reservoirs, vleis; rocky distribution and the number of rivers and streams. The definitions are as follows:-

(a) Rock surface - the land surface covered by an exposed surface area.

(b) Boulder cover - the land surface covered by rock fragments greater than 25cm in diameter.

(c) Gravel cover - the land surface covered by rock fragments between 2 and 25cm in diameter.

(d) Rocky distribution - the distribution of the boulder cover.

(e) Gully - the land surface covered by a water-worn channel.

(f) Koppie - the land surface covered by a boulder-strewn hillock.

(g) Natural land feature - the presence of a natural land feature with aesthetic or conservational value.

(h) Vlei - an area of ill-drained land.

(i) Lake - the land surface covered by a natural or a man-made lake in which the water is held by a non-earthwork dam.

(j) Reservoir - the land surface covered by a man-made reservoir in which the water is held by an earthwork dam.

(k) River - the presence of a river.

(l) Stream - the presence of a stream.

3.4.2 Accessibility (The potential for reaching a point on or below the land surface with or without mechanised equipment)

The relief and particular features of the land surface present obstacles to its accessibility. The required accessibility is dependent upon the land use, eg. the movement of mechanised transport is more readily restricted by the land than are pedestrians or livestock. Mining la uses are also restricted by the ease of access to the rock material below the land surface.

Relief forms may be grouped into those which are elevated above an arbitrary point, ie. hills, and those which are depressed below this point, ie. valleys. The hillslope may be qualitatively divided into five elements (Brink, 1979) as illustrated in Figure 2. These elements are

(a) Crest which is generally of a rocky nature.

(b) Waxing slope

(c) Free face (scarp) which is the rocky face.

(d) Talus slope (middle slope).

(e) Pediment (footslope) which is covered by transported soil and leads into the valley bottom.

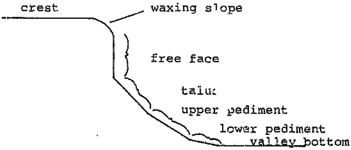

Figure 2 - The Elements of the Hillslope

Quantitative measurements of relief are the slope gradient and the slope length. These may be calculated from relief maps of 1 : 50 000 (Ivy, 1977). The correspondence between the slope gradient measured as a percentage and the hillslope elements are given in Table 4.

Table 4 - The Slope Gradient corresponding to each Hillslope Element

Hillslope element	Code	Scope % Gradient
Crest	1	
Waxing slope	2	Variable
Free face	3	> 25
Talus	4	16 - 25
Upper pediment	5	6 - 15
Lower pediment	6	1 - 5
Valley bottom	7	0

Relief influences the economics of mechanised transport. Running costs are high on slopes exceeding eight per cent (Horak and du Toit, 1977), while the construction costs of roads substantially increases with slopes greater than five per cent (Kiefer, 1972). Gradients greater than twelve per cent are not easily accessible to implements and those exceeding twenty-five per cent are only accessible to livestock (Edwards, 1970) and humans.

The accessibility of the bedrock for excavation is influenced by the soil depth above it, as this must first be removed or by-passed. Such measurements are generally only available from local studies. The slope gradient and the soil depth are interrelated. Weinert (1978) states that flat slopes are waterlogged with deep soils, steep slopes have shallower soil due to soil erosion loss and slopes exceeding sixty degrees are rocky outcrops.

The accessibility of a mineral deposit is influenced by its depth below the land surface and the water table, and the particular rock above it. The drilling machinery available, the funds available for mining, the market price of the mineral and the quality of the ore will determine whether the deposit will be mined or not. These depend upon the economic situation and thus only the depth to the mineral ore deposit will be considered.

The set of land characteristics expressing accessibility are the hillslope element, the slope gradient, the slope length, the depth to the bedrock and the depth to the mineral ore deposit. These are defined as follows:-

(a) Hillslope element - a particular component of a hillslope (Fig.2).

(b) Slope gradient - the steepness of a slope, expressed as a percentage.

(c) Slope length - the length of a slope of constant gradient.

(d) Depth to the bedrock - the distance from the ground surface to the underlying bedrock.

(e) Depth to the mineral ore deposit - the distance from the ground surface to the underlying mineral ore bearing rock.

3.4.3 Durability (The resistance of a natural rock to weathering)

Chemical and mechanical weathering of rock material occur simultaneously but either one will predominate, depending upon the climatic conditions present. Weinert (1978) observed the weathering of Karoo Dolerite in different parts of the Republic of South Africa and concluded that the moisture supply and the temperature may be used to determine areas of different weathering rates and dominant weathering processes. He developed his Climatic N-value to define the boundaries of these different areas and which is defined as

$N = \frac{12\ E_j}{P_a}$ where:-

E = computed evaporation in January based on Olivier's formula (Weinert, 1978)

P_a = total annual precipitation

Contour maps of the different climatic N values for the Republic have been drawn (Weinert, 1970). Chemical weathering causes a chemical change in the primary rock material and the secondary rock minerals produced, will have different properties. Mechanical weathering causes only a physical change to the rock mineral.

Rock materials are required for different constructio purposes, eg. surfacing, base, sub-base, subgrade fill and wearing course for roads as well as for concrete aggregates. The rock material is durable if the change in its physical and chemical properties during the construction and life of the engineering structure, remains within limits which do not invalidate the design. The required durability thus depends upon the particular structure and the section for which the rock material is needed, ie. upon the land use.

Chemical weathering is 'technically the more deleterous mode of weathering' (Weinert, 1969). It occurs particularly where the climatic N-value is less than five and for those rocks with minerals which oxidise or hydrate under atmospheric conditions (Weinert, 1970). The durability of a rock is thus a function of its petrological properties and the environmental conditions at its place of occurrence (Weinert, 1970) and use. The hardness of a rock is an indication of the extent of weathering which has occurred. Weathered rocks are softer than fresh rocks (Jennings et al 1973) and are thus less durable. The presence of quartz in a rock is an impr . erminant of its durability since it is the most re. ock mineral to weathering. Soil is the rock weathering stage in equilibrium with the environment (Weinert, 1978).

Weinert (1969) classified the natural rocks of South Africa into nine groups based upon their durability in an attempt to relate the petrological properties to engineering material and the secondary rock minerals produced, will have different properties. Mechanical weathering causes only a physical change to the rock mineral.

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Weinert (1969) classified the natural rocks of South Africa into nine groups based upon their durability in an attempt to relate the petrological properties to engineering requirements. General statements of their engineering properties for road and concrete aggregates, together with their durability are given for each group by Weinert (1970).

The quantitative measurements of durability are:-

(a) <u>The ten per cent Fines Aggregate Crushing test</u>.- This measures the pressure under which ten per cent of the sample is crushed into fines.

(b) <u>The Secondary Minerals present</u>. This is measured as the percentage seen under the microscope. This, together with the climatic N-value, gives the soundness of the material (Weinert, 1970).
The results of these tests which indicate that the rock is durable for particular purposes are given (Weinert, 1969, 1970). Such tests are generally only performed after the rock has already been chosen as construction material and are not available when the land is surveyed.

The set of land characteristics considered when durability is expressed is the natural rock group, the climatic N-factor at its place of use, the rock hardness, the ten per cent fines aggregate test and the secondary mineral test. These are defined as follows:-

(a) <u>Climatic N-factor</u> - the climatic weathering zone defined by Weinert (1970).

(b) <u>Natural rock group</u> - the natural rock group as classified by Weinert (1969).

(c) <u>Rock hardness</u> - the unconfined strength of rock

(d) <u>Secondary minerals</u> - the percentage of secondary minerals in a rock sample seen under the microscope.

(e) <u>Ten per cent fines test</u> - the pressure which must be applied to a rock sample to produce t n per cent of fines.

3.4.4 Flooding Hazard (The potential for a river, stream reservoir or lake to overflow and flood the land surface)

Land adjacent to a static or flowing water body, viz. rivers, streams, reservoirs and lakes, is susceptible to flooding. The probability of the water body flooding owing to the surface runoff and precipitation received from individual storms, is a complex interaction of the rainfall intensity and duration of the storm, the profile of the water body floor (a steep, deep profile will cover less land surface area than a shallow flat profile containing the same volume of water) the slope and roughness of the water body floor and of the flood plain, etc. The probable flood line of a water body may be calculated from storm data using a complex, computerised procedure (Hydrological Research Unit, 1972). However the vertical height above a water body is a sufficient indicator of the possible flood hazard (Pitman, 1978, personal communication).

The land characteristic of the height above water will be used to express the flooding hazard. It is defined as the vertical height above a lake, reservoir, river or stream.

3.4.5 Slope Stability (The resistance of a slope to displacement)

A sloping rock or soil surface is subject to forces which tend to cause a movement of its mass from a high to a low point. If this occurs, the slope is said to have failed. The stability of a slope is a measure of its safety against such a failure (Sutton, 1975).

The factors determining the stability of a rock and must be applied to a rock sample to produce ten per cent of fines.

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The land characteristic of the height above water will be used to express the flooding hazard. It is defined as the vertical height above a lake, reservoir, river or stream.

3.4.5 Slope Stability (The resistance of a slope to displacement)

A sloping rock or soil surface is subject to forces which tend to cause a movement of its mass from a high to a low point. If this occurs, the slope is said to have failed. The stability of a slope is a measure of its safety against such a failure (Sutton, 1975).

The factors determining the stability of a rock and a soil slope differ since their behaviour under stress is not the same. This is due to the differences in the geometry of the spaces between the solid material and the interlocking properties of the basic components (Piteau, 1970). Soil is essentially a continuous medium consisting of an assemblage of uncemented, angular to round particles whose size is micro when compared with the slope scale. The void spaces may or may not be filled with water. A rock mass is a discontinuous medium consisting of aggregates of blocks separated by planes of weakness. These blocks are macro in size when compared with the slope scale and the space between them may or may not be filled with water and/ or soft or hard material (Piteau, 1970).

The shear strength of a rock slope is dependent upon the shear strength of the planes of weakness. A vast number may exist giving rise to anistropy in the shear strength of the slope (Piteau, 1970). The slope failure is directional along these planes of weakness. Faults and continuous through-going structures in the rock, ie. geological discontinuities, have a greater influence upon the slope stability than do the joints and minor discontinuities (Patton and Deere, 1970). The ground water level, the degree of weathering which has occurred and the fluid pressure within the discontinuities which acts as a shearing force, all influence the stability of a rock slope (Patton and Deere, 1970). The actual stability may be determined from a detailed joint survey of the slope in which each plane of weakness is systematically analysed (Piteau, 1970).

The shear strength of a soil slope depends on the intrinsic strength of the soil mass itself. This decreases with an increase in the soil moisture content owing to the decrease in the soil pore water suction pressure (Capper and Cassie, 1976). Non-cohesive soil slopes are stable if the slope angle inclination is less than the angle of shearing resistance of the soils. The stability of a cohesive soil slope is also influenced by the density and cohesion of the soil and the height of the slope (Sutton, 1975). The slip surface (failure plane) of a soil slope and the direction of the acting forces, may be determined from a detailed survey of the slope cross-section.

The factor of safety (F) is calculated from the slope survey. It is the ratio of the resisting forces, ie. the strength of the soil or rock, to the disturbing forces, ie. gravity (Golder, 1970). Various methods to determine F are available (Pentz, 1970; Golder, 1970; Capper and Cassie, 1976). A slope where F exceeds one is stable although slopes with an F value below one have also been known to be stable (Reynolds and Protopapadalis, 1959). F will vary with the water pressure between the soil particles and the rock aggregates (Golder, 1970).

Engineering techniques to improve the slope stability are available and involve the removal of the slide, the control or unloading of the slide, drainage and artificial stabilization, eg. external support, etc. (Stewart and Kennedy, 1970; Capper and Cassie, 1976).

The land characteristics expressing slope stability are the factor of safety, the slope gradient, the hillslope element and the presence of geolog[illegible]al discontinuities.

The definitions are as follows:-

(a) Hillslope element - defined in section 3.4.2.

(b) Slope gradient - defined in Section 3.4.2.

(c) Geological discontinuities - a plane of weakness eg. a fault or a fracture in the bedrock.

(d) Factor of safety - the ratio of the strength of a soil or rock slope to the disturbing forces.

3.4.6 Erodibility (The susceptibility of the site to soil loss by the action of wind and water)

Soil erosion is due to the action of wind or water at the soil surface.

(a) Water erosion - There are four phases in the movement of soil by water, viz. the disruption of the soil structure, the detachment of the soil particles, their transportation and subsequent deposition at some other site. These phases are carried out by the action of the raindrop and the runoff water, the former being the major factor. Any land characteristic intercepting the raindrop or preventing the build-up of runoff water, will decrease the soil loss.

American research (Tilmann and Mokma, 1976) revealed that the following factors determine the erosivity of an area:-

(a) The erosive potential of the rainfall determined by EI30. This is the product of the rainfall energy and the maximum sustained intensity over a thirty minute period.

(b) The slope length and the slope gradient.

(c) A crop management factor.

(d) A conservation practice factor.

Zimbabwean research (Elwell, 1977) modified these findings to the African situation as follows:-

(a) The linear relationship between EI30 and soil loss as shown by the American research, did not hold true in the African situation (Elwell, 1977). A more suitable parameter for indicating the erosive potential of the rainfall was found to be the total kinetic energy per season.

Total rainfall kinetic values derived from the mean annual rainfall values are given in Table 5. The derivation was based upon rainfall energy values characteristic of Zimbabwean rainfall and are only best estimates since the relationship between the mean annual rainfall and the rainfall kinetic energy is not exact (Elwell and Sto[illegible], [illegible]976). Since no equivalent data are available for t[illegible]svaal rainfall, the Zimbabwean data are used.

(b) The increase in soil loss with the slope gradient and the slope length was found to be the same. D'Souza and Morgan (1976) found that the soil loss increased linearly with slope gradient until a slope of six to seven per cent is reached. After this, soil loss increases exponentially with slope gradient. Soil loss will also change in the same manner between hillslope elements of different steepness.

(c) The crop management factor is a combination of the soil management and the crop type. These two factors were separated into the vegetal cover and a soil erodibility index which included the soil management. An initial index value based on the soil texture was modified by 0,5, one or two, depending upon the tillage technique used (Elwell, 1977).

Table 5 - The Values of the Rainfall Energy Equivalent to the Mean Annual Rainfall

Mean Annual Rainfall mm a^{-1}	Energy J $m^{-2} a^{-1}$	EI30 J/m^{-2} a^{-1}
400 - 500	10 400	163 000
500 - 600	12 200	200 000
600 - 700	14 000	240 000
700 - 800	15 800	280 000
800 - 900	17 600	320 000
900 - 1 000	19 000	350 000
1 000 - 1 100	21 000	380 000
1 100 - 1 200	23 000	410 000
1 200 - 1 500	28 000	525 000
>1 500	30 000	560 000

The quantitative measurement of vegetal cover depends upon:-

(a) The plant type under cultivation or the vegetation type.

(b) The germination density or the vegetation density.

(c) The growth stage of the plant or plants within the vegetation type, at the time of measurement.

(d) The soil fertility.

(e) The plant or vegetation vigour.

(f) The climate.

(g) The planting date and the management system.

Vegetal cover measurements are thus time-dependent since only variable (a) is independent of time.

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Crop canopy cover curves showing the degree of protective covering with time, were drawn for tobacco, maize and cotton crop canopy cover values measured with a special sighting frame (Elwell and Wendelaar, 1977). It was apparent from these curves that the erosion hazard varied throughout the season and between the crops themselves. The curves were superimposed upon the rainfall energy distribution for the same period to determine the cover interception factor. This factor was then used as a crop erosion hazard rating and a list for various crops was given. Future adjustments to these values will be necessary since these were derived from research data of a particular area, planting date and management system. However, the authors assume that the order of the crops in the list will remain the same. Scotney (1977) listed average crop cover interception values for selected crops in Natal, planted at certain densities. Future research will cause adjustments to these values, particularly with reference to the Transvaal.

The values obtained for the natural vegetation canopy cover will depend on variables (a) to (g), the time measurement and the particular land tract. To overcome this time dependence, the soil erodibility will be assessed for the most vulnerable period, ie. no vegetation cover.

The cohesive nature of the soils is influenced by:-

(a) The soil texture - The force of attraction between the soil particles varies inversely with the particle size (Brady, 1974).

(b) The soil structure - (Young, 1976) This is improved by the addition of organic matter which not only attracts the soil particles due to its collodial properties but it is also decomposed by soil microbes. Their activity stabilises the soil structure due to the polysaccharide gums produced by the soil bacteria and by the presence of fungal hyphae (Russell, 1973).

(c) The soil moisture content which is a function of the soil texture and the moisture available.

The runoff velocity and thus soil erosion, is increased if the infiltration of water into the soil profile is impeded, eg. by soil capping or waterlogged conditions, etc. In the former situation, the soil moisture status is also poor. This decreases the cohesive nature of the soil, causing a further increase in its erodibility.

Certain soils are known from experience to be more erodible than others. Using this knowledge, Scotney (1977) derived a soil erodibility index for all the South African soil series classified by MacVicar et al (1977). Each index was developed by awarding an initial value to each soil series depending upon its general soil texture. This value was subsequently modified by the average conditions of the soil depth, the degree of leaching, the soil permeability, the organic matter status and the surface conditions found in the field. The application of these indices is limited as they are a subjective assessment related to conditions in the province of Natal.

No data were found which objectively elucidated the relationship between soil texture and soil loss other than the information that light soils are more erodible than heavy soils (Elwell, 1977). This is insufficient information upon which to base a quantitative capability assessment of different soil textures. The soil erodibility index was developed from practical field knowledge and until future research is available, it is thought to be a more valid indication of soil texture erodibility than a soil texture measurement alone. Research as to the exact validity of the index is required. The soil erodibility index value ranges from 1 - 8 where:-

$\leqslant$2,0 - very high erosion potential

2,5 - 3,5 - high erosion potential

4,0 - 4,5 - moderate erosion potential

5,0 - 5,5 - low erosion potential

$\geqslant$6,0 - very low erosion potential

(d) The conservation practice factor may modify the slope and the soil erodibility. This is omitted as a separate influencing factor as it is not a fundamental feature of the land.

(b) Wind Erosion - Chepil (1945) showed that three phases are involved in the movement of soil by wind, viz. initiation of soil particle movement, its transportation and subsequent deposition at another site. The minimum wind velocity at which wind erosion occurs, ie. the threshold velocity, is dependent upon the soil particle size since this size is related to the soil's cohesive properties. A non-cohesive particle, ie. sand, requires less energy than a cohesive particle, eg. floculated clay to initiate its movement. Once initiation has occurred, the particles move by saltation which is a creeping movement over the earth's surface. The impact of these moving particles initiates the movement of other stationary particles even if the wind velocity is below their threshold velocity. A rough land surface hinders saltation and aids in the deposition of the wind-borne soil particles. However, the measurement of a surface roughness value will be of a temporary nature and will vary with the land preparation method. Thus, it does not meet the requirements for being included in an expression of a land quality in this procedure.

The general threshold velocity for wind erosion, neglecting the soil type, is 5,85 m s^{-1} at 0,3m above a smooth surface (Chepil, 1945). Any interception of the wind velocity will decrease its erosive potential. The slope gradient modifies the wind velocity which is twenty per cent greater at the crest of a landform than on flat ground, regardless of whether the wind is on the lee or windward side of the landform (Lynch, 1971).

The wind erodibility of an area increases with the length of previously exposed soil eg. a fallow field, or a gully, until a critical value is reached, above which the soil loss is constant. This value depends upon the surface roughness, the soil texture, etc. of the land.

The occurrence of wind erosion is greatest when the soil is dry, the vegetation cover is low and the probability of the wind velocity being greater than 5,85 m s^{-1} is high This will be during the dry months of September to November inclusive which is the windiest period for the Transvaal (S.A.W.B. Part 8, 1965).

The set of land characteristics chosen to express the erodibility of the land are rainfall energy, slope gradient, slope length, hillslope element, soil erodibility index, exposed soil length and the wind velocity. They are defined as follows:-

(a) Hillslope element - defined in Section 3.4.2

(b) Slope gradient - defined in Section 3.4.2.

(c) Slope length - defined in Section 3.4.2

(d) Soil erodibility index - the potential erodibility of the exposed soil as determined by Scotney (1977).

(e) Exposed soil length - the length of bare previously eroded soil.

(f) Wind velocity - the mean wind velocity for the months of September to November inclusive.

3.4.7 Soil Drainage (The movement of water into and through the soil profile)

Soil drainage is a dynamic situation and thus its measurement will always be of a temporary nature. The velocity (v) of the downward flow of water into and through unconsolidated soil is expressed by Miller (1977):-

$$V = \frac{K \partial \Psi}{\partial x}$$

K = conductivity which is a measure of the soil's permeability.

x = distance moved by the water.

Ψ = capillary potential which is a measure of the forces moving the water through the profile.

Soil permeability is the ease of water movement through the soil pores. For a saturated soil, the permeability is dependent upon the size and configuration of these pores ie. upon the soil texture and structure. For unsaturated soil, the permeability is a function of the soil water potential of the profile which involves additional variables eg. the amount of water present in the soil pores. Both K and ψ vary with the soil moisture status and thus the velocity of the water movement will also vary at any point within an unsaturated soil profile.

Water moves through the soil profile by two processes viz. infiltration and water conductivity.

(a) Infiltration - This is the movement of water through the surface of the soil. Any impediment to infiltration will therefore decrease the amount of water reaching the soil (assuming that no sub-surface soil moisture flow from adjacent land occurs). The important factors influencing infiltration are:-

(a) Soil porosity - Soil porosity is determined by soil texture and structure. The infiltration rate of water into a soil increases with the soil porosity (Kelly and Walker, 1976). Soil porosity is an indication of the moisture holding capacity of the soil which is increased by the presence of collodial organic molecules and clay particles. A quantitative measure of the soil structure will change since the structure is easily destroyed by poor management techniques. Thus, it is not included in the expression of soil damage.

(b) Surface capping - A surface cap is formed when the soil pores are blocked by a suspension of clay/silt particles as a result of the action of the raindrop and surface runoff (E.herington, 1975). This will develop more readily on soils of low porosity and will cause a further decrease in their infiltration rate.

(c) Vegetation cover - Research has shown (Miller, 1977) that vegetation cover increases infiltration due to a number of interrelated factors, eg. improved soil structure, the active absorption of water by the plant roots etc. Surface cap formation also increases on certain soil types when the vegetation cover has been removed (Barnes and McNeill, 1978). The vegetation cover is also a determinant of the litter cover present. Kelly and Walker (1976) found that the infiltration rate was nine times faster for soil with a complete litter cover than for bare soil. The amount of vegetation cover present varies with the rainfall received per season (Barnes and McNeill, 1978), the degree of root activity, the species composition of the vegetation, etc. However, as the vegetation cover varies with the time of measurement, it is not included in the expression of the soil drainage.

(d) Antecedent soil moisture - This is a function of the time period between the water applications. The longer the period the greater is the water loss from the soil profile by evaporation, utilization and the downward flow to the ground water supply. The initial infiltration rate depends on the initial moisture status of the topsoil. This changes with infiltration and causes a subsequent change to the infiltration rate itself. The infiltration rate also depends on the moisture status of the underlying subsoil. If this soil is dry, water will flow fairly rapidly downwards from the topsoil into it. This allows for the infiltration of more water until both the topsoil and the subsoil are saturated. Kelly and Walker (1976) found that there was no significant difference in the infiltration rate between soils at different moisture contents of up to twenty per cent dry weight.

(e) The delivery rate of the water supply - Land receiving a high water supply (which is composed of the rainfall supply and the surface runoff from adjacent lands) does not necessarily indicate a better moisture of the soil. This is because the amount of water infiltrating depends on the difference between the delivery rate of the water and the infiltration rate. The rainfall delivery rate is indicated by its intensity which is used to express rainfall energy by Elwell and Stocking (1973):-

$$E = a - \frac{b}{I}$$

where:- E = rainfall energy
I = rainfall intensity
a and b = constants

The rainfall energy indicates the capping action of the rainfall which effectively increases its intensity as the soil porosity and thus the infiltration rate, are reduced.

Direct infiltration measurements are made by timing the disappearance of a known volume of water from the soil surface. However, these measurements are dependent upon the moisture status of the soil profile and the vegetation cover which are both dynamic land characteristics. Since the infiltration rate is closely linked with the soil texture through its influence upon the soil porosity, this land characteristic is preferred to that of the direct measurement as it is not a dynamic variable.

(b) Water conductivity - This is the flow of water through saturated or unsaturated subsoil. The term hydraulic conductivity is not used as it refers only to the saturated flow of water (Miller, 1977). The important factors influencing the water conductivity are:-

(a) Antecedent soil moisture - Moisture flows from a more saturated to a less saturated soil.

(b) Moisture-holding capacity of the different textural horizons within the soil profile - The velocity of the soil movement will vary between different soil horizons due to differences in their soil structure and texture. The presence of a different horizon acts as an initial obstruction to the downward flow of the water until the field capacity of that horizon is reached. After this, the flow of the water is independent of the soil water potential (Miller, 1977).

(c) Slope gradient - The lateral movement of soil moisture will occur if there is a lower site to which the water may drain. Soils on a slope drain more easily than do soils on a flat slope provided that all other variables are constant.

Direct conductivity measurements are possible (Yaron, 1973) but these will be of a temporary nature, for the same reasons as given for the direct measurement of the infiltration rate. The soil texture measurement is preferred for the same reason.

The moisture capacity of a soil profile, and thus the volume of water which may drain into it, is a function of the moisture capacity of each horizon and the soil

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(a) Antecedent soil moisture - Moisture flows from a more saturated to a less saturated soil.

(b) Moisture-holding capacity of the different textural horizons within the soil profile - The velocity of the soil movement will vary between different soil horizons due to differences in their soil structure and texture. The presence of a different horizon acts as an initial obstruction to the downward flow of the water until the field capacity of that horizon is reached. After this, the flow of the water is independent of the soil water potential (Miller, 1977).

(c) Slope gradient - The lateral movement of soil moisture will occur if there is a lower site to which the water may drain. Soils on a slope drain more easily than do soils on a flat slope provided that all other variables are constant.

Direct conductivity measurements are possible (Yaron, 1973) but these will be of a temporary nature, for the same reasons as given for the direct measurement of the infiltration rate. The soil texture measurement is preferred for the same reason.

The moisture capacity of a soil profile, and thus the volume of water which may drain into it, is a function of the moisture capacity of each horizon and the soil profile depth. This is delineated either by the water table, below which the soil is saturated, or by an impermeable layer. The correlation between this depth and the moisture capacity of the soil profile is not direct due to the influence of the soil texture on the moisture capacity of each horizon, eg. a deep, sandy soil will have a similar moisture capacity to that of a shallow clay soil (Crafford and Nott, 1972).

Scotney (1977) listed certain soil series, based upon field experience, having one of the following restrictions to permeability, viz. no restriction, a slight restriction, a moderate restriction or a severe restriction. Although this is a subjective list requiring verification by research, it will be used to award a soil permeability index to the dominant soil series present in the soil profile where:-

4 - no restriction to permeability

3 - a slight restriction to permeability

2 - a moderate restriction to permeability

1 - a severe restriction to permeability

This subjective index is preferable in the absence of soil texture measurements rather than the complete omission of this factor.

The set of land characteristics expressing the soil drainage will be the slope gradient, the hillslope element, the soil horizon type, the topsoil and the subsoil textures, the soil permeability index, the rooting water table and bedrock depths and the rainfall energy. The definitions are as follows:-

(a) Hillslope element - defined in Section 3.4.1.

(b) Slope gradient - defined in Section 3.4.1.

(c) Depth to the bedrock - defined in Section 3.4.2

(d) Subsoil texture - the soil texture class of the soil horizons below the topsoil and within 150cm of the soil profile. (See Table 6)

(e) Topsoil texture - the soil texture class of the top soil. (See Table 6)

(f) Soil horizon type - defined in Section 3.4.9.

(g) Soil permeability index - the potential ease of water movement through the dominant soil series of the unconsolidated soil.

(h) Depth to the water table - the distance from the ground surface to that level at which all the soil or rock is saturated.

(i) Rainfall energy - defined in Section 3.4.6.

Table 6 - The Soil Texture Types as Classified by MacVicar et al (1977) and their Codes

Texture Class	Code
Sand	1
Silt	2
Loamy sand	3
Sandy loam	4
Loam	5
Silt loam	6
Sandy clay loam	7
Sandy clay	8
Clay loam	9
Silty clay loam	10
Silty clay	11
Clay	12

3.4.8 Soil Failure Hazard (The potential of the soil profile to support a man-made structure without failure)

An engineering structure exerts a load[1] on the soil upon which it is built. This load is determined by the structure's dimensions, the materials used in its construction, etc. If the load is greater than the bearing capacity of the soil, i.e. the load distributed over a certain area which may be supported by the soil, soil failure results causing damage to the engineering structure. Rock is the strongest natural material but the difficulties experienced in constructing foundations in it are great and thus it is generally not used.

The bearing capacity is measured by certain tests and varies with each soil horizon owing to differences in the soil texture and the soil moisture which is a function of the soil porosity for which the soil texture is the main determining factor. The infiltration and movement of water through the soil and the soil moisture capacity, are related to the soil porosity. This is discussed in the land quality of the soil drainage.

The shear strength of the soil is proportional to the load which will cause the soil to fail and depends on the soil moisture present. For non-cohesive soils, the shear strength is:-

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1. For engineering purposes, soil is that material with a strength below 700 kPa (Jennings et al, 1973).

$s = \sigma' \tan \phi_e$ where:-

ϕ_e = effective angle of friction

σ' = resultant force of the pore water pressure and the effective stress (intergranular stress), which the individual soil grains exert on one another. (Bowles, 1977)

A cohesion factor is added for cohesive soils.

Since the pore water pressure is a dynamic variable changing with the seasonal and daily fluctuations of the pore water, the shear strength will also vary. Thus, this temporary measurement and that of the soil moisture are excluded from the expression of this land quality.

Soil below the ground water table is saturated while soil above it may be either saturated or unsaturated. This latter section of the soil profile will exhibit a varying shear strength and thus engineering behaviour. The level of the water table varies inter- and intra-seasonally depending upon the water supply, its rate of delivery and infiltration, its movement through the soil profile and the rate of soil moisture loss. Thus the volume of soil above the water table is not constant. De Bruyn (1973) describes a water table as being relatively close to the surface at depths of less than 6 metres, 3 metres and 1,5 metres in clay, sandy clay and sand respectively. A mathematical treatise of the influence of the soil moisture upon the shear strength and the relation of the latter to the water table level is given by Donaldson (1966). The bearing capacity of the soil generally increases with soil depth as the material is more consolidated, less weathered and less subject to moisture fluctuations, particularly if it is below the water table. However, drainage problems are experienced at such depths.

The effective stress (intergranular stress) of the soil is a function of the intergranular distance. A change in this distance may result in a volume change of the whole soil profile (Donaldson, 1966). These volume changes cause heaving movements, ie. displacements in the engineering structure built upon the soil. If the soil moisture is above field capacity, the engineering load is carried by the pore water itself, leaving the effective stress unchanged. However, if the soil moisture is at or below field capacity, the engineering load is carried by the soil particles causing a decrease in the intergranular distance and thus an increase in the effective stress (Donaldson, 1966). This compaction occurs in non-cohesive soils and is a decrease in the void space volume between the granular soil particles.

Soils with a large clay fraction exhibit volume changes owing to the capacity of the clay particles to absorb molecules into their crystal lattice and so expand. As soil moisture is loose, the pore water suctior pressure increases and water moves from the clay crystal lattice into the soil pores resulting in a shrinkage of the crystal lattice (Donaldson, 1966). The soil profile volume will change in a corresponding manner if these movements are significant. These soils also exhibit rheological behaviour, ie. flow behaviour, which depends on the soil moisture. Soil consistency is a measure of the soil's resistance to flow and thus of its rheological behaviour. However, it is a subjective measurement based upon feel and is of a temporary nature since it varies with the soil moisture. It is therefore excluded from the expression of this land quality.

Atterberg limits are objective laboratory measurements of this behaviour. Three limits for arbitrary moisture contents are defined (Capper and Cassie, 1976):-

(a) Liquid limit (W_L) - minimum moisture content at which the soil will flow under its own weight.

(b) Plastic limit (W_p) - minimum moisture content at which the soil can be rolled into a 3mm diameter without breaking, ie. the soil is exhibiting plastic properties.

(c) Shrinkage limit - moisture content at which further moisture loss does not cause a decrease in the volume of the soil.

The plasticity index (W_L - W_p) is an indication of the type and quantity of clay present. The greater the clay content, the greater is the plasticity of the soil due to the greater volume of water which may be held. The strength of a clay soil also increases with the plasticity index (Yong and Warkentin, 1975). Van der Merwe (1964) classified soils into very high, high, medium and low degrees of potential expansiveness, based upon the relationship between the plasticity index and the percentage of the clay fraction. This is the soil activity (Mitchell, 1976).

Soil with rheological properties will exhibit a dynamic engineering behaviour if periodic drying and wetting of the soil occurs. This situation is common in the Transvaal owing to the seasonal rainfall supply and the presence of dry periods within the rainy season. Soils in humid climates where the rainfall supply is not seasonal in its distribution, will exhibit a constant behaviour unless an unusual dry period should occur. Soil in arid climates where the rainfall is so low that the soil is generally dry, will also exhibit a relatively constant soil engineering behaviour (Donaldson, 1966).

Soil profile information is obtained from soil pits or auger holes. Jennings et al (1973) describe those soil properties which should be noted for each soil horizon, viz. the soil moisture, the soil colour, the soil consistency, the soil structure, the soil type (soil texture, Table 7),

Table 7 - The Codes for the Soil Texture Types as Classified by Jennings et al (1973)

Texture class	Code
Sand	1
Silty sand	2
Clayey sand	3
Sandy silt	4
Sand-silt	5
Silt	6
Clayey silt	7
Sandy clay	8
Sand-clay	9
Silty clay	10
Silt-clay	11
Clay	12

and the soil origin. The depth of each horizon is also noted. This is called the MCCSSO code. Soil moisture and soil consistency are excluded from an expression of the soil failure hazard for reasons previously given. The soil colour is a diagnostic criterion of the soil type and is an aid in correlating the same soil horizon in different auger holes within the same area but it has no relation to the failure hazard. Soil structure is the presence and nature of joints in the soil. It is an indication of the soil's engineering behaviour. Slickensiding, shattering and micro-shattering indicate heaving conditions.

A soil failure hazard may be due to the presence of subsurface erosion, pseudokarst formations, expansive soils and collapsing soils (Brink, 1979). Collapsing soils are non-cohesive soils with kaolinite clay particles between the granular soil particles. These clay particles may be leached out of the soils, causing a high void ratio and a collapsible grain structure to develop. The application of an extra load will cause these soils to collapse, ie. compaction occurs. No further collapse will occur unless more kaolinite particles which may be leached out, are still present.

The soil profile generally consists of both residual and transported soils. Residual soil is the soil material formed <u>in situ</u> by weathering and with depth passes into the parent rock from which it was derived (Jennings et al, 1973). The stratigraphic unit (a succession of certain rock types) gives the origin of this soil and is indicative of the soil's engineering behaviour (Brink, 1979). Those units found in the Transvaal are given in Table 8. Transported soil is

Table 8 – The Stratigraphic Unit and Associated Rocks found in the Transvaal with their Codes

Stratigraphic Unit and Associated Rocks		Code	Stratigraphic Unit and Associated Rocks		Code
BASEMENT COMPLEX		1	VENTERSDORP SYSTEM		20
Granite gneiss	– semi-and warm	2	Sub-humid warm		21
	– sub-humid warm	3	Humid warm		22
	– humid warm	4	TRANSVAAL SYSTEM		23
Greenstones	– semi-and warm	5	Pretoria series	– shale	24
	– sub-humid warm	6		– quartzite	25
	– humid warm	7	Ongeluk larva	– sub-humid warm	26
WITWATERSRAND SYSTEM				– humid warm	27
UPPER DIVISION		8	Dolomite series	– dolomite/chert	28
Main – Bird	– shale	9	Block reef series	– shale	29
	– quartzite	10		– quartzite	30
Kimberley-Elsburg	– shale	11		– wad	31
	– quartzite	12	BUSHVELD COMPLEX		32
LOWER DIVISION		13	Intensive diabase		33
Jeppestown names	– shale	14	Granite		34
	– quartzite	15	Mafic rocks		35
Government reef series	– shale	16	WATERBERG SYSTEM		36
	– quartzite	17	Sandstone		37
			Shale		38
Hospital Hill series	– shale	18	LOSKOP SYSTEM		39
	– quartzite	19	Sandstone		40
			Shale		41

Note Either the unit or a particular rock within the unit may be recorded.

that soil material which has been transported by a natural agency (wind, water and gravity) during relatively recent geological times (Table 9). There is often a relationship between the landform and the soil's origin. The pebble marker, a characteristic of the South African profile, is a band of gravel forming a line of demarcation between the transported soil which overlies it and the country rock or residual soil which underlies it. Thus, the boundaries of these two main soil types may be easily identified.

Table 9 - The Transported Soil Origin types found in the Transvaal with their Code

Transported Soil Origin	*Code*
Aeolian	1
Alluvium	2
Biotic	3
Gully wash	4
Hillwash	5
Slide debris	6
Talus	7
Vlei	8

General statements as to the engineering behaviour and possible type of failure hazard of residual and transported soils may be made from their origin (Brink, 1979) in the absence of detailed soil profile information. However, it is essential that the exact nature and extent of the failure hazard and engineering behaviour by a detailed site survey be made before the construction of a proposed engineering structure.

The set of land characteristics expressing the soil failure hazard are the stratigraphic unit, the transported soil origin and the depth to the water table. For each soil horizon, the soil joint structure, the soil activity and the soil horizon type are used. The definitions are as follows:-

(a) Stratigraphic unit - a particular succession of rock types.

(b) Transported soil origin - the landscape position of soil which has been transported by a natural agent in recent geological times.

(c) Soil horizon type - the soil texture class as described by Jennings *et al* (1973) (see Table 7).

(d) Depth to the water table - defined in Section 3.4.7.

(e) Soil activity - the ratio of the plasticity index to the percentage clay fraction for a soil horizon.

(f) Soil structure - the presence of joints in a soil horizon.

3.4.9 Soil Fertility (The physical rooting conditions aeration and nutrient status of the soil)

Soil texture is an important influence upon the nutrient status of the soil as it determines the porosity and cation exchange capacity. The latter property is the amount of cations which can be released into the soil solution, from where the nutrients are absorbed by the plant roots. It depends on the amount of collodial clay and organic matter particles present in the soil since these adsorb cations onto their surfaces and are thus a source of nutrients. Russell (1973) defines the cation exchange capacity as the total amount of exchangeable cations the soil is actually holding as determined by leaching with a neutral solution such as IN KCl or 0,IN $BaCl_2$. These solutions are meant to replace the calcium, magnesium, aluminium and other exchangeable cations present.

Soils with a high porosity are generally of a low nutrient status owing both to their low cation exchange capacity and to the ease with which the nutrients may be leached out of the soil.

The total concentration of dissolved salts in the soil solution may be estimated by measuring the conductivity of an electrical current through this solution. The electrical conductivity depends upon the dissolved salt concentration and the temperature. The exact composition of the soil solution depends upon the moisture content of the soil, the rate of plant growth and the activity of the microbial population (Russell, 1973). These are all dynamic variables. An electrical conductivity measurement is of less importance to a land evaluation study than the presence of a deficient or toxic nutrient. Since the soil conductivity is a total measure, such a situation will not be indicated and, as its measurement is of a temporary nature, this land characteristic is excluded from the expression of this land quality.

The deficient and toxic levels of plant nutrients vary because different plants require different concentrations of plant nutrients, the presence of one nutrient at a particular concentration may affect the availability of another, the nutrient may be present in a chemical form which is not absorbed by the plant, the deficiency of a plant nutrient depends on whether it is a primary or secondary nutrient or a trace element, the availability of nutrients varies with pH eg. a low pH has a higher concentration of aluminium and manganese ions and a lower concentration of calcium, bicarbonate and molybate ions (Russell, 1973). This may result in toxic concentrations for the former group and deficient concentrations in the latter group. A measurement of soil nutrient deficiency or toxicity will be nutrient specific and plant specific as the tolerance level for different nutrients varies between plant species.

The organic matter present in the soil acts as a source of nutrients, enhances the cation exchange capacity of the soil and the moisture capacity (Young, 1976). It is relatively constant under undisturbed vegetation but not so under agriculture as the plant matter is removed and not returned to the ecosystem as litter. Young (1976) states that the agricultural significance of the organic matter is greater than any other factor with the exception of soil moisture. The reason for this is that a decline in the organic matter is accompanied by a deterioration of the soil structure (which leads to soil erosion) and by a decrease of soil fertility.

Soil pH depends upon the salt concentration of the soil solution and the carbon dioxide concentration of the soil air, both of which change (Russell, 1973). pH measurements thus vary within the soil profile, over an area of the same soil. pH is significant in its influence upon the solubility of plant nutrients and it is mainly through this effect that plants are sensitive to pH. pH measurements are only included in an expression of this land quality as an indication of the possible availability of the plant nutrients.

Soil salinization is of particular importance to irrigation systems and may arise from:-

(a) A rise in the ground water table level particularly if the water is saline. The water table rises with each water application until, with time, the root zone is reached where evaporation and transpiration causes the precipitation of the salts.

(b) The application of saline water. Water with an electrical conductivity of $<$100m mS m^{-1} (the optimum value is $<$25m mS m^{-1}) only, should be applied (MacVicar, 1978, personal communication). The ionic composition of the irrigation water is also important, particularly:-

(i) Sodium, which may be directly toxic to the plants and/or cause calcium deficiency since it causes the precipitation of this ion in an unavailable nutrient form for root uptake. Sodium also causes poor soil aeration, poor soil water transmission and soil compaction (Young, 1976). The sodium absorption ratio (SAR) is:-

$$SAR = \frac{Na^{+}}{\sqrt{\dfrac{Ca^{2+} + Mg^{2+}}{2}}} \quad \text{where the concentrations are in me } l^{-1}$$

For irrigation water, this should be <10 with a maximum of twenty (MacVicar, 1978, personal communication).

(ii) The bicarbonate anion aids in the precipitation of calcium by sodium, indirectly increasing the calcium deficiency and the sodium toxicity. This concentration in the irrigation water should be <1,25 me l^{-1} with a maximum of 2,5 me l^{-1} (Young, 1976).

(iii) Boron is toxic at concentrations exceeding 250ppm and it is difficult to leach out of the soil (Young, 1976). The concentration of the irrigation water should be <2ppm.

(c) The irrigation of saline soils. The initial downward flow of water is followed by an upward movement as the water is utilized, causing the salts to be brought to the surface where they precipitate out. Crops may be initially cultivated on saline soils but with time, the salt concentration reaches toxicity levels and the land is rendered non-arable. Soils with an electrical conductivity of <1 000m mS m^{-1} (the optimum value is <200m mS m^{-1}) only should be irrigated (MacVicar, 1978, personal communication).

The physical characteristics of the soil, viz. the rooting depth, the soil structure and the soil consistency, define the soil zone available to the plant (Young, 1976). The soil structure is easily destroyed by poor management while the soil consistency varies with the soil moisture content. Thus both these land characteristics are excluded from the expression of this land quality. The rooting depth is delimited by the depth to the consolidated soil material, ie. the C horizon or its equivalent. A soil which is too shallow (<25cm, Ivy, 1977) will not provide sufficient anchorage for most crop plants and will have low nutrient capacity.

Litter is an important nutrient source (Young, 1976). Humus accumulates in the top soil and thus the measured values of soil cation exchange capacity, soil pH and soil organic matter become less with depth.

The set of land characteristics expressing the soil fertility will be the pH, cation exchange capacity, organic matter and salinity of the soil, the sodium absorption ratio of the irrigation water, soil deficiency and soil toxicity, and the texture of the topsoil and subsoil.

The definitions are as follows:-

(a) Subsoil texture - defined in Section 3.4.7.

(b) Topsoil texture - defined in Section 3.4.7.

(c) Rooting depth - the distance from the ground surface to consolidated material or the water table should this be above the former.

(d) Soil deficiency - the presence within the topsoil of a plant nutrient at an insufficient concentration to support plant growth.

(e) Soil toxicity - the presence within the topsoil of a chemical or plant nutrient at a concentration toxic to plant growth.

(f) Soil salinity - the electrical conductivity of the topsoil.

(g) Soil pH - the hydrogen ion concentration in the topsoil.

(h) Sodium absorption ratio - $Na^+/(Ca^{2+} + Mg^{2+}/2)$

(i) Soil cation exchange capacity - the total amount of exchangeable cations within the topsoil determined by leaching with either IN KCl or 0,1N $BaCl_2$.

(j) Soil organic matter - the organic matter in the topsoil.

3.4.10 Growth Climate (The climatic conditions present to support productive plant growth)

The Transvaal is characterised by a dry winter season and a wet summer season with dry periods. The rainy season is defined by the South African Weather Bureau (S.A.W.B. Part 10, 1972) as being those months during which more than 8,3 per cent of the annual rainfall occurs. This period extends from October to April inclusive.

Two important rainfall parameters are:-

(a) The total annual rainfall.

(b) The rainfall distribution. The rainy season is divided into certain time periods viz. months, weeks, pentades, and the total rainfall for each period is recorded. A pentade is described as being rainy if it is the centre one of three pentades which together total more than 38mm of rain with only one of these three with less than 7,5mm of rain being permissible (Robertson, 1972). Doubt as to the usefulness of this definition has been expressed (Ivy, 1979 personal communication).

The water budget of the land is more important to land evaluation studies than the actual quantity of rainfall received. The water budget is the balance between the moisture supply and the moisture loss from utilization and evaporation (Mather, 1978). A climagram, based on yearly records of the mean monthly precipitation and evaporation of the land, shows the periods of moisture surplus, soil moisture usage and moisture deficit which occurs when the potential evapotranspiration exceeds the precipitation.

The energy supply for soil water evaporation is in three forms, viz. solar radiation, the heat exchange between the air and the water (Miller, 1977). This energy supply is extremely variable, depending upon the season of the year, the length of the day, the position of the sun, the heat capacities of the soil and the air, the intensity of the radiation received, etc. The most accepted method for the measurement of total evaporation is that of the Class 'A' evaporation pan. This measures the evaporation from a water surface resulting from the solar radiation received. It is thus an inaccurate measurement of the evaporation from the soil surface as it does not consider the other forms of energy supply. Also a soil surface differs in wetness, roughness and exposure from that of a water surface.

The evaporation measurements vary vertically due to the interception of the solar radiation by the vegetation and the distance from the heat energy of the soil is also different. The standard position for a Class 'A' pan is at ground level at a site representative of the land as a whole (Meterlerkamp, 1975).

A further complication to the measurement of the soil moisture loss, is that lost by the physical process of transpiration which is species specific. As yet, no direct measurement of evapotranspiration is known, although attempts have been made to determine its potential eg. Thornwaite (1948) and Miller (1977) describe the attempts of Penman, Mather and others. Each of these methods determine a different value, indicating an incomplete knowledge of the measurement of this process. The most widely used method in the Transvaal is that of Thornwaite. Yet, he has expressed the need to modify his equation owing to its dependence upon the air temperature (Miller, 1977). Possibly, the inclusion of the other energy sources are required.

Although Class 'A' evaporation pan measurements for total evaporation are inaccurate, the errors introduced into the land evaluation analysis by the exclusion of evaporation are likely to be greater than those due to the inclusion of this inaccurate measurement. Maps compiled by the Department of Water Affairs (Midgley and Pitman, 1969) show isometric lines of gross annual evaporation from a Symons pan (1,8 m^2, sunk 0,6m into the ground). Such gross figures will only be indicative of the evaporation situation.

A land use causing a change in the vegetation will change the water deficit of the land due to the interrelationship of the soil moisture utilization and the vegetation. The change in the water deficit will be important to the land evaluation for that land use. However, such a change is not measurable until the land use has been implemented. The Class 'A' evaporation measurements do not consider vegetation, thus any change in it will not influence the measurement. For this reason, the latter is preferred as a land characteristic to that of the water deficit period. The duration of this period is important as the effect of a water deficit becomes more marked with time.

The quality of the rainy season is the number of rainy pentades occurring throughout its duration. The probability of a dry period coinciding with a moisture sensitive life cycle stage of a plant is increased if this figure is low. The severity of this period is a function of the amount of rain received before its onset, the temperature during this period, the water holding capacity of the soil, the particular life stage of the plant, etc. It is not an accurate measurement of the season quality as it neglects the incidence of the dry periods with the moisture sensitive stages of the plants which stages are species specific. If the onset of each stage is known (which information is generally only available for crops), the number of rainy pentades present throughout these stages may be measured. This value would only be applicable in a land evaluation analysis for that particular species or crop-type. The season quality as defined previously will be the most common form measured.

The length of the summer growing season depends on the reliability of the rainfall supply. From a study of the 'Annual March of Rainfall' for the Transvaal (S.A.W.B. Part 10, 1972), the period with above ten per cent of the total rainfall per annum was chosen as representing a rainfall reliable period within the rainy season. The number of days over which this period extends, is recorded as the season length. The quality and length of the fruiting season are of importance to fruit producing crops. This period should also be frost-free to prevent frost damage to the fruit. The fruiting season is thus the number of days during which no frost occurs.

Thunder storms are potential hail storms, causing damage to vegetation, vehicles, buildings, etc. The probable number of hail storms may be determined from past weather records. The mean maximum number of days with hail per rainy season is measured.

Temperature measurements are an indication of the degree of hotness experienced and not of the actual heat energy received. Both temperature and heat energy measurements vary inversely with the degree of cloud cover. The South African Weather Bureau (S.A.W.B. Part 8, 1965) describes three day types:-

(a) Hot days - maximum temperature exceeds 35°C.

(b) Warm days - maximum temperature exceeds 30°C and includes (a).

(c) Cold days - maximum temperature is below 10°C.

Extreme temperatures indicate limitations to land use more than do mean temperatures. These are the mean daily maximum temperature of the hottest month ie. January, and of the coldest month ie. July, and the minimum temperature which is given by the frost temperature. Hoar frost is common in the Transvaal during the winter months, particularly from mid-May to mid-September. Light frost occurs at temperatures of 2,5°C to 0°C even if no frost is visible, moderate frost occurs at temperatures of 0°C to 2,5°C and heavy frost at temperatures below -2,5°C (S.A.W.B. Part 8, 1965). The mean annual lowest frost temperature is measured. Temperature is influenced by altitude, latitude, the aspect of the slope (temperatures are less on South facing slopes than on North facing slopes at the same altitude and latitude) and the sun's position with regard to the tropics. Quantified information as to the exact effect of altitude and latitude upon the temperature was not found.

Wind causes damage to the vegetation, buildings, etc. and is an agent for soil erosion. According to the Beaufort scale (Brunt, 1942), a fresh breeze causes small trees to sway while a strong wind (velocity of 11,25 m s^{-1}) causes large branches to move. This velocity will be taken to be the threshold wind velocity below which wind damage is negligible.

The set of land characteristics expressing the growth climate are the daily maximum January and July temperatures, the frost temperature, the hail occurrence, the total rainfall, the evaporation, the water deficit period, the season length, the season quality, the wind velocity, the fruiting season length and the aspect of a slope. The definitions are:-

(a) Aspect of a slope - the direction in which a slope faces.

(b) Evaporation - the mean annual evaporation from a Class 'A' evaporation pan.

(c) Frost temperature - the mean annual lowest frost temperature.

(d) January temperature - the mean daily maximum January temperature.

(e) July temperature - the mean daily maximum July temperature.

(f) Hail occurrence - the mean annual maximum number of days with hail.

(g) Fruiting season length - the mean annual length of the frost-free period.

(h) Season length - the mean time period during which above ten per cent of the annual rainfall is received.

(i) Season quality - the number of rainy pentades within the season length.

(j) Water deficit period - the mean time period during which the evaporation exceeds the precipitation.

(k) Wind velocity - defined in Section 3.4.6.

(l) Rainfall total - the mean annual precipitation.

3.4.11 Comfortable Climate

Recreation is enhanced by a climate which is comfortable. The sensation of comfort experienced by a person depends upon his cultural background, the activity which he is performing and his previous experience. Thus, the objective measurement of this land quality is extremely difficult and since man is able to counteract this land quality, it is excluded from the land capability procedure.

3.4.12 Water Catchment (The potential run-off of precipitation from the land)

All land may be regarded as having a water catchment quality in that the run-off may feed some river, stream, reservoir or subterranean water supply. The hydrological cycle for a catchment area may be represented by

$P = E_t + Q + S$ where P = precipitation
E_t = evapotranspiration
Q = streamflow
S = storage

(Kruger and Wicht, 1976).

The precipitation is lost by evaporation from the open water surfaces, the soil surface, the intercepted water on the plant surfaces and by transpiration. Water reaching the soil surface will either become surface flow or it will infiltrate into the soil where it may percolate to t e stream channels or to the ground water supply. The term Q corresponds to the water remaining after evapotranspiration and percolation to the ground water supply.

Vegetation cover has the greatest influence upon the streamflow owing to transpiration and interception. Wicht and Kruger,(1976)state that, in humid catchments the mean annual streamflow is inversely proportional to the plant biomass, all other factors being equal. An area with light vegetation will have greater water yields but the amount of silt present in the discharge is greater, ie. the water quality is less. This will increase the siltation of the rivers, reservoirs, etc. Since this measurement is of a temporary nature (Section 3.4.13) the vegetation type (a) will be used.

The availability of the water resource is a function of the precipitation, the runoff (which is influenced by the rainfall (Section 3.4.6) and the soil drainage (Section 3.4.7), and the storage provided which is a function of the economic situation and the efficiency of its management (Midgley, 1971).

A general characterization of the catchment areas for the whole of the Republic of South Africa has been given by Midgley and Pitman (1969). Eleven zones of similar rainfall runoff relationship were listed using the mean annual run-off (MAR) and mean annual precipitation (MAP) data from measured catchment areas. Equations were derived to represent this relationship assuming that the MAR increased non-linearly with the MAP until the losses due to evaporation had been compensated for. After this, the relationship became linear. These equations were used to determine the MAR for particular MAP values within each zone which were delineated on a map of the country using geological, soil, relief and vegetation (Acocks , 1975) information. The catchment characteristics, viz. the runoff zone, MAP, MAR, area for all the sub-catchment areas within each zone, are given.

For land within each sub-catchment, the runoff total may be measured directly or estimated from the rainfall energy which depends on the rainfall total (Section 3.4.6), the vegetation cover and the soil drainage as described by the soil permeability index or the soil texture.

The set of land characteristics expressing water catchment are the runoff total, the rainfall energy, floristic and physiognomic vegetation type; the soil permeability index, and the topsoil and subsoil textures. The definitions are:-

(a) Rainfall energy - defined in Section 3.4.6.

(b) Runoff total - the mean annual surface runoff.

(c) Soil permeability index - defined in Section 3.4.7.

(d) Subsoil texture - defined in Section 3.4.7.

(e) Topsoil texture - defined in Section 3.4.7.

(f) Floristic vegetation type - defined in Section 3.4.13.

(g) Physiognomic vegetation type - defined in Section 3.4.13.

3.4.13 Flora

The natural vegetation is a community of plant species adapted to the ecological conditions under which they have developed. Human intervention in any ecosystem generally results first in the degradation of the vegetation as seen by a loss of cover and change in the species' composition. The former leads to soil erosion while the latter causes a change in the vegetation community present and often to the aesthetic appeal of the land. The importance of the natural vegetation as a resource has been realised and it is becoming increasingly apparent that environmental impact studies should be a pre-requisite for any large-scale development.

Vegetation is measured quantitatively eg. density, frequency, percentage cover or qualitatively eg. Acocks' (1975) floristic classification and Greenway's (1973) physiognomic classification, (Table 10). Both classifications should only be included in an evaluation if different aspects of the vegetation are to be considered eg. the former may be used to indicate the presence of wildlife habitats and the latter the woody canopy cover.

The conservation value of the vegetation generally depends upon the observer and it is thus a subjective measurement. However, rare, endangered or threatened species are shortlisted in Ordinance Number 17 (1967) of the Transvaal (Ordinance Number 17, 1967). These are protected by law and thus their presence will be an objective measurement of the conservation value of the vegetation. In terms of Ordinance Number 17 (1967) a protected species may be destroyed if required by the land use. Specially protected species, eg. Genus Encephalartos, endangered species, eg. certain aloe species and rare species, eg. members of the Orchidaceae and Cyatheaceae (tree form) may not be destroyed and may only be moved by the local authorities. This latter group is considered as being protected vegetation for this procedure.

Table 10 - The Symbols and Codes for the Physiognomic Vegetation Types Classified by Greenway (1973)

	Vegetation Type	*Symbol*	*Code*		*Vegetation Type*	*Symbol*	*Code*
I	FORESTS (M)	F	1	V	PERMANENT SWAMP VEGETATION (M)	M	26
	Lowland Rain Forests	Fl	2		Grass Swamps	Mg	27
	Upland Rain Forests	Fu	3		Reed (Papyrus) Swamps	Mr	28
	Lowland Dry Evergreen Forests	Fe	4		Rush Swamps	Mt	29
	Upland Dry Evergreen Forests	Fd	5		Fern Swamps	Mf	30
	Deciduous Forests	Fa	6	VI	BUSHLAND, THICKETS AND SCRUB (M)	B	31
	Ground water Forests				Upland Evergreen Bushlands	Bu	32
	Rivenne Forests (ST)	Fr	7		Upland Moor (ST)	Bo	33
	Swamp Forests (ST)				Succulent Evergreen Bushlands	Bs	34
	Freshwater Swamp Forests (ST)	Ff	8		Euphorbia Bushland [illegible] Thickets (ST)	Bse	35
	Saline water Swamp Forests (ST)	Fs	9		Salt Bush (ST)	Bss	36
II	WOODLANDS (M)		10		Semi-evergreen Bus[illegible]	Be	37
	Evergreen, Semi-evergreen Woodlands	We	11		Deciduous Bushlan[illegible]	Bd	38
	Deciduous Woodland				Tall Deciduous T[illegible] (ST)	Bdt	39
	Compound leaved, strongly dominant	Wb	12		Dry Scrub with trees	Bds	40
	Mixed, mainly compound leaved dominant	Wbc	13		Grass Thickets	Bg	41
	Mixed, mainly simple leaved dominant	Wbc	14		Bamboo Thickets (ST)		
	Simple leaved, strongly dominant	Wc	15		*Moist Bamboo (ST)*	Bgm	42
III	WOODED GRASSLANDS (M)	S	16		Dry Bamboo (ST)	Bgd	43
	Grouped Tree Grasslands	Sg	17		Giant Grass Thickets (ST)		
	Scattered Tree Grasslands	Ss	18		Elephant or Napier Grass Thickets(ST)	Bge	44
	Palm Stands Grasslands	Sp	19		Giant Thatching Grass Thickets (ST)	Bgt	45
	Shrub or Dwarf Tree Grasslands	Sd	20	VII	SEMI-DESERT VEGETATION (M)	D	46
IV	GRASSLANDS (M)	G	21		Semi-desert Scrub	Ds	47
	Flood plain, Pan or Valley Grasslands	Gf	22		*Semi-desert Grassland*	Dt	48
	Seasonal Swamp Grasslands	Gs	23		CULTIVATION	C	49
	Upland Grasslands	Gu	24				
	Moorland Grasslands (ST)	Gm	25				

Key (ST) Subtype
(M) Main type

The quantity and distribution of the vegetation cover, particularly that of the woody cover which is the more permanent component of the vegetation, is important for certain land uses. The distribution of the woody cover (woody distribution land characteristic) will be recorded in the same manner as that for the rocky distribution land characteristic discussed under the land quality of the land surface (Section 3.4.1).

Vegetation provides habitats for fauna of all kinds including disease vectors and can itself act as a host for pathogens eg. rust species. The presence of disease is economically important to agriculture but its measurement is impractical as the possible host species are almost infinite. Vegetation with poisonous species should not be grazed.

The set of land characteristics expressing the flora are the physiognomic vegetation type, the floristic vegetation type, the woody cover, the woody distribution and the protected plant species. The definitions are:-

(a) Physiognomic vegetation type - the vegetation type or sub-type, as classified by Greenway (1973) Table 10.

(b) Floristic vegetation type - the vegetation type as classified by Acocks (1975).

(c) Woody cover - the land surface covered by a woody canopy.

(d) Woody distribution - the distribution of the woody cover.

(e) Protected plant species - a higher plant species listed as specially protected, rare or endangered, in the Transvaal Ordinance Number 17 (1967).

3.4.14 Fauna

Three groups of fauna which are important to land use are:-

(a) Game fauna

(b) Conserved fauna ie. protected by legislation

(c) Host fauna ie. fauna which are host species for a pathogen.

Ordinance Number 17 (1967), of the Transvaal shortlists those species which are protected game, ordinary game, wild animals, problem animals, exotic animals, rare and endangered fauna. The latter two groups may not be hunted while wild and exotic animals may only be hunted for special reasons, eg. damage to property. Protected game may only be hunted for educational, scientific or conservation purposes. A game species land characteristic will record the presence of species which may be hunted, ranched or viewed for recreational purposes. A protected animal species land characteristic (where animal refers to reptiles, mammals, birds and fish) will record the presence of a species which is listed in Ordinance Number 17 as being a wild, exotic, rare or endangered species. An animal host land characteristic records the species which is host for a disease-causing organism, eg. Trypanosomiasis and the tsetse fly, Glossina species. The presence of such fauna is important to human and livestock health and to the growth of crops.

The set of land characteristics used to express the fauna are the game species, the protected animal species and the animal host species. They are defined as follows:-

(a) Game species - a higher animal species listed as ordinary game in the Transvaal Ordinance Number 17 (1967).

(b) Animal host species - a higher animal species acting as a host for a pathogen.

(c) Protected animal species - a higher animal species not listed as pests or ordinary game in the Transvaal Ordinance Number 17 (1967).

3.4.15 Man-made Structures and Boundaries

Man-made structures and boundaries are not fundamental features of a land resource and thus, they are not components of a land quality expression. However, their presence may not be neglected and their measurement as land characteristics is still in accordance with their definition. These land characteristics may be grouped as follows:-

(a) Man-made structures - eg. townships, roads, railways and powerlines. The last three structures dissect the land into units which may be of an uneconomic or non-usable size. They also obstruct the accessibility of and the manouverability over the land. Paved and unpaved roads are recorded as separate land characteristics as they carry different traffic densities, require different maintenance and represent different degrees of permanency.

The area covered by a township or industrial area is unavailable for other land uses due to the high costs required to revert the land. Although a dam is a man-made structure, it is not considered here as the reservoir behind it is a land resource and is dealt with as an expression of the quality of the land surface.

(b) Declared areas

(i) Mountain catchment areas - These areas are usually situated in the higher rainfall regions of South Africa and supply forty-seven per cent of the country's total water yield (Van Rensburg, 1979, personal communication). The importance of these areas to the national water resources is obvious and, in 1970, the Mountain Catchment Areas Act was passed. This stipulates that the management, use, conservation and control of land in any such defined areas are to be directed at the conservation of the water source so as to secure a sustained flow of silt-free water. This involves the prevention of soil erosion, the protection and treatment of the natural vegetation and the eradication of alien vegetation (Ackerman, 1976).

The major criterion for declaring these areas is the importance of the streams and rivers arising on them in meeting the present and future water needs of the country. Studies of most mountain areas have been initiated and several of these have been declared as Mountain Catchment Areas (Table 11). Other areas are due to be declared (Van Rensberg, 1979, personal communication).

State-owned Forest land in mountain catchment areas are not officially declared as such since they are already being managed as though they were. For the purposes of this procedure, all mountain catchment areas in State-owned Forest land whi are not forests are presumed to have been officially declared so. The land characteristic of the

Table 11 - Declared Mountain Catchment Areas on Private Land in 1979 (Department of Forestry Annual Reports (1971-1979)

Name of area	Province	Area ha.
Sterkspruit	Eastern Transvaal	10 120
Sederberg	Western Cape	58 362
Groot Swartberg	Southern Cape	9 508
Klein Swartberg	Southern Cape	32 064
Swartberg-oos	Southern Cape	10 097
Anysberg	Southern Cape	6 096
Kammanassie	Southern Cape	24 306
Rooiberg	Southern Cape	12 581

mountain catchment area is used to measure these areas which are published in the Department of Forestry Annual Reports.

(ii) Conservation areas - The fauna and flora of South Africa is protected by legislation which includes the establishment of Nature Reserves. The management of these areas is directed towards the conservation of the fauna and flors and they may be National, Provincial, Municipal or Private Reserves. Each is measured as a separate land characteristic and may be obtained from the Conservation Status and priority map of the Transvaal (Wild Life Society of South Africa, 1976).

In 1971, the Forest Act of 1968 was amended to provide for the declaration of Wilderness areas to preserve forests, plant communities and natural scenery. These areas are protected against encroachment by roads, railways and powerlines which protection does not apply to Nature reserves. The primary aim for setting aside such areas is that they should remain virtually unaltered by modern progress and unscarred by technical civilization (Ackerman, 1976). Thus, the activities allowed within them are more limited than those in a Nature Reserve. They are unavailable for other land uses unless the declaration is revised.

The set of land characteristics selected to measure those features which are not natural resources are township, settlement, industrial area, railway, paved road, unpaved road, powerline, Mountain Catchment Area, Park, Provincial Park, Municipal Park, Private Park and Wilderness Area. The definitions are:-

Industrial Area) Settlement) Township)	The land surface covered by an industrial area, a significantly sized group of buildings or the non-industrial area of a town, city or village, respectively.
Powerline) Railway) Paved road) Unpaved road)	The presence of paved roads, high voltage transmission lines, railways and unpaved roads with drains, respectively
National Park) Provincial Park) Municipal Park) Private Park) Mountain Catchment Area)	Land declared as such under the Mountain Catchment Act of 1970 or land surface covered by a Nature Reserve managed by Municipal, National, Private or Provincial authorities respectively.
Wilderness Area -	land declared as such under the amended Forest Act 1971.

Table 12 - The Land Characteristics Expressing each Land Quality and Man-made Structure or Boundary

Code	Land Characteristic	LAND QUALITY													
		Land surface	Accessibility	Durability	Flooding hazard	Slope stability	Erodibility	Soil drainage	Soil failure hazard	Soil fertility	Growth climate	Water catchment	Flora	Fauna	Man-made structures and boundaries
	LAND COVER														
1	Rock surface	*													
2	Boulder cover	*													
3	Gravel cover	*													
4	Rocky distribution	*													
5	Lake	*													
6	Reservoir	*													
7	Vlei	*													
8	River	*													
9	Stream	*													
	RELIEF														
10	Hillslope element		*			*	*	*							
11	Slope gradient		*			*	*	*							
12	Slope length		*				*								
13	Aspect of a slope										*				
14	Height above water				*										
15	Koppie	*													
16	Natural land feature	*													
17	Gully	*													
	GEOLOGY														
18	Stratigraphic Unit								*						
19	Transported soil origin								*						
20	Natural rock group			*											
21	Mineral ore deposit*														
22	Depth to mineral ore		*												
23	Depth o bedrock		*					*							
24	Geological discontinuities					*									
25	Factor of safety					*									

Code	Land Characteristic	LAND QUALITY													
		Land surface	Accessibility	Durability	Flooding hazard	Slope stability	Erodibility	Soil drainage	Soil failure hazard	Soil fertility	Growth climate	Water catchment	Flora	Fauna	Man-made structures and boundaries
	GEOLOGY (contd.)														
26	Rock hardness			*											
27	Secondary minerals			*											
28	Ten per cent fines			*											
	SOIL														
29	Subsoil texture					*		*		*		*			
30	Topsoil texture					*		*		*		*			
31	Soil horizon type							*	*						
32	Soil erodibility type						*								
33	Soil permeability index							*				*			
34	Rooting depth									*					
35	Depth to water table							*	*						
36	Exposed soil length						*								
37	Soil joint structure								*						
38	Soil activity								*						
39	Soil deficiency									*					
40	Soil toxicity									*					
41	Soil salinity									*					
42	Soil pH									*					
43	Sodium absorption ratio									*					
44	Soil cation exchange capacity									*					
45	Soil organic matter									*					
	CLIMATE														
46	Climatic N-factor			*											
47	Wind velocity						*				*				
48	Frost temperature										*				
49	January temperature										*				
50	July temperature										*				
51	Hail occurrence										*				
52	Fruiting season length										*				
53	Season length										*				
54	Season quality										*				

Code	Land Characteristic	LAND QUALITY													
		Land surface	Accessibility	Durability	Flooding hazard	Slope stability	Erodibility	Soil drainage	Soil failure hazard	Soil fertility	Growth climate	Water catchment	Flora	Fauna	Man-made structures and boundaries
	<u>CLIMATE</u> (contd.)														
55	Water deficit period										*				
56	Evaporation										*				
57	Rainfall total										*				
58	Rainfall energy						*	*				*			
59	Runoff total											*			
	<u>BIOLOGICAL CHARACTERISTICS</u>														
60	Physiognomic vegetation type											*	*		
61	Floristic vegetation type											*	*		
62	Woody cover											*	*		
63	Woody distribution												*		
64	Game species													*	
65	Protected plant species												*		
66	Animal host species													*	
67	Protected animal species													*	
	<u>MAN-MADE STRUCTURES AND BOUNDARIES</u>														
68	Township														*
69	Industrial area														*
70	Settlement														*
71	Powerline														*
72	Railway														*
73	Paved road														*
74	National Park														*
75	Provincial Park														*
76	Municipal Park														*
77	Private Park														*
78	Mountain catchment area											*			*
79	Wilderness area														*
80	Unpaved road														*

<u>Note</u>.

* Mineral ore deposit does not express any of the land qualities described in this study.

3.5 The Evaluation of the Land for its Capability to Support a Given Land Use

The land conditions required by a land use define the limits within which it may be implemented. The comparison of these conditions with the present conditions will classify the land into two types:-

(a) Land which cannot support the land use as it is defined.

(b) Land which can support the land use, the degree of this support being dependent upon its present condition compared with the optimal condition required for that use.

Management techniques are available to overcome certain land limitations. The use of such techniques is equivalent to changing the land use and will often involve more expense. This would be assessed in the economic stages of the land use plan.

3.5.1 The Creation of a Land Data Set Consisting of the Measured Land Characteristic Values which may be Evaluated

The land characteristic measures the land qualities which express the land conditions. Land surveys measuring the land at a selected scale generally present the results in a mapped form to retain the spatial distribution of the measured values. These maps can be stored as a data set in a computer by subdividing the information into:-

(a) Geographic reference.

(b) Data string composed of a number of data items eg. the data items for a protected animal species land characteristic is its name and numerical code for that name. The storage of its name means that information concerning the presence and the type of such an animal species is available. Section 4.3 describes the data storage in more detail.

The procedure creates a data set of grid cells by overlaying a grid of selected cell size upon each survey map. A grid cell has a geographic reference based on the georeference of the survey maps, and a data string. The data items are the measured values of the land characteristic which have been selected from the data string of the mapped data set. The particular data item selected from this data string corresponds to two objectives of this study, viz. the data evaluated should be objectively measured and be independent of time. The presence of other data items which are important to the resource inventory does not affect the creation of the gridded data set. Thus the survey maps have been combined into one data set and the number of data items in each string is a function of the number of survey maps overlaid. Section 4.4.1.2 describes the creation of this gridded data set in more detail.

3.5.1 .1 The Inclusion of Soil Horizon Measurements in the Land Data Set to be Evaluated

The number of soil texture measurements possible is a function of the number of soil horizons present in the soil profile. The particular soil texture land characteristic measured may be the soil horizon type recorded by engineers and used in the Urban and Rural Development and the Communication Land Use Systems, or the subsoil and topsoil texture land characteristics. Engineers also record the soil joint structure and the soil activity of each horizon. The number of soil horizons permitted is deliberately not stated so as to maintain the flexibility of the procedure without wasting computer storage by stating a greater number than is necessary. The number of soil horizons is included by considering each land characteristic measured for a soil horizon as a new land characteristic eg. soil joint structure, soil activity and soil horizon type will be three new land characteristics for each horizon measured. If n horizons are measured, three times n new land characteristics are added. The code numbers could be 129, 130, 131; 229, 230, 231; ..... n29, n30, n31, corresponding with the relevant code numbers given (See Table 12). Each new land characteristic would be evaluated separately and thus the pertinent information in the control data sets (see Section 4.4.2) would be repeated n times.

3.5.2 The Land Characteristics Selected from the Created Land Data Set to be Evaluated for a Land Use

The set of land characteristics chosen to evaluate the capability of land for a land use, depends on the land use definition. This can range from a general to a very specific definition ie. from that for a land use system to a land use. The latter will be more sensitive to differences and similarities in the land than the former which covers a range of land uses and thus its analysis must be of a more general nature.

The capability analysis is not influenced by the present land use unless that use has degraded, removed or ties up a land resource necessary for the land use being evaluated eg. a township or reservoir influences any agricultural land use as the land covered by these features is non-arable. But a nature reserve is still an arable surface and thus the presence of such does not influence the agricultural use of the land ie. this particular status of the land is disregarded. This reserve is important to conservation and recreation land uses and to the analysis of the foreclosure in option for land use (See section 3.5.3).

In sections 3.5.2.4 - 3.5.2.10 some major land use types are defined for each land use system included in this study. The set of land characteristics needed to analyse the land for its capability to support these land use types are listed in Tables 13, 16, 18 to 23 (each is placed after the land use system to which it refers) and will be selected from the gridded land data set by the analysis programme each time a land use type is studied. There is no hierarchy between the land use types, all are considered to have equal status so that any types may be combined together to give a new land use type which incorporates all features of the individual ones combined (See Section 4.5(c)). In this manner, land use types which have not been specifically defined in this study may still be evaluated. It is also possible to add other land use types, land use systems and land characteristics to the procedure (See Section 4.6). No land uses are defined because of the specific nature of their definition. However, most land uses have been included in the broader definition of the land use type. A change in the permissible values (Sectic[illegible].2) to apply specifically to a land use will [illegible] that land use alone is analysed and not the land u[illegible].

The influence of a land characteristic upon the final capability of the land is a function of the number of land characteristics evaluated. The greater the number, the less is the influence of all the characteristics. The effect of a major land characteristic is lowered by including too many minor land characteristics. This is overcome by weighting the land characteristics according to their influence upon a land use (See Section 3.5.7) and only the major characteristics are listed in Tables 13, 16, and 18-24).

3.5.2 .1 <u>The Selection of Land Characteristics which appear to Measure the Same Land Feature</u>

A cursory study of Tables 13, 16, and 18-24 will seem to indicate that a land feature is being evaluated more than once where two or more land characteristics, all measuring the same feature, have been selected. However, an effect of a land feature upon the land use is not evaluated more than once and these land characteristics have been included for the following reasons:-

(a) All possible land characteristics measuring a land feature are tested as different users may measure different possibilities eg. water deficit period and the interrelationship of evaporation and rainfall total. The evaluation of all possibilities will be similar to giving the land feature a high weighting value (See Section 3.5.7). Thus only one possibility is evaluated by including only one in the gridded data set or the control data set (See Section 4.4.2).

(b) The land characteristics measure the land feature at different survey scales (See Section 3.4, Table 3) eg. hillslope element and slope gradient and length.

(c) Different aspects of a land feature are being evaluated eg. the physiognomic vegetation type is used to reflect the possible woody cover present in the absence of a woody cover measurement, the general climatic conditions prevalent and the cultivated land present while the floristic vegetation type may be used to indicate wildlife habitats. These aspects are considered when the capability ratings of each vegetation type is awarded (See Section 3.5.6).

3.5.2 .2 The Optimum and Permissible Values of the Land Characteristics Evaluated for a Land Use

The capability of each land characteristic to support a land use is confined within certain limits outside of which the condition of the land with respect to that characteristic will not support the l[illegible]e. The maximum capability for each characteristic [illegible] optimum value within these limits. Tables 13, 16, and 18-23 list the optimum and permissible values for each land characteristic selected to evaluate a major land use type within a land use system and Table 24 r[illegible]ers to the land characteristics used in the analysis of t[illegible] foreclosure of options in land use. These values are the result of a literature survey and discussions with various people (Appendix A). The tables are stored as part of the control data set (S[illegible]ction 4.2.2). It is impossible to give values applicable t[illegible] every situation for all the land characteristics and a user m[illegible] wish to change certain values as described later in S[illegible]tion 4.6.2. The values already stored are not destroyed so that a subsequent user is not affected by any chan[illegible]s a previous user may have made. For certain land characteristics, to attempt to give an optimum or limiting value independent of the present situation on the area of land represented by a grid cell is invalid, eg. the number of railways permitted within a cell depends on the cell size, the land use, etc.

In such cases the permitted range of values is gi en by the user and are indicated in the tables by X_O (optimum value) and X_L (limiting value). A default value ie. a value chosen by the computer program in the absence of one given by the user, is given so that the execution of the program will not cease as a result of missing information. The 'n' in the Tables indicates that the specification of a value is not applicable for that land use type. If both the optimum and limiting values are represented by a dash, the land characteristic is not a member of the set of characteristics required to evaluate the land capability for that land use type.

3.5.2 .3 <u>Usable and Non-usable Surface Areas and Inhibiting and Non-inhibiting Networks with Respect to a Land Use</u>

The land characteristics measuring a surface area eg. woody cover, National Park, are grouped into one of two types:-

(a) <u>Usable surface area</u> - is land covered by a land feature eg. woody cover or a man-made structure, or demarcated by a man-made boundary eg. Mountain Catchment Area. These areas are necessary for the implementation of the land use being studied.

(b) <u>Non-usable surface area</u> - is land covered by a land feature or a man-made structure or demarcated by a man-made boundary and it cannot be utilized by the land use being analysed.

The land characteristics measuring a network are also grouped into one of two groups:-

(a) <u>Inhibiting networks</u> - are permitted on the land below a certain limit but their presence is a hindrance to the utilization of the land with respect to the land use being studied.

(b) Non-inhibiting networks - do not hinder the utilization of the land when they are present in amounts below the permitted limit.

The grouping of these land characteristics means that the time required to analyse a study area is decreased.

3.5.2 .4 Agricultural Land Use System

Agricultural land uses may be defined in terms of the plants' longevity ie. perennial, biennial and annual, the agricultural growing season ie. winter or summer, the management techniques employed ie. ploughing, pitting and irrigation, the type of pasture ie. natural vegetation, veld reclaimed, veld reinforced and veld replaced pastures which are described below, and livestock production.

The different ways of defining agricultural land uses given above are accepted as major land use types to ensure the inclusion of most agricultural land uses. Table 13 lists the land characteristics, together with their optimum and permissible values, which are evaluated for each major land use type. It is assumed for all the land use types that the management system includes soil conservation methods, eg. contour construction, ploughing against the slope, control of gully erosion, etc. and the application of fertilizer and lime. The term 'soil' refers to the unconsolidated material of the soil profile.

(a) Farming land - is capable of being ploughed and is fit for tillage. This land use type is mainly

Table 13 – The Optimum and Permissible Values of the Land Characteristics Evaluated for the Agriculture Land Use System

Land Characteristic	Unit	L A N D U S E T Y P E																							
		Farming Land		Pit Prepared Land		Sprinkler Irrigation		Surface Irrigation		Summer Season Cropping		Winter Season Cropping		Subtropical B/P Crops		Temperate B/P Crops		Natural Veld Pasture		Veld Reclaimed Pasture		Veld Reinforced Pasture		Veld Replaced Pasture	
		Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
LAND COVER																									
Rock surface	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Boulder cover	%	0	<5	0	<10	0	<5	0	<5	–	–	–	–	–	–	–	–	–	–	0	<90	0	<15	0	<15
Gravel cover	%	0	<10	0	<10	0	<10	0	<10	–	–	–	–	–	–	–	–	–	–	0	<25	0	<25	0	<25
Rocky distribution	class	0	<2	0	<3	0	<2	0	<2	–	–	–	–	–	–	–	–	–	–	0	<3	0	<2	0	<2
Lake	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Reservoir	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Vlei	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	–	–	–	–	–		0	<90
*River	number	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	–	–	–	–	–	–	–	–	0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$
*Stream	number	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	–	–	–	–	–	–	–	–	0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$
RELIEF																									
a.Hillslope element	class	5-6	1 or>4	5-6	1 or>3	5-6	1 or>4	6	1 or>5	–	–	–	–	–	–	–	–	5	1 or>3	5	1 or>3	5	1 or>3	5	1 or>4
Slope gradient	%	2-4	0,5-12	2-4	0,5-12	2-4	0,5-12	0,5-2	0,5-2	–	–	–	–	–	–	–	–	2-4	0,5-60	2-4	0,5-2,5	2-4	0,5-25	2-4	0,5-12
**Slope length	m	n	>10	n	>1	n	>10	n	>10	–	–	–	–	–	–	–	–	n	>1	n	>10	n	>10	n	>10
Height above water	m	–	–	–	–	–	–	–	–	>10	>10	–	–	>10	>10	>10	>10	–	–	–	–	–	–	–	–
Koppie	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	–	–	0	<90	0	<90	0	<90
Gully	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
SOIL																									
b-Subsoil texture	class	7-8	1-12	7-8	1-12	7-8	1-12	7-8	2-12	–	–	7-8	8-12	–	–	–	–	7-8	1-12	7-8	1-12	7-8	1-12	7-8	1-12
b.Topsoil texture	class	4	1-12	4	1-12	4	1-12	7	2-12	–	–	7	7-12	–	–	–	–	4	1-12	4	1-12	4	1-12	4	1-12
c.Soil erodibility index	class	>6	>3,5	>6	>2,5	>6	>3,5	8	>4,5	–	–	–	–	–	–	–	–	>6	>2,5	≥6	>2,5	>6	>3	>6	>3,5
d.Soil permeability index	class	4	>2	4	>2	4	>2	3	2-3	–	–	–	–	–	–	–	–	4	>2	4	>2	4	>2	4	>2
Rooting depth	m	>2	>0,25	>2	>0,25	>2	>0,25	>2	>0,25	–	–	>2	>0,9	–	–	–	–	–	–	>1	>0,25	>1	>0,25	>1	>0,25
Depth to water table	m	>3	>1,5	>3	>1,5	>3	>1,5	>3	>1,5	–	–	–	–	–	–	–	–	–	–	>0,25	>0	>0,25	>0	>0,25	>0
***Exposed soil length	m	0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$	–	–	–	–	–	–	–	–	0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$
Soil deficiency	code	0	<1	0	<1	0	<1	0	<1	–	–	–	–	–	–	–	–	0	<1	0	<1	0	<1	0	<1
Soil toxicity	code	0	<1	0	<1	0	<1	0	<1	–	–	–	–	–	–	–	–	0	<1	0	<1	0	<1	0	<1
Soil salinity	$mS.m^{-1}$	–	–	–	–	<200	≤1 000	<200	≤1 000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Soil pH		5-6	4-9	5-6	4-9	5-6	4-9	5-6	4-9	–	–	–	–	–	–	–	–	–	–	5-6	4-9	5-6	4-9	5-6	4-9
Sodium absorption ratio		–	–	–	–	<10	<20	<10	<20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 13 – The Optimum and Permissible Values of the Land Characteristics Evaluated for the Agriculture Land Use System

Land Characteristic	Unit	LAND USE TYPE: Farming Land		Pit Prepared Land		Sprinkler Irrigation		Surface Irrigation		Summer Season Cropping		Winter Season Cropping	
		Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
LAND COVER													
Rock surface	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Boulder cover	%	0	<5	0	<10	0	<5	0	<5	–	–	–	–
Gravel cover	%	0	<10	0	<10	0	<10	0	<10	–	–	–	–
Rocky distribution	class	0	<2	0	<3	0	<2	0	<2	–	–	–	–
Lake	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Reservoir	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Vlei	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
*River	number	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	–	–	–	–
*Stream	number	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	–	–	–	–
RELIEF													
a.Hillslope element	class	5–6	1 or>4	5–6	1 or>3	5–6	1 or>4	6	1 or>5	–	–	–	–
Slope gradient	%	2–4	0,5–12	2–4	0,5–12	2–4	0,5–12	0,5–2	0,5–2	–	–	–	–
**Slope length	m	n	>10	n	>1	n	>10	n	>10	–	–	–	–
Height ab[illegible]ater	m	–	–	–	–	–	–	–	–	>10	>10	–	–
Koppie	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Gully	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
SOIL													
b.Subsoil texture	class	7–8	1–12	7–8	1–12	7–8	1–12	7–8	2–12	–	–	7–8	8–12
b.Topsoil texture	class	4	1–12	4	1–12	4	1–12	7	2–12	–	–	7	7–12
c.Soil erodibility index	class	>6	>3,5	>6	>2,5	>6	>3,5	8	>4,5	–	–	–	–
d.Soil permeability index	class	4	>2	4	>2	4	>2	3	2–3	–	–	–	–
Rooting depth	m	>2	>0,25	>2	>0,25	>2	>0,25	>2	>0,25	–	–	>2	>0,9
Depth to water table	m	>3	>1,5	>3	>1,5	>3	>1,5	>3	>1,5	–	–	–	–
***Exposed soil length	m	0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$	–	–	–	–
Soil deficiency	code	0	<1	0	<1	0	<1	0	<1	–	–	–	–
Soil t xicity	code	0	<1	0	<1	0	<1	0	<1	–	–	–	–
Soil salinity	$mS.m^{-1}$	–	–	–	–	<200	<1 000	<200	<1 000	–	–	–	–
Soil pH		5–6	4–9	5–6	4–9	5–6	4–9	5–6	4–9	–	–	–	–
Sodium absorption ratio		–	–	–	–	<10	<20	<10	<20	–	–	–	–

Land Characteristic	Subtropical B/P Crops		Temperate B/P Crops		Natural Veld Pasture		Veld Reclaimed Pasture		Veld Reinforced Pasture		Veld Replaced Pasture	
	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
LAND COVER												
Rock surface	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Boulder cover	–	–	–	–	–	–	0	<90	0	<15	0	<15
Gravel cover	–	–	–	–	–	–	0	<25	0	<25	0	<25
Rocky distribution	–	–	–	–	–	–	0	<3	0	<2	0	<2
Lake	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Reservoir	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Vlei	0	<90	0	<90	–	–	–	–	–	–	0	<90
*River	–	–	–	–	0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$
*Stream	–	–	–	–	0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$
RELIEF												
a.Hillslope element	–	–	–	–	5	1 or>3	5	1 or>3	5	1 or>3	5	1 or>4
Slope gradient	–	–	–	–	2–4	0,5–60	2–4	0,5–2,5	2–4	0,5–25	2–4	0,5–12
**Slope length	–	–	–	–	n	>1	n	>10	n	>10	n	>10
Height ab[illegible]ater	>10	>10	>10	>10	–	–	–	–	–	–	–	–
Koppie	0	<90	0	<90	–	–	0	<90	0	<90	0	<90
Gully	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
SOIL												
b.Subsoil texture	–	–	–	–	7–8	1–12	7–8	1–12	7–8	1–12	7–8	1–12
b.Topsoil texture	–	–	–	–	4	1–12	4	1–12	4	1–12	4	1–12
c.Soil erodibility index	–	–	–	–	>6	>2,5	>6	>2,5	>6	>3	>6	>3,5
d.Soil permeability index	–	–	–	–	4	>2	4	>2	4	>2	4	>2
Rooting depth	–	–	–	–	–	–	>1	>0,25	>1	>0,25	>1	>0,25
Depth to water table	–	–	–	–	–	–	>0,25	>0	>0,25	>0	>0,25	>0
***Exposed soil length	–	–	–	–	0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$
Soil deficiency	–	–	–	–	0	<1	0	<1	0	<1	0	<1
Soil t xicity	–	–	–	–	0	<1	0	<1	0	<1	0	<1
Soil salinity	–	–	–	–	–	–	–	–	–	–	–	–
Soil pH	–	–	–	–	–	–	5–6	4–9	5–6	4–9	5–6	4–9
Sodium absorption ratio	–	–	–	–	–	–	–	–	–	–	–	–

Table 13 (contd.)

Land Characteristic	Unit	Farming Land		Pit Prepared Land		Sprinkler Irrigation		Surface Irrigation		Summer Season Cropping		Winter Season Cropping		Subtropical B/P Crops		Temperate B/P Crops		Natural Veld Pasture		Veld Reclaimed Pasture		Veld Reinforced Pasture		Veld Replaced Pasture	
		Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
Soil cation exchange capacity	me%	>75	>0	>75	>0	>75	>0	>75	>0	–	–	–	–	–	–	–	–	–	–	>75	>0	>75	>0	>75	>0
Soil organic matter	%	>75	>0	>75	>0	>75	>0	>75	>0	–	–	–	–	–	–	–	–	–	–	>75	>0	>75	>0	>75	>0
CLIMATE																									
Wind velocity	$m\ s^{-1}$	<5	<20	<5	<20	<5	<20	<5	<20	–	–	–	–	–	–	–	–	–	–	<5	<20	<5	<20	<5	<20
Frost temperature	°C	–	–	–	–	–	–	–	–	–	–	>2,5	>-2,5	>2,5	>2,5	>2,5	>-2,5	–	–	–	–	–	–	–	–
January temperature	°C	–	–	–	–	–	–	–	–	n	<45	–	–	–	–	n	<30	–	–	–	–	–	–	–	–
July temperature	°C	–	–	–	–	–	–	–	–	–	–	n	≥12	n	≥12	–	–	–	–	–	–	–	–	–	–
Hail occurrence	day	–	–	–	–	–	–	–	–	0	<3	–	–	0	<1	0	<1	–	–	–	–	–	–	–	–
Fruiting season length	day	–	–	–	–	–	–	–	–	–	–	–	–	>180	>150	>180	>150	–	–	–	–	–	–	–	–
Season length	day	–	–	–	–	–	–	–	–	>170	>100	>170	>100	–	–	–	–	–	–	–	–	–	–	–	–
Season quality	pentade	–	–	–	–	–	–	–	–	>42	>25	>42	>25	>42	>25	>42	>25	–	–	>42	>25	>42	>25	>42	>25
Water deficient period	day	–	–	–	–	–	–	–	–	0	<170	0	<170	0	<170	0	<170	0	<170	0	<170	0	<170	0	<170
Evaporation	$mm\ a^{-1}$	–	–	–	–	–	–	–	–	n	>0	n	>0	n	>0	n	>0	n	>0	n	>0	n	>0	n	>0
Rainfall total	$mm\ a^{-1}$	–	–	–	–	–	–	–	–	>800	>600	>800	>600	>1000	>850	>1000	>850	>800	>250	>800	>400	>800	>400	>800	>400
Rainfall energy	$J\ m^{-2}a^{-1} \times 10^3$	0	<30	0	<30	0	<30	0	<30	–	–	–	–	–	–	–	–	0	<30	0	<30	0	<30	0	<30
BIOLOGICAL CHARACTERISTICS																									
**Physiognomic vegetation type	code		15–49		15–49		15–49		15–49		15–45		15–45		2–24		2–25		15–33		15–33		15–33		15–33
**Floristic vegetation type	code																								
Woody cover	%	0	<100	0	<100	0	<100	0	<100	–	–	–	–	–	–	–	–	<10	<100	<10	<100	<10	<100	<10	<100
Woody distribution	class	0	<2	0	<3	0	<2	0	<2	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–
Animal host species	code	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	0	0	0	0	0	0	0
MAN-MADE STRUCTURES AND BOUNDARIES																									
Township	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Industrial area	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Settlement	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
**Powerline	number	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$									0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$
**Railway	number	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$									0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$
**Paved road	number	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	–	–	–	–	–	–	–	–	0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$
Maintain catchment area	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
**Unpaved road	number	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	<1	$<X_L$	–	–	–	–	–	–	–	–	0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$

Note. a. classes described in section d.
b. classes described in Table 6.
c. Classes described in section 3.4.6
d. classes described in section 3.4.7
e. Optimum values given in Table 28. Classes described in Table 10.
f. Values given by the user. No default table.
* Default is 5
** Default is 160.
*** Default is 100

concerned with the physical landscape features which will influence the land preparation and the area of land available, and with soil fertility which is essential to crop growth.

An upper limit to the number of railways, powerlines, paved and unpaved roads, rivers and streams allowed is necessary since these features dissect the land unit into smaller units which may be of an uneconomical size. The type of land surfaces which may not be utilized are man-made structures viz. industrial areas, settlements, townships, lakes, reservoirs and Mountain Catchment Areas and rocky surfaces, gullies and gravel and boulder cover. Woody cover may be removed below a certain upper li [illegible] verned by the cost and the conservation value of the [illegible] Boulder and gravel cover may also be removed but with greater difficulty and expense. Therefore these three forms of cover are not considered to represent land which may be utilized in standard farm management programmes. The capability ratings given to the physiognomic vegetation types should consider the cover and the woody cover if the land characteristic is not measured.

Ploughing removes the natural vegetation and the crop remains. This exposed soil is more vulnerable to wind and water erosion and thus highly erodible soils, steep gradients and high wind velocities are excluded. Areas of previously eroded soils are low in soil fertility. Gradients greater than twelve per cent are not easily accessible to implements (Edwards, 1970) while a slope length less than ten metres limits the manoeuvrability possible. A soil depth of greater than 0,25 metres is necessary for ploughing (Ivy, 1977) but, for woody plants, this must be modified to a value of 0,9m which is the minimum rooting zone required (Poynton, 1978, personal communication).

(b) Pit prepared land - is incapable of being ploughed but homogeneous stands of woody plants may be tilled if the individuals are planted in separate pits. Fire may be used to reduce the vegetation cover competition (Poynton, 1960). This land use type is concerned with the physical landscape features and the soil fertility for the reasons given above.

The considerations discussed above are applicable except that less stringent limits may be given to the land characteristics because the whole vegetation cover is not removed and a homogeneous surface for ploughing is not required. Slope gradients exceeding twenty-five per cent are excluded since they are only accessible to livestock (Edwards, 1970). A shorter slope length is allowed as the use of mechanised vehicles is not essential. A soil depth of greater than 0,9 metres is required for the rooting zone of a woody plant (Poynton, 1978, personal communication).

(c) Sprinkler irrigation scheme - is the overhead application of supplementary water during the whole or part of the growing season. Before the implementation of such a scheme, two aspects of the land requiring detailed study are:-

(i) The quantity and quality of the water supply. The former aspect includes economic factors and thus it is omitted.

(ii) The quantity of land capable of being irrigated. This concerns the physical landscape features influencing irrigation and the arability of the land.

The discussion for the arable land use type is applicable. Water and soil with a salinity of greater than 100mS m^{-1} and greater than 1 000mS m^{-1} respectively are excluded (MacVicar, 1978, personal communication). The limitations of the season quality, the season length and the rainfall total are overridden, but the erosive potential of the rainfall is still present. It is assumed that the irrigation water is applied at a rate which is of negligible erosive potential.

(d) Surface irrigation scheme - is the application of supplementary water at the ground surface during the whole or part of the growing season. The discussion for the above land use type is applicable. However, the erosive potential of the land is more critical as the water is transported to the plants over the soil surface in furrows or it is allowed to flow undirected. Slope gradients exceeding eight per cent are excluded (Loxton, 1977) as are highly permeable soils, since they will hinder the flow of the water to all parts of the crop.

(e) Summer season cropping - is the cultivation of annual crops from September to April inclusive, ie. during the Transvaal rainy season. This land use type is concerned with the climatic conditions present and the physiological requirements of the crop and the type of land surface.

The mean daily maximum January temperature which is the hottest month (S.A.W.B. Part 8, 1965) will be a limiting factor. Rainfall is a major limiting resource in South Africa (Midgley and Pitman, 1969) and its quantity and distribution are indicated by the balance between the precipitation received and evaporation, or the water deficit period length, and the season quality and the season length. The vegetation type is an indicator of the probable climatic conditions prevalent and this will be reflected in the capability ratings given to either of the vegetation type land characteristics used. The damaging action of wind and hail to the plants is considered while lands with a flooding hazard or potential for waterlogging are excluded as they will limit crop growth and productivity.

(e) Winter season cropping is the cultivation of crops from April to September inclusive, ie. the Transvaal rainy season is not included. This land use type is concerned with the climatic conditions present and the physiological requirements of the crop and the type of land surface.

Productive cultivation during this season depends upon the storage of sufficient moisture during the previous summer rainy season. This storage is assured for lands with a rainfall total exceeding 600mm, a soil depth greater than 90cm, a soil with a clay content more than forty-five per cent and the cultivation of no summer crop (Van der Merwe and Van der Mey, 1976).

The mean daily maximum temperature of the coldest month, ie. July (S.A.W.B. Part 8, 1965) and the frost temperature will be limiting factors. Lands with a latter temperature of $-2,5^{\circ}C$, ie. heavy frost occurrence, will be excluded. Lands with a flooding or waterlogging potential are included since the crops are cultivated outside the rainy season. Hail damage is not considered for the same reason.

(f) Subtropical Biennial and Perennial crops - is the cultivation of plants for their vegetative component, eg. tea and sugarcane, or for their fruiting bodies, eg. citrus and coffee. This land use type is concerned with the climatic conditions present and the physiological requirements of the crop and the type of land surface.

The discussion for the summer season cropping land use type is applicable except that a subtropical climate does not average less than 6^{O}C for any month (Monkhouse, 1970). Thus the limiting temperatures of the mean daily maximum July temperature and the frost temperature are considered. The latter must exceed 2,5^{O}C since these plants are sensitive to all frost. The plants will withstand drought provided that the soil moisture does not reach wilting point down to maximum rooting depth (Young, 1974). The drought resistance of woody plants increases with maturity. Physical plant damage, ie. leaf and fruit loss, fruit bruising, broken branches, etc. may result from exposure to wind and hail. Damage to the fruit decreases its marketing value and the possibility of disease entry through the damaged parts is increased. The degree of hail damage is dependent upon the hail intensity which is generally greater at higher altitudes (Poynton, 1978, personal communication). Thus, lands subject to hail and high wind velocities are excluded.

(g) Temperate biennial and perennial crops - The above discussion, excluding the temperature limitations, is applicable. Only temperatures below 0^{O}C are excluded since these plants can withstand light frost. Frost damage to the fruiting bodies will decrease their market value and therefore the fruiting season length should be sufficient to allow the fruits to mature without exposure to frost. The frost resistance of a woody plant increases with maturity and growth as the sensitive buds are lifted off the ground where the frost temperature occurs (Poynton, 1977). The mean daily maximum January temperature is limiting to these plants rather than the cold winter temperatures which are required to break dormancy.

Pasture The grassland management, eg. the control of the stocking rate, the intensity of the herbage utilization, burning, the provision of stock watering facilities, the use of fencing to control the stocking density, the duration of grazing and the spacing of livestock movement, is important in determining the productivity of the pasture or grassland. No agreement as to the optimum management system has been reached since so many variables exist within any pasture, eg. the condition and species composition of the veld, the season period during which defoliation occurs, the livestock preference for certain species, and plant parts and areas in the sward (Edwards, 1977). Thus, no particular grassland management system is assumed to be in operation. However, soil conservation management, eg. control of gulley erosion, prevention of overgrazing, etc. is implemented as well as the fencing of railways and all roads excluding tracks, to prevent livestock loss.

The livestock carrying capacity of the natural grassland maybe low due to the presence of unpalatable species and/or a poor veld condition. This capacity may be improved by:-

(i) Veld reclamation - The degenerate veld is restored to something approximating a stable condition by resting from grazing, reseeding, pest control, mechanical measures and incomplete soil disturbance (Edwards, 1977). The original indigenous components are often re-established and the cultivation is never complete.

(ii) Veld improvement - This has become an established practice in livestock farming and results in an increase in the carrying capacity (Theron and Harwin, 1976). Radical veld improvement is the use of radical measures (cultivation, overseeding, herbicides, fertilizers) in the development of the full grazing herbage production potential of veld areas (Edwards, 1977). Two methods exist and are classified according to the extent of their modification on the biome (Edwards, 1977):-

Veld reinforcement - The pasture land is developed by the addition of more desirable plants (overseeding) and /or the addition of plant nutrients by fertilizer application. Overseeding is usually accompanied by measures designed to reduce the competition of the existing sward.

Veld replacement - The pasture land is developed by the complete and immediate replacement of whole areas of the veld by more desirable plants.

(h) Natural veld pasture This land use type is concerned with the grazing of livestock on natural vegetation. Any veld improvement methods used do not involve the introduction of grass species and are not dependent on the use of mechanised implements. The presence of animal life which is a host to a pathogen, or the presence of poisonous plants at certain times will limit the pastoral use of the land. Paved and unpaved roads and railways should be fenced and inhibit the utilization of the land. The upper limits to the number of such permitted on the land are dependent on the economics of fencing and are thus given by the user. Land subject to flooding is grazed during the dry season to prevent the loss of livestock from drowning. Woody cover is required for shade but the herbaceous growth is limited. The soil structure of a non-cohesive soil is easily destroyed by the trampling action of the livestock. Puddles formed in the soil surface will increase the incidence of foot rot. Thus neither highly cohesive or non-cohesive soils are desirable. Gradients exceeding sixty per cent have no soil cover (Weinert, 1978) and are inaccessible to livestock. The surface area available for grazing is that which is not covered by a water surface, koppie, gully, rock surface, industrial area, settlement or a township. Since lands subject to flooding may be grazed in the winter season, they are not excluded. The capability ratings given to the floristic vegetation type should consider the overall palatability of the vegetation while those given to the physiognomic vegetation type should consider the cover and the woody cover available if the latter land characteristic is omitted.

(i) Veld reclaimed pasture - This land use type and those of (j) and (k) below are concerned with the physical landscape features which will influence the land available for grazing and the preparation of the pasture, the moisture supply and the soil fertility which will influence the pasture's productivity. The discussion for (h) is applicable except that gradients exceeding twenty-five per cent are not accessible to mechanised vehicles (Edwards, 1970) and the soil fertility is analysed.

(j) Veld reinforced pasture - The total veld area is not necessarily reinforced. Often it is confined to selected or random spots, sites or strips of veld. The quality of the resulting pasture is improved by a good mixing of the fertilizer, seed and soil and is dependent upon the proportion of the total area which is disturbed (Edwards, 1977). The above discussion for land use type (h) is applicable except that gradients exceeding twenty-five per cent are not accessible to mechanised vehicles (Edwards, 1970) and the soil fertility is analysed. The degree of soil disturbance is greater and thus highly erodible soils are not grazed.

(k) Veld replaced pasture - The above discussion on veld reclaimed and veld reinforced pastures are applicable. However, since the natural vegetation is completely removed initially by ploughing, that portion of the veld which is to be replaced, highly erodible soils and slopes exceeding twelve per cent (Edwards, 1970) are not grazed.

(l) Livestock production - Grazing animals are dairy cattle, beef cattle, sheep, goats and game species. The farming of each particular type of livestock will involve pastures of some sort. Thus this land use type is considered by analysing one of the land use types, viz (h) - (k). The particular animal host species would be evaluated with respect to the livestock for whose production the land is being evaluated.

Livestock kept under cover, eg. poultry and pigs, are not considered under this land use system since their production will involve an analysis of the building conditions present on the land. These conditions would be analysed under one of the land use types in the township development land use system. However, the production of food crops for consumption by these livestock, would be considered under the appropriate land use type described above.

Agricultural land uses - The cultivation of a specific crop, a pasture grass species, or the production of specific livestock is a land use and the values given in Table 13 are replaced where necessary so as to apply to the species concerned. Tables 14 and 15 list the values of certain land characteristics which will replace the appropriate value in Table 13. These lists are not complete and future additions will be possible as more information becomes available. They refer to some important crops and the values given were obtained from the literature and various people (Appendix A).

Table 14 – Optimum and Range Values for Certain Annual Crops

NB These values are to be used as a general guideline. They depend on the environmental conditions and the crop type. Common names are given as these values do not apply to any particular variety.

CROP	L A N D C H A R A C T E R I S T I C																	
	1 Main daily temperature °C		Rainfall m ma^{-1}		Soil texture		Rooting depth m		Drainage		pH ($CaCl_2$)		Growing season days		Frost °C		Other
	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	
Barley		0–22		≤900	L		≥1		well		7–8	>6		60–70			-
Burley Tobacco	19	15–22	850	700–1000	SCL-C	S-C	0,9	≥0,3	well			5–5,5		<200	–	–	
Cabbage	cool		moist		SL	S-C		0,4–1,8			6,5	6–6,5		110–116			
Cotton	25–30	20–30	800	600–1000	SL	S-CL	1,5	≥0,5	well			5,5–7,5		180–200	–	–	Slope <3%
Dry bean	15,5–21	15,5–22	650	600–700	L	LS-CL	1,3		well		6,5–7	6–7		100–130			
Groundnuts	22–30	21–30	550		SL	S-L	1,3	≥0,6	well			5,3–5,8		100–200	–	–	
Maize	19–25	16–30	600	≤950	LS-L	SL-C		≥0,5			5,5–6	5–6,5		120–160			
Oats	19–25	≤33	moist	>600	L	S-C						4,6–5,5		>-5			similar to wheat
Onions	13–25				SL	S-C	1,3	≥0,6	well			6–6,5		195–215	–	–	
Peas	21	7–24			SL							5,3–6,5		165–1100			
Potatoes	15–21	15–22	800	>400	L	S-C	1,3	≥0,5	well		5–5,5	4,2–5,8			–	-1	
Sorghum (grain)	27–30	20–30	500	<950	L	S-CL	1,3	≥0,6			5,5–6,5	5–8,5	130–140	>120			
Soyabean	22–27,5	19–30	600		L	S-L		≥0,5	well		5,5–6	5,3–7		120–160	–	–	
Sunflower		21–28			LS-L	SL-C	≥2,5	≥0,50	well			6,0–7,5		≥120			
Sugarcane	26	21–38	high		SL		≥2	>1,15	well		6,1–7,7	4,5–8,3			–	–	
Sweet Potatoe		22–28	≥900	≥600		S-C			well			5,2–6			–	–	
Tomatoe	21–25	15–25	650	≤1150	SL	S-C	0,6	≥0,4	well		5–5,8	4,3–6,5		100–140	–	–	
Virginia Tobacco	19	15–22	850	700–1000	S-SL	S-SCL	>0,90	≥0,3	well		5–5,5	5,0–6,8					
Wheat (winter)	19–25	15,5–27,5		>600	S-CL	LS-C	≥0,9	≥0,9			5,2–5,6	>4,5		120–200			

Key · * May be considered as a biennial.
+ Generally cultivated in greenhouses
1 January or July, depending upon the season of cultivation.
* [illegible]

Table 15 – Optimum and Range Values for Selected Biennial and Perennial Crops

NB The values depend on the environmental conditions present and upon the crop type. Thus the common name for each crop is used as these figures do not apply to any particular variety.

CROP	LAND CHARACTERISTIC																	
	January day temperature °C		July day temperature °C		Rainfall m ma^{-1}		Soil texture		Rooting depth m		Drainage		pH ($CaCl_2$)		Frost °C		Aspect	
	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
Apple	18-20	13-27	9-11	<17	700	>600	L	CL-L	>0,9	>0,45	well		5-6,5		–	>-3		
Citrus	20-30	10-35		>3	1 900 – 2 400	>1270		S-CL	>2	>1	well		5,5-6	4-9		>0 light		
Coffee	26					1000-1900	LS-CL	S-CL	1,3	>0,6	well		4,5-5,5		–	mild	SE	
Grape	25-30	<35	> 10		>550	550-1000	LS-CL	S-C	>0,9	>0,45			6-7	5-7,8				
Lucerne		13-30			600		LS	LS-C	>1,2		well			6,2-7,8				
Peach	18-20	13-27	9-11	<17	≥600			CL-SL	>0,6	>0,3	well		5,5					
Pear	18-20	13-27	9-11	<17	>600		SL	L-S	>0,9	>0,45	well		5,5					
Sugarcane	26	21-38		≥12	high		SL		≥2	>1,15	well		6,1-7,7	4,5-8,3	–	–		
Tea		11-17				≥1270	L-CL	S-C	3-4,2	≥2,4	well		5-6	4,4-6,2	–	light	SE	

Key
S Sand
L loam
LS loamy sand
CL clay loam
SL sandy loam
C clay

Figures obtained from various persons (Appendix A) and the literature

3.5.2. 5. Forestry Land Use System

These land use types may be described in the same terms as those for agricultural land uses. The management system and the definition of the term soil applies as before. Table 16 lists the land characteristics together with their optimum and permitted values which are evaluated for each major land use type.

(a) and (b) Arable and Pit prepared Land - The discussion for these land use types under the agricultural land use system (Section 3.5.2.4) is applicable except that the root zone requirement for tree species must be considered.

(c) Sub-tropical forestry - This is the cultivation of non-coniferous, sub-tropical woody species for commercial timber. The two main plant genera involved are *Acacia* and *Eucalyptus*, eg. *Acacia mearnsii* (wattle) and *Eucalyptus grandis*. The earlier discussion on sub-tropical perennial and biennial crops is applicable. A rainfall exceeding 650mm a^{-1} is necessary (Poynton, 1978, personal communication). Lands subject to high hail intensity are excluded as the damage to the bark increases the potential for pathogen entry which damage the timber.

(d) Temperate forestry - Apart from the requirements that the rainfall must exceed 900mm a^{-1} (Poynton, 1978, personal communication) and that land subject to a high hail intensity is excluded, the conditions necessary for this land use are the same as those for temperate biennial and perennial crops (Section 3.4.2.4).

Table 16 - The Optimum and Permissible Values of the Land Characteristics Evaluated for the Forestry Land Use System

Land Characteristic	Unit	L A N D		U S E		T Y P E			
		Farming land		Fit prepared land		Sub-tropical forestry		Temperate forestry	
		Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
LAND COVER									
Rock surface	%	0	<90	0	<90	0	<90	0	<90
Boulder cover	%	0	<5	0	<10	-	-	-	-
Gravel cover	%	0	<10	0	<10	-	-	-	-
Rocky distribution	class	0	≤2	0	≤3	-	-	-	-
Lake	%	0	<90	0	<90	0	<90	0	<90
Reservoir	%	0	<90	0	<90	0	<90	0	<90
Vlei	%	0	<90	0	<90	0	<90	0	<90
*River	number	0	$\leq X_L$	0	$\leq X_L$	-	-	-	-
*Stream	number	0	$\leq X_L$	0	$\leq X_L$	-	-	-	-
RELIEF									
a. Hillslope element	class	5-6	1 or≥4	5-6	1 or≥3	-	-	-	-
Slope gradient	%	2-4	0,5-12	2-4	0,5-25	-	-	-	-
**Slope length	m	n	≥10	n	≥10	-	-	-	-
Aspect of a slope	degree	-	-	-	-	270-90	0-360	270-90	0-360
Height above water	m	>10	≥10	>10	>10	>10	≥10	≥10	≥10
Koppie	%	0	<90	0	<90	0	<90	0	<90
Gully	%	0	<90	0	<90	0	<90	0	<90
SOIL									
b. Subsoil texture	class	7-8	1-12	7-8	1-12	-	-	-	-
b. Topsoil texture	class	4	1-12	4	1-12	-	-	-	-
c. Soil erodibility index	class	≥6	≥3,5	≥6	≥2,5	-	-	-	-
d. Soil permeability index	class	4	≥2	4	≥2	-	-	-	-
Rooting depth	m	≥2	≥0,9	≥2	≥0,9	-	-	-	-
Depth to water table	m	≥3	≥1,5	≥3	≥1,5	-	-	-	-
***Exposed soil length	m	0	$\leq X_L$	0	$\leq X_L$	-	-	-	-
Soil deficiency	code	0	<1	0	<1	-	-	-	-
Soil toxicity	code	0	<1	0	<1	-	-	-	-
Soil pH		5-6	4-9	5-6	4-9	-	-	-	-
Soil cation exchange capacity	me %	>75	≥0	>75	≥0	-	-	-	-
Soil organic matter	%	>75	≥0	>75	≥0	-	-	-	-

Table 16 (contd.)

Land Characteristic	Unit	L A N D U S E T Y P E							
		Farming land		Pit prepared land		Subtropical forestry		Temperate forestry	
		Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
<u>CLIMATE</u>									
Wind velocity	$m\ s^{-1}$	<5	<20	<5	<20	<5	<20	<5	<20
Frost temperature	°C	-	-	-	-	>2,5	>2,5	>2,5	>2,5
January temperature	°C	-	-	-	-	-	-	n	<30
July temperature	°C	-	-	-	-	n	>12	-	-
Hail occurrence	day	-	-	-	-	0	<3	0	<3
Season quality	pentade	-	-	-	-	>42	>25	>42	>25
Water deficit period	day	-	-	-	-	0	<170	0	<170
Evaporation	$mm\ a^{-1}$	-		-		n	>0	n	>0
Rainfall total	$mm\ a^{-1}$	-	-	-	-	>1000	850-1200	>1000	900-1200
Rainfall energy	$Jm^{-2}a^{-1}x10^{3}$	0	<30	0	<30	-	-	-	-
<u>BIOLOGICAL CHARACTERISTICS</u>									
e, Physiognomic vegetation type	class		17-49		17-49		2-15		2-15
f, Floristic vegetation type	class								
Woody cover	%	0	<100	0	<100	-	-	-	-
Woody distribution	class	0	<2	0	<3	-	-	-	-
<u>MAN-MADE STRUCTURES AND BOUNDARIES</u>									
Township	%	0	<90	0	<90	0	<90	0	<90
Industrial area	%	0	<90	0	<90	0	<90	0	<90
Settlement	%	0	<90	0	<90	0	<90	0	<90
*Powerline	number	0	$<X_L$	0	$<X_L$	-	-	-	-
*Railway	number	0	$<X_L$	0	$<X_L$	-	-	-	-
*Paved road	number	0	$<X_L$	0	$<X_L$	-	-	-	-
Mountain catchment area	%	0	<90	0	<90	0	<90	0	<90
*Unpaved road	number	<1	$<X_L$	<1	$<X_L$	-	-	-	-

<u>Note</u>

a Classes described in Section 3.4.2
b Classes described in Table 6
c Classes described in Section 3.4.6.
d Classes described in Section 3.4.7
e *Optimum* values given in Table 32. Classes described in Table 10.
f Values given by the user. No default table.
* Default is 5.
** Default is 160
*** Default is 100.

Forestry Land Uses

Within any of the four preceding major land use types, the cultivation of a particular woody species ie. a land use, may require changes to the values in Table 16 to apply to the species concerned. Poynton (1971) divided the Republic of South Africa into silvicultural zones based on rought and frost, being the two main climatic factors which limit tree establishment and growth in this country. Thornwaite's (1948) thermal and humidity zones were used. to derive these zones. Climatic data for different tree species grown for their commercial timber, may be derived from this map when it is used in conjunction with Poynton's Table II of Recommended Silvicultural Zones (1977). This Table lists the recommended zone for different species. Table 17 derived from the literature and discussions with people (Appendix A) may also be used.

3.5.2 .6 Conservation Land Use System

The South African Government Policy is to protect areas of exceptional beauty and unique phenomena and areas where rare species occur, against indiscriminate exploitation and environmental pollution, and to conserve these areas for the benefit and enjoyment of man (Department of Planning and the Environment, 1973). This protection is not by means of exclusion but by means of management.

Only one major land use type is defined, namely conservation area which may also correspond to areas for informal recreation. It is assumed that the management system involves soil and water conservation, eg. control of gully erosion, protection of the vegetation cover, etc. the propagation and distribution of rare indigenous species and

Table 17 - The Optimum and Permissible Values for Some Tree Genera

NB. The figures do not necessarily apply to a species within the genus.

Woody Plant	LAND CHARACTERISTIC													
	Jan Day Temp °C		Rainfall		Soil Texture		Rooting Depth m		pH $CaCl_2$		Frost		Slope %	
	Opt	Ran	Opt	Ran	Opt	Ran	Opt	Ran	Opt	Ran	Opt	Ran	Opt	Ran
Eucalyptus			1 000	850-1 200	L		>1	>0,5	6-7		0	0		5-30
Pinus			1 000	900-1 200	L		>1	>0,5						0-30
'Commercial Acacias'	17	15-19	1 000	850-1 200	L		2,5	>0,5					0-10	0-30

Key

L = loam
Ran = Range
Opt = Optimum

the control of the recreational activities pursued. The land characteristics with their optimum and permitted values which are evaluated for this land use type, are listed in Table 18.

(a) <u>Conservation area</u> - Land with legal conservation status, ie. National, Provincial, Municipal and Private Parks, Mountain Catchment and Wilderness Areas are automatically considered as land to be used for this purpose. The upper limit for the number of roads, railways and powerlines depends on the permitted degree of development. Land covered by man-made structures eg. industrial areas, townships and settlements and Mountain Catchment Areas, represent land which may not be utilized for this purpose. The conservation value of cultivated land (Type 49 of the Physiognomic vegetation classification (Table 10)) has been removed and is also non-usable. The capability ratings given to the floristic vegetation types should reflec. the conservation value of the vegetation including the conservation of wildlife habitats. The wind velocity, rainfall energy and the soil erodibility index are indicators of the soil erosion hazard.

(b) <u>Conservation land uses</u> - Specification of a particular legal conservation status of the land, eg. National Park, Wilderness Area, is a land use. This legal status defines the management of the area, the degree of development allowed and indirectly, the recreation permitted, eg. Wilderness Areas are almost completely without development (Ackerman, 1976). The values given in Table 18 will be changed where necessary to indicate this.

the control of the recreational activities pursued. The land characteristics with their optimum and permitted values which are evaluated for this land use type, are listed in Table 18.

(a) <u>Conservation area</u> - Land with legal conservation status, ie. National, Provincial, Municipal and Private Parks, Mountain Catchment and Wilderness Areas are automatically considered as land to be used for this purpose. The upper limit for the number of roads, railways and powerlines depends on the permitted degree of development. Land covered by man-made structures eg. industrial areas, townships and settlements and Mountain Catchment Areas, represent land which may not be utilized for this purpose. The conservation value of cultivated land (Type 49 of the Physiognomic vegetation classification (Table 10)) has been removed and is also non-usable. The capability ratings given to the floristic vegetation types should reflect the conservation value of the vegetation including the conservation of wildlife habitats. The wind velocity, rainfall energy and the soil erodibility index are indicators of the soil erosion hazard.

(b) <u>Conservation land uses</u> - Specification of a particular legal conservation status of the land, eg. National Park, Wilderness Area, is a land use. This legal status defines the management of the area, the degree of development allowed and indirectly, the recreation permitted, eg. Wilderness Areas are almost completely without development (Ackerman, 1976). The values given in Table 18 will be changed where necessary to indicate this.

Table 18 - The Optimum and Permissible Values of the Land Characteristics Evaluated for the Conservation Land Use System

Land Characteristic	Unit	Land Use Type: Conservation Area – Optimum	Land Use Type: Conservation Area – Range
LAND COVER			
Lake	%	100	≥0
Reservoir	%	100	≥0
Vlei	%	100	≥0
*River	number	≥1	$\leq X_L$
*Stream	number	≥1	$\leq X_L$
RELIEF			
a. Hillslope element	class	≥4	≤7
Slope gradient	%	>12	≤100
**Slope length	m	n	>0
Koppie	%	100	≥0
Natural land feature	code	>0	>0
Gully	%	100	≥0
SOIL			
b. *Soil erodibility index*	*class*	≤3,5	≤8
***Exposed soil length	m	0	$\leq X_L$
CLIMATE			
Wind velocity	$m\,s^{-1} \times 10^3$	<5	≤27
Rainfall energy	$Jm^{-2}a^{-1} \times 10^3$	0	n
BIOLOGICAL CHARACTERISTICS			
c. Physiognomic vegetation type	class		<49
d. Floristic vegetation type	class		
Protected plant species	code	≥1	>0
Protected animal species	code	≥1	>0

Land Characteristics	Unit	Land Use Type: Conservation Area – Optimum	Land Use Type: Conservation Area – Range
MAN-MADE STRUCTURES AND BOUNDARIES			
Township	%	0	<90
Industrial area	%	0	<90
Settlement	%	0	<90
*Powerline	number	0	$\leq X_L$
*Railway	number	0	$\leq X_L$
*Paved road	number	0	$\leq X_L$
National Park	%	100	>0
Provincial Park	%	100	>0
Municipal Park	%	100	>0
Private Park	%	100	>0
Mountain catchment area	%	100	>0
Wilderness area	%	100	>0
*Unpaved road	number	≤1	$\leq X_L$

a. Classes described in Section 3.4.2.
b. Classes described in Section 3.4.6.
c. Classes described in Table 10. Values given by the user. No default table.
d. Values given by the user. No default table.
* Default is 5.
** Default is 160.
*** Default is 100.

?.5.2. .7 Recreation Land Use System

The range of activities encompassed by this land use system is so wide that it almost defies classification (Edington and Edington, 1977). One form of classification is in terms of the recreational activity, viz. cultural, arranged sport and informal activities. Cultural activities and indoor sports form part of Urban and Rural Development and are not included as Recreation Land Uses. Informal activities, defined as being any leisure pursuit in the countryside or in undeveloped urban open spaces, since they depend on environmental resources, are included.

The major land use types are therefore open space (including playgrounds, outdoor sports and camping sites) water recreation and informal activities. The basic difference between the first and the last land use types is that the former requires the development of the land surface in some way while, in the latter, the natural state is retained. Table 19 lists the land characteristics, together with their optimum and permissible values, which are evaluated for each of these major lanc use types.

(a) Open space - This land use type is concerned with the physical landscape features which influence the development of the land surface. The natural vegetation is removed by ploughing and thus, a soil depth exceeding 25cm (Ivy, 1977) and a slope gradient of less than or equal to twelve per cent (Edwards, 1970) are required. The wind velocity and rainfall energy will indicate the potential soil erosion hazard from the cleared soil. A slope length of ten metres will limit the manoeuvrability possible. A toxic

Table 19 - The Optimum and Permeable Values of the Land Characteristics Evaluated for the Recreation Land Use System

Land Characteristics	Unit	LAND USE TYPE					
		Open Space		Informal activities		Water recreation	
		Optimum	Range	Optimum	Range	Optimum	Range
LAND COVER							
Rock surface	%	0	<90	-	-	-	-
Boulder cover	%	0	<10	-	-	-	-
Rocky distribution	class	0	<3	-	-	-	-
Lake	%	0	<90	0	<90	100	>10
Reservoir	%	0	<90	0	<90	100	>10
Vlei	%	0	<90	n	≤100	100	>0
*River	number	0	$<X_L$	-	-	≥1	$1-X_L$
*Stream	number	0	$\leq X_L$	-	-	≥1	$1-X_L$
RELIEF							
a.Hillslope element	class	>6	1-7	5-6	≤7	-	-
Slope gradient	%	<4	≤15	X_0	≤100	-	-
**Slope length	m	n	≥10	-	-	-	-
Koppie	%	0	<90	-	-	-	-
Natural land feature	code	0	<1	≥1	≥0	-	-
Gully	%	0	<90	0	<90	-	-
SOIL							
b.Subsoil texture	class	7-8	1-12	-	-	-	-
b.Topsoil texture	class	4	1-12	-	-	-	-
c.Soil erodibility index	class	≥6	≥3,5	≥6	≥2,5	-	-
d.Soil permeability index	class	4	≥2	4	≥1	-	-
CLIMATE							
Wind velocity	$m\ s^{-1}$	<5	≤20	<5	≤20	-	-
Rainfall energy	$Jm^{-2}a^{-1}$ $\times 10^3$	0	<30	0	<30	-	-
BIOLOGICAL CHARACTERISTICS							
e.Physiognomic vegetation type	class		15-48		2-48		27-30
Floristic vegetation type	class						
Woody cover	%	0	≤100	n	≤100	-	-
Game species	code	-	-	n	≥0		≥0

Table 19 (contd.)

Land Characteristics	Unit	LAND USE TYPE: Open space Optimum	Range	Informal activities Optimum	Range	Water recreation Optimum	Range
MAN-MADE STRUCTURES AND BOUNDARIES							
Industrial area	%	0	<90	0	<90	-	-
*Powerline	number	0	$\leq X_L$	0	$\leq X_L$	-	-
*Railway	number	≤ 1	$\leq X_L$	0	$\leq X_L$	-	-
*Paved road	number	≤ 1	$\leq X_L$	≤ 1	$\leq X_L$	-	-
National Park	%	0 or 100	<90	100	< 100	-	-
Provincial Park	%	0 or 100	≥0	100	≥0	-	-
Municipal Park	%	0 or 100	≥0	100	≥0	-	-
Private Park	%	0 or 100	≥0	100	≥0	-	-
Mountain catchment area	%	0	<90	0	<90	-	-
Wilderness area	%	0	<90	100	≥0	-	-
*Unpaved road	number	≤ 1	$\leq X_L$	≤ 1	$\leq X_L$	-	-

Note

* Default is 5
** Default is 160
a Classes described in Section 3.4.2
b Classes described in Table 6
c Classes described in Section 3.4.6.
d. Classes described in Section 3.4.7.
e. Optimum values given in Table 37. Classes described in Table 10.
f. Given by the user. No default table.

saline or nutrient deficient soil will limit the growth of the vegetation cover is one is necessary. These are minor land characteristics. Woody, gravel and boulder cover may be removed but an upper limit, depending upon the finances involved in this action, is required. The capability ratings given to the physiognomic vegetation types should consider the cover and the woody cover present if the latter land characteristic is not measured.

The presence of a road or railway is an advantage as the accessibility of the land is increased. However, a permissible upper limit to these features and to powerlines, rivers and streams is necessary since they dissect the land into smaller units which may not be of a usable size. Mountain Catchment Areas (Ackerman, 1976), industrial areas, reservoirs, vleis and lakes represent land which may not be utilized. Land within the precincts of settlements and townships may be used.

(b) Informal activities - Any recreational activity which does not require the development of the land surface but depends on the natural state of the land, eg. mountaineering, is considered to be an informal activity. No natural features are removed and the natural state is undisturbed by technology. The vegetation is subject to trampling whose effects are:-

(i) Bruising of the vegatation - Most species are reduced in abundance or eliminated although some more resistant species may increase through competition. There is a reduction in the vegetation height and flowering frequency.

(ii) Compaction of the soil surface - This results in an increased potential for soil erosion and a decrease in the water-holding capacity of the soil profile.

(iii) Disturbance of the animal life - Certain species' numbers are reduced, often as a result of immigration. (Goldsmith, 1974)

The capability ratings given to the physiognomic vegetation types should consider the cover provided and the woody cover if this land characteristic is not measured. Those ratings given to the floristic vegetation should reflect the trampling resistance if this is known and the presence of particular habitats for game species.

The enjoyment derived from these informal activities is often negatively correlated with the population density which is governed by the accessibility of the land and the popularity of the activity. Thus, an upper limit is given to the number of roads and railways allowed and also to the number of powerlines since all these will also disturb the natural state of the land. The distance between land where these informal recreational activities are pursued and a township, is also a determinant of the potential population density in the former. However, distance is omitted as it is not a fundamental feature of the land. Its inclusion is necessary in the later stages of a land use plan.

Mountain Catchment Areas, industrial areas and lakes represent land which may not be utilized. Land within settlements and townships may be used provided that it is undeveloped.

(c) Water recreation - The recreation activities involved range from bird watching to motor-boat racing.

This land use type is concerned with the presence of a water body namely a river, a stream, a lake and a reservoir. Vleis are also included. The evaluation of this land use type basically involves an assessment of the water bodies present and their coverage as well as the presence of water game species. If each type of water body were evaluated as limiting land characteristics (Section 3.5.5) ie. a presence or absence only is of importance, the coverage of each would not be considered. Also, in the evaluation programme, the occurrence of only one limiting land characteristic outside the permissible limits will cause the whole land unit to have a capability of zero. For this land use type, such a rating is only to be given to land with no water of any type present. The required development of the adjacent land surface is considered by a combination of this land use type with either land use type (a) or (b) as described in Section 4.5. The capability rating for the physiognomic vegetation type considers the presence of vlei vegetation.

Recreation Land Use

A particular recreational activity under any of these land use types is a land use. The values of certain of the land characteristics given in Table 19 will be replaced by those applying specifically to the activity. Montgomery and Edminister (1966) list certain required land characteristic values for selected activities.

3.5.2 .8 Urban and Rural Development Land Use System

The construction of an engineering structure regardless of the resulting land degradation which may occur, is possible almost anywhere provided that the technology and finance are available. But land degradation is an important criterion of an ecological land evaluation and thus the concept that an engineering structure may be built anywhere regardless of land degradation, is not acceptable. Engineering constructions require a supply of construction aggregate obtained from natural rock. The presence of such material in the vicinity of a construction site is important as the transportation costs will increase the overall construction costs. However, the presence and capability of natural rock for this purpose is considered as a separate land use system or it would not be known whether the capability value for the land is due to its capability to support an engineering structure or to the presence of such construction aggregate.

Urban and rural development land use types may be described in terms of the function of the building. The major land use types are rural residential buildings, urban residential buildings, commercial buildings (including high rise residential buildings and shopping complexes) and industrial buildings. The construction of streets is important to Town Planning and it is considered as a separate land use type in the communications land use system. Only the accessibility of the land is included in these land use types given.

Table 20 lists the land characteristics, together with their optimum and permissible values, which are used in the evaluation of the land use types. It is assumed that the term 'soil' refers to soil material with a strength less than 700 kPa (Jennings et al, 1973). The management

Table 20 - The Optimum and Permissible Values of the Land Characteristics Evaluated for the Urban and Rural Development Land Use System

Land Characteristics	Unit	L A N D U S E T Y P E S							
		Rural Residential Building		Urban Residential Building		Commercial Building		Industrial Building	
		Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
LAND COVER									
Rock surface	%	0	<90	0	<90	0	<90	0	<90
Boulder cover	%	0	<25	0	<25	0	<25	0	<25
Lake	%	<50	<90	0	<90	0	<90	0	<90
Reservoir	%	<50	<90	0	<90	0	<90	0	<90
Vlei	%	n	<50	0	<90	0	<90	0	<90
* River	number	≤1	$\leq X_L$	0	$\leq X_L$	0	$\leq X_L$	0	$<X_L$
* Stream	number	≤1	$\leq X_L$	0	$\leq X_L$	0	$<X_L$	0	$<X_L$
RELIEF									
a.Hillslope element	class	6	1 or 4-6	6	1 or 4-6	6	1 or 5-6	6	1 or 6
Slope gradient	%	1-4	0,3-12	2-5	0,3-20	2-5	0,3-12	0,3-4	0,3-5
**Slope length	m	n	≥10	n	≥10	n	≥10	n	≥10
Aspect of a slope	degree	270-90	0-360	270-90	0-360	-	-	-	-
Height above water	m	≥10	≥10	≥10	≥10	≥10	≥10	≥10	≥10
Koppie	%	<50	<90	0	<90	0	<90	0	<90
Gully	%	0	<90	0	<90	0	<90	0	<90
GEOLOGY									
b.Stratigraphic unit	class		≤41		≤41		≤41		≤41
c.Transported soil origin	class	4	1-8	4	1-8	4	1-8	4	1-8
***Depth to bedrock	m	X_o	≥1,5	X_o	≥0,9	X_o	≥3	X_o	≥0,9
Geological discontinuities	code	0	≤1	0	≤1	0	≤1	0	≤1
Factor of safety		1,25-1,5	≤2	1,25-1,5	≤2	1,25-1,5	≤2	1,25-1,5	≤2
SOIL									
d. Soil horizon type	class	X_o	1-12	X_o	1-12	X_o	1-12	X_o	1-12
e. Soil erodibility index	class	≥6	≥2	≥6	≥2	≥6	≥2	≥6	≥2
f. Soil permeability index	class	2	≤3	2	≤4	2	≤4	2	≤4
***Depth to water table	m	X_o	≥2	X_o	≥1	X_o	≥3	X_o	≥1
Soil joint structure	code	0	n	0	n	0	n	0	n

Table 20 (contd.)

Land Characteristics	Unit	LAND USE TYPES							
		Rural Residential Building		Urban Residential Building		Commercial Building		Industrial Building	
		Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
Soil activity		0	< 2	0	< 2	0	≤2	0	<2
CLIMATE									
Wind velocity	$m\ s^{-1}$	<5	≤20	<5	≤20	<5	≤20	<5	≤20
Rainfall energy	Jm^{-2} a^{-1} $\times 10^{-3}$	0	≤30	0	≤30	0	≤30	0	≤30
BIOLOGICAL CHARACTERISTICS									
g. Physiognomic vegetation type	class	24-25	11-49	24-25	11-49	24-25	11-49	24-25	11-49
h. Floristic vegetation type	class								
Woody cover	%	< 50	< 100	0	≤100	0	≤100	0	≤100
MAN-MADE STRUCTURES AND BOUNDARIES									
Industrial area	%	0	< 90	0	< 90	0	< 90	-	-
* Powerline	number	0	$<X_L$	0	$<X_L$	0	$<X_L$	1	$\le X_L$
* Railway	number	0	$\le X_L$	0	$<X_L$	0	$\le X_L$	1	$<X_L$
* Paved road	number	1	$<X_L$	1	$<X_L$	1	$\le X_L$	1	$<X_L$
Mountain catchment area	%	0	< 90	0	< 90	0	<90	0	< 90
Wilderness area	%	0	<90	0	< 90	0	< 90	0	< 90
* Unpaved road	number	1	$\le X_L$	1	$<X_L$	1	$\le X_L$	1	$<X_L$

Note.

a. Classes described in Section 3.4.2
b. Values given in Tables 39-44. Classes described in Table 6.
c. Classes described in Table 9.
d. Classes described in Table 7. Values given by the user. No default table.
e. Classes described in Section 3.4.6.
f. Classes described in Section 3.4.7.
g. Classes described in Table 10.
h. Values given by the user. No default table.
* Default is 5.
** Default is 160.
*** Default is 30.

system involves the restoration of the land, upon the completion of the construction, by revegetation or the construction of pavements. Fertilizer and moisture applications are included in the former method of restoration and thus soil nutrient deficiencies and the climatic moisture limitations are overriden.

(a) Rural residential buildings - These buildings are normally less than three stories high and their siting depends upon the aesthetic appeal of the land. This social value is not a fundamental component of the land but is indicated by the presence of certain land features, eg. rivers, koppies, etc. These buildings are not necessarily within a municipal area and thus those within recreational areas, eg. rest camps, would be included here. The method of sewage disposal is via a septic tank. This land use type is mainly concerned with the physical features influencing the construction of a building, with the potential soil and slope failure of the land, the construction of the septic tanks and those features indicative of the aesthetic appeal of the land.

The functioning of a septic tank depends upon the percolation rate of the effluent into the surrounding soil. Since direct measures of percolation do not take into account long-term viability, nature of the effluent, etc. (Malan, 1964), the capability of a site with respect to percolation will be estimated as a function of soil texture and permeability indices. Soils of a moderate permeability are optimal since those with a low permeability do not allow for sufficient percolation while those with a high permeability do not allow for sufficient infiltration of the effluent.

Soils less than 1,5 metres deep and water tables less than two metres deep do not provide a sufficient depth for the leaching of the effluents and present obstacles to the construction of the tank itself (Kiefer, 1972). The effluent must not reach the ground water system as it will deliver excessive pathogens to this water supply. Hence the tank should not be situated on limestone or dolomite (Malan, 1964). Expansive soils are also problematic. Lands subject to flooding (0,3 per cent slope, Kiefer, 1972) are excluded since the effluent will contaminate the flood water, the tank may 'ride up' out of the ground and the land is difficult to drain (Lynch, 1971).

The outlet of the tank is near the ground surface. The tank should be situated on a slope as it is not possible to have a liquid level in the tank greater than 23cm below the ground level (Malan, 1964). Slopes greater than twelve per cent offer installation problems and the control of the effluent down the slope is difficult (Kiefer, 1972).

Railways and powerlines are inhibiting networks as they decrease the aesthetic appeal of the land. Industrial areas are non-usable as the aesthetic appeal has been degraded. Koppies, vleis, gullies and rock surfaces are not built on because of the engineering problems present. However, they are indicative of the aesthetic appeal of the land and are permitted within certain limits. Lakes, reservoirs and woody cover represent non-usable land surfaces with aesthetic appeal and this appeal of the vegetation is considered when awarding the capability ratings to the floristic vegetation types. The cover and woody cover, if the latter land characteristic is not measured, is reflected by the physiognomic vegetation type as is the presence of cultivated land which is non-usable. Gravel, boulder and woody cover are a hindrance to building construction and may be removed. The cost and difficulty involved will determine the limits above which such action would not be taken. The initial construction stage requires the removal of the natural vegetation and thus the soil erosion hazard by wind and water is increased.

The capability rating given to the stratigraphic unit may indicate a general, compressive, expansive, sub-soil erosion or any other type of soil failure hazard. Each hazard is represented by a different capability table (Table 39).

(b) Urban residential buildings - This land use type only differs from rural residential buildings in that the aesthetic appeal of the land is not considered and sewage works are present. The presence of vleis, rock surfaces, koppies, the floristic vegetation type, gullies and woody cover is evaluated in terms of the engineering problems that may be encountered and not with regard to any aesthetic appeal. Thus the permissible limits of these features are more stringent than those for the rural residential buildings. Shallow soils (0,9m) and water tables (less than one metre) limit the construction of the foundations (Little, 1978, personal communication). The construction of these buildings adjacent to industrial areas is not desirable due to noise and air pollution. Apart from these changes, the discussion for rural residential buildings is pertinent.

(c) Commercial buildings - These are high-rise, generally expensive buildings with basements. They may be built on more problematic sites than residential buildings as the finance is available to remedy some soil failure and unstable slope problems using sophisticated techniques. This land use type is mainly concerned with the physical features influencing building construction and with the potential soil and slope failure hazard.

Soil less than three metres in depth present obstacles to the construction of the basements (Blight, 1978, personal communication) while drainage problems arise if the water table is above this depth. A slope gradient exceeding five per cent offers a large restriction to the construction of these buildings but slopes of up to twelve per cent are still utilized (Kiefer, 1972). The discussion on urban residential buildings applies to commercial buildings with these modifications.

(d) Industrial buildings - These are usually single-storey buildings without basements, extending over a relatively large area. Industrial areas are not considered to indicate any degree of capability for the reasons given in Section 3.5.1.

Slopes of twelve per cent may be utilized (Kiefer, 1972) but since the cost of excavating such slopes to provide the relatively flat area needed is high, slopes below five per cent are preferred. Railways and powerlines are not inhibiting networks. Apart from these differences, the discussion on urban residential buildings is relevant.

Urban and Rural Development Land Uses

The construction of a particular building of known dimensions under any of these land use types requires a soil of known bearing capacity, etc. and is a land use. The values of certain land characteristics as given in Table 20 will be replaced by those applying specifically to the building.

?.5.2. .9 Communications Land Use System

A continuous corridor of land, even if it is nested between areas of totally incapable land for this land use system, is sufficient for the construction of a communication network for motorised or energy transportation ie. a power transmission line. Ideally this corridor should traverse the shortest distance between two points. For motorised transportation land uses it should also be over flat land to ensure maximum visibility and efficient engine performance. However, this is not often possible as insurmountable land features must be circumnavigated or spanned by bridges and flat land presents drainage problems. The location of bridging sites is not considered here as this is not a route but only a corridor selection. These sites are important in the selection of the final route and involve the financial considerations of the different types of bridge structures possible.

The major land use types are road construction and railway construction and transmission lines. Table 21 lists the land characteristics used in the evaluation of these land use types, together with their optimum and permissible values. The meaning of the term 'soil' and the management

Table 21 - The Optimum and Permissible Values of the Land Characteristics Evaluated for the Communications Land Use System

Land Characteristic	Unit	Road Construction		Railway Construction		Transmission Line Construction	
		Optimum	Range	Optimum	Range	Optimum	Range
LAND COVER							
Rock surface	%	0	<95	0	<95	0	<95
Boulder cover	%	0	<25	0	<25	-	-
Lake	%	0	<95	0	<95	0	<95
Reservoir	%	0	<95	0	<95	0	<95
Vlei	%	0	<95	0	<95	0	<95
* River	number	0	$<X_L$	0	$\leq X_L$	0	$<X_L$
* Stream	number	0	$<X_L$	0	$<X_L$	-	-
RELIEF							
a.Hillslope element	class	6	1 or 5-6	6	1 or 6	6	1 or >3
Slope gradient	%	0,3-1	0,3-8	0-2	<4	0,3-8	<45
Slope length	m	n	>10	n	≥10	-	-
Height above water	m	>10	≥10	≥10	≥10	≥10	≥10
Koppie	%	0	<95	0	<95	0	<95
Gully	%	0	<95	0	<95	0	<95
GEOLOGY							
b.Stratigraphic unit	class		<41		<41		<41
c. Transported soil origin	class	4	1-8	4	1-8	4	1-8
**Depth to bedrock	m	X_0	≥0,6	X_0	≥0,6	X_0	≥0,6
Geological discontinuities	code	X_0	≥1	X_0	≥1	X_0	≥1
Factor of safety		1,25-1,5	≤2	1,25-1,5	≤2	1,25-1,5	≤2
SOIL							
d.Soil horizon type	class	X_0	1-12	X_0	1-12	X_0	1-12
e.Soil erodibility index	class	≥6	≥2	≥6	≥2	-	-
f.Soil permeability index	class	2	≤4	2	≤4	2	≤4
**Depth to water table	m	X_0	≥1	X_0	≥1	X_0	≥1
Soil joint structure	code	0	n	0	n	0	n
Soil activity		0	≤2	0	≤2	0	≤2

system given for urban and rural development, is applicable here. The construction of any communication network for motorised transport involves the use of earth-moving vehicles, the dumping of construction aggregates and waste material from cut and fill operations, etc. These activities may occur over a distance of many kilometres and thus the area of land susceptible to degradation is far greater.

(a) Road construction - This land use type is mainly concerned with the physical land features influencing road construction and the potential soil and slope failure hazard.

An upper limit is given to the number of rivers and streams allowed as the potential number of bridges required, and consequently the overall construction costs are increased. Running costs increase with the slope gradient, particularly above eight per cent (Horak and du Toit, 1977). Flatter slopes are constructed by cut and fill operations which are expensive. Slopes less than o,3 per cent (Kiefer, 1972) present flooding hazards and drainage problems. The initial stage in the construction of a road involves the removal of the vegetation. This increases the potential for soil erosion and thus highly erodible soils are excluded.

Koppies, lakes, rock surfaces, settlements, gullies, townships, vleis, industrial areas and boulder and woody cover represent land which is not usable. The boulder and woody cover may be removed below a given limit dependent upon the cost to do so. The capability ratings given to the physiognomic vegetation types should consider the cover present and the woody cover if this latter land characteristic is not measured. The presence of paved roads, railways and powerlines will inhibit the utilization of the land as the available area to construct more of the same is decreased.

(b) Railway construction - The same comments apply here as to the land use type of road construction except that the slope gradient limitation is more stringent. Upgrades exceeding four per cent are non-economic for the running of a locomotive (Pfleider, 1968).

(c) Power transmission line construction - This land use type is mainly concerned with the physical land features influencing the construction of this network and with the potential soil failure hazard. An upper limit is given to the number of rivers permitted as these must be spanned and this will increase the construction costs. These costs are also increased by an increase in the slope gradient which hinders the construction of these networks as it limits the use of mechanical construction vehicles. Townships and settlements should not be traversed. Woody vegetation will be removed in the construction of these networks but the lower stories would remain and thus the soil erosion hazard is not evaluated. The cover present will be reflected in the phsysiognomic vegetation type as will be the woody cover if this land characteristic is omitted. An upper limit is given to the number of paved roads, railways and powerlines for the reason stated in (a).

Communication Land Uses

Motorways, highways, paved and non-paved roads carry different traffic densities, require different construction techniques, etc. Railways constructed for long distance haulage or commuter services also differ. Transmission lines may be of different types of cable. Thus, the construction of a particular road, railway or transmission line is considered as a land use. The given values of certain land characteristics in Table 21 will be replaced by those applying specifically to the land use.

3.5.2 .10. Excavation of Minerals and Construction Material Land Use System

These land use types may be described with regard to the presence of rock or mineral ore to be excavated and to the particular mine working which may be used. Both descriptions are accepted and thus the major land use types are mineral ore deposit, construction material, open pit mining, quarry and underground mines.

Borrow pits are a surface working for the excavation of soft, friable material which is used for its bulk. The quality of the material is important when used as a base course and sub-base (Brink, 1979, personal communication) but it is unimportant when used as fill (Martinson, 1979, personal communication). Since this working is not concerned with the crushing of solid rock after its excavation, it is not included in this land use system.

Mining activities render the land derelict, ie. unfit for other forms of land use, due to the mine dumps and the stripping operations. Thus, it is assumed that the management system of those land use types describing the mine working, involves the restoration and reclamation of the land.

Restoration is the recreation of the original topography and the re-establishment of the previous land use upon the cessation of the mining activities. Reclamation is any treatment which is not restoration (Down and Stokes, 1977). Both may include ..evegetation methods.

Table 22 lists the land characteristics used in the evaluation of these land use types, together with their optimum and permissible values.

(a) Mineral [illegible] it - The land use type is concerned with the [illegible] a mineral deposit which is a solid rock mass containing mineral ore. Its value, which is dependent upon its extent, its quality, the market value and the mining costs at that time, is not considered as the last ones are economic variables.

(b) Construction material - The presence and durability of natural rock which is crushed and used as road or concrete aggregate are important. Concrete aggregate which is mixed with cement should be chemically inert, durable, hard, roughly cubical in shape after crushing and capable of good adhesion with the cement paste (Fulton, 1964). Road aggregate should have similar properties except that there is a greater emphasis upon the properties of compaction and resistance to abrasion and weathering. The polishing properties are also important since the skidding hazard increases with high polishing (Sinclair, 1969). These differences in the required properties lead to differences in the required durability and capability of the rock. Thus, the use of aggregate in concrete or in road building are two distinct land uses.

Table 22 - The Optimum and Permissible Values of the Land Characteristics Evaluated for the Excavation Land Use System

Land Characteristic	Unit	LAND USE TYPE									
		Mineral Ore Deposit		Construction Material		Open Pit Mining		Quarry		Underground Mine	
		Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
LAND COVER											
Rock surface	%	-	-	100	>0	0	<100	100	>0	0	<100
Boulder cover	%	-	-	100	>0	0	<100	100	>0	0	<100
Lake	%	-	-	-	-	0	<100	0	<100	0	<100
Reservoir	%	-	-	-	-	0	<100	0	<100	0	<100
* Vlei	%	-	-	-	-	0	<90	0	<90	0	<90
* River	number	-	-	-	-	<1	$\leq X_L$	≤1	$\leq X_L$	≤1	$\leq X_L$
* Stream	number	-	-	-	-	≤1	$\leq X_L$	<1	$\leq X_L$	≤1	$\leq X_L$
RELIEF											
a. Hillslope element	class	-	-	-	-	5	1 or 3-6	4-5	1 or 3-6	6	1 or 4-7
Slope gradient	%	-	-	-	-	5-30	5-60	5-30	5-60	2-4	≤30
Slope length	m	-	-	-	-	n	>0	n	>0	n	>0
Height above water	m	-	-	-	-	≥10	≥10	≥10	≥10	≥10	≥10
GEOLOGY											
b. Natural rock group	class	-	-	7	1-9	-	-	7	1-9	-	-
Mineral ore deposit	code	n	≥1	-	-	n	≥1	-	-	n	≥1
** Depth to mineral ore deposit	m	-	-	-	-	0	$\leq X_L$	-	-	0	$\leq X_L$
** Depth to bedrock	m	-	-	-	-	-	-	0	$\leq X_L$	-	-
Geological discontinuities	number	-	-	-	-	0	≤1	0	≤1	0	≤1
Factor of safety		-	-	-	-	1,25-1,5	≤2	1,25-1,5	<2	1,25-1,5	≤2
Rock hardness	MPa	-	-	X_O	≥10	-	-	X_O	≥10	-	-
Secondary minerals	%	-	-	0	<100	-	-	0	<100	-	-
Ten per cent fines	kN	-	-	X_O	$> X_L$	-	-	X_O	$> X_L$	-	-
SOIL											
c. Subsoil texture	class	-	-	-	-	1	1-12	1	1-12	1	1-12
c. Topsoil texture	class	-	-	-	-	7	1-[illegible]	7	1-12	7	1-12
d. Soil erodibility index	class	-	-	-	-	≥6	≥3,5	≥6	≥3,5	≥6	≥2,5
e. Soil permeability index	class	-	-	-	-	4	≥1	4	≥1	4	≥1
**Depth to water table	m	-	-	-	-	n	≥0,5	n	≥0,5	n	≥0,5

Table 22 (contd.)

Land Characteristic	Unit	LAND USE TYPE									
		Mineral Ore deposit		Construction Material		Open Pit Mining		Quarry		Underground Mining	
		Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
<u>CLIMATE</u>											
Climate *N-factor*				<5	1-10	-	-	<5	1-10	-	-
Wind velocity	m s-1	-	-	-	-	<5	< 20	<5	≤20	<5	≤20
Rainfall energy	$Jm^{-2}a^{-1} \times 10^3$	-	-	-	-	0	<30	0	<30	0	<30
<u>BIOLOGICAL CHARACTERISTICS</u>											
f. Physiognomic vegetation type	class	-	-	-	-		11-49		11-49		11-49
g. Floristic vegetation type	class										
Woody cover	%	-	-	-	-	0	<100	0	<100	0	<100
<u>MAN-MADE STRUCTURE AND BOUNDARIES</u>											
Township	%	0	<100	0	<100	0	<90	0	<90	0	<90
Industrial area	%	0	<100	0	<100	0	<90	0	<90	0	<90
Settlement	%	0	<100	0	<100	0	<90	0	<90	0	<90
* Powerline	number	-	-	-	-	1	$\leq X_L$	1	$\leq X_L$	1	$\leq X_L$
* Railway	number	-	-	-	-	1	$<X_L$	1	$\leq X_L$	1	$\leq X_L$
* Paved road	number	-	-	-	-	1	$<X_L$	1	$\leq X_L$	1	$\leq X_L$
Mountain catchment area	%	0	<90	0	<90	0	<90	0	<90	0	<90
Wilderness area	%	0	<90	0	<90	0	<90	0	<90	0	<90
* Unpaved road	number	-	-	-	-	1	$<X_L$	1	$\leq X_L$	1	$\leq X_L$

<u>Note</u>

a. Classes described in Section 3.4.2.
b. Classes described in Table 53.
c. Classes described in Table 7.
d. Classes described in Section 3.4.6.
e. Classes described in Section 3.4.7.
f. Optimum values given in Table 54. Classes described in Table 10.
g. Values given by the user. No default table.
* Default is 5.
** Default is 160.
***Default is 100.

The selection of natural rock for construction purposes is based upon the economic situation and its durability which has been proven by experience or by appropriate tests (Fulton, 1964). The common tests are the ten per cent fines aggregate crushing text ie. the pressure required to reduce ten per cent of the sample to fines and the percentage of secondary minerals present (Weinert, 1968). The climatic conditions, represented by the climatic N-factor, indicate the durability of the rock at the excavation site which is assumed to be the same as that for the construction site.

(c) Open pit mine - This land use type is concerned with the presence of a mineral deposit, the safety of the mine and the degradation of the land surface. It is a mine working, open to the land surface, from which mineral ore is excavated. Any soil or non-mineral bearing rock overlaying the deposit is removed by stripping. Thus, although this form of mining is generally cheaper than underground mining, its environmental impact in terms of 'visual intrusion, noise and airblasts, vibration, air and water pollution and dereliction' is greater (Down and Stokes, 1977).

An objective of this particular type of mining is the removal of the mineral with minimum excess excavation. This is achieved by keeping the slope of the mining face as steep as is possibly consistent with safety (Sinclair, 1969). This gradient is determined by the cutting operation which is dependent upon the existing slope gradient and its inherent stability. The excavation depth required is important as it will determine the amount of stripping necessary.

Powerlines will provide the necessary power supply and rivers and streams the necessary water requirements which will compensate for the hindrance present regarding the accessibility of the mine once these land features must be bridged. The access to the mine is increased by the presence of a road or railway. All land characteristics are considered to be non-inhibiting networks. The mining operations will involve a removal of the vegetation. The physiognomic vegetation type will reflect the cover present and the woody cover if this latter feature is not measured.

(d) Quarry - A surface working for the excavation of natural solid rock to be used as construction aggregate is a quarry. The material removed is used for its structural strength (Martinson, 1979, personal communication). The above discussion of the open pit mine is pertinent. These working are generally not as extensive as those of an open-pit mine and the material removed is of comparatively low value.

(e) Underground mine - The presence of an ore, the safety of the mine and the degradation of the land surface are important to this land use type. The safety of the mine depends upon the faults present, the water table relative to the mineral ore deposit, the safety measures implemented and the direction and cutting of the mine shafts and passages. Thus, the first factors will only be indicative of the mine's safety. The discussion pertaining to the accessibility of the mine given under the open pit mine land use type is relevant.

Excavation Land Uses

The excavation of a particular mineral or natural rock with specific properties for use as road or concrete aggregate and the specification of a particular mining depth, slope safety, etc. are land uses. The values of particular land characteristics in Table 22 will be changed to these specifications.

3.5.2 .11 Water Catchment Land Use System

The conservation of water and not the land or living organisms is of concern in this land use system. Thus, it is distinct from the conservation land use system. Water is conserved by storing it in lakes, reservoirs, etc. and by conserving the water source itself so as to ensure the continued pr[illegible]ion of silt-free water. The initial construction costs of a reservoir are extremely high and the storage volume required depends upon the existing, forecast and potential water needs which are expressed in economic terms. Thus, the storage of the water will not be considered. However, the streamflow of the water catchment is a determinant of the storage volume required to secure the desired water yields with a degree of assurance (Wicht, 1971).

Only one land use type is present, ie. water catchment are and Table 23 lists the land characteristics, together with their optimum and permitted values, which are used in its evaluation. The management system involves soil conservation methods, eg. the maintenance of vegetation cover, and water conservation methods, eg. the control of the vegetation cover.

Table 23 - The Optimum and Permissible Values of the Land Characteristics Evaluated for the Water Catchment Land Use System

Land Characteristics	Unit	Land Use Type: Water Catchment	
		Optimum	Range
LAND COVER			
Lake	%	100	≥0
Reservoir	%	100	≥0
Vlei	%	0	≤100
RELIEF			
a. Hillslope element	class	2-3	≤6
Slope gradient	%	2-6	≥2
*Slope length	M	0	≥0
Gully	%	0	<100
SOIL			
b. Subsoil texture	class	7-8	1-12
b. Topsoil texture	class	a	1-12
c. Soil erodibility index	class	≥6	≥2,5
d. Soil permeability index	class	1	≤4
**Depth to water table	M	0	>0
**Exposed soil length	M	0	$<X_L$
CLIMATE			
Rainfall energy	$Jm^{-2}a^{-1}x10^3$	0	<30
Runoff total	$m^3km^{-2}x10^3$	≥10	≥1
BIOLOGICAL CHARACTERISTICS			
e. Physiognomic vegetation type	class		2-49
f. Floristic vegetation type	class		
Woody cover	%	0	<100

Land Characteristics	Unit	Land Use Type: Water Catchment	
		Optimum	Range
MAN-MADE STRUCTURES AND BOUNDARIES			
Industrial area	%	0	<100
Township	%	0	<100
Settlement	%	0	<100
***Railway	Number	0	$<X_L$
***Paved road	Number	0	$<X_L$
Mountain catchment area	%	100	≥0
***Unpaved road	Number	0	$\leq X_L$

Note

a Classes described in Section 3.4.2
b Classes described in Table 6.
c Classes described in Section 3.4.6.
d Classes described in Section 3.4.7.
e Optimum values given in Table 60. Classes described in Table 10.
f Values given by user. No default
* Default value is 160.
** Default value is 100.
***Default value is 5.

Water Catchment Area

Those natural features determining the streamflow from the land and its silt component are of importance. The streamflow results from the rainfall and is that remaining after evaporation and storage in the soil or upon the vegetation which intercepts the precipitation (Kruger and Wicht, 1976). It is either an overland flow or a flow through the soil to the stream channels and to the ground water supply. Owing to the difficulties of measuring the latter, the streamflow is equated with the run-off from the land. This same equation was adopted by Midgley and Pitman (1969). These authors calculated general mean annual run-off (MAR) for different catchment areas of the Republic, based on the precipitation, vegetation cover, geology, relief and soils at a regional scale. The vegetation cover is the main influencing factor upon the streamflow as it affects the volume of water intercepted and thus stored by the vegetation, the duration of and the volume vaporized from this storage and the evapotranspiration occurring (Wicht, 1971). In humid catchments, the mean annual streamflow is indirectly proportional to the plant biomass, all other factors being equal (Kruger and Wicht, 1976). The optimum vegetation cover is assumed to be that vegetating mountain catchment areas. This cover is mainly North Eastern Mountain Sourveld, Highveld Sourveld and Themeda-Festuca Alpine Veld (Nanni, 1976).

The capability ratings given to the physiognomic vegetation types should reflect the cover, the presence of vleis and the woody cover if this cover is not measured as a separate land characteristic. Gullies are non-usable.

surfaces due to the silting problem present. Industrial areas, townships and settlements, all of which are not natural land features, do not represent land which catches or stores water. Paved and unpaved roads and railways are inhibiting networks since the natural vegetation has been disturbed. These man-made structures do give clean run-off but as they are not natural land features, this aspect is not considered. A user may however include them by changing them to usable and non-inhibiting networks respectively.

Rowe and Colman (1965) state that two objectives of watershed management are:-

(a) To induce as much streamflow as possible to be fed by the sub-surface flow through the soil.

(b) To decrease the evaporative loss of water so as to increase the quantity of the water yielded by the land. Both these objectives depend on the soil moisture capacity for their fulfilment. Soil with a large capacity will provide a greater temporary storage from which the streams may be fed and also hinder the evaporation loss of the water. Thus the soil permeability index, the subsoil and topsoil textures and the depth to the water table must be evaluated.

Water Catchment Land Uses

A catchment area of particular requirements, ie. size, streamflow, etc. is a land use. The values of particular land characteristics in Table 23 will be changed as necessary.

3.5.2 .12 Dam Construction Land Use System

The siting of a dam is mainly dependent upon the economic and social resources which determine the required storage volume. This depends upon the particular demands for the water, eg. hydro-electrical power, irrigation schemes, water supply for a township, etc. (Wahlstrom, 1974). The land is only important in its provision of the water resources providing such a volume and of a damable site for it.

A potential dam site depends upon the geology of the land, the relief profile at that site, the construction material available, the finances, the techniques available, etc. (Wahlstrom, 1974) and an analysis of the streamflow to determine the storage volume needed to secure the required water yields at a desired degree of assurance (Midgley and Pitman, 1969). The geology of the site requires careful investigation before, during and after the construction of the dam since the reservoir is a cyclic, dynamic system with a constantly changing water level. New faults may arise due to the dam and reservoir load, leading to water seepage and possible dam failure at its foundations or abutments (Wahlstrom, 1974). Also, the failure of the slopes around the dam and reservoir may develop as the soil becomes wet (Caper and Cassie, 1976). The required strength of the land to sustain the dam depends upon the type and dimensions of the latter which are a function of the water demands and the dam site.

An evaluation for this land use requires a specific, detailed analysis of the land at particular locations in relation to the economic situation. Thus, a land evaluation of the fundamental land features without reference to the economic situation is invalid, ie. a land capability analysis is of little use and this land use system is omitted from this procedure.

3.5.3 The Foreclosure of Options in Land Use

The evaluation of a land use in isolation assumes that the land should be used for only one land use. Such an assumption is of course invalid and will readily result in the foreclosure of other future land use options. This is so particularly if the land use being studied changes, removes, 'ties up' the land resources, ie. renders them unavailable, or their restoration impossible or uneconomic. The probability of this occurring is greatest for the communication network, urban and rural development and dam construction land use systems.

The possible foreclosure of options in land use is included in the procedure to be performed when requested by the user. *Each land use system dependent on the natural* resources ie. agriculture, conservation, forestry, excavation, recreation and water catchment, is evaluated. Since the evaluation is at the land use system level, the results are a broad assessment of the capability of the land for each system. Only significant land characteristics are evaluated and their permitted range of values covers all the major land use types. The results for each land use system are printed separately. A more detailed evaluation is obtained if the land is evaluated for a particular land use or land use type within each land use system.

Table 24 lists the land characteristics chosen to evaluate each of the land use systems listed before, together with their optimum and permissible values. These

Table 24 - The Optimum and Permissible Values of the Land Characteristics for the Evaluation of the Foreclosure of Options in Land Use

Land Characteristic	Unit	LAND USE SYSTEM											
		Agriculture		Forestry		Conservation		Recreation		Excavation		Water Catchment	
		Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
LAND COVER													
Rock surface	%	0	<90	0	<90	-	-	-	-	100	>0	-	-
Lake	%	0	<90	0	<90	100	>0	100	>0	0	<90	100	>0
Reservoir	%	0	<90	0	<90	100	>0	100	>0	0	<90	100	>0
Vlei	%	0	<90	0	<90	100	>0	100	>0	0	<90	0	<100
*River	number	<1	$<X_L$	<1	$<X_L$	>1	$<X_L$	>1	$<X_L$	-	-	-	-
RELIEF													
a.Hillslope element	class	5-6	1 or >3	5-6	1 or >3	>4	<7	5-6	<7	4-6	1 or >3	2-3	<6
Slope gradient	%	0,5-4	<60	2-4	0,5-25	>12	<100	<4	<100	2-30	<60	2-6	>2
Height above water	m	>10	>10	>10	>10	-	-	-	-	-	-	-	-
Koppie	%	0	<90	0	<90	100	>0	-	-	-	-	-	-
Natural land feature	code	-	-	-	-	>0	>0	>0	>0	-	-	-	-
Gully	%	0	<90	0	<90	100	>0	0	<90	-	-	0	<100
GEOLOGY													
b.Natural rock group	class	-	-	-	-	-	-	-	-	7	1-9	-	-
Mineral ore deposit	code	-	-	-	-	-	-	-	-	n	>1	-	-
SOIL													
c.Subsoil texture	class	7-8	1-12	7-8	1-12	-	-	7-8	1-12	1	1-12	7-8	1-12
c.Topsoil texture	class	4	1-12	4	1-12	-	-	4	1-12	7	1-12	n	1-12
d.Soil erodibility index	class	>6	>2,5	>6	>2,5	<3,5	<8	>6	>2,5	>6	>2,5	>4	>2,5
e.Soil permeability index	class	4	>2	4	>2	-	-	4	>1	4	>1	1	<4
Rooting depth	m	>1	>0,25	>2	>0,9	-	-	-	-	-	-	-	-
**Exposed soil length	m	0	$<X_L$	0	$<X_L$	0	$<X_L$	-	-	-	-	-	-
Soil deficiency	code	0	<1	0	<1	-	-	-	-	-	-	-	-
Soil toxicity	code	0	<1	0	<1	-	-	-	-	-	-	-	-

Table 24 (contd.)

Land Characteristic	Unit	LAND USE SYSTEM											
		Agriculture		Forestry		Conservation		Recreation		Excavation		Water Catchment	
		Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range	Optimum	Range
<u>CLIMATE</u>													
Climatic N-factor		-	-	-	-	-	-	-	-	<5	1-10	-	-
Wind velocity	$m\ s^{-1}$	<5	<10	<5	<20	<5	<27	<5	<30	<5	<20	-	-
Rainfall total	$mm\ a^{-1}$ $\times 10^3$	>800	>2[illegible]	>1000	650-1200	-	-	-	-	-	-	-	-
Rainfall energy	$Jm^{-2}a^{-1}$ $\times 10^3$	0	<30	0	<30	0	n	0	<30	0	<30	0	<30
Runoff total	$m^3\ km^{-2}$ $\times 10^3$	-	-	-	-	-	-	-	-	-	-	>10	>1
<u>BIOLOGICAL CHARACTERISTICS</u>													
f. Physiognomic vegetation type	class		2-49		2-49		<49		2-48		11-49		2-49
g. Floristic vegetation type	class												
Woody cover	%	0	<100	0	<100	n	-	n	<100	0	<100	0	<100
Game species	code	-	-	-	-	-	-	n	>0	-	-	-	-
Protected plant species	code	-	-	-	-	n	>0	-	-	-	-	-	-
Animal host species	code	0	0	-	-	-	-	-	-	-	-	-	-
Protected animal species	code	-	-	-	-	n	>0	-	-	-	-	-	-
<u>MAN-MADE STRUCTURES AND BOUNDARIES</u>													
Township	%	0	<90	0	<90	0	<90	-	-	0	<90	0	<90
Industrial area	%	0	<90	0	<90	0	<90	0	<90	0	<90	0	<90
Settlement	%	0	<90	0	<90	0	<90	-	-	0	<90	0	<90
*Powerline	number	0	$<X_L$	0	$<X_L$	0	$<X_L$	0	$<X_L$	1	$<X_L$	-	-
*Railway	number	0	$<X_L$	0	$<X_L$	0	$<X_L$	<1	$<X_L$	1	$<X_L$	0	$<X_L$
Paved road	number	0	$<X_L$	0	$<X_L$	0	$<X_L$	<1	$<X_L$	1	$<X_L$	0	$<X_L$
Mountain catchment area	%	0	<90	0	<90	100	>0	0	<90	0	<90	100	>0
Wilderness area	%	-	-	-	-	100	>0	100	>0	0	<90	-	-

<u>Note</u>.

a. Classes described in Section 3.4.2.
b. Classes described in Table 37
c. Classes described in Table 6.
d. Classes described in Section 3.4.6.
e. Classes described in Section 3.4.7.
f. Optimum values given in Table 64. *Classes described in Table 10.*
g. Values given by the User. No default table.
* Default is 5.
** Default is 100.

values are a general requirement so that at least one land use type may be implemented on the land. The set of land characteristics chosen for the evaluation of each land use system depended upon their specificity, or that of their limit, for a land use system so that the evaluation concentrated upon those land conditions which were particularly necessary.

The soil erodibility and topographical conditions are important to all the land use systems considered. Industrial areas, townships and settlements represent developed land which may not be utilized by any of the land use systems ie. the future options in land use have been closed. The other conditions required for each system are:-

(a) Agriculture - Climatic and soil fertility conditions indicated by the rainfall total and rooting depth, soil toxicity and deficiency respectively. The physiognomic vegetation type will reflect the cover present while the floristic vegetation type may be used to indicate the possible dominant climatic conditions. A rocky surface, Mountain Catchment Areas, lakes and reservoirs, represent non-usable land.

(b) Forestry - Apart from different rainfall and rooting depth requirements, this is the same as (a).

(c) Conservation - The conservat[illegible] value of the land is represented by the protecte[illegible] resent and the floristic vegetation type which a[illegible]cates the wildlife habitats present. All networks are inhibiting except for rivers and streams, vleis, lakes, reservoirs and rocky surfaces are usable.

(d) Recreation - The land surface condition eg. presence of water bodies, and the presence of game species are important. The floristic vegetation type may indicate the presence of wildlife habitats. All networks are inhibiting except for rivers and streams.

(e) Excavation - The presence of natural rock and mineral deposits are important conditions. The physiognomic vegetation type indicates the cover present which would be removed by the excavation activities. All networks are non-inhibiting. Vleis, lakes and reservoirs are assumed to be non-usable land surfaces.

(f) Water catchment - The streamflow and soil conditions for infiltration are important ie. runoff total, presence of water bodies, soil texture and the permeability index. The physiognomic vegetation type may be used to reflect the possible cover. Unpaved and paved roads and railways are inhibiting networks.

3.5.4 The Interrelationships of the Land Characteristics

Land is a system of interrelated components and the relationships between the land characteristics must be considered when the land is evaluated. Owing to the lack of information in this field, it is possible to consider only a few major interrelationships, and even these have not been fully quantified. The two major land characteristics involved in each interaction are considered, one of which exerts a controlling influence upon the other. This control results in a modification of the measured field value of the latter, the degree of this modification being dependent on the measured field value of the controlling characteristic. It is an admittedly over-simplistic presentation of the interrelationships, but it has been adopted due to the lack of available information.

The major interrelationships identified and included in this procedure are:-

(a) Slope gradient and slope length - Runoff velocity and hence soil loss and the water catchment increases with both of these land characteristics. The soil moisture content is decreased as a result of the increased runoff. This interrelationship has been quantified for Zimbabwe (Elwell, [illegible]) where much research on soil erosion has been performed.

(b) Rainfall energy and the soil erodibility - Erodibility is a measurement of the texture, depth, permeability, organic matter and surface conditions of the soil in terms of the possible soil loss. It is thus a measurement of these interrelationships between the land characteristics according to their effect upon soil erosion. Elwell (1977) has shown that soil loss increases with the rainfall energy received and with the soil erodibility index.

(c) Climate and durability of the natural rock - The chemical weathering of natural rock, particularly that of crystalline acidic and basic rocks (Brink, 1978) predominate in regions where the Climatic N-value is less than five.

(d) The depth to the water table and the texture of the soil profile - The soil water capacity of the soil profile is greater for collodial than for non-collodial soils, due to the adsorption properties of the former. De Bruyn (1973) describes a water table as being relatively close to the surface at depths of less than six metres for clay, less than three metres for sandy-clay and le s than 1,5 metres for sand.

(e) The rooting depth and the texture of the soil profile - For the reason given in Section 3.4.7 a shallow clay soil will have more soil moisture and hence a greater effective rooting depth than a shallow sandy soil.

(f) Evaporation and rainfall - The evaporation measured by a Class 'A' evaporation pan is an indication of the sunlight duration and intensity. Land of dissimilar radiation but having the same rainfall, will have different evaporation rates and thus different soil moisture conditions. A study of the weather reports (S.A.W.B. 1975) indicated that the evaporation in the Transvaal exceeds the rainfall received for most areas.

It is very important that the effects of the 'controlling' land characteristics are not included twice *ie. in an interaction and independently.* This will give it a greater influence upon the overall land capability. However, if such a land characteristic has more than one effect which is not included in one or more interaction, then it must also be evaluated independently.

The following methods may be used to computerise an interrelationship:-

(a) The measurement of a composite land characteristic eg. the soil erodibility index.

(b) Their inclusion in the development of the capability graphs and tables. However, this was not feasible due to the availability of insufficient research information.

(c) A choice of several possible capability graphs and tables is made depending upon the measured field value of the controlling land characteristic. This would necessitate that a vast number of these graphs and tables be stored. As a consequence, the data storage required and the computer execution time to sort through and retrieve the required graph or table, would be increased. However, the inclusion of extra columns within a table to account for an interrelationship would not significantly increase the storage requirements.

(d) The modification of the measured land characteristic field value by the controlling land characteristic, prior to the rating of its capability.

(e) The modification of the capability rating itself. This will require knowledge of how the interactions exactly influence the capability. Very little, if any, research in this field has been performed, possibly due to a lack of previous concern and the very specific nature of such research ie. its dependence upon the land use as it is defined.

Method (d) does not require the knowledge mentioned in point (e). A certain amount of information, mainly qualitative, is available and can be used to modify the measured field value of the appropriate member of each pair of land characteristics given in the above six interrelationships. This is the chosen method. Method (a) is desirable as the computer time is decreased because no modification of any measured values is needed. However the research in this field to identify such land characteristics and to describe their measurement has not been performed. Method (c) is used for qualitative land characteristics for which an extra column in the relevant capability table is added.

The value of the modified land characteristic is changed by adding, subtracting, dividing or multiplying it by a factor whose value depends on the measured field value of the controlling characteristic. The value of the factor is obtained from graphs called factor graphs which relate the value of the control land characteristic to the value of the factor. The scale on the axis for the latter was derived to reflect the relationship between the pairs of interacting land characteristics as explained below for the six interactions:-

(a) The slope length is modified by the slope gradient. Information obtained from Figure 3 (Elwell, 1977), showed that the soil loss increase between a slope length of ten metres and 100 metres was 11,20, 6,10, 2,65, 1,00, 0,45 for slope gradients of twenty per cent, fourteen per cent, eight per cent, four per cent and one per cent respectively (Fig.3). The ratio between the first values is 25 : 14 : 6 : 3 : 1 and is the scale used on the y-axis of the factor graph (Fig.4).

The measured field value for the slope length is divided by the factor value obtained from factor graph 1 (Fig.4) so that its effective slope length and consequently its capability rating is reduced. This interrelationship accounts for the effect of the pair of characteristics upon soil erosion, soil drainage and the water catchment ie. streamflow. However, slope length also affects the manoeuvrability over the land, a long slope having more capability with respect to manoeuvrability than a short slope, while slope gradient affects the accessibility. Thus these two characteristics are evaluated further independently of one another.

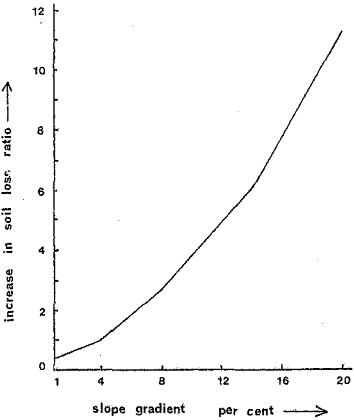


Fig.3 The increase in the soil loss ratio with slope gradient on slopes between 10m and 100m in length.

<u>Note</u>

Soil loss ratio is the ratio of soil lost from a crop with a certain crop cover to that of bare fallow (Elwell, 1977).

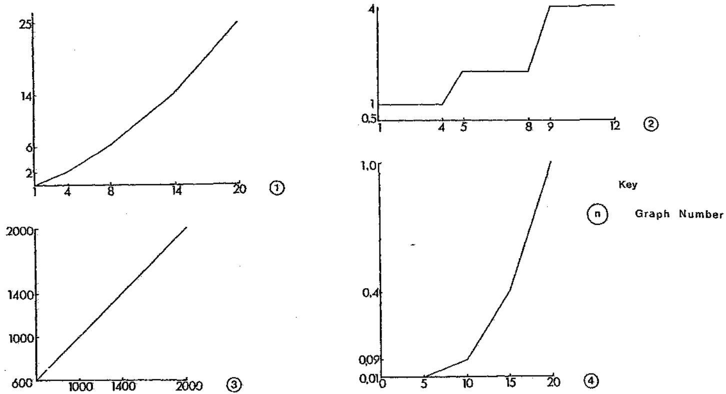


Fig.4 The factor graphs used for the interrelationship between the slope gradient and length, the subsoil texture and the rooting or water table depth, the rainfall and the evaporation and the rainfall energy and the soil erodibility index.

(b) The durability of the natural rock is modified by the Climatic N-value. Since the natural rock is a qualitative land characteristic, the capability rating given from the capability table (Table 49) will be chosen from one of two columns, depending upon whether the latter characteristic has a value above or below 5. The computerization of this choice is described later (Section 4.5).

(c) The depth to the water table is modified by the soil texture. The values quoted by De Bruyn (1973) give a ratio of 4:2:1 for clay : sandy clay : sand. A clay soil requires a water table depth four times that of a sand to be of an equivalent depth. Therefore the measured field value of the former land characteristic is divided by the value of the factor obtained from factor graph 2 (Fig.4). The soil texture considered is that of the subsoil or the soil horizon type depending on which is relevant to the land use being evaluated. The engineering behaviour of the soil horizon type is not considered in this interrelationship and thus it is also evaluated as an independent land characteristic.

(d) The rooting depth is modified by the subsoil texture. On the basis given in (c), a sandy soil has twenty-five per cent of the soil water capacity of a clay soil of the same depth. Thus its rooting depth is equivalent to 0,25 that of a clay soil. The measured field value of the rooting depth is multiplied by the factor value obtained from graph 2 (Fig.4). These two interrelationships do not account for the fertility of the subsoil. Therefore it is evaluated further as an independent land characteristic.

(e) The rainfall is modified by the evaporation. The evaporation is subtracted from the rainfall and the x and y axes of factor graph 3 have the same scale (Fig.4).

(f) The soil erodibility index is modified by the rainfall energy. Information obtained from Figure 1 in Elwell (1977), showed that the increase in soil loss between soil with a soil erodibility index of 4 and 9 respectively, was 2, 20, 86 and 230 t ha^{-1} a^{-1} for total rainfall energies of 5, 10, 15, 20 x 10^3 $Jm^{-2}a^{-2}$. (Fig.5) rat. between the first values is 1 : 10 : 43 :115 or 0,01 : 0,01 : 0,4 : 1 and is the scale used on the y-axis of the factor graph. The measured field value of the former land characteristic is modified by subtracting the factor value obtained from factor graph 4 (Fig.4).

3.5.5 The Analysis of the Land Characteristics for their Capability to Support the Land Use

A scale from 0 to 10 inclusive was chosen to represent increasing capability. Each land characteristic will have a rating along this scale with respect to its measured value and the land use being evaluated. A land characteristic has a capability rating of zero if its measured field value falls outside the permitted range of values. No further analysis of the land characteristic will occur. Every land characteristic is given a capability rating except in the following instances:-

(a) The effect of a certain land characteristic, defined as limiting land characteristics, on the overall capability of the land for a land use is assumed to be one of presence or absence. Provided that these characteristics are present within the required range,.

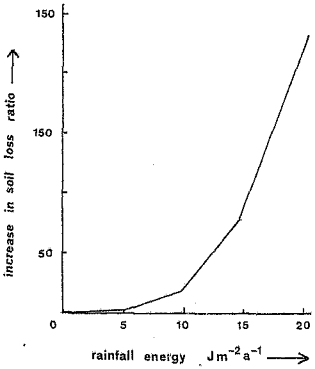


Fig.5 The increase in the soil loss ratio with rainfall energy on soils with a soil erodibility index between 4 and 9.

Note

Soil loss ratio is the ratio of soil lost from a crop with a certain crop cover to that of bare fallow (Elwell, 1977).

the land is capable of sustaining the land use with respect to them. The capability rating that would be derived for these characteristics is the same for all their values above their required range. If they are present outside of this range, the land is incapable of sustaining the land use. The whole land unit is given a capability of zero and no further analysis of its occurs eg. land adjacent to water and below a certain height is subject to flooding. Thus the height above water is evaluated as a limiting land characteristic.

(b) As mentioned previously (Section 3.5.4), 'controlling' land characteristics in an interrelationship will require no further analysis if their effect upon the overall capability of the land for the land use being evaluated has been completely considered by the interrelationship. For example evaporation modifies the rainfall. This is the only effect which it has upon the overall capability of the land and thus no further capability rating for it is required.

Soil texture affects the nutrient status as well as the effective depth of the soil profile. This former effect is neglected by both the interrelationships it is involved in (Section 3.5.4) and thus a further analysis of it independently is required.

The relationship between the qualitatively measured land characteristics and the capability scale is represented graphically. The optimum measured field values will have the highest capability ie. 10. The possible range of values between this and the permitted range of values is large. However, the advantage of this graphical representation is that the exact capability value for all these possibilities need not be known by the user as they may be determined directly in the computer from the graph. This is important if raw (ie. unclassified) data are to be used.

It was hoped that the graphical relationships incorporating the influence of any interrelationships with other land characteristics, would be obtainable from the literature or persons visited. However, for the majority of characteristics it was only possible to obtain a general graphical relationship with none incorporating any interrelationship. Most graphs are a simple linear relationship between the optimum and limiting values owing to a lack of detailed information. Thus it is realised that these graphs will be subject to future modification as this detailed information becomes available. The procedure allows for such modifications and Section 4.6.2 describes how this is done. In several instances, the relationship between the land characteristics measured field value and its capability was qualitatively described eg. 'high' rainfall, and this necessitated its interpretation into quantitative terms.

3.5.5 .1 The Analysis of the Usable and Non-usable Surface Area and the Inhibiting and Non-inhibiting Networks

The usable and non-usable surface area and the number of inhibiting and non-inhibiting networks within a grid cell is a function of the land use studied and the grid cell size. eg. water surfaces are non-usable to agricultural land uses but are usable and in fact necessary for water recreation. The set of land characteristics grouped as either usable and non-usable surface area and either inhibiting or non-inhibiting networks will thus depend on the land use.

The amount of usable land present is represented both by the land characteristic grouped as representing usable surface area and by those which are grouped as non-usable. To give both sets of land characteristics for a land use is thus repetition and for each land use system, only one set of land characteristics is included in the control data set (Section 4.4.2). This is the non-usable surface cover and will include both ground and water surfaces. All possible types of ground surfaces have not been included in the sets of land characteristics used to evaluate the land as this was unnecessary. All those representing non-usable ground surface cover have been included. For those land uses which require a water surface, the set of land characteristics for non-usable surface cover will not include all the ground surface. Thus, in these instances the usable surface area which is all water surfaces is given instead of the non-usable surface area.

The feasibility of utilizing a grid cell of a known capability is influenced by the area of usable land present. A capability rating derived for the amount of this area will not be a function of the land but of the selected grid cell size. A great advantage in being able to select different grid cell sizes is that the degree of detail captured in the overlay and thus evaluated, may be increased by choosing a cell size representing a smaller area of the land. The evaluation will be more sensitive to differences in the land due to the increased detail present in the data.

Any difference in the capability derived for the land between analyses using different grid cell sizes would also be due to the differing amounts of usable surface area. Thus the capability rating of the usable land present is unreasonable. A capability rating for the number of inhibiting networks which effectively decrease the usable surface area, is also unreasonable. Yet, the exclusion of these features will limit the usefulness of the capability results obtained. Therefore a map of the usable surface area remaining within a cell after the amount of inhibiting networks and non-usable surface area has been calculated, is printed.

The number of inhibiting networks must be converted to a surface area figure for its inclusion in this calculation. The number of these networks equivalent to a particular surface area coverage depends on the grid cell size which is a user variable and thus these values must be given by the user. Defaults are present as follows:-

>5	$\equiv$	100 per cent cover
4 - 5	$\equiv$	80 per cent cover
2 - 3	$\equiv$	40 per cent cover
1	$\equiv$	10 per cent cover.

Non-inhibiting networks become inhibiting above the permitted value given for the land use being studied, in which case the capability value derived for this group of land characteristics is zero. Below the permitted value, the derived capability value is 10. The same capability values are derived for those land characteristics grouped as usable land surface cover for those land uses requiring a land surface.

The advantage of the graphical representation does not apply to qualitatively measured land characteristics as the values recorded do not normally follow a numerical trend which can be graphically represented. Therefore capability tables are used in which each possible recorded value is given a separate capability rating. These tables may also be changed as more information becomes available.

It is assumed that the relationship between the measured field value of a land characteristic and the capability scale, are constant within a land use system. This is a reasonable assumption at present since insufficient information is available to indicate the differences between the land use types. However, it is hoped that this situation will change and enable these differences to be incorporated into the procedure, thus increasing its sensitivity. This will compensate for the possible loss in execution speed resulting from the increased number of graphs and tables which will need to be retrieved.

3.5.6 The Capability Graphs and Tables

For a full understanding of the graphs (Figs. 6 - 14 and Tables 25 - 60) Section 3.5.2.4 - 3.5.3 must be referred to.

Three groups of capability graphs are present:-

(A) The scale of the x-axis is common to all the land use types within the land use system.

(B) The scale of the x-axis varies between the land use types owing to differences in the permitted range and optimum values. Each difference is treated as a separate graph which is identical in shape and number of points. This is important as certain steps in the computer program require that this be so.

(C) The optimum or the end point of the x-axis, or both are given by the user, because the specific values are dependent on the particular land studied and other variables eg. economic variables. Default values have been included (Section 4.4.2) and are given in the Figures. A fourth group exists which is a combination of Groups B and C.

The capability graphs and tables used in the evaluation of each land use system are given in Figs. 6-14. and Tables 25-60 respectively. The capability ratings given in certain tables are completely dependent upon the situation present and are thus not given a default table in this dissertation. The tables concerned are indicated in Tables 62-70. The definitions of each land characteristic is repeated below for easier reference and a clearer understanding of these graphs and tables. The considerations used in their development are briefly described:-

(a) <u>Land Cover and Man-made Structures and Boundaries</u>

Rock surface Lake Reservoir Township Industrial area	The presence of usable and non-usable land surface. Either effect increases with their coverage. For the former, the capability is 10.

Settlement National park Provincial park Municipal park Private park Mountain Catchment Area Wilderness area	The presence of usable and non-usable land surface. Either effect increases with their coverage. For the former, the capability is 10.

Vlei - A waterlogged condition and non-usable land for most land uses. These effects increase with its coverage.

Boulder cover Gravel cover Rocky distribution	The manoeuvrability over the land is reduced while land preparation methods are hindered with an increase in these values.

River Stream Powerline Railway Paved road Unpaved road	The accessibility of the land, the possibility of its dissection into smaller units and the removal of usable land increases with the number present.

(b) <u>Relief</u>

Hillslope element Slope gradient Slope length	The surface runoff increases with slope gradient and length. Thus soil erosion and water catchment increases while soil infiltration and the probability of waterlogging decreases. Manoeuvrability and accessibility also decrease.

Aspect of a slope - North-facing slopes receive more solar radiation than south-facing slopes.

Height above water - The probability of flooding is present below ten metres.

Koppie - The manoeuvrability and accessibility of the land is low. The land is non-usable for most land use and this effect increases with its coverage.

Natural land feature - The presence of a desirable or undesirable feature. This effect depends on the type present.

Gully - The land is vulnerable to soil erosion and is non-usable for most land uses. These effects increase with its cover.

(c) Geology

Stratigraphic unit Transported soil origin	The soil failure hazard depends on their values
Natural rock group	The durability depends upon the particular group.
Mineral ore deposit	The presence of a desirable land feature and this desirability depends on the type present.
Depth to mineral ore deposit Depth to bedrock	The excavation costs increase with depth. Also the ease of constructing foundations and soil strength increases with the bedrock depth.

Geological discontinuity - The potential soil failure hazard is a function of the type present.

Factor of safety - The safety of a slope increases above a value of 1.

Rock hardness - The durability increases with their value.

Secondary minerals - The durability decreases with their increase in value

(d) Soil

Subsoil texture - The water movement through the soil profile and the cation exchange capacity depends on its value.

Topsoil texture - The soil infiltration and thus soil erosion and streamflow, and the cation exchange capacity depends on its value.

Soil horizon type - The water retention and thus soil failure hazard depends on its type.

Soil erodibility index - The potential soil loss decreases with an increase in its value.

Soil permeability index - The water infiltration and movement through the soil profile increases with its value.

Rooting depth - The limitation to root extension decreases and water capacity increases with depth.

Depth to water table - The ease of foundation construction, soil strength and the water holding capacity increases with depth.

Exposed soil length	- The soil erosion hazard increases with length
Soil joint structure	- The potential soil failure hazard is a function of the different types present.
Soil activity	- The soil failure hazard increases with activity.
Soil salinity Sodium adsorption ratio	- The soil salinity hazard increases with an increase in their values.
Soil deficiency Soil toxicity	- The presence of an undesirable land condition and this effect depends on the different types present.
Soil pH	- The soil fertility depends on its value.
Soil cation exchange capacity	- The soil fertility increases with an increase in its value.
Soil organic matter	- The soil fertility, infiltration and water retention increase with it.

(e) Climate

Climate N-factor	- The durability of natural rock is greater above the value of 5.
Wind velocity	- The damage to vegetation and man-made structures and the potential soil loss increases with wind velocity.
Frost temperature January temperature July temperature	Limiting temperatures to plant growth.

Fruiting season length Season length	- The probability of economic produce increases with their length.
Season quality Rainfall total Water deficit period	- The limitation to plant growth decreases with their increased value
Rainfall energy Runoff total	- The surface runoff and thus soil erosion and water catchment increase while soil infiltration decreases with increases in their value.

(f) <u>Biological Characteristics</u>

Physiognomic vegetation type	- The possible cover and climatic conditions present depend on its type.
Floristic vegetation type	- The possible presence of desirable and undesirable species, and climatic conditions depends on its type.
Woody cover Woody distribution	- The manoeuvrability over the land is reduced while land preparation methods are hindered with increases in their values.
Game species Protected plant species Animal host species Protected animal species	- The presence of undesirable or desirable species and this effect is a function of the types present.

The land characteristic definitions given below describe whether the consideration of the land characteristic as a usable or non-usable surface area or an inhibiting or non-inhibiting network is pertinent (*Section 3.5.5.1*), the units of measurement used in the capability analysis procedure and the manner of deriving the capability rating. Unless otherwise stated, the capability rating of each land characteristic is derived from a capability graph. Where reference is made to numerical codes, these are derived by the user himself if they have not already been developed for the resource inventory used. The spatial distribution of all the land characteristics must be recorded in their measurement eg. the area boundary within which a protected species is found is measured and stored as the geo-reference for that particular species whose name and numerical code are stored in the data string.

(a) Land Cover

The percentage area within a grid cell is calculated for the following which are treated as either usable or non-usable surface areas:-

Rock surface - the land surface covered by an exposed rock surface.

Boulder cover - the land surface covered by rock fragments greater than 25 cm in diameter.

Gravel cover - the land surface covered by rock fragments between 2 and 25 cm in diameter.

Lake - the land surface covered by a natural or man-made lake in which the water is held by a non-earthwork dam. The name and numerical code are stored.

Reservoir - the land surface covered by water held behind an earthwork dam. The name and numerical code are stored.

Vlei - an ill-drained land surface.

Rocky distribution - the distribution of the boulder cover. Indicated by '1' for a single clump; '2' for scattered clumps; and '3' for a scattered distribution.

The number within a grid cell is calculated for the following which are treated as either inhibiting or non-inhibiting networks:-

River - the presence of a river whose name and numerical code is stored.

Stream - the presence of a stream.

(b) Relief

Hillslope element - a particular component of a hillslope, indicated by a class number (Section 3.4.2). The capability is derived from a capability table.

Slope gradient - the percentage steepness of a slope.

Slope length - the length of a constant slope gradient in metres.

Aspect of a slope - the direction in which a slope faces. Measured in degrees from true north.

Height above water - the vertical distance in metres above a lake, reservoir, river or stream. This is a limiting land characteristic.

Natural land feature - the presence of a natural land feature with aesthetic or conservational value. A name and numerical code are stored.

For the following, the percentage cover within a grid cell is calculated and they are treated as either usable or non-usable surface areas:-

Koppie - the land surface covered by a boulder-strewn hillock.

Gully - the land surface covered by a water-worn channel.

(c) Geology

Stratigraphic unit - a particular succession of rock types. A name and numerical code are stored (Table 8). A capability table is used to derive the capability rating for each type with respect to the general or a particular soil failure hazard eg. sub-surface erosion.

Transported soil origin - the landscape position of soil which has been transported by a natural agent in recent geological times. A name and numerical code for each type of origin are stored (Table 49). A capability table is used to derive the capability ratings.

Natural rock group - a natural rock group as classified by Weinert (1969) and the class number is stored. A capability table is used.

Mineral ore deposit - the presence of underlying mineral ore-bearing rock. A name and a numerical code for each mineral type is stored. A capability table is used.

Depth to the mineral ore deposit - the distance in metres from the ground surface to the underlying mineral ore-bearing rock.

Depth to the bedrock - the distance in metres from the ground surface to the underlying bedrock.

Geological discontinuity - a plane of weakness eg. a fault or a fracture in the bedrock. A name and a numerical code signifying the nature of the weakness is stored. A capability table is used.

Factor of safety - the ratio of the strength of a soil or rock slope to the disturbing forces.

Rock hardness - the unconfined strength of a rock measured in M Pascals.

Secondary minerals - the percentage of secondary minerals in a rock sample seen under the microscope.

Ten per cent fines test - the pressure in kN which must be applied to a rock to reduce ten per cent of it to fines.

(d) Soil

Subsoil texture - the soil texture of each horizon below the topsoil and within 150 cm of the soil profile. The textural class as defined by MacVicar et al (1977) is recorded together with the relevant class number (Table 6). A capability table is used.

Topsoil texture - the soil texture of the topsoil. The textural class as defined by MacVicar et al (1977) together with the relevant class number (Table 6) is stored. A capability table is used.

Soil horizon type - the soil textural class as described by Jennings et al (1973)(Table 7). A capability table is used.

Soil erodibility index - the potential

erodibility of exposed soil as determined by Scotney (1977), indicated by a number (Section 3.4.6).

Soil permeability index - the potential ease of water movement through the dominant soil series of the unconsolidated soil, indicated by a number (Section 3.4.7).

Rooting depth - the distance in metres from the ground surface to consolidated material or the water table should this be above the former.

Depth to the water table - the distance in metres from the ground surface to that level at which all the soil or rock is saturated.

Exposed soil length - the length in metres of bare, previously eroded soil.

Soil joint structure - the presence of joints in a soil horizon. A numerical code and name for the type of joint (Jennings et al, 1973) is stored. A capability table is used.

Soil activity - the ratio of the plasticity index to the percentage clay fraction for a soil horizon.

Soil deficiency - the presence within the topsoil of a plant nutrient at an insufficient concentration to support plant growth. The name and code of the nutrient is stored. This is a limiting land characteristic.

Soil toxicity - the presence within the topsoil of a chemical or plant nutrient at a concentration toxic to plant growth. The name and code are stored. This is a limiting land characteristic.

Soil salinity - the electrical conductivity in mS m^{-1} within the topsoil.

Soil pH - the hydrogen ion concentration in the top soil.

Sodium absorption ratio $= \dfrac{Na^{+}}{\dfrac{Ca^{2+} + Mg^{2+}}{2}}$ in mel^{-1} in water

Soil cation exchange capacity - the total amount of exchangeable cations in me per cent within the top soil determined by leaching with either 1NKCl or 0,1N$BaCl_2$.

Soil organic matter - the percentage organic matter in the topsoil.

(e) Climate

Climatic N-factor - the value of the climatic weathering zone defined by Weinert (1978). It is a 'controlling' land characteristic which is not awarded a capability rating.

Wind velocity - the mean wind velocity in m s^{-1} for the months of September to November inclusive.

Frost temperature - the mean annual lowest frost temperature in degrees centigrade.

The following limiting land characteristics:-

(a) January temperature - the mean daily maximum January temperature in degrees centigrade.

(b) July temperature - the mean daily maximum July temperature in degrees centigrado.

Hail occurrence - the mean number of days with hail per annum.

Fruiting season length - the mean length in days of the frost free period.

Season length - the mean time period in days during which above ten per cent of the annual rainfall is received.

(6) Season quality - the mean number of rainy pentades within the season length.

(7) Water deficit period - the mean annual time period during which the evaporation exceeds the rainfall or the water deficit period shown in a climagram.

(8) Evaporation - the mean annual evaporation from a Class 'A' evaporation pan measured in mm a^{-1}. This 'controlling' land characteristic is not given a capability rating.

(9) Rainfall total - the mean annual precipitation measured in mm a^{-1}.

(10) Rainfall energy - the mean annual rainfall energy measured in $Jm^{-2}a^{-1}$.

(11) Runoff total - the mean annual surface runoff measured in $m^3 \cdot km^{-2}$. The conversion of morgan feet mile $^{-2}$ to $m^3 km^{-2}$ is 8 565,180 x 0,346 (Survey Department 1979, personal communication).

(f) Biological Characteristics

The name and numerical code are stored for the vegetation types whose capability is de...ved from a capability table.

Physiognomic vegetation type - the vegetation stype or subtype classified by Greenway (1973).

Floristic vegetation type - the vegetation type classified by Acocks (1975).

Woody cover - the land surface covered by a woody canopy. The percentage covered in a grid cell is calculated and treated as either a non-usable or a usable surface area.

Woody distribution - the distribution of the woody cover as recorded for rocky distribution.

The name and code for the following are stored and a separate capability table for each is used.

Game species - a higher animal species listed as ordinary game in the Transvaal Provincial Ordinance No.17.

Protected plant species - a higher plant species listed as specially protected, rare or endangered in the Transvaal Provincial Ordinance No.17.

Animal host species - a higher animal species acting as a host for a pathogen.

Protected animal species - a higher animal species not listed as pests or ordinary game in the Transvaal Provincial Ordinance No.17.

(g) Man-made Structures and Boundaries

The percentage covered within a grid cell is calculated for the following land characteristics which are treated as either a non-usable or a usable surface area.

Township - the land surface covered by the non-industrial section of a town, city or a group of buildings larger than a settlement. The name and numerical code for the township are recorded.

Industrial area - the land surface covered by industry.

Settlement - the land surface covered by a group of buildings.

National park - the land surface covered by a nature reserve managed by the National Parks Board. The name and numerical code are stored.

Provincial park - the land surface covered by a nature reserve, managed by a Provincial authority. The name and a numerical code are stored.

Municipal Park - the land surface covered by a nature reserve managed by a municipal authority. The name and a numerical code are stored.

Private park - the land surface covered by a nature reserve managed by a private authority. The name and a numerical code are stored.

Mountain Catchment Area - land declared as such under the Mountain Catchment Area Act of 1970, or unforested land within state managed forest land. The name and a numerical code are stored.

Wilderness area - land declared as such under the Amended Forest Act, 1971. The name and a numerical code are stored.

The number of each of the following land characteristics within a grid cell is calculated and they are treated as inhibiting or non-inhibiting land characteristics.

Powerline - the presence of a high voltage transmission line.

Railway - the presence of a main or tributary railway line.

Paved road - the presence of a paved road.

Unpaved road - the presence of an unpaved road with drains.

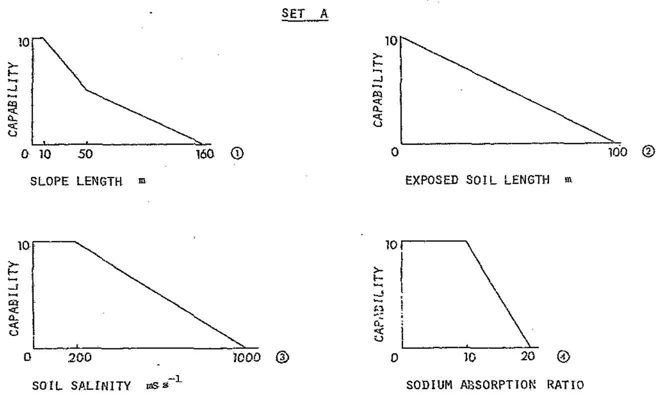


Fig.6 The capability graphs used to analyse the land's capability to support an Agricultural Land Use.

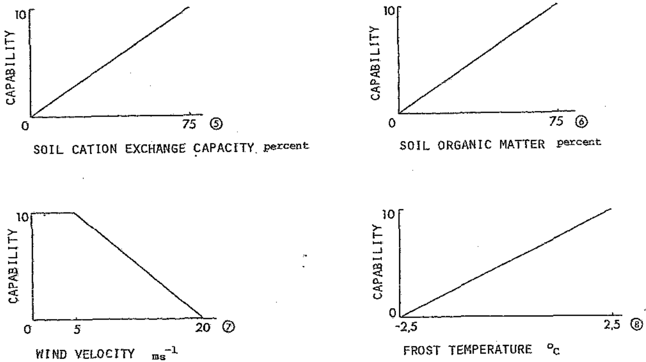

CAPABILITY
10
0
75 ⑤
SOIL CATION EXCHANGE CAPACITY percent
CAPABILITY
10
0
75 ⑥
SOIL ORGANIC MATTER percent
CAPABILITY
10
0
5
20 ⑦
WIND VELOCITY ms-1
CAPABILITY
10
0
-2,5
2,5 ⑧
FROST TEMPERATURE °C

Fig.6 (contd.)

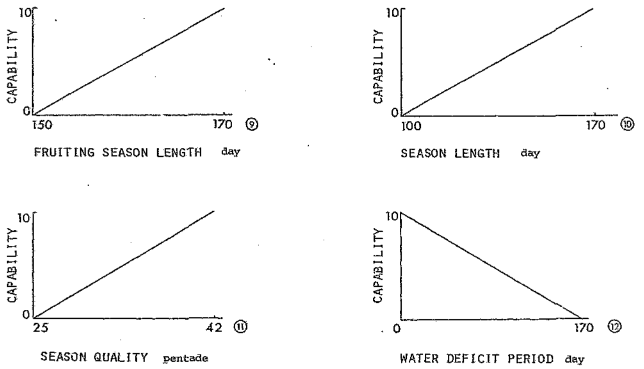

10
CAPABILITY
0
150
170
⑨
FRUITING SEASON LENGTH day
10
CAPABILITY
0
100
170
⑩
SEASON LENGTH day
10
CAPABILITY
0
25
42
⑪
SEASON QUALITY pentade
10
CAPABILITY
0
170
⑫
WATER DEFICIT PERIOD day

Fig.6 (contd.)

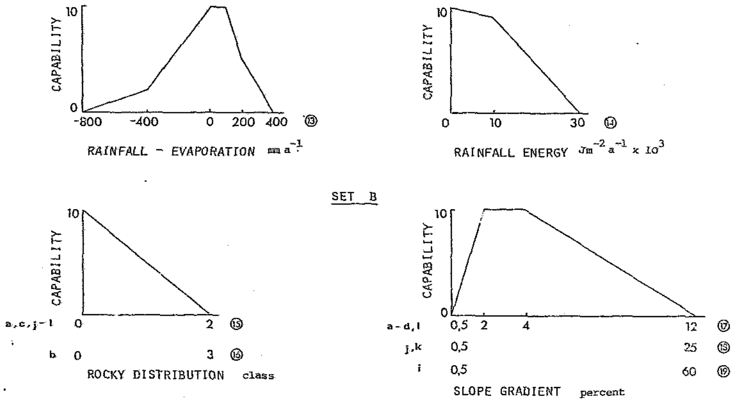

CAPABILITY
10
0
-800 -400 0 200 400 ⑬
RAINFALL - EVAPORATION mm a^{-1}
CAPABILITY
10
0 10 30 ⑭
RAINFALL ENERGY Jm^{-2} a^{-1} x 10^{3}
SET B
CAPABILITY
10
a,c,j-l 0 2 ⑮
b 0 3 ⑯
ROCKY DISTRIBUTION class
CAPABILITY
10
0
a-d,l 0,5 2 4 12 ⑰
j,k 0,5 25 ⑱
i 0,5 60 ⑲
SLOPE GRADIENT percent

Fig.6 (contd.)

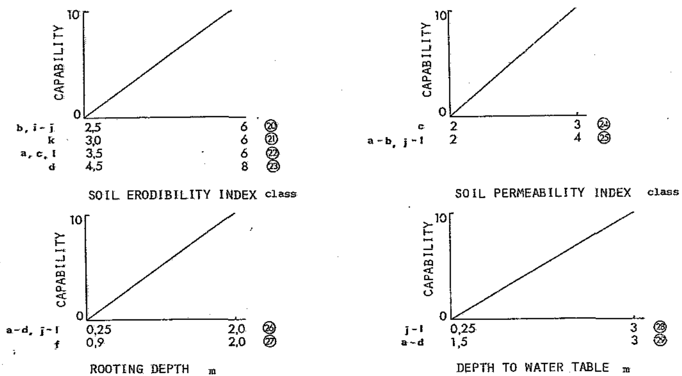
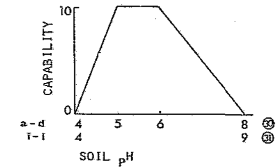
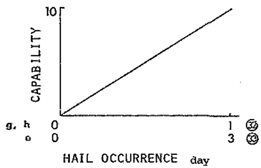

CAPABILITY
10
0
b, i-j 2,5 6 20
k 3,0 6 21
a, c, l 3,5 6 22
d 4,5 8 23
SOIL ERODIBILITY INDEX class
CAPABILITY
10
0
c 2 3 24
a-b, j-l 2 4 25
SOIL PERMEABILITY INDEX class
CAPABILITY
10
0
a-d, j-l 0,25 2,0 26
f 0,9 2,0 27
ROOTING DEPTH m
CAPABILITY
10
0
j-l 0,25 3 28
a-d 1,5 3 29
DEPTH TO WATER TABLE m

Fig.6 (contd.)





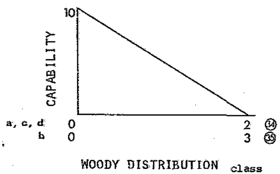


Fig.6 (contd.)

KEY

n - Graph number n
a - Farming land
b - Pit prepared land
c - Sprinkler irrigation
d - Surface irrigation
e - Summer season cropping
f - Winter season cropping
g - Subtropical Biennial/Perennial crops
h - Temperate Biennial/Perennial crops
i - Natural veld pasture
j - Veld reclaimed pasture
k - Veld reinforced pasture
l - Veld replaced pasture

Table 25 - The Capability Ratings of the Hillslope Elements for the Agriculture Land Use System

Land use type	Code	HILLSLOPE ELEMENT						
		Crest	Waxing slope	Free face	Talus	Upper pediment	Lower pediment	Valley bottom
		1	2	3	4	5	6	7
Farming land	1	5	0	0	0	5	10	5
Pit prepared land	2	5	0	0	3	10	10	5
Sprinkler irrigation scheme	3	5	0	0	0	5	10	5
Surface irrigation scheme	4	5	0	0	0	0	7	10
Natural vegetation pasture	9	5	0	0	0	5	10	5
Veld reclaimed pasture	10	5	0	0	0	5	10	5
Veld reinforced pasture	11	5	0	0	0	5	10	5
Veld replaced pasture	12	5	0	0	3	5	10	5

Table 26 - The Capability Ratings of the Subsoil Texture Classes for the Agriculture Land Use System

Land use type	Code	SUBSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Farming land Pit-prepared land Sprinkler irrigation scheme Surface irrigation scheme	1) 2) 3) 4)	1	5	4	5	6	7	10	10	8	8	7	6
Winter season cropping	6	0	0	0	0	0	0	10	10	8	8	7	6
Natural vegetation pasture Veld reclaimed pasture Veld reinforced pasture Veld replaced pasture	9) 10) 11) 12)	1	5	4	5	6	7	10	10	8	8	7	6

Note

The moisture regime ie. ability to take up moisture, store and release it (Crafford and Nott, 1972) is considered when assigning the capability values.

Table 27 - The Capability Ratings of the Topsoil Texture Classes for the Agriculture Land Use System

Land use type	Code	TOPSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Arable land	1)												
Pit-prepared land	2)	5	5	5	10	9	9	8	5	4	4	3	3
Sprinkler irrigation scheme	3)												
Surface irrigation scheme	4	0	4	4	6	7	8	10	9	8	8	7	6
Winter season cropping	5	0	0	0	0	0	0	10	10	8	8	7	6
Natural vegetation pasture	9)												
Veld reclaimed pasture	10)	5	5	5	7	7	7	9	6	4	4	3	3
Veld reinforced pasture	11)												
Veld replaced pasture	12)												

Note

Rainfall infiltration, soil erodibility and resistance to trampling are considered where appropriate when assigning the capability ratings.

Table 28 - The Capability Ratings of the Physiognomic Vegetation Types for the Agricultural Land Use System

Land Use Type	Code	VEGETATION TYPE CODES																									
		2	3	4	5	6	7	8	9	11	12	13	14	15	17	18	19	20	24	25	[illegible]	41	44	45	47	48	49
Farming land Pit-prepared land	1) 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	[illegible]	[illegible]	10	10	10	10	7	7	0	0	10
Sprinkler irrigation scheme Surface irrigation scheme	3) 4)	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	7	7	10	10	10	10	7	7	7	10	10
Summer season cropping Winter season cropping	5) 6)	10	10	3	3	0	0	0	0	7	7	7	7	7	10	10	10	7	5	10	5	5	5	5	0	0	0
Sub-tropical biennial/ perennial crops	7	10	10	3	3	0	0	0	0	7	7	7	7	7	5	5	5	5	1	0	1	0	0	0	0	0	0
Temperate biennial/ perennial crops	8	0	10	3	3	0	0	0	0	7	7	7	7	7	5	5	3	5	5	5	5	0	0	0	0	0	0
Natural vegetation pasture	9	0	0	0	0	0	0	0	0	5	5	5	5	5	10	10	10	10	10	10	7	1	1	1	1	1	0
Veld reclaimed pasture Veld reinforced pasture Veld replaced pasture	10) 11) 12)	0	0	0	0	0	0	0	0	1	1	1	1	1	10	10	10	7	10	10	7	1	1	1	0	0	0

Note Vegetation type names and codes given in Table 10.
The possible woody cover and general climatic conditions are mainly considered when assigning the capability ratings.

SrT A

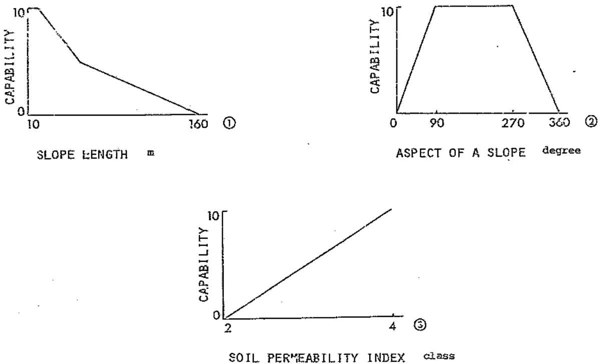


Fig.7 The capability graphs used to analyse the land's capability to support a Forestry Land Use.

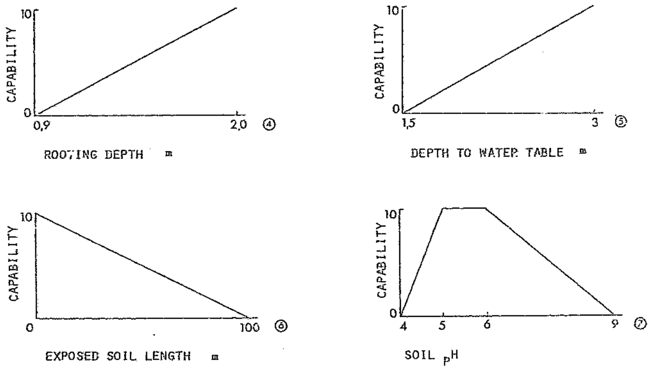

CAPABILITY
10
0
0,9
2,0
④
ROOTING DEPTH m
CAPABILITY
10
0
1,5
3
⑤
DEPTH TO WATER TABLE m
CAPABILITY
10
0
100
⑥
EXPOSED SOIL LENGTH m
CAPABILITY
10
0
4
5
6
9
⑦
SOIL pH

Fig.7 (contd.)

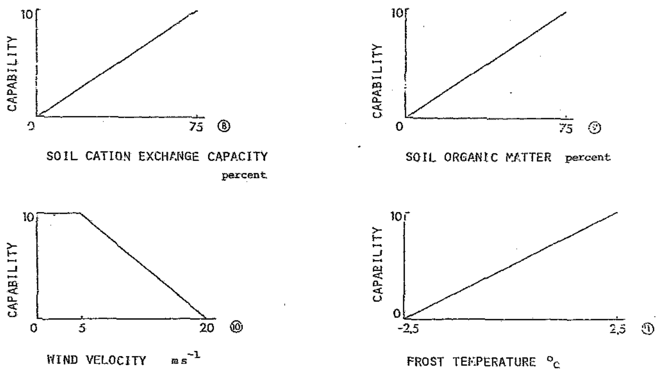
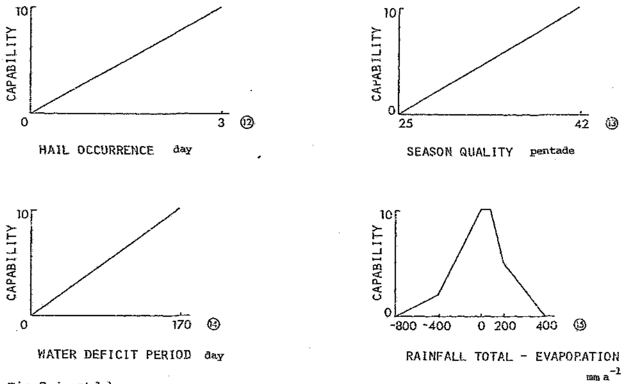

CAPABILITY
10
0
75
8
SOIL CATION EXCHANGE CAPACITY percent
CAPABILITY
10
0
75
9
SOIL ORGANIC MATTER percent
CAPABILITY
10
0
5
20
10
WIND VELOCITY m s-1
CAPABILITY
10
0
-2,5
2,5
11
FROST TEMPERATURE °C

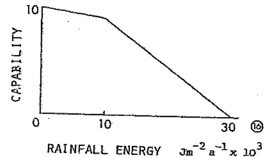
Fig.7 (contd.)

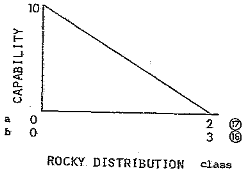


10
CAPABILITY
0
3
⑫
HAIL OCCURRENCE day
10
CAPABILITY
0
25
42
⑬
SEASON QUALITY pentade
10
CAPABILITY
0
170
⑭
WATER DEFICIT PERIOD day
10
CAPABILITY
0
-800 -400 0 200 400
⑮
RAINFALL TOTAL - EVAPORATION
mm a-1

Fig.7 (contd.)

SET B





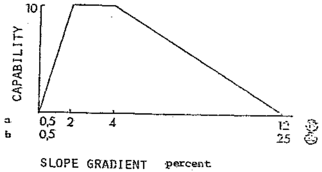
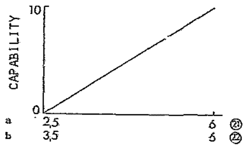
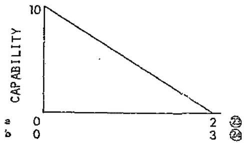


Fig.7 (contd.)





KEY

n – Graph number n
a – Farming land
b – Pit-prepared land
c – Subtropical forestry
d – Temperate forestry

Fig.7 (contd.)

Table 29 – The Capability Ratings of the Hillslope Elements for the Forestry Land Use System

Land Use Types	Code	HILLSLOPE ELEMF						
		Cre:.t	Waxing slope	Free face	Talus	Uppe: pedime	:er .iment	Valley bottom
		1	2	3	4	5	6	7
Farming land	1	5	0	0	0	5	10	5
Pit-prep*red land	2	5	0	0	3	10	10	5

Table 30 - The Capability Ratings of the Subsoil Texture Classes for the Forestry Land Use System

Land Use Types	Code	SUBSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Farming land Pit-prepared land	1)) 2)	1	5	4	5	6	7	10	10	8	8	7	6

The moisture regime (Crafford and Nott, 1972) is considered when assigning the capability ratings.

Table 31 - The Capability Ratings of the Topsoil Texture Classes for the Forestry Land Use System

Land Use Types	Code	TOPSOIL TEXTURE CLASS											
		Sand	Silt	Loamy Sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Farming land Pit-prepared land	1)) 2)	5	5	5	10	9	9	8	5	4	4	3	3

Rainfall infiltration and soil erodibility are considered when assigning the capability ratings

SET A

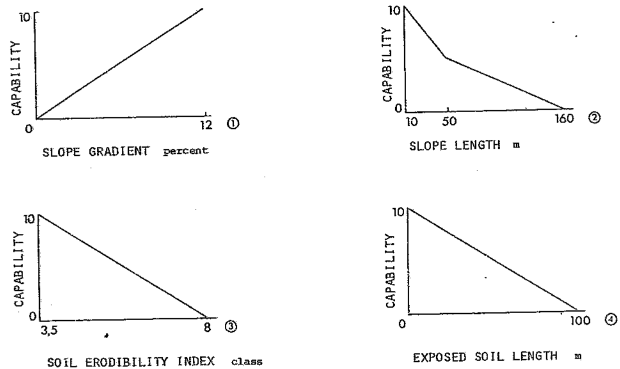
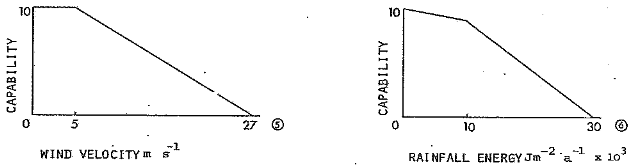


Fig.8 The capability graphs used to analyse the land's capability to support a Conservation Land Use.



KEY

n ~ Graph number n

Fig.8 (contd.)

Table [illegible] - The Capability Ratings of the Physiognomic Vegetation Types
Forestry Land Use System

Land Use Types	Code	VEGETATION TYPES																							
		2	3	4	5	6	7	8	9	11	12	13	14	15	17	18	19	20	24	25	33	41	44	45	49
Farming land Pit-prepared land	1) 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	7	7	10	10	10	10	7	7	10
Subtropical forestry	3)	10	10	3	3	0	0	0	0	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0
Temperate forestry	4)	0	10	3	3	0	0	0	0	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0

The Vegetation type names and codes are given in Table 10.
The possible woody cover and general climatic conditions are mainly considered when assigning the capability ratings.

Table 33 – The Capability Ratings of the Hillslope Elements for the Conservation Land Use System

Land Use Type	Code	HILLSLOPE ELEMENT						
		Crest	Waxing slope	Tree face	Talus	Upper pediment	Lower pediment	Valley bottom
		1	2	3	4	5	6	7
Conservation	1	5	10	10	8	5	3	1

Note

The soil erosion hazard is considered when assigning the capability ratings.

SET A

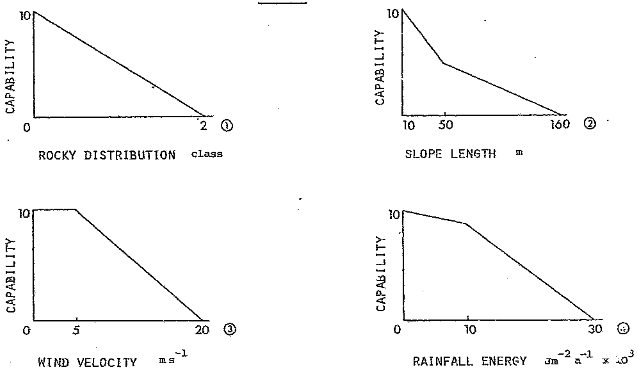
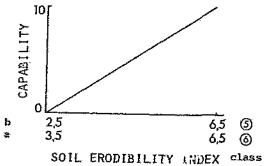
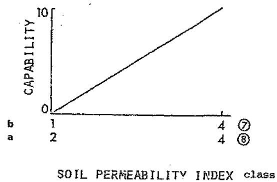


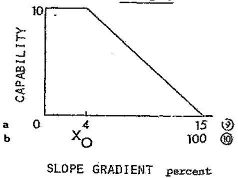
Fig.9 The capability graphs used to analyse the land's capability to support a Recreation Land Use.

SET B





SET B/C



KEY

n – Graph number n
a – Open space
b – Informal activities
c – Water recreation

Fig.9 (contd.)

Table 34 - The Capability Ratings of the Hillslope Elements for the Recreation Land Use System

Land Use Type	Code	HILLSLOPE ELEMENT						
		Crest	Waxing slope	Tree face	Talus	Upper pediment	Lower pediment	Valley bottom
		1	2	3	4	5	6	7
Open space	1	0	0	0	0	3	10	10
Informal activities	2	8	5	3	8	10	10	8

Table 35 - The Capability Ratings of the Subsoil Texture Classes for the Recreation Land Use System

Land Use Type	Code	SUBSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Open space Informal activities	1)) 2)	1	5	4	5	6	7	10	10	8	8	7	6

The moisture regime is considered when assigning the capability ratings.

Table 36 - The Capability Ratings of the Topsoil Texture Classes for the Recreation Land Use System

Land Use Type	Code	TOPSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Open Space Informal activities	1)) 2)	5	5	5	10	9	9	8	5	4	4	3	3

The rainfall infiltration and soil erosion are considered when assigning the capability ratings.

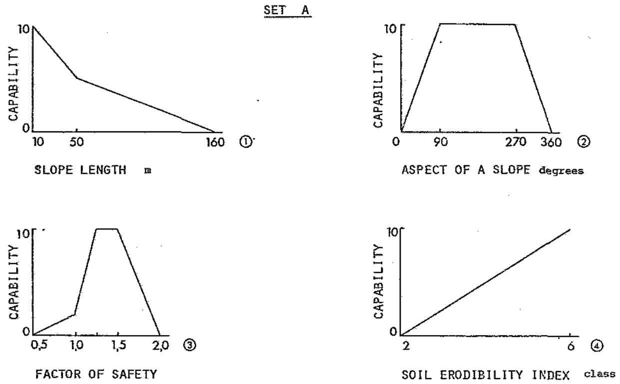


Fig.10 The capability graphs used to analyse the land's capability to support an Urban and Rural Development Land Use.

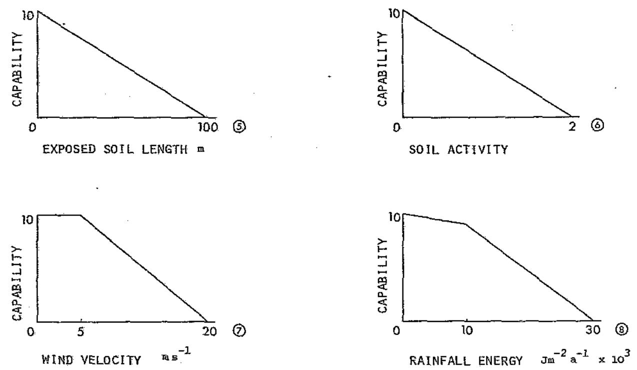
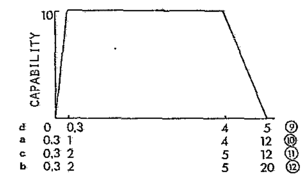
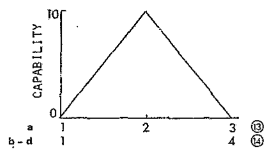

10
CAPABILITY
0
100
⑤
EXPOSED SOIL LENGTH m
10
CAPABILITY
0
2
⑥
SOIL ACTIVITY
10
CAPABILITY
0
5
20
⑦
WIND VELOCITY m s^{-1}
10
CAPABILITY
0
10
30
⑧
RAINFALL ENERGY Jm^{-2} a^{-1} x 10^{3}

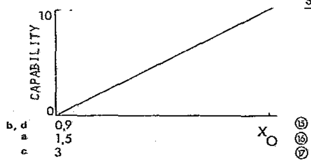
Fig.10 (contd.)

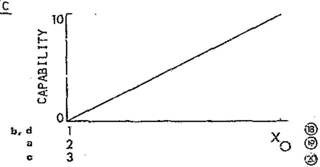
SET B





SET B/C





KEY

n – Graph number n
c – Commercial buildings
a – Rural residential buildings
d – Industrial buildings
b – Urban residential buildings

Fig.10 (contd.)

Table 37 – The Capability Ratings of the Physiognomic Vegetation Types for the Recreation Land Use System

Land Use Type	Code	VEGETATION TYPE																														
		2–9	11–15	17	18	19	20	22	23	24	25	27	28	29	30	32	33	34	35	36	37	38	39	40	41	42	43	44	45	47	48	49
Open Space	1	0	0	5	5	5	5	10	0	10	10	0	0	0	0	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0
Informal activities	2	8	10	10	10	10	10	10	10	10	10	8	8	8	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10	8	8	0
Water recreation	3	0	0	0	0	0	0	0	0	0	0	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note

The vegetation type codes are given in Table 10.
The possible woody -esence of vleis are mainly considered when ass'gning the capability ratings.

Table 38 - The Capability Ratings of the Hillslope Elements fo. the Urban and Rural Development Land Use System

Land Use Type	Code	HILLSLOPE ELEMENT						
		Crest	Waxing slope	Free face	Talus	Upper pediment	Lower pediment	Valley bottom
		1	2	3	4	5	6	7
Rural residential building	1	5	0	0	2	5	10	0
Urban residential building	2	5	0	0	2	5	10	0
Commercial building	3	5	0	0	0	2	10	0
Industrial building	4	5	0	0	0	.5	10	0

Table 39 - The capability ratings of the Stratigraphic Units and Associated Rocks According to the Potential Type of Soil Failure for the Urban and Rural Development Land Use System

Land Use Type	Code	Stratigraphic Unit and Associated Rocks																General Hazard																
		2	3	4	5	6	7	9	10	11	12	14	15	16	17	18	19	21	22	24	25	26	27	28	29	30	31	33	34	35	37	38	40	41
Rural Residential Building	1)																																	
Urban Residential Building	2)																																	
Commercial Building	3)	10	5	2	10	5	2	7		[illegible]	7	5	10	10	10	10	10	5	1	5	5	5	2	1	10	10	1	5	5	1	10	10	10	10
Industrial Building	4)																																	

Land Use Type	Code	Stratigraphic Unit and Associated Rocks																Compression Hazard																
		2	3	4	5	6	7	9	10	11	12	14	15	16	17	18	19	21	22	24	25	26	27	28	29	30	31	33	34	35	37	38	40	41
Rural Residential Building	1)																																	
Urban Residential Building	2)	10	5	2	10	10	10	10	10	10	10	10	10	10	10	10		[illegible]	1	10	5	10	10	10	10	10	1	10	5	10	10	10	10	10
Commercial Building	3)																																	
Industrial Building	4)																																	

Land Use Type	Code	Stratigraphic Unit and Associated Rocks																Expansion Hazard																
		2	3	4	5	6	7	9	10	11	12	14	15	16	17	18	19	21	22	24	25	26	27	28	29	30	31	33	34	35	37	38	40	41
Rural Residential Building	1)																																	
Urban Residential Building	2)	10	10	10	10	5	2	10	10	10	10	5	10	10	10	10	10	5	10	5	10	5	2	10	10	10	10	5	10	1	10	10	10	10
Commercial Building	3)																																	
Industrial Building	4)																																	

Table 39(contd.)

Land Use Type	Code	Stratigraphic Unit and Associated Rocks																Sub-surface Erosion Hazard																
		2	3	4	5	6	7	9	10	11	12	14	15	16	17	18	19	21	22	24	25	26	27	28	29	30	31	33	34	35	37	38	40	41
Rural Residential Building	1)	10	7	5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	1	10	10	10	10	10	10	10	10	10	10
Urban Residential Building	2)																																	
Commercial Building	3)																																	
Industrial Building	4)																																	

Land Use Type	Code	Stratigraphic Unit and Associated Rocks																Other Hazard																
		2	3	4	5	6	7	9	10	11	12	14	15	16	17	18	19	21	22	24	25	26	27	28	29	30	31	33	34	35	37	38	40	41
Rural Residential Building	1)	7	7	7	10	10	10	7	7	7	7	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Urban Residential Building	2)																																	
Commercial Building	3)																																	
Industrial Building	4)																																	

Note

Stratigraphic unit and associated rocks names and corresponding code numbers are given in Table 8.
Only those found in the Transvaal are considered.

Table 40 - The Capability Ratings of the Transported Soil Origin for the Urban and Rural Development Land Use System

Land Use Type	Code	TRANSPORTED SOIL ORIGIN							
		Aeolian	Alluvium	Biotic	Gully wash	Hillwash	Slide debris	Talus	Vlei
Rural residential building Urban residential building Commercial building Industrial building	1) 2) 3) 4)	5	1	5	10	5	1	3	5

Note

Pyroclastic and littoral deposits are not found in the Transvaal (Brink, 1979).

Table 41 – The Capability Ratings of the Soil Horizon Type for the Urban and Rural Development Land Use System

Land Use Type	Code	SOIL HORIZON TYPE TEXTURAL CLASS											
		Sand	Silty Sand	Clayey sand	Sandy silt	Sand-silt	Silt	Clayey silt	Sandy clay	Sand-clay	Silty clay	Silt-clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Rural residential building	1	1	5	4	5	5	6	6	3	3	3	3	1
Urban residential building Commercial building Industrial building	2) 3) 4)	1	3	1	5	5	5	5	3	3	2	2	1

The potential soil failure hazard is considered when assigning the capability ratings.

Table 42 – The Capability Ratings of the Physiognomic Vegetation Types for the Urban and Rural Development Land Use System

Land Use Type	Code	VEGETATION TYPE																										
		11	12	13	14	15	17	18	19	20	24	25	32	33	34	35	36	37	38	39	40	41	42	43	44	45	47	48	49
Rural residential building	1	1	1	1	1	1	10	10	10	10	10	10	7	7	7	7	7	7	7	7	7	5	5	5	5	5	1	1	1
Urban residential building	2	0	0	0	0	0	7	7	7	7	10	10	7	7	7	7	7	7	7	7	7	7	5	5	7	7	5	5	5
Commercial building	3	0	0	0	0	0	5	5	5	5	10	10	7	7	7	7	7	7	7	7	7	9	7	7	9	9	5	6	5
Industrial building	4	0	0	0	0	0	5	5	5	5	10	10	7	7	7	7	7	7	7	7	7	9	7	7	9	9	5	6	5

The vegetation type names and code numbers are given in Table 10.
The possible aesthetic appeal and woody cover are mainly considered when giving the capability ratings.

SET A

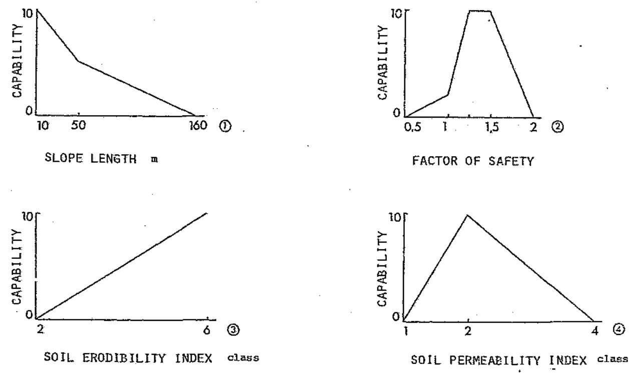


Fig.11 The capability graphs used to analyse the land's capability to support a Communications Land Use.

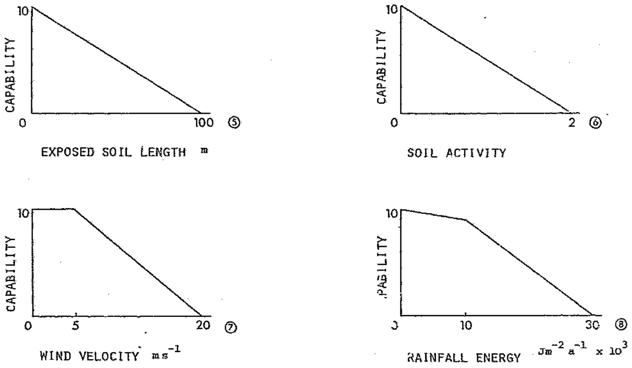
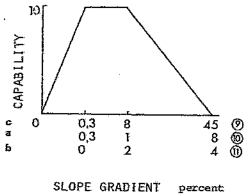
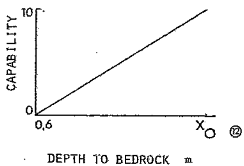

10
CAPABILITY
0
100
⑤
EXPOSED SOIL LENGTH m
10
CAPABILITY
0
2
⑥
SOIL ACTIVITY
10
CAPABILITY
0
5
20
⑦
WIND VELOCITY ms-1
10
PABILITY
10
30
⑧
RAINFALL ENERGY Jm-2 a-1 x 10^3

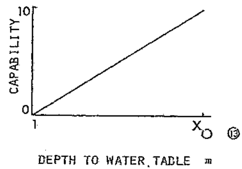
Fig.11 (contd.)

SET B



SET C





KEY

n – Graph number n   a – Road construction   b – Railway construction
c – Transmission line construction

Fig.11 (contd.)

Table 43 - The Capability Ratings of the Hillslope Elements for the Communications Land Use System

Land Use Type	Code	HILLSLOPE ELEMENT						
		Crest	Waxing slope	Free face	Talus	Upper pediment	Lower pediment	Valley bottom
		1	2	3	4	5	6	7
Road construction	1	5	0	0	0	5	10	0
Railway construction	2	5	0	0	0	5	10	0
Power transmission line construction	3	5	0	0	3	8	10	8

Table 44 - The Capability Ratings of the Stratigraphic Unit and Associated Rocks for the Communications Land Use System

Land Use Type	Code	STRATIGRAPHIC UNIT AND ASSOCIATED ROCKS																																
	.	2	3	4	5	6	7	9	10	11	12	14	15	16	17	18	19	21	22	24	25	26	27	28	29	30	31	33	34	35	37	38	40	41
Road construction	1)																																	
Railway construction	2)	10	5	2	10	5	2	7	7	7	7	5	10	10	10	10	10	5	1	5	5	5	2	1	10	10	1	5	5	1	10	10	10	10
Power transmission line construction	3)																																	

Note

Only those units and rocks found in the Transvaal are considered.
The unit and rock names with their corresponding code numbers are given in Table 7.

Table 45 - The Capability Ratings of the Transported Soil Origin for the Communications Land Use System

Land Use Type	Code	TRANSPORTED SOIL ORIGIN							
		Aeolian	Alluvium	Biotic	Gully wash	Hillwash	Slide debris	Talus	Vlei
		1	2	3	4	5	6	7	8
Road construction Railway construction Power transmission line construction	1)) 2))) 3))	5	1	5	10	5	1	3	5

Table 46 - The Capability Ratings of the Soil Horizon Type Classes for the Communications Land Use System

Land Use Type	Code	Sand	Silty sand	Clayey sand	Sandy silt	Sand-silt	Silt	Clayey silt	Sandy clay	Sand-clay	Silty clay	Silt-clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Road construction Railway construction Power transmission line construction	1) 2) 3)	1	3	1	5	5	5	5	3	3	2	2	1

Note The potential soil failure hazard is considered when awarding the capability ratings.

Table 47 – The Capability Ratings of the Physiognomic Vegetation Types for the Communications Land Use System

Land Use Type	Code	VEGETATION TYPE																										
		11	12	13	14	15	17	18	19	20	24	25	32	33	34	35	36	37	38	39	40	41	42	43	44	45	47	48	49
Road construction Railway construction	1) 2)	0	0	0	0	0	7	7	7	7	10	10	7	7	7	7	7	7	7	7	7	9	7	7	9	9	5	6	5
Power transmission line construction	3	5	5	5	5	5	7	7	7	7	10	10	7	7	7	7	7	7	7	7	7	9	7	7	9	9	5	6	5

Note

The possible woody cover is mainly considered when awarding the capability ratings.
Table 10 gives the vegetation type names and their code numbers.

SET A

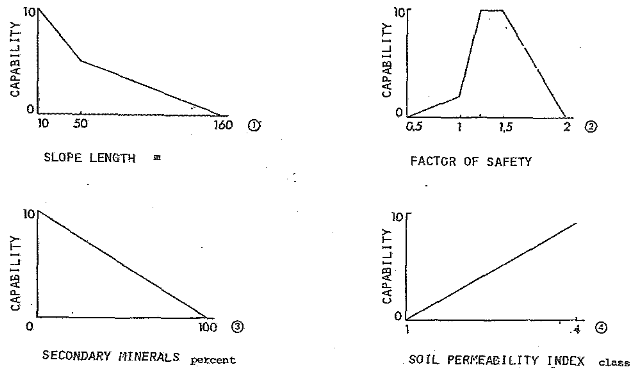


Fig.12 The capability graphs used to analyse the land's capability to support an Excavation Land Use.

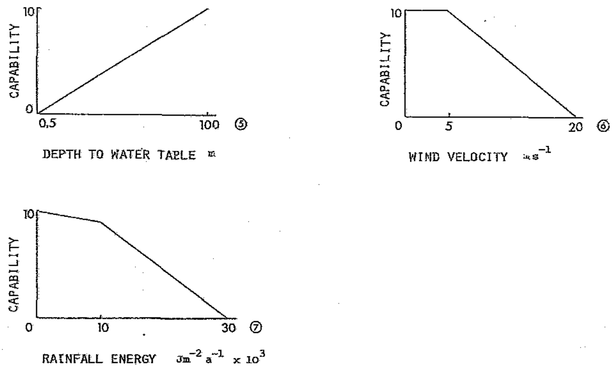

CAPABILITY
10
0
0,5
100
5
DEPTH TO WATER TABLE m
CAPABILITY
10
0
5
20
6
WIND VELOCITY ms^{-1}
CAPABILITY
10
0
10
30
7
RAINFALL ENERGY Jm^{-2} a^{-1} x 10^{3}

Fig.12 (contd.)

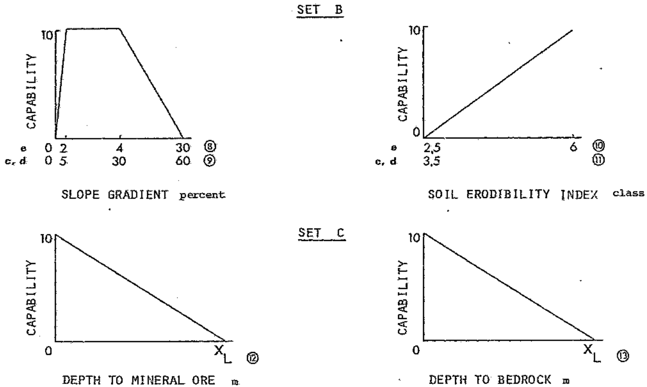
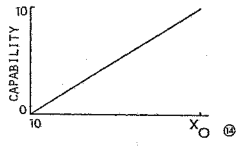
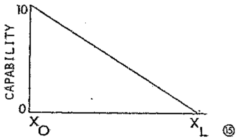

SET B
10
CAPABILITY
0
e 0 2 4 30 ⑧
c, d 0 5 30 60 ⑨
SLOPE GRADIENT percent
10
CAPABILITY
0
e 2,5 6 ⑩
c, d 3,5 ⑪
SOIL ERODIBILITY INDEX class
SET C
10
CAPABILITY
0
X_L ⑫
DEPTH TO MINERAL ORE m
10
CAPABILITY
0
X_L ⑬
DEPTH TO BEDROCK m

Fig.12 (contd.)





KEY

n – Graph number n
c – Open pit mining
a – Mineral ore deposit
d – Quarry
b – Construction material
e – Underground mine

Fig.12 (contd.)

Table 48 - The Capability Ratings of the Hillslope Elements for the Excavation Land Use System

Land Use Type	Code	HILLSLOPE ELEMENT						
		Crest	Waxing slope	Free face	Talus	Upper pediment	Lower pediment	Valley bottom
		1	2	3	4	5	6	7
Open-pit mine	3	5	0	1	5	10	5	0
Quarry	4	5	0	1	10	10	5	0
Underground mine	5	5	0	0	0	7	10	0

Table 49 - The Capability Ratings of the Natural Rock Type for the Excavation Land Use System

Land Use Type	Code	NATURAL ROCK TYPE																	
		Acid crystalline		Argill-aceous		Aren-aceous		Basic crystalline		Cal-careous		Cata-clysmic		High illica		Metallic		Pedogenic aterial	
		1	1,5	2	2,5	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8	8,5	9	9,5
Construction material Quarry	1)) 2)	7	8	3	3	5	5	6	7	5	5	7	7	10	10	5	5	5	5

Note. A Climatic N-factor greater than 5 causes the rating of this land characteristic by those columns with one decimal place.

Table 50 - The Capability Ratings of the Subsoil Texture Classes for the Excavation Land Use System

Land Use Type	Code	SUBSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Open pit mine Quarry Underground mine	3) 4) 5)	10	8	8	6	6	6	5	4	3	4	2	1

Note

A dry soil does not hinder excavations. The moisture regime of the soil is considered when awarding the capability ratings.

Table 51 - The Capability Ratings of the Topsoil Texture Classes for the Excavation Land Use System

Land Use Type	Code	TOPSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	11
Open pit mine Quarry Underground mine	3) 4) 5)	5	5	5	7	9	9	10	9	8	8	6	6

Note

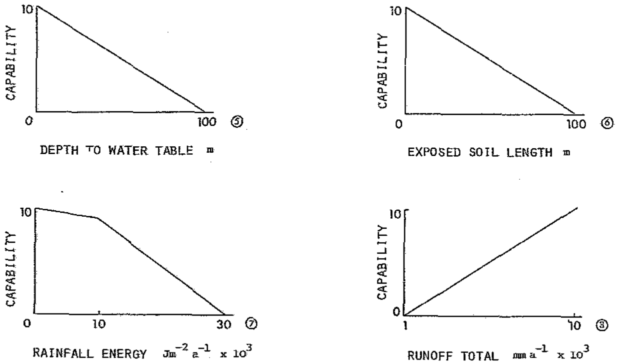
The rainfall infiltration and soil erosion hazard is considered when awarding the capability ratings.

Table 52 – The Capability Ratings of the Physiognomic Vegetation Type for the Excavation Land Use System

Land Use Type	Code	VEGETATION TYPE																											
		11	12	13	14	15	17	18	19	20	22	24	25	32	33	34	35	36	37	38	39	40	41	42	43	44	45	47	48	49
Open-pit mine Quarry Underground mine	3) 4) 5)	1	1	1	1	1	5	5	5	5	2	10	10	7	7	7	7	7	7	7	7	7	10	7	7	10	10	5	5	5

Note

The possible woody cover is mainly considered when the capability ratings are assigned.
The vegetation type names and code numbers are given in Table 10.



KEY

n – Graph number n

Fig.13 The capability graphs used to analyse the land's capability to support a Water Catchment Land Use

SET A

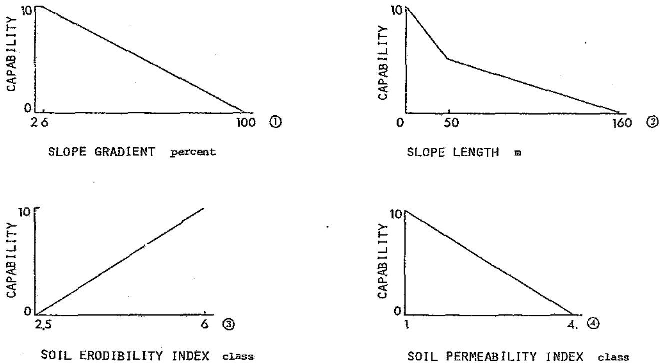


Fig.13 (contd.)

Table 53 - The Capability Ratings of the Hillslope Elements for the Water Catchment Land Use System

Land Use Type	Code	HILLSLOPE ELEMENT						
		Crest	Waxing slope	Free face	Talus	Upper pediment	Lower pediment	Valley bottom
		1	2	3	4	5	6	7
Water Catchment	1	0	10	10	8	5	1	0

Table 54 - The Capability Ratings of the Subsoil Texture Classes for the Water Catchment Land Use System

Land Use Type	Code	SUBSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Water Catchment	1	1	3	5	5	6	7	10	10	8	7	5	3

<u>Note</u> The soil water movement through the soil profile is considered when assigning the capability values.

Table 55 - The Capability Ratings of the Topsoil Texture Classes for the Water Catchment Land Use System

Land Use Type	Code	TOPSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	C[illegible]
		1	2	3	4	5	6	7	8	9	10	11	12
Water catchment	1	1	3	5	6	6	6	9	7	3	3	2	2

Note

The soil infiltration is considered when assigning the capability ratings.

Table 55 - The Capability Ratings of the Topsoil Texture Classes for the Water Catchment Land Use System

Land Use Type	Code	TOPSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Water catchment	1	1	3	5	6	6	6	9	7	3	3	2	2

Note

The soil infiltration is considered when assigning the capability ratings.

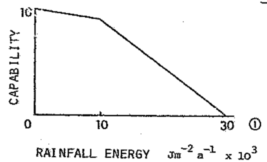
Table 56 – The Capability Ratings of the Physiognomic Vegetation Type for the Water Catchment Land Use System

Land Use Type	Code	VEGETATION TYPE																																		
		2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	23	24	25	31	32	33	34	35	36	37	38	39	40	42	43	44	45	49
Water Catchment	1	1	1	1	1	1	1	1	1	3	3	3	3	3	5	5	5	5	5	1	1	10	10	5	7	9	5	5	5	5	5	5	5	5	5	7	7	1

Note

The vegetation type names and code numbers are given in Table 10.
The possible woody cover and the presence of vleis are mainly considered when assigning the capability ratings.

SET A



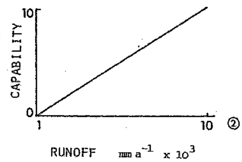


Fig.14 The capability graphs used to analyse the land for a Foreclosure of Options in Land Use

SET B

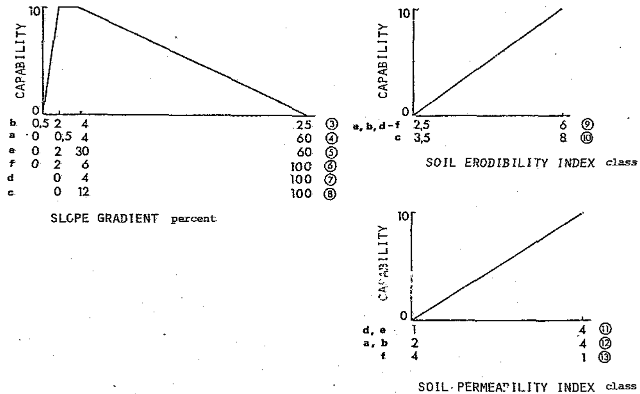


Fig.14 (contd.)

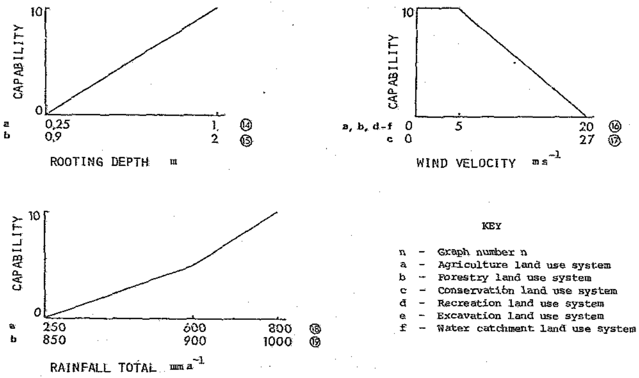

10
CAPABILITY
0
a 0,25 1 ⑭
b 0,9 2 ⑮
ROOTING DEPTH m
10
CAPABILITY
a, b, d-f 0 5 20 ⑯
c 0 27 ⑰
WIND VELOCITY m s-1
10
CAPABILITY
0
a 250 600 800 ⑱
b 850 900 1000 ⑲
RAINFALL TOTAL mm a-1
KEY
n - Graph number n
a - Agriculture land use system
b - Forestry land use system
c - Conservation land use system
d - Recreation land use system
e - Excavation land use system
f - Water catchment land use system

Fig.14 (contd.)

Table 57 - The Capability Ratings of the Hillslope Elements for the Foreclosure of Options in Land Use

Land Use System	Code	HILLSLOPE ELEMENT						
		Crest	Waxing slope	Free face	Talus	Upper pediment	Lower pediment	Valley bottom
		1	2	3	4	5	6	7
Agriculture	1	5	0	0	3	5	10	5
Forestry	2	5	0	0	3	5	10	5
Conservation	3	5	10	10	8	5	3	1
Recreation	4	8	5	5	8	10	10	8
Excavation	5	0	0	1	10	10	5	0
Water Catchment	6	0	10	10	8	5	1	0

Table 58 - The Capability Ratings of the Subsoil Texture Classes for the Foreclosure of Options in Land Use

Land Use Systems	Code	SUBSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay	Silty clay loam	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Agriculture	1	1	5	4	5	6	7	10	10	8	8	7	6
Forestry Recreation	2)) 4)	1	5	4	5	6	7	10	10	8	8	7	6
Excavation	5	10	8	8	6	6	6	5	4	3	4	2	1
Water catchment	6	1	3	5	5	6	7	10	10	8	7	5	3

Table 59 – The Capability Ratings of the Topsoil Texture Classes for the Foreclosure of Options in Land Use

Land Use Systems	Code	TOPSOIL TEXTURE CLASS											
		Sand	Silt	Loamy sand	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	Clay loam	Silty clay loam	Silty clay	Clay
		1	2	3	4	5	6	7	8	9	10	11	12
Agriculture	1	5	5	5	10	9	9	9	5	4	4	3	3
Forestry Recreation	2)) 4)	5	5	5	10	9	9	9	5	4	4	3	3
Excavation	5	5	5	5	7	9	9	10	9	8	8	6	6
Water catchment	6	1	3	5	6	6	6	9	7	3	3	2	2

Table 60 – The Capability Ratings of the Physiognomic Vegetation Types for the Foreclosure of Options in Land Use

Land Use Type	Code	VEGETATION TYPE																											
		2	3	4	5	6	7	8	9	11–15	17	18	19	20	22	23	24	25	27–30	32	33	34–40	41	42	43	44	45	47	48	49
Agriculture	1	5	10	3	0	0	0	0	0	7	7	7	5	7	0	0	1	1	0	0	1	0	5	0	0	5	5	3	3	10
Forestry	2	5	10	3	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5
a. Conservation	3	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	0
Recreation	4	5	5	5	5	5	5	5	5	5	5	5	5	5	10	10	10	10	10	10	10	10	10	10	10	10	10	5	5	0
Excavation	5	0	0	0	0	0	0	0	0	1	5	5	5	5	2	2	10	10	0	7	7	10	10	7	7	10	10	5	5	5
Water Catchment	6	1	1	1	1	1	1	1	1	2	5	5	5	5	1	1	10	10	0	7	9	5	5	5	5	7	7	0	0	0

<u>Note</u>

a. User defined capability ratings should be given.

3.5.7 The Weighting of the Land Characteristics

The relative importance of all the land characteristics evaluated, to the overall capability of the land for a land use, is not the same. Yet the capability rating derived for each land characteristic is based on the same scale as though all were of equal importance. The difference in their relative importance is included by weighting the capability values of each land characteristic by an assigned value which depends on their importance with regard to that land use.

All land characteristics given a capability rating have a weighting value of at least one. It was hoped that a default set of weighting values greater than one for those land characteristics of greater importance would be obtained from the literature and from discussions with various specialists. However, the only information available was their identification. Information on the relative importance between them was simply unavailable. This is partly a result of the fact that these weighting values may be used to reflect the dynamic economic situation, the particular environment concerned, etc., and are thus subject to change. Only a list of those land characteristics identified is given below. The values stored in the control data set (Section 4.4.2) are all one except for those in this list. These are given values $\geqslant 2$ to distinguish them as being of more importance and is not a true reflection of their relative importance. A user will change these values as desired (Section 4.6.2). The relative importance of a land characteristic will differ between the land use types within each land use system eg.

a lake is of greater importance to water recreation than to informal recreational activities; the slope gradient offers a greater limitation to arable land than to natural vegetation pastures. The weighting values given to the land characteristics grouped as usuable surface area are the same, since only one capability value is derived. The same course of action is followed for those land characteristics grouped as non-inhibiting networks.

Considering each land use system:-

(a) Agriculture The topography (Edwards, 1970), climate (Vink, 1975), moisture regime (Crafford and Nott, 1972) and soil erosion (Elwell, 1977) are important. The land characteristics involved are the slope gradient and length, the hillslope element, the rainfall total and energy, the season length and quality, the fruiting season length, the water deficit period, the subsoil and topsoil textures, the rooting depth and the soil erodibility index, the wind velocity and the soil permeability index.

(b) Forestry as for agriculture, except for the season length and the fruiting season length are omitted.

(c) Conservation The protection and conservation of land and species are important (Department of Planning and the Environment, 1973). The land characteristics involved are the protected animal and plant species, both vegetation types, the natural land feature, the Wilderness and Mountain Catchment areas, the National, Municipal, Provincial and Private Parks, the soil erodibility index, the rainfall energy, the wind velocity, the slope gradient and length and the hillslope element.

(d) Recreation The topography (Montgomery and Edminston, 1966) the trampling of the vegetation, the soil permeability (Vink, 1975), the water and the wildlife present are important. The land characteristics involved are the physiognomic and floristic vegetation types, the slope gradient, the hillslope element, the natural land feature, the soil permeability index and the topsoil and subsoil textures, the game species, lake, reservoir, vlei, river and stream.

(e) and (f) Urban and Rural Development and Communications The topography (Horak and du Toit, 1977; Kiefer, 1972) tne soil depth (Kiefer, 1972) the soil strength, volumetric change and permeability (Jennings et al, 1973) are of importance. The land characteristics involved are the slope gradient and length, the hillslope element, the depths to the water table and bedrock, the stratigraphic unit, the transported soil origin, the soil joint structure, activity and horizon type.

(g) Excavation The durability of the rock material is important (Weinert, 1969) as well as the topography (Weinert, 1978). The land characteristics involved are the slope gradient, the hillslope element, the natural rock group, the mineral ore deposit, the rock hardness, the percentage of secondary minerals and the ten per cent fines test.

(h) Water Catchment The runoff, the vegetation cover (Midgley and Pitman, 1969) and the soil moisture capacity (Rowe and Colman, 1957) are important. The land characteristics involved are the runoff total, the physiognomic and floristic vegetation types, the soil permeability index, the subsoil and topsoil textures, the depth to the water table and the Mountain Catchment Area.

Foreclosure in options For each land use system involved, the following land characteristics are important:-

(a) and (b) Agriculture and Forestry - rainfall total, rainfall energy, wind velocity, soil erodibility index, slope gradient, hillslope element, soil permeability index and topsoil and subsoil textures, and rooting depth.

(c) Conservation - natural land features, protected animal and plant species and the vegetation types, Wilderness and Mountain Catchment Areas, Municipal, National, Private and Provincial Parks, slope gradient, hillslope element, rainfall energy and soil erodibility index.

(d) Recreation - hillslope element, slope gradient, game species, reservoir, vlei, lake, river, stream, natural land features, soil erodibility index and rainfall energy.

(e) Excavation - mineral ore deposits, natural rock group, slope gradient and hillslope element.

(f) Water Catchment - Mountain catchment area, the physiognomic and floristic vegetation, runoff total, soil permeability index and subsoil and topsoil textures.

3.5.8 The Combination of the Individual Weighted Capability Values to give an Overall Capability Value

The individual weighted capability values of each land characteristic are summed to give the overall capability value of a cell.

The number of land characteristics analysed depends upon:-

(a) <u>The land use</u> Each land use system and land use type or land use within a system, involves the analysis of a different number of land characteristics.

(b) <u>The secondary land data set</u> (Section 4.4.1.2). This data set is complete when all possible land characteristics have been measured. However, this will often not be the case. Thus it is foreseen that a land characteristic required for the evaluation of a land use will not have been measured and will be omitted.

(c) <u>The survey scale at which the evaluation is to occur</u> A land characteristic which has not been measured at the required survey scale will be substituted if possible, by a land characteristic or set of such at the alternative survey scale (Sections 3.4 and 4.5(d)). If this cannot be done, that land characteristic is omitted. Incomplete substitution may occur if a set of land characteristics substitutes one land characteristic and not all those in this set have been measured.

For these reasons, the overall capability of a cell will vary between different land uses analysed for the same land data sets and between different land data sets analysed for the same land use. A further reason for variation in the overall capability is due to the different weighting values assigned with respect to the land use. In order to compare the results of different capability analyses, these differences are removed by calculating the overall capability of a cell as the weighted mean.

$$C = \sum_{i=o}^{n} W_i C_i \Big/ \sum_{i=o}^{n} (WC_{max})_i$$

where:-

C is the overall capability of a cell

n is the number of land characteristics evaluated

W is the weighting value of a land characteristic

C is the capability rating of a land characteristic

C_{max} is the maximum capability possible for a land characteristic ie. 10.

The final value is given as a percentage.

The validity of each capability map printed is defined as the ratio of the number of land characteristics present in the secondary land data set to the number required for the evaluation of the land use at the survey scale selected. This ratio is printed with each map and should be considered when comparisons are made between them as it will indicate the completeness of the analysis. A low ratio means that a large proportion of the necessary data in the land data set is not present and thus all the land characteristics needed for the analysis were not evaluated.

CHAPTER 4

4. THE COMPUTERISED PROCEDURE

4.1 The Approach

The land is surveyed at a selected survey scale for a selected number of land characteristics. results are mapped to depict the spatial arrangement of these land characteristics and this arrangement may be in the form of polygons, networks or discrete points. Each map is digitised and stored as a primary data set in a data base. The land characteristics measured at discrete points may represent a polygonal distribution eg. rainfall gauges measure the precipitation of an area. Such data are interpolated to produce continuous cover maps by the program INTER (Section 4.2), before they are stored as a primary data set.

The digitising program CONTOR and relevant editing programs (Section 4.4.1.1) create the primary data sets. The land capability analysis program, CAPANAL, requires that the land data evaluated be in the form of grid maps (secondary data sets). These grid maps of a selected grid cell size are set up by overlaying the digitised maps (primary data sets) using the program OVER3 (Section 4.4.1.2) and are stored within or linked to the same data base where the primary data sets are stored.

Each land characteristic within a cell is evaluated separately with respect to a land use. The information describing the method used to evaluate each characteristic viz. whether it is a limiting characteristic, whether its capability is derived from a capability table or graph, whether it interacts with another land characteristic, whether it represents either a usable or non-usable surface area or an inhibiting or non-inhibiting network etc. is stored in control data sets within or linked to the same data base system where the primary data sets are stored. The capability graphs and tables, the factor graphs and the names and codes of the land use types and the land characteristics are also stored in these control data sets. This information may be updated and changed by the interactive program PREP (Section 4.7). The secondary data sets to be evaluated and the control data sets for the land uses to be studied, are selected by the user under the direction of an interactive program, EVPREP (Section 4.7). Other information concerning the running of CAPANL, must also be given by the user and is specified in Section 4.5. The main programs of the capability analysis procedure, from these used to create the primary data sets to the execution of CAPANL, are linked together by a suite of interactive programs.

The interactive computerised procedure as just described, is summarized below:-

a. Collection of the data as polygons, networks or points and their presentation as survey maps.

b. Digitisation of the survey maps and their storage as primary data sets.

c. Creation of secondary data sets at a selected grid cell size.

d. Selection and editing of a control data set to be used to evaluate the secondary data set for its capability to support a land use.

e. Selection of the options available in the execution of CAPANL.

f. The running of CAPANL.

Flowcharts of the programs written for this study are given in the following sections, as well as a listing of all the programs. Not all the computer statements of a program or section thereof are presented in these flowcharts. Only those necessary to illustrate the fundamental task being performed are given so that the flow of the program is clear. The computer statement numbers, variable names, array names, do loop variables etc. used in the flow charts are identical to those used in the program or program section being illustrated so that direct reference between the flowcharts and programs is possible.

4.2 The Interpolation of Data Collected at Discrete Points to Produce Continuous Cover Maps

Two basic two-dimensional interpolation techniques are surface fitting and numerical approximation (MacDougall, 1976). The former technique assumes that the spatial pattern between the points is known and is represented by an equation. A program which computed the interpolated value from the equation given below was tested.

$$Z(x, y) = \sum_{h=o}^{2} \sum_{k=o}^{2} a_{hk}\, x^h\, y^k$$

where Z is the interpolated value at co-ordinates x, y a is a constant calculated from the x and y co-ordinate values h and k increment between zero and two.

The polygon boundaries produced could be likened to contours of a relief map. However, environmental data rarely have this form since the controlling factors themselves rarely have a continuous negative or positive rate of change over the land. The pattern is often abruptly interrupted, eg. a mountain range will produce a rain shadow effect. The results from this program were therefore unsatisfactory and misleading.

The numerical approximation technique assumes that the spatial pattern between the points is unknown. The interpolated value at a given location is determined by the distances between it and the values of a number of surrounding data points. The simplest form of interpolation by this method is to weight the average values of these surrounding points by the reciprocal distance (McDougall, 1976), eg.:

$$X = \sum_{k=1}^{M} (Z_k / D^2_k) / \sum_{k=1}^{M} (1 / D_k^2)$$

where X is the interpolated value

where Z_k are the surrounding M data values

D_k are the distances from X to these points.

By squaring the distance, more emphasis is placed on the nearby points. The difficulty with this approach is the specification of M which depends upon the spacing of the data points and the spatial variation within the map. Generally the best values for M range from 6 to 9 (MacDougall, 1976). INTERP listed by MacDougall was modified to include the mean X value determined from this range of M values. The results were not misleading but their accuracy is open to question. This program is available but it is preferred that mapped data using more sophisticated interpolation techniques should be used rather than the filed point data, provided that the detail represented by these maps complements that of the other data items.

4.3 Data Storage

It is assumed that the data collected are stored in a resource inventory which will be a data base of different data sets. - data elements for each data set are the values and reference determined by the map compilation m.. . (Tomlinson, 1970), for one land characteristic. The map co-ordinates used, from which the georeferences are derived, are specified either by the requirements of the resource inventory or the user. Each data set is created by digitizing the survey maps into the computer by means of a digitiser. This consists of a flat surface to which the map is fixed, and a cursor which is positioned on the point to be digitised. When the cursor button is depressed, the co-ordinates of that point are read into the computer. Thus the spatial arrangement of the data, which is essential to land use planning, is retained.

The data base to which the evaluation program is linked should be:-

(a) Simple and easy to use.

(b) The data items should be retrievable by a georeference and/or by land characteristic value.

(c) The linkage between the base and the procedure should be quick and efficient.

Two data base systems available at the Witwatersrand Computer Centre are OSIRIS (Organised Set of Integrated Routines for Investigations with Statistics) and SAS (Statistical Analysis System), both written primarily for Statistical Data. Their application for ecological data were investigated. The data sets for both systems consisted of rows of observations and columns of variables. For this procedure, the observations are equivalent to land characteristics and the columns to their values and georeference. Additional data sets containing the study area names, locations, size, details of the land characteristics measured, etc. would also be required.

It was found that these data base systems could be used but certain disadvantages existed:-

(a) Each system has a language of its own. Any user of the procedure would require a knowledge of this as well as FORTRAN in which the procedure's programs are written.

(b) The cost of using the procedure is increased due to the linking of two different systems, ie. the data bank and the program of the procedure.

(c) Any interaction between the two will be complex and expensive as they cannot be directly linked to one another (since the languages are not the same).

(d) The procedure will only be usable at computer installations having both a FORTRAN compiler and the data bank system chosen.

(e) SAS was the easier system to use but the data elements are only retrievable through the observations and not through the variables.

(f) Programs to transform the data items into gridded data are still necessary.

For these reasons, it was decided against using either system. The ideal situation is the development of a data base system for the purposes of the procedure in the same language as that of the procedure's program. It should allow for the retrieval of data items via their value, variable name or georeference. The programs and base should be one unit. Computer languages such as PL/I and COBOL are able to handle both data matrices and data structures, the latter being the form used in data bases (Martin, 1977). FORTRAN is unable to handle these structures.

A data base system need not be only for storage and retrieval. Appropriate software can generate additional information from that already stored and this facility will increase its power and versatility. The potential of this facility will depend upon the amount and type of data stored. The data base system would contain two types of data :-

(a) Geographical data being the georeference information describing the boundaries of polygons, the location of networks and points for which various measurements have been made.

(b) Descriptive data ie. the measured information. The possible type of additional information generated is a function of the number of data items stored.

The development of an efficient multipurpose data base system of this kind is beyond the scope of this study, being one in its own right. Only a very simple interactive system was written for this study. This was in Wits FORTRAN, being the only language used or interactive programs at this Computer Centre. It is realised that the system is more cumbersome than if a language able to handle data structures was used, but the desired interactive facility would have been unavailable.

4.4 The Data Base System

The data required for this land capability analysis are:-

(a) The land data consisting of geographical references and measured information ie. geographic and descriptive data. The power of a data base system is increased if additional information other than that required for a land capability analysis is stored. The descriptive data for each land characteristic consists of a string of data items all having the same spatial distribution and being referenced by the same geographical information stored in the geographical data string. This procedure only requires the selection of a data item from the descriptive data string which corresponds to the land characteristic definition given in Section 3.5.5. During the digitising of the primary land data set (Section 4.4.1.1), two data items viz an alphabetical name and a quantitative value may be stored. Either value will be selected, according to the formula given by the user, and stored in the secondary land data set (Section 4.4.1.2).

(b) The information controlling the evaluation of a land use, ie. the control data sets.

4.4.1 The Land Data Sets

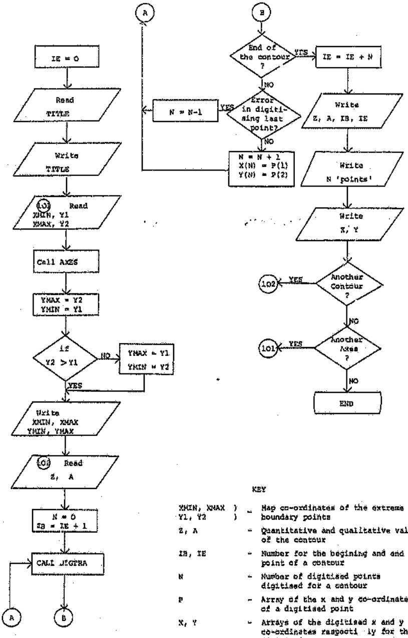
The capability analysis program CAPANL requires that the land data be stored and retrieved in grid cells. The advantages of this method are that straightforward computer operations, simple data manipulations of complex data sets and simple graphic display is possible (Tomlinson, 1970). If the land data are only stored in this form, its use for other purposes and even for the capability analysis, is restricted. For the former, a gridded form may be undesirable and, for both, the grid cell size may not be of the required scale and the loss of detail (described in Section 2.2.1.2) which is an unavoidable consequence of using a grid, may be significant. These restrictions are removed if the data are stored in a map compilation form (primary data sets). These data may be overlaid by a grid of user cell size to give gridded data sets (secondary data sets). This concept was followed.

4.4.1 .1 Primary Land Data Sets

The primary data sets are created by means of a digitiser which inputs the co-ordinates of a point into the computer. A simple program transforms these digitiser co-ordinate values into those of the georeference system selected by the user and writes them into a data set. An interactive program (CONTOR), modified from one written by A. Stuart of the Mining Engineering Department at the University of the Witwatersrand, was used.

CONTOR (Fig.15)

The map title followed by the origin and extreme boundary points are given by the user before any points are digitised. From the latter information, the map axes are set up upon which the co-ordinates of all the digitised



KEY

XMIN, XMAX) Y1, Y2)	– Map co-ordinates of the extreme boundary points
Z, A	– Quantitative and qualitative value of the contour
IB, IE	– Number for the begining and end point of a contour
N	– Number of digitised points digitised for a contour
P	– Array of the x and y co-ordinates of a digitised point
X, Y	– Arrays of the digitised x and y co-ordinates respectively for the digitised contours

Fig.15 Simplified flowchart of the program CONTOR for digitising a map into a primary data set.

points will be based. The georeference system is therefore use-defined. The National grid system increases numerically from the equator to the poles, resulting in the situation where the y-axis is reversed, ie. the northernmost co-ordinate (y max) value is less than the southernmost one (y min). If this system is used, CONTOR reverses these two points so that y max refers to the southern co-ordinate, the largest in numerical value. This will prevent errors from occurring in later programs which require that the maximum value be such. This reversal is ignored when the axes are created and is not necessary for the x-axes since the co-ordinates increase numerically from west to east, ie. in the positive direction of the x-axis.

CONTOR assumes that each point has three values, viz. an x, y and z value. This last value is the contour value which is the value bounded by the polygon or the value of the network or that of the discrete point being digitised. The z value is supplied by the user whenever a new contour is digitised and it is composed of two values, viz. a numeric and an alphabetic value so that either quantitative or qualitative data or both may be stored. Both values are stored in the descriptive data string from which either may be retrieved for use in the capability analysis procedure. CONTOR counts and stores the number of points digitised per contour, the maximum allowed being 600. Networks are treated as unclosed polygons and point data as separate, one point contours. The digitising time is decreased for the latter if points of the same z value are treated as being on the same contour, ie. one z value is given for a number of points Networks of the same z value

value may be combined into one network provided that the first point is digitised twice to mark their beginning. This will again decrease the digitising time particularly if the networks are short as th[illegible] program steps to end a contour and begin a new one are not executed.

Each contour is stored as a linear array containing the x and y co-ordinate of each point. These points are numbered sequentially throughout the array. Thus the numbers of the beginning and end points of each contour are stored with the z value ie. the value of the contour, in separate arrays.

CONTOR is an interactive program. Only data sets in the WITS data base system can be assessed by interactive programs executed at this University's computer installation. Thus the digitised data are stored initially as a file in the WITS data base. The point co-ordinates are stored according to the format F10.3.

<u>EDIT, [illegible]TLF, EDITPT</u> (Figs. 16, 17)

The program (OVER3), which creates the gridd[illegible]d data sets (secondary data sets) assumes that all polygons are closed and that no polygon or network extends beyond the map boundaries. However, human error in digitising the maps will be present, resulting in the possibility that these assumptions would be invalid. All the digitised data sets are edited to remove such errors. Three interactive programs dealing with the three forms of data, viz. polygon, network and discrete points, are available. All non-required contours or sections thereof are deleted using the WITS editor (WIT850 1977) before these programs are entered. These edit programs renumber the contours to allow for this deletion. A qualitative z value must be given a numerical code for computer use eg. the name of a game species may have been stored previously by CONTOR and a numerical code is required. These programs add the appropriate code value to the descriptive data string by selecting the correct code from a table listing each alphabetic value and its numerical code. This table is given by the user.

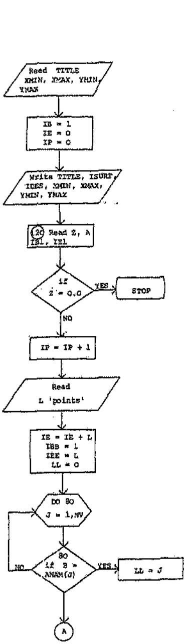
Each program searches for any points lying outside the map boundaries. These are replaced by one point lying on the boundaries so that the extension to these boundaries is not lost. For point data, this is not necessary and such points are deleted. In addition:-

EDIT (deals with polygon data) sets the last point equal to the first point to ensure that each polygon is closed and is illustrated in Fig.16.

EDITLF (deals with network data) separates any networks which may have been combined together and is illustrated in Fig.17.

EDITPT (deals with point data) breaks up any chains of points into individual points. The separation steps are fundamentally the same as those depicted in Fig.17.

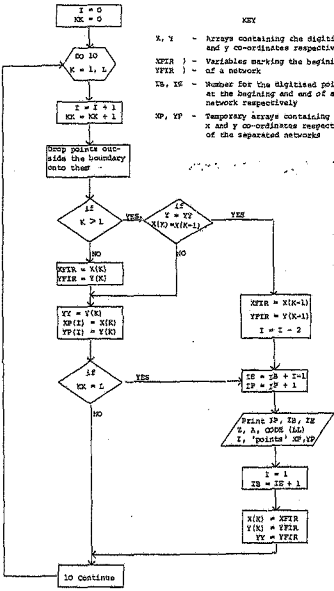
The edited primary data sets are stored as files in the WITS data base since the unedited data sets are already in this data base and they may be accessed by the interactive facility.



KEY

XMIN, XMAX) YMIN, YMAX)	-	Extreme boundary co-ordinates of the map
IB, IE,) ISB, IGE)	-	Number for the begining and end point respectively of the unedited and edited contour
IP	-	Counter for the number of polygons
ISURF	-	Value is 1 if the surface cover is to be calculated
IDES	-	Value is 1 if the polygons are discrete, i.e. no neighbours
X, Y	-	Arrays of the x and y co-ordinates for the digitised contours

Fig.16 Simplified flowchart of the program EDIT to edit the data digitised from a map consisting of polygons.



KEY

X, Y - Arrays containing the digitised x and y co-ordinates respectively

XFIR } - Variables marking the begining
YFIR } - of a network

IB, IE - Number for the digitised points at the begining and end of a network respectively

XP, YP - Temporary arrays containing the x and y co-ordinates respectively of the separated networks

Fig.17 Simplified flowchart of the section in program EDITLF dealing with the separation of several networks which have been digitised as one network.

The data in the primary land data sets at the completion of the editing is:-

Title

NOPT This indicates the spatial distribution of the digitised points. Polygons, networks and discrete points are coded by 1, 2 and 3 respectively.

ISURF indicates whether the surface cover of the land characteristic is to be calculated during the transformation of the map into a grid map (Section 4.4.1.2).

IDES is 1 of the polygons digitised are discrete ie. none of its boundaries are shared with another polygon.

NUMBER is the number of polygons, networks or discrete points stored.

CRE is the value by which the map co-ordinates increase.

SCALE is the scale of the map eg. a map at 1:100 000 has a scale of 100 000.

AXMIN)
AXMAX) are the southern, northern, western and
AYMIN) eastern co-ordinates of the map.
AYMAX)

4.4.1 .2 Secondary Land Data Sets

These sets contain the gridded land data created by separately overlaying a number of edited primary data sets with a square grid of user selected dimensions. Each grid cell of these data sets contains a number of values corresponding to the number of primary land data sets overlaid and the sets are created by two programs, SETUP and

OVER3. The data sets are written by unformatted write statements which are faster than formatted ones (MacDougall, 1976) and thus a variable data record length is required (a variable blocked open record format was used). The WITS interactive system cannot retrieve such records and thus these sets are not written into a WITS file. Other peripheral storage is used, eg. a tape or a disc.

SETUP creates a secondary data set with zero values for each grid cell. OVER3 writes the results of each overlay of the primary land data sets into this data set.

It is preferable to use existing bug-free computer programs that perform a desired task than to repeat work which has already been done. Several programs overlaying a grid of square cells upon a map were found:-

(a) UCLMAP had been obtained from the University of London by a member of this computer centre. Unfortunately, its potential use could not be investigated as two subroutines were found to be missing.

(b) BOUNDRY2 (MacDougall, 1976). An attempt to run this program unearthed several bugs which the author was unaware of at the time of publication. Correspondence with MacDougall did not overcome the problem as no bug-free version was available.

(c) GRDGEN was obtained through correspondence with MacDougall (1978, personal communication). It was written for a CDC Machine and required certain modifications before it could be run on the IBM machine at this computer centre. Thus, it was not completely bug-free.

(d) PLAN was written by the Mining Engineering Research Unit at this University. It was bug-free and available for use. The Mining Department were concerned with overlaying maps showing mined and unmined areas only. The most dominant of these two alternatives was stored each grid cell.

In this procedure, a grid cell may have a range of possible measured values ie. not only two as PLAN caters for and the data may have an area, network or point distribution. Certain changes to PLAN were necessary and eventually a completely new program (OVER3) had to be written.

The dimensions of the digitised map are limited by the peripheral storage available at the computer installation. The dimensions of the grid are restricted by the smaller CPU storage and may thus be smaller than the dimensions required to overlay the map completely. The grid dimensions depend on the number of grid cells required to overlay the map and is a function of the grid cell size. If these dimensions exceed the CPU storage, the map must be overlaid in sections.

This may be done by:-

(a) The polygons, networks or points are retrieved and overlaid individually. However, the problem of combini g these separate overlays into one grid map which accurately depicts the spatial relationsh[illegible] [illegible]en the individual polygons, etc. is extremel[illegible] It is also more efficient in computer time to retri[illegible] overlay more than one polygon, network or point at a time.

(b) The grid is laid down over a particular section of the map and all polygons, networks or points lying beneath it are retrieved and overlaid. The grid is moved systematically to new positions until the whole map has been overlaid. However, sections of a polygon or network could lie beneath the grid and, if only these sections are retrieved, the polygon is not closed. This increases the complexity of the program unless the polygons are closed before they are overlaid. This proved to be very difficult as all possible polygon shapes must be catered for. An attempt to close the polygons was made but it could not be guaranteed that all possible shapes had been catered for. Retrieving the whole polygon is a method of assuring that the polygon is closed. The attempt to close the polygons was discarded in favour of this method.

SETUP

The user enters the information describing the set, viz. the title, the number of these two alternatives was stored each grid cell will contain, the scale of the digitised map stored in the primary data sets the grid cell size and units and the extreme map co-ordinates of the area to be overlaid. This may be the whole or a section of the map. The north co-ordinate is always the maximum even if this is not so on the map eg. if National Grid co-ordinates are used. The code numbers of all the land characteristics in the order in which they are to be stored, is also given.

The selected grid cell size is used to calculate the number of grid cells in the whole overlay. If this is greater than the allowed grid dimensions (50, 50), the primary data set is divided into sections. This division begins at the extreme south-west corner and moves in an easterly direction before moving in a northerly direction as illustrated in Fig.18.

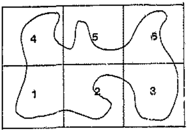


Figure 18. The order in which the grid is overlaid upon a map

For each section, the x and y co-ordinates of all the grid cells are calculated by incrementing the map origin by the product of the selected grid cell the increment between the map co-ordinates. This is 0,001 as CONTOR writes the co-ordinate values to three significant places. The selected grid cell size is the ratio between the grid-map and the original map:-

(a) A grid cell size of one indicates a 1:1 ratio between these two, ie. there is no change between them and the increment between each grid row and column is 0,001.

(b) A grid cell size of 0,5 indicates a ratio of 0,5:1,ie. the grid-map is twice that of the original map and the increment between its rows and columns is 0,0005.

(c) A grid cell size of 2 indicates a ratio of 2:1, ie. the grid-map is half that of the original map and the increment between its rows and columns is 0,002.

All values of each grid cell are set to zero.

The state of the secondary data set when SETUP has run is:-

Title, number of values, scale, grid cell size, units and extreme map co-ordinates.

Number of cells (N), number of rows,)
number of columns) Repeated for
x co-ordinate, y co-ordinate,) repeated) each overlay
n zero values) N times) section

OVER3 (Fig.19)

This program lays a grid of square cells upon the surface of a map and stores one representative value for each grid cell. The heterogeneity of a grid cell is a function of the map scale, the detail recorded, the grid cell size and the land characteristic mapped. A choice from the possibilities present must be made when storing one representative value per grid cell.

Before any polygons or networks are retrieved for overlaying, each is enclosed by a box. The co-ordinates of these boxes are compared with the extreme grid co-ordinates and any polygon or network whose box lies completely or partially within the grid, are retrieved. In this manner it is assured that complete polygons or networks are retrieved. Only those sections which are within the grid itself, are overlaid. No boxes are placed around the point data.

Considering each form of data separately:-

(a) Polygon. For each polygon, the x co-ordinates of the intercept of any of its digitised boundary segments with the median line of a grid row are determined and stored, together with the value measured for that polygon. Similar triangle geometry is used to calculate the intercept. Each boundary segment, delimited by two digitised points, is taken. If it intercepts with the median line, the intercept is calculated.

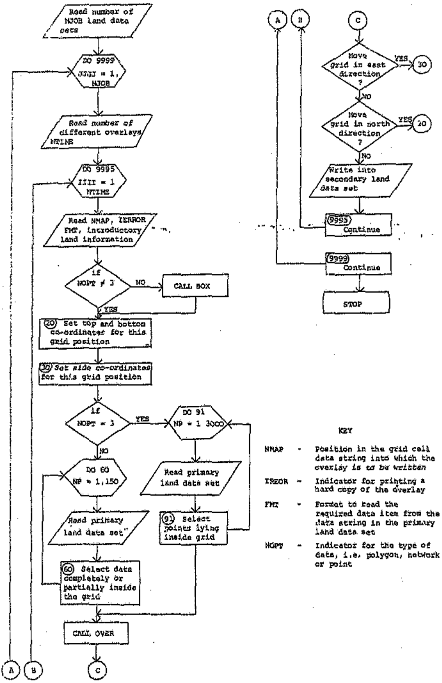


Fig.19 Simplified flowchart of the main steps in the overlay program OVER3

Consider Fig.20.

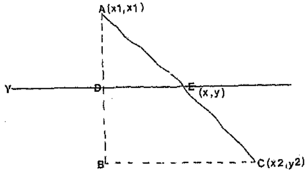


Figure 20 The interception of a boundary segment AC, with the median line YE of a grid cell.

Boundary segment AC intercepts with the median line YE.

$$A\hat{B}C = A\hat{D}E$$

$$\frac{DE}{BC} = \frac{AD}{AB} \times BC$$

Substituting in the co-ordinate values :-

$$(x - x1) = \frac{(y1 - y)}{y1 - y2)} \times (x2 - x1)$$

Each polygon is retrieved sequentially in the order in which they were digitised and thus the order of the intercepts for all the polygons intercepting with the grid row in question, will be of that order.

Each grid row is filled in turn before another row is dealt with. When the x intercept values are calculated, the full extension of the grid row, across the whole map is considered but only that part within the particular grid section is filled. Since the polygons are closed, an even number of intercepts will occur in pairs.

The x intercept co-ordinates are arranged into ascending order with a corresponding arrangement of the polygon measured values. The sort routine given by MacDougall (1976) was used.

Three types of cover represented by polygons are possible:-

(i) Complete cover, eg. a soil map. Each polygon has a neighbouring one.

(ii) Incomplete cover, eg. reservoirs. No polygons have a neighbour.

(iii) Complete and incomplete cover, eg. farms. A polygon may or may not have a neighbour.

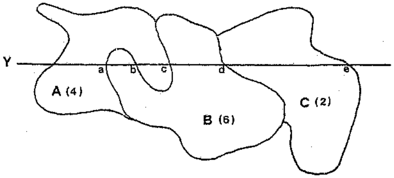
Each cover type must be overlaid in a different manner as blank grid cells are necessary in cover type (b) but are incorrect for cover type (a).

(i) Complete cover Neighbouring polygons will have common boundaries and thus common x intercept values. Each polygon is digitised separately by CONTOR and thus a common boundary will be digitised more than once. It is absolutely necessary that the digitised co-ordinate values of all the points along a common boundary be the same to the third significant figure, so that they may be found by the program. This equality cannot be assumed to be present due to the probability of human error having occurred during the digitising process. Before the intercept values are ordered, this error is corrected by making any x intercepts with a difference in value of $\pm$ 0,001, equal. During the ordering, the polygon value stored with the x intercept value, may remain with any of these identical x intercept values. Should it remain with the wrong possibility, it may be separated from its partner (the intercepts occur in pairs). This will cause an incorrect arrangement of the polygon values although the intercept arrangement is correct. This situation (illustrated in Fig.21) will occur if the polygons are not digitised in a west to east direction which is the direction in which the grid is filled. The sequential retrieval of each polygon means that the order in which they are retrieved is that in which they were digitised.

OVER3 corrects such situations by swopping the position of the identical intercept values together with the measured polygon value. These sorted x intercept values are used to fill up all the grid cells in the row with a measured polygon value.

The x intercept values are compared sequentially with the x co-ordinate of the first grid cell's median point until the first x intercept value, which is greater than this point, is found. If this intercept is the first of a group of identical intercepts, the last of this group is selected. The west boundary of the grid and that of the map section being overlaid, will now correspond. The next median point is taken and compared with this intercept and its neighbour. The distance between these two intercepts will describe the cover of the polygon. If the median point lies between these two intercepts, the measured polygon value of the left-hand point is stored. This will not necessarily be the desired dominant cover. However, the closer it is to the left boundary of the grid cell, the probability of it being so is increased, assuming that the polygon extends over the whole cell in the north to south direction.

The choice of the dominant cover each time may only



The intercept value arrangement if the order in which the polygons are digitised is A B C and each polygon is digitised in a clockwise direction:-

	A			B				
Intercept	a	b	c	d	c	b	a	
Polygon value	4	4	4	6	6	6	6	2

The intercept value arrangement if the order in which the polygons are digitised in C B A.

C		B				A		
e	d	d	a	b	c	c	b	a
2	2	6	6	6	6	4	4	4

Sort ↓

a	a	b	b	c	c	d	d	e
6	4	6	4	6	4	2	6	2

Correction ↓

a	b	a	b	c	c	d	d	e
6	6	4	4	6	4	6	2	2

Fig.21 The correction of the intercept arrangement occurring in program OVER3.

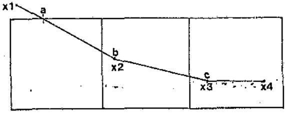
be assured if the area covered by each polygon within the cell is calculated. This is possible (Baxter, 1976) and requires a significant increase in execution time and program complexity. The accuracy of the area calculation will be a function of the digitising process The greater the number of points digitised for each boundary, the greater is the accuracy of its reconstruction. The greater the heterogeneity within a cell, the less is the probability of a dominant value being present. Considering all these factors, it was decided that the required increase in expense in calculating the area would counteract any increased accuracy achieved in choosing the dominant value. In most instances, a smaller grid cell size will decrease the heterogeneity within it and thus increase the probability of the dominant value being chosen. A calculation of the area covered was not performed by any of the overlay programs found. MacDougall (1978, personal communication) in BOUNDRY2, chose that value of the polygon at the bottom right-hand corner with which to fill the cell. It is thought that the use of the median point of the grid cell is preferable as the probability of a polygon about this point being that of the dominant cover is greater than that point used by MacDougall. The median point of the next grid cell is taken and compared with the two intercepts. The grid cell is filled with the same polygon value. This is repeated until a median point lying to the right of the right-hand intercept is encountered. The next pair of intercepts is taken and the whole process is repeated. In this manner, the whole row is filled. It is then checked for any blank grid cells. If any are present, they are filled with the grid cell value to the left.

(ii) Incomplete cover   The method used to determine the intercepts and fill the grid cells is the same as for (a) except that no corrections for common intercept values and for blank cells is made.

(iii) Complete and incomplete cover   It is assumed that no incomplete cover is present. Thus areas with no measured cover are digitised and given a zero value. This value will be stored in those grid cells which overlie this area. The x-scale of the capability graphs for certain land characteristics are a percentage surface cover value. However, since no area is calculated, such values are not available. To correct for this situation, OVER3 stores a value of fifty per cent instead of the polygon value if the percentage surface cover value is required. Variable ISURF in the descriptive data of each primary data set (Section 4.4.1.1) is given a value of 1, if this action is required. The capability graphs and the permissible limits have not been deleted since the facility to calculate the surface cover will be a useful future addition should the extra expense be considered worthwhile.

(b) Network   Each complete network is retrieved sequentially. The x co-ordinate of the intercept of any segments of the network with the top boundary of a grid row are calculated as above, and stored together with the value measured for the network. If the grid row is the most southern one of the grid-map, the bottom boundary is also included.

A network segment may not intercept with the top boundary, but still be within the grid row. Or it may run horizontally directly beneath this boundary. In both instances, both the end points of the segment are stored unless, in the former instance, the segment is totally included within the grid cell. If this is so, only the left-hand end point is stored. Duplicate values will be stored stored (Fig.22) since each network segment is considered separately.



Value a is stored for line segment x1, x2

Value b or c are stored for line segment x2, x3

Value c is stored for line segment x3, x4

Value c is stored twice.

Figure 22. The interception of a network x1, x4 with a grid row

Before the intercepts are sorted into ascending order, the duplicate points are removed.

The number of different networks within each grid cell of a grid row is calculated before another row is considered. The x values in the intercept array are compared sequentially with the grid western boundary until the first value within this boundary is encountered. This value is compared with the right hand boundary of each grid cell. Should it lie to the left of this boundary, the value stored for that grid cell is incremented by one provided that the network value is different to any others present. Subsequent grid cell boundaries are compared until this value in the intercept array is less than the particular cell boundary being considered. The next x value in the intercept array is then taken. This is repeated until all the grid cells and values in the intercept array have been considered.

The stored value in a grid cell for network data is thus the number of individual networks within the cell. The actual network type present is not lost because each type is considered to be a different land characteristic, eg. paved road, unpaved road, etc.

(c) Point The x co-ordinates of all points lying within or on the top boundary of a grid row are stored together with the value measured for each point. If the grid row is the most southern one of the grid map, the bottom boundary is also included. These x co-ordinates are sorted into ascending order and the number of points having different measured values within a grid cell is calculated in the same manner as for networks.

The program dimensions allow a total of 3 000 digitised points to be retrieved for one overlay. A map having more than this number may be overlaid provided that the total points selected for a particular section of the map to be overlaid is less than 3 000. The maximum number of intercept per grid row is 6 000. Error messages are written and the program terminates if either value is exceeded. The user must then create subsets of the data set being overlaid so that these values are not exceeded.

Once the whole map has been overlaid, it is inserted into the secondary data set as one of the land characteristic values, which are stored for each grid cell. The insertion method used is inefficient since the FORTRAN language is used. Each grid cell with its data string is one record in the data set. For every overlay, only one data item is changed. This could be done by retrieving the record, changing the item and re-writing the record before the next record is retrieved. However, FORTRAN cannot be used to re-write an unformatted record to the same position if each record is read sequentially. The record is retrieved, changed and written to temporary disc. Once the whole secondary data set has been retrieved, it is overwritten by that on the temporary disc. Thus, the whole secondary data set is re-written several times which is a tedious, inefficient process. It could be rectified by a data base system in which a land characteristic within a gnd cell is retrieved separately and re-written back to the same place, before the next grid cell is retrieved.

4.4.2 <u>The Control Data Sets</u>

Various questions must be asked before a capability analysis for a particular land use may be performed. These are:-

(a) Which land characteristics must be analysed for that scale at which the land was surveyed?

(b) Is there an interrelationship between any of the land characteristics and if so, how should it be analysed?

(c) Can the measured value of a land characteristic be combined with another to give one value which is then given a capability rating?

(d) How are the different land characteristics given a capability rating?

(e) What capability graphs, tables and factor graphs are required?

The answers to these questions for each land use type are the control data stored in a number of arrays. Each land use system and the foreclosure of options in land use is a separate data set containing all these arrays which are:-[1]

1. INDEX stores the land characteristic code numbers in ascending order, of all those analysed for a land use type, for any survey scale. Where a particular land characteristic is not analysed for a land use type, a zero is stored so that each land use type has the same amount of information. Each land use type is stored in one row.

2. ICGD stores the capability graph numbers used to give a capability rating to the land characteristics for each land use type. The order of these numbers corresponds to that of the land characteristics stored in INDEX. A zero is stored if the land characteristic is not given a capability rating by this method. Each land use type is stored in one row.

3. INDCT stores the land characteristic code numbers which are given a capability rating from a capability table, and the number of rows and columns in this table. The order of the land characteristics given corresponds to the order in which the capability tables are stored in CAPT (point 13).

1. The array type viz. real or integer, is indicated by its name unless otherwise stated.

(e) What capability graphs, tables and factor graphs are required?

The answers to these questions for each land use type are the control data stored in a number of arrays. Each land use system and the foreclosure of options in land use is a separate data set containing all these arrays which are:-[1]

1. INDEX stores the land characteristic code numbers in ascending order, of all those analysed for a land use type, for any survey scale. Where a particular land characteristic is not analysed for a land use type, a zero is stored so that each land use type has the same amount of information. Each land us type is stored in one row.

2. ICGD stores the capability graph numbers used to give a capability rating to the land characteristics for each land use type. The order of these numbers corresponds to that of the land characteristics stored in INDEX. A zero is stored if the land characteristic is not given a capability rating by this method. Each land use type is stored in one row.

3. INDCT stores the land characteristic code numbers which are given a capability rating from a capability table, and the number of rows and columns in this table. The order of the land characteristics given corresponds to the order in which the capability tables are stored in CAPT (point 13).

---

1. The array type viz. real or integer, is indicated by its name unless otherwise stated.

4. IS stores the land characteristic code numbers which are analysed at a large scale (Row 1) and at a small scale (Row 2). The number or numbers of the land characteristics which may substitute a particular land characteristic at the alternative scale (Section 3.4) are indicated by a minus sign in the row for the scale at which it is used as a substitute (Table 61) eg. land characteristic 25 (factor of safety) analysed at a large scale, is substituted by land characteristic 24 (geological discontinuities) if it is absent, and vice versa. Table 61 is used to set up IS for each land use system by omitting those columns for the land characteristics which are not required by the system.

5. TL and BL store the permitted upper and lower limits respectively for the land characteristics in their order given in INDEX. These values are inclusive ie. the values themselves are permitted. Each land use type is stored in one row.

6. WGT stores the weighting value for each land characteristic in their order given in INDEX. Each land use type is stored in one row.

7. IFAC The land characteristic code number of that which is modified (Column 1) and that which controls (Column 2) together with the code indicating how the modification is performed (Column 3) are stored. Each interrelationship is stored in one row. The codes are:-

1 - addition

2 - subtraction

3 - multiplication

Table 61 – The Land Characteristic Code Numbers Analysed at a Large or Small Survey Scale (see text for explanation)

Survey Scale	LAND CHARACTERISTIC CODE NUMBERS																												
Large	1	2	3	4	5	6	7	8	9	-11	-12	11	12	13	14	15	16	17	-37	-38	-37	-38	20	21	22	23	-25	25	-27
Small	1	0	0	0	5	6	7	8	9	10	10	-10	-10	13	0	15	16	17	18	18	19	19	20	21	0	0	24	-24	26
Large	-28	27	28	29	30	31	32	-29	-30	-31	34	35	36	37	37	38	38	39	40	41	42	43	44	45	46	47	48	49	50
Small	26	-26	-26	-33	-33	-33	32	33	33	33	0	0	36	-18	-19	-18	-19	39	40	0	0	0	0	0	46	47	48	49	50
Large	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
Small	51	52	53	54	55	56	57	58	59	60	61	0	0	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
Large	80																												
Small	80																												

4 - division

5 - capability table.

eg. the soil erodibility index (code number 32) is modified by the rainfall energy (code number 57) and this modification is performed by multiplying the soil erodibility index, by a factor derived from a factor graph. The information stored in the relevant row in IFAC will be 32 57 3.

8. FAC is an integer array storing the factor graph numbers required by the interrelationships given in IFAC. The order of these numbers corresponds to the order of the interrelationships given in IFAC. However, if the modification involves a capability table, the value of the controlling land characteristic governing the choice of the relevant column in the table, is given eg. for the interaction between the Climatic N-factor and the durability of the natural rock, a value of 5 is stored as chemical weathering predominates below this value.

9. ISA, ISAU contain the land characteristic code numbers of those which are representative of either usable or non-usable surface areas respectively (Section 3.5.5.1).

10. INA, INU contain the land characteristic code numbers of those which are inhibiting and non-inhibiting networks respectively (Section 3.5.5.1).

11. LENGTH, XAR, YAR are the arrays in which the capability graphs are stored sequentially in ascending order of their graph numbers. LENGTH contains the number of points within each graph, XAR the x co-ordinates and YAR the y-co-ordinates

12. FLEN, FXAR, FYAR are the arrays in which the factor graphs are stored sequentially in the same manner as for the capability graphs. FLEN is an integer array.

13. CAPT stores all the capability tables in ascending order of their table numbers. For each table, the first row contains the possible values of the land characteristics which may be measured and the remaining rows contain the capability values awarded for these measured values. Each of these latter rows refers to a land use type. The first column in each row contains the land use type code number except for row one where a zero is stored. Thus, each table has n + 1 rows where n is the number of land use types involved and m + 1 columns where m is the number of land characteristic values possible. A land use type for which the land characteristic is not evaluated, is omitted.

14. ANLT, ICNLT contain the name and numerical code respectively of each land use type. The latter is its position in the order in which these are described for each land use system (Sections 3.5.2.4 - 3.5.3).

15. ANAM, ICODE contain the name and numerical code, respectively (Table 12) of each land characteristic in INDEX in ascending order of the code number.

16. The number of land characteristics in INDEX (NLC), of land use types (NLT), of capability graphs (NCG) and tables (NCT) of limiting land characteristics (NEX), of land characteristics representing usable and non-usable surface area and inhibiting and non-inhibiting networks (NSA, NSAU, NNA, NNU), of land characteristics in IS (survey scale array), of interrelationships (NFAC) and of factor graphs (NFG) are also required.

17. A title for each control data set is stored in array TITLE.

Default control sets of the above information for each land use system and the foreclosure of options in land use are stored in the Wits data base system having been obtained from the following figures and tables. (The listing of these control data sets are given in Appendix B.):-

i. INDEX, TL, BL Tables 13, 16, 17-24.

ii. WGT Tables 62-70.

iii. ICGD Tables 62-70 and Figs. 6-14.

A choice of capability graphs is needed for a land characteristic where a difference between the land use types exists as indicated by a difference in values in Tables 13, 16, 17-24. The column containing the capability graph numbers in the Tables 62-70, gives all possible choices. The correct number is chosen by comparing the values in TL and BL with the graph in the relevant figure (Figs. 6-14)

iv. INDCT, CAPT Tables 25-60

The column containing the capability table numbers used for the evaluation of each land use system (Tables 62-70) indicates those for which no default set is given. If the user does not supply the required table, this omission is indicated in CAPT by a blank row.

v. XAR, YAR, LENGTH Figures 6-14.

vi. IFAC, FAC Tables 62-70 and Figure 4. respectively.

vii. FLEN, FXAR, FYAR Figure 4.

viii. ISA, ISAU, INA, INU, IEX Tables 62-70.

ix. ANLT, ICNLT Section 3.5.2.4 - 3.5.3

x. ANAM, ICODE. Table 12.

Table 62 - The Manner in which the Land Characteristics are Analysed for the Agriculture Land Use System

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling Land Char-acteristic	Arithmetic Function Code	Factor Graph Number
LAND COVER												
Rock surface	1						*					
Boulder cover	2						*					
Gravel cover	3						*					
Rocky distribution	4			15,16								
Lake	5						*					
Reservoir	6						*					
Vlei	7						*					
River	8								*			
Stream	9								*			
RELIEF												
Hillslope element	10	*			1							
Slope gradient	11	*		17-19								
Slope length	12	*		1						11	4	1
Height above water	14		*									
Koppie	15						*					
Gully	17						*					
SOIL												
Subsoil texture	29	*			2							
Topsoil texture	30	*			3							
Soil erodibility index	32			20-23						58	2	4
Soil permeability index	33	*		24-25								
Rooting depth	34	*		26,27						29	3	2
Depth to water table	35			28,29						29	4	2
Exposed soil length	36			2								
Soil deficiency	39		*									
Soil toxicity	40		*									
Soil salinity	41			3								
Soil pH	42			30,31								
Sodium absorption ratio	43			4								

Table 62 (contd.)

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling land characteristic	Arithmetic function code	Factor graph number
SOIL (contd.)												
Soil cation exchange capacity	44			5								
Soil organic matter	45			6								
CLIMATE												
Wind velocity	47			7								
Frost temperature	48			8								
January temperature	49		*									
July temperature	50		*									
Hail occurrence	51			32,33								
Fruiting season length	52	*		9								
Season length	53	*		10								
Season quality	54	*		11								
Water deficit period	55	*		2								
Evaporation	56											
Rainfall total	57	*		13						56	2	3
Rainfall energy	58	*		14								
BIOLOGICAL CHARACTERISTICS												
Physiognomic vegetation type	60				4							
Floristic vegetation type	61				*5							
Woody cover	62						*					
Woody distribution	63			34,35								
Animal host species	66				**6							
MAN-MADE STRUCTURES AND BOUNDARIES												
Township	68						*					
Industrial area	69						*					
Settlement	70						*					
Powerline	71								*			
Railway	72								*			
Paved road	73								*			
Mountain catchment	78						*					
Unpaved road	80								*			

Note * No default capability table. ** Default capability table only considers one species

Table 63 - The Manner in which the Land Characteristics are Analysed for the Forestry Land Use System

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling Land Characteristic	Arithmetic Function Code	Factor Graph Number
LAND COVER												
Rock surface	1						*					
Boulder cover	2						*					
Gravel cover	3						*					
Rocky distribution	4			17,18								
Lake	5						*					
Reservoir	6						*					
Vlei	7						*					
Stream	8								*			
River	9								*			
RELIEF												
Hillslope element	10	*			1							
Slope gradient	11	*		19,20								
Slope length	12	*		1						11	4	1
Aspect of a slope	13			2								
Height above water	14		*									
Koppie	15						*					
Gully	17						*					
SOIL												
Subsoils texture	29	*			2							
Topsoil texture	30	*			3							
Soil erodibility index	32	*								58	2	4
Soil permeability index	33	*		3								
Rooting depth	34	*		4						29	3	2
Depth to water table	35			5						29	4	2
Exposed soil length	36			6								
Soil deficiency	39		*									
Soil toxicity	40		*									
Soil pH	42			7								
Soil cation exchange capacity	44			8								
Soil organic matter	45			9								

Table 63 (contd.)

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area: Usable	Surface area: Non-usable	Net-works: Non-inhibiting	Net-works: Inhibiting	Interrelationships: Controlling Land Char-acteristic	Interrelationships: Arithmetic Function Code	Interrelationships: Factor Graph Number
CLIMATE												
Wind velocity	47			10								
Frost temperature	48			11								
January temperature	49		*									
July temperature	50		*									
Hail occurrence	51			12								
Season quality	54	*		13								
Water deficit period	55	*		14								
Evaporation	56											
Rainfall total	57	*		15						56	2	3
Rainfall energy	58	*		16								
BIOLOGICAL CHARACTERISTICS												
Physiognomic vegetation type	60				4							
Floristic vegetation type	61				*5							
Woody cover	62						*					
Woody distribution	63			23,24								
MAN-MADE STRUCTURES AND BOUNDARIES												
Township	68						*					
Industrial Area	69						*					
Settlement	70						*					
Powerline	71								*			
Railway	72								*			
Paved road	73								*			
Mountain catchment area	78						*					
Unpaved road	80								*			

* No default capability table.

Table 64 - The Manner in Which the Land Characteristics are Analysed for the Conservation Land Use System

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling Land Char-acteristic	Arithmetic Function Code	Factor Graph Number
LAND COVER												
Lake	5					*						
Reservoir	6					*						
Vlei	7					*						
River	8							*				
Stream	9							*				
RELIEF												
Hillslope element	10	*			1							
Slope gradient	11	*		1								
Slope length	12	*		2						11	4	1
Koppie	15					*						
Natural land feature	16	*			*2							
Gully	17					*						
SOIL												
Soil erodibility index	32	*		3						58	2	4
Exposed soil length	36			4								
CLIMATE												
Wind velocity	47			5								
Rainfall energy	58	*		6								
BIOLOGICAL CHARACTERISTICS												
Physiognomic vegetation type	60	*			3							
Floristic vegetation type	61	*			**4							
Protected plant species	65	*			*5							
Protected animal species	67	*			*6							
MAN-MADE STRUCTURES AND BOUNDARIES												
Township	68						*					
Industrial area	69						*					
Settlement	70						*					
Powerline	71								*			
Railway	72								*			

Table 64 (contd.)

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling Land Characteristic	Arithmetic Function Code	Factor Graph Number
Paved road	73								*			
National Park	74	*				*						
Provincial Park	75	*				*						
Municipal Park	76	*				*						
Private Park	77	*				*						
Mountain catchment area	78	*				*						
Wilderness area	79	*				*						
Unpaved road	80								*			

<u>Note</u>

* Default capability table only considers one feature or species.
** No default capability table.

Table 65 - The Manner in which the Land Characteristics are Analysed for the Recreation Land Use System

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area: Usable	Surface area: Non-usable	Networks: Non-inhibiting	Networks: Inhibiting	Interrelationships: Controlling Land Characteristic	Interrelationships: Arithmetic Function Code	Interrelationships: Factor Graph Number
LAND COVER												
Rock surface	1					* or	*					
Boulder cover	2					* or	*					
Rocky distribution	4			1								
Lake	5	*				* or	*					
Reservoir	6	*				* or	*					
Vlei	7	*				* or	*					
River	8	*						* or	*			
Stream	9	*						* or	*			
RELIEF												
Hillslope element	10	*			1							
Slope gradient	11	*		5,6								
Slope length	12			2						11	4	1
Koppie	15					* or	*					
Natural land feature	16	*			*2							
Gully	17						*					
SOIL												
Subsoil texture	29	*			3							
Topsoil texture	30	*			4							
Soil erodibility index	32			7,8						58	2	4
Soil permeability index	33	*		9,10								
CLIMATE												
Wind velocity	47			3								
Rainfall energy	58			4								
BIOLOGICAL CHARACTERISTICS												
Physiognomic vegetation type	60	*			5							
Floristic vegetation type	61	*			**6							
Woody cover	62						*					
Game species	64	*			*7							

Table 65 (contd.)

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling Land Characteristic	Aithmetic Function Code	Factor Graph Number
<u>MAN-MADE STRUCTURES AND BOUNDARIES</u>												
Industrial area	69						*					
Powerline	71							*				
Railway	72							*				
Paved road	73							*				
National Park	74					*						
Provincial Park	75					*						
Municipal Park	76					*						
Private Park	77					*						
Mountain catchment area	78						*					
Wilderness area	79					* or	*					
Unpaved road	80							*				

<u>Note</u>

* Default capability table only considers one feature or species.
** No default capability table.

Table 66 - The manner in which the Land Characteristics are Analysed for the Urban and Rural Development Land Use System

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area: Usable	Surface area: Non-usable	Net-works: Non-inhibiting	Net-works: Inhibiting	Interrelationships: Controlling Land Characteristic	Interrelationships: Arithmetic Function Code	Interrelationships: Factor Graph Number
LAND COVER												
Rock surface	1						*					
Boulder cover	2						*					
Lake	5					* or	*					
Reservoir	6					* or	*					
Vlei	7					* or	*					
River	8							* or	*			
Stream	9							* or	*			
RELIEF												
Hillslope element	10	*			1							
Slope gradient	11	*		9-12								
Slope length	12	*		1						11	3	1
Aspect of a slope	13			2								
Height above water	14		*									
Koppie	15					* or	*					
Gully	17						*					
GEOLOGY												
Stratigraphic unit	18	*			2							
Transported soil origin	19	*			3							
Depth to bedrock	23	*		15-17								
Geological discontinuities	24				*4							
Factor of safety	25			3								
SOIL												
Soil horizon type	31	*			5							
Soil erodibility index	32			4						58	2	4
Soil permeability index	33			13,14								
Depth to water table	35	*		18-20						31	4	2
Soil joint structure	37	*			*6							
Soil activity	38	*		6								
CLIMATE												
Wind velocity	47			7								
Rainfall energy	58			8								

Table 66 (contd.)

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area: Usable	Surface area: Non-usable	Networks: Non-inhibiting	Networks: Inhibiting	Interrelationships: Controlling Land Characteristic	Interrelationships: Arithmetic Function Code	Interrelationships: Factor Graph Number
<u>BIOLOGICAL CHARACTERISTICS</u>												
Physiognomic vegetation type	60				7							
Floristic vegetation type	61				**8							
Woody cover	62						*					
<u>MAN-MADE STRUCTURES AND BOUNDARIES</u>												
Industrial area	69						*					
Powerline	71							* or	*			
Railway	72							* or	*			
Paved road	73							*				
Mountain catchment area	78						*					
Wilderness area	79						*					
Unpaved road	80							*				

<u>Note</u>

* Default capability table only considers one measurement
** No default capability table.

Table 67 - The Manner in which the Land Characteristics are Analysed for the Communications Land Use System

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling Land Characteristic	Arithmetic Function Code	Factor Graph Number
LAND COVER												
Rock surface	1						*					
Boulder cover	2						*					
Lake	5						*					
Reservoir	6						*					
Vlei	7						*					
River	8								*			
Stream	9								*			
RELIEF												
Hillslope element	10	*			1							
Slope gradient	11	*		9-11								
Slope length	12	*		1						11	4	1
Height above water	14		*									
Koppie	15						*					
Gully	17						*					
GEOLOGY												
Stratigraphic unit	18	*			2							
Transported soil origin	19	*			3							
Depth to bedrock	23	*		12								
Geological discontinuities	24				*4							
Factor of safety	25			2								
SOIL												
Soil horizon type	31	*		5								
Soil erodibility index	32			3						58	2	4
Soil permeability index	33			4								
Depth to water table	35	*	13	13						31	4	2
Soil joint structure	37	*		*7	*6							
Soil activity	38	*			7							
CLIMATE												
Wind velocity	47			7								
Rainfall energy	58			8								

Table 67 (contd.)

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling Land Char-acteristic	Arithmetic Function Code	Factor Graph Number
BIOLOGICAL CHARACTERISTICS												
Physiognomic vegetation type	60				8							
Floristic vegetation type	61				**9							
Woody cover	62						*					
MAN-MADE STRUCTURES AND BOUNDARIES												
Township	68						*					
Industrial area	69						*					
Settlement	70						*					
Powerline	71								*			
Railway	72								*			
Paved road	73								*			
Mountain catchment area	78						*					
Wilderness area	79						*					
Unpaved road	80								*			

Note

* Default capability table only considers one measurement
** No default capability table.

Table 68 - The Manner in which the Land Characteristics are Analysed for the Excavation Land Use System

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling Land Char-acteristic	Arithmetic Function Code	Factor Graph Number
LAND COVER												
Rock surface	1					* or	*					
Boulder cover	2					* or	*					
Lake	5						*					
Reservoir	6						*					
Vlei	7						*					
River	8							*				
Stream	9							*				
RELIEF												
Hillslope element	10	*			1							
Slope gradient	11	*		8,9								
Slope length	12			1						11	4	1
Height above water	14		*									
GEOLOGY												
Natural rock group	20	*			2					46	5	0
Mineral ore deposit	21	*										
Depth to mineral ore deposit	22			12								
Depth to bedrock	23			13								
Geological discontinuities	24				*3							
Factor of safety	25			2								
Rock hardness	26	*		14								
Secondary minerals	27	*		3								
Ten per cent fines	28	*		15								
SOIL												
Soil erodibility index	32			10,11						58	2	1
Soil permeability index	33			4								
Depth to water table	35			5						29	4	2
Subsoil texture	29				4							
Topsoil texture	30				5							
CLIMATE												
Climate N-factor	46											
Wind velocity	47			6								
Rainfall energy	58			7								

Table 68 (contd.)

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling Land Characteristic	Arithmetic Function Code	Factor Graph Number
<u>BIOLOGICAL CHARACTERISTICS</u>												
Physiognomic vegetation type	60				6							
Floristic vegetation type	61				**7							
Woody cover	62						*					
<u>MAN-MADE STRUCTURES AND BOUNDARIES</u>												
Township	68						*					
Industrial area	69						*					
Settlement	70						*					
Powerline	71							*				
Railway	72							*				
Paved road	73							*				
Mountain catchment area	78	*					*					
Wilderness area	79	*					*					
Unpaved road	80							*				

<u>Note</u>

* Default capability table only considers one measurement
** No default capability table.

Table 69 - The Manner in which the Land Characteristics are Analysed for the Water Catchment Land Use System

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area: Usable	Surface area: Non-usable	Networks: Non-inhibiting	Networks: Inhibiting	Interrelationships: Controlling *Land Characteristic*	Interrelationships: Arithmetic Function Code	Interrelationships: Factor Graph Number
LAND COVER												
Lake	5					*						
Reservoir	6					*						
Vlei	7						*					
RELIEF												
Hillslope element	10											
Slope gradient	11			1								
Slope length	12			2								
Gully	17						*					
SOIL												
Subsoil texture	29	*			2							
Topsoil texture	30	*			3							
Soil erodibility *index*	32			3								
Soil permeability index	33	*		4								
Depth to water table	35	*		5						29	4	2
Exposed soil length	36			6								
CLIMATE												
Wind velocity	47											
Rainfall energy	58			7								
Runoff total	59			8								
BIOLOGICAL CHARACTERISTICS												
Physiognomic vegetation type	60	*			4							
Floristic vegetation type	61	*			*5							
Woody cover	62						*					
MAN-MADE STRUCTURES AND BOUNDARIES												
Township	68						*					
Industrial Area	69						*					
Settlement	70						*					
Railway	72								*			
Paved road	73								*			
Mountain catchment area	78	*				*						
Unpaved road	80								*			

Note

* No default capability table

Table 70 - The Manner in which the Land Characteristics are Analysed for the Foreclosure of Options in Land Use

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling Land Char-acteristic	Arithmetic Function Code	Factor Graph Number
LAND COVER												
Rock surface	1					* or	*					
Lake	5	*				* or	*					
Reservoir	6	*				* or	*					
Vlei	7	*				* or	*					
River	8	*						* or	*			
RELIEF												
Hillslope element	10	*			1							
Slope gradient	11	*		3-9								
Height above water	14		*									
Koppie	15					* or	*					
Natural land feature	16	*			*2							
Gully	17					* or	*					
GEOLOGY												
Stratigraphic unit	18											
Transported soil origin	19											
Natural rock group	20	*								46	5	0
Mineral ore deposit	21	*										
SOIL												
Subsoil texture	29	*			*3							
Topsoil texture	30	*			*4							
Soil erodibility index	32	*		9,10						58	2	4
Soil permeability index	33	*		11-13								
Rooting depth	34	*		14,15						29	3	2
Exposed soil length	36											
Soil deficiency	39		*									
Soil toxicity	40		*									
CLIMATE												
Climate N-factor	46											
Wind velocity	47			11,17								
Rainfall total	57	*		18,19								
Rainfall energy	58	*		1								
Runoff total	59	*		2								

Table 70 (contd.)

Land Characteristic	Code	Weighted	Limiting	Capability Graph Number	Capability Table Number	Surface area		Net-works		Interrelationships		
						Usable	Non-usable	Non-inhibiting	Inhibiting	Controlling Land Char-acteristic	Arithmetic Function Code	Factor Graph Number
<u>BIOLOGICAL CHARACTERISTICS</u>												
Physiognomic vegetation type	60	*			5							
Floristic vegetation type	61	*			**6							
Woody cover	62						*					
Game species	64	*			*7							
Protected plant species	65	*			*8							
Animal host species	66				*10							
Protected animal species	67	*			*9							
<u>MAN-MADE STRUCTURES AND BOUNDARIES</u>												
Township	68											
Industrial area	69											
Settlement	70											
Powerline	71							* or	*			
Railway	72							* or	*			
Paved road	73							*	or *			
Mountain catchment area	78	*				* or	*					
Wilderness area	79	*				* or	*					

<u>Note</u>

* Default capability table only considers one measurement
** No default capability table

The non-linear arrays viz. INDEX, ICGD, INDCT, IS, TL, BL, WGT, IFAC, XAR, YAR, FXAR, FYAR and CAPT, are written and stored in the form AC(cols rows)which is the form corresponding to the computer memory organization. This increases the speed of information retrieval and storage from these arrays when they are in the central processing unit (MacDougall, 1976).

Users may wish to add or change information in the default control data sets particularly as research reveals more information. The facility to do this is provided and is described in Section 4.6.2.

4.5 The Capability Analysis Program CAPANL (Fig.23)

The efficiency of the program in terms of its execution time is less than that originally hoped for as no data bank with software to retrieve required portions of the control data is available. All the control data for a land use system must be retrieved, from which the required information is selected and combined as needed by the program itself. Certain subroutines in the program are only concerned with this and, being in FORTRAN, their efficiency is not as great as might be if another language able to handle data strings had been used. When a data bank with the required software becomes available these subroutines will be obsolete and can be removed, thus increasing the efficiency of the program.

The program retrieves a secondary land data set whose data set name, and other data descriptions are given in the job control language. It is analysed for one or more land uses from one or more land use systems. A foreclosure of options in land use may also be performed.

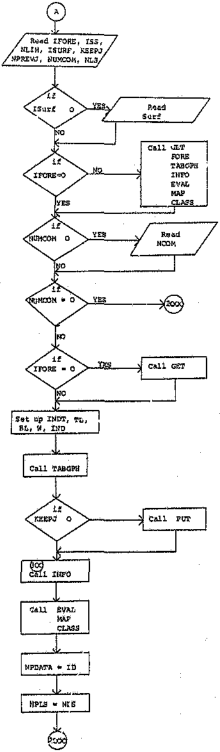


Fig.23 Simplified flowchart of the linkages between the main subroutines of the land capability analysis program CAPANL.

(See Table 71 and text for the definition of the variable names.)

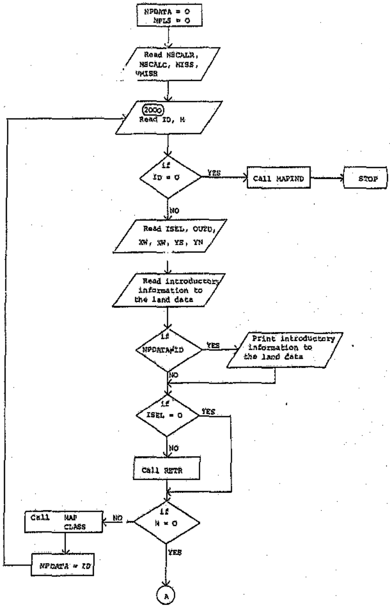

NPDATA = O
NPLS = O
Read NSCALR, NSCALC, NISS, VMISS
2000
Read ID, M
if ID = O
YES
Call MAPIND
STOP
NO
Read ISEL, OUTD, XW, XW, YS, YN
Read introductory information to the land data
if NPDATA≠ID
YES
Print introductory information to the land data
NO
if ISEL = O
YES
NO
Call RETR
if M = O
NO
Call MAP CLASS
NPDATA = ID
YES
A

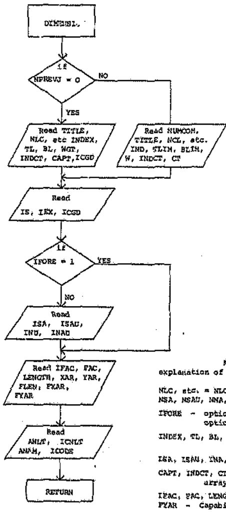
Fig.23 (contd.)

Another data set may be retrieved when all the land uses for the former data set have been analysed or when a particular land use is being analysed. This is decided entirely by the user according to the order in which the information selecting the secondary land data sets and land use system control data sets are given (See Table 71).

The main steps in the program are:-

(a) The title of the secondary land data set to be analysed and the dictionary array, INDEXD, which contains the land characteristic code numbers in their stored order in this data set are read. If only a certain portion of this set is required, subroutine RETR reads the whole data set and writes the selected portion to temporary disc. This selected portion is delimited by four boundary co-ordinates, the extreme west, east, north and south co-ordinates, and may be permanently kept. The co-ordinates of the line printer map to be printed are derived from the co-ordinates of the secondary land data set which are read to four significant decimal places. These are printed as integer numbers as it is complex to print the decimal point since each digit of the co-ordinates must be printed separately. This integer conversion involves a multiplication of the extreme boundary co-ordinates by a factor of 10^4 so that no decimal places are lost.

(b) The required land use system control data set is read in by subroutine GET (Fig.24). Much of this subroutine will be unnecessary if a data bank, which can retrieve selected portions rather than the whole data set, becomes available.



KEY (see text for explanation of the arrays)

NLC, etc. = NLC, NEX, NCT, NCG, NMAX, NSA, NSAU, NNA, NNU, NLT, NFAC, NFG.

IFORE - option for foreclosure of options in land use.

INDEX, TL, BL, WGT - Control arrays.

ISA, ISAU, INA, INU - Control arrays.

CAPT, INDCT, CT - Capability table arrays.

IFAC, FAC, LENGTH, XAR, YAR, FLEN, FXAR, FYAR - Capability and factor graph arrays.

ANLT, ICNLT - Arrays of the names and codes for the land use types.

ANAM, ICODE - Arrays of the names and codes for the land characteristics.

Fig.24 Simplified flowchart of subroutine Get which reads the control data set.

(c) The code number of the land use type to be analysed in the land use system is read in. Several of the land use types present (Section 3.5.2.4 - 3.5.3) may be combined to give one composite land use type eg. temperate forestry and pit prepared land will give the composite land use *of temperate forestry on non-ploughed land.* If this is desired, the code numbers of the land uses concerned are given. The control information which would be used if each land use type were analysed separately, must be combined to give the composite land use type. The rows in array INDEX indicating which land characteristics are to be analysed for each land use type being combined, are compared with one another (Fig.25). If the characteristic occurs in at least one of the rows, the land use type code number is stored in an array, NPRES. When all the required land use types have been compared, the temporary control arrays to contain the permissible minimum and maximum measured values (BLIM, TLIM), the weighting values (W) and the code number and capability graph number (IND) for each characteristic, are initialized with the values stored in the permanent control arrays BL, TL, WGT, INDEX and ICGD, for the first land use type to be combined. These initial values are then compared with the values of the other land use types in these latter arrays to find the common range of values permitted ie. the lowest value in TL and the highest value in BL, the highest weighting value in WGT, and to ensure that no required land characteristic has been omitted in error. The temporary control arrays may be kept. A maximum of five output sets including those

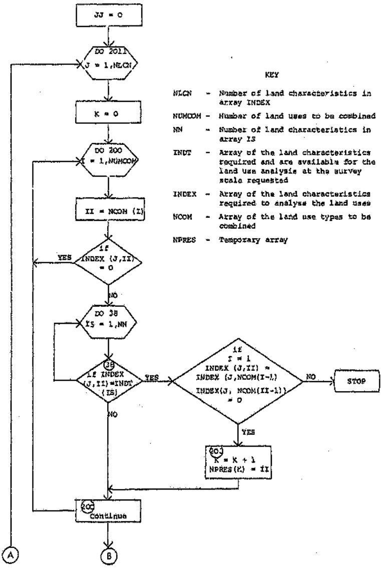
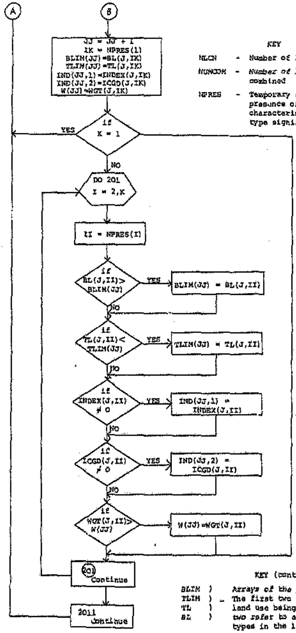


Fig.25 Simplified flowchart of the main section of program CAPANL dealing with the selection of the land characteristics, their capability graphs, their weights and permissible limits required in the capability analysis of the land use.



KEY

NLCN	-	Number of land characteristics
NUMCOM	-	Number of land use types to be combined
NPRES	-	Temporary array indicating the presence of a land characteristic in the land use type signified by counter II

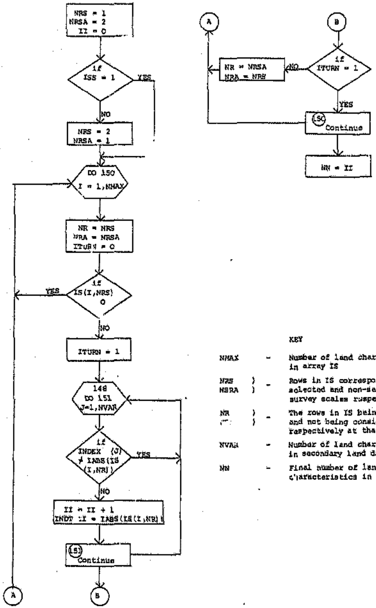
KEY (cont)

BLIM) TLIM) TL) BL)	-	Arrays of the permissible limits. The first two arrays refer to the land use being analysed. The last two refer to all the land use types in the land use system.
INDEX) ICGD) WGT)	-	Arrays of the land characteristics, their capability graphs and their weights respectively, required to analyse all the land use types in the land use system.
IND) W)	-	As for INDEX except that it refers only to the land use being analysed.

Fig.25 (contd.)

from point 1 may be written per computer job.

(d) It is possible that all the land characteristics required in the analysis at the selected scale have not been measured. If this is so, but those at the alternative scale have been measured (Table 3) and may thus be substituted, this course of action is preferred rather than the omission of a land characteristic's influence altogether. Before the temporary arrays in (c) are set up, the array IS which contains a list of the land characteristic's code numbers measured at a large or small survey scale, and INDEX, containing the code numbers of the land characteristics required in the analysis, are compared with INDEXD which has the characteristic's code numbers stored in the secondary land data set. If a required land characteristic is missing in the last array, the IS array is checked to determine whether a substitution can be made (see Fig.26). The result of this comparison and substitution is a temporary array INDT containing the land characteristic code numbers, or the alternative code numbers, required for the analysis of any land use type at the user selected scale and are available in the secondary land data set. The validity of the printed land capability map is one if all the land characteristics to be analysed for the land use type at the selected scale, are present. If this is not so, the validity is less than one. The validity is the ratio of the number of required land characteristics present in the secondary land data set, to the total number of required land characteristics for the land use, be it a single or composite land use, at the selected survey scale (Fig.27).



KEY

NMAX	–	Number of land characteristics in array IS
NRS) NSRA)	–	Rows in IS corresponding to the selected and non-selected survey scales respectively
NR) [illegible])	–	The rows in IS being considered and not being considered respectively at that moment
NVAR	–	Number of land characteristics in secondary land data set INDTXD
NN	–	Final number of land characteristics in array INDT

Fig.26 Simplified flowchart of the main section of program CAPANI dealing with the determination of the land characteristics required for the analysis at the survey scale selected.

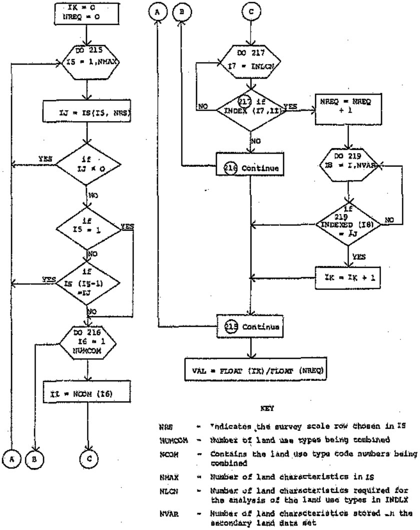


Fig.27 Simplified flowchart of the main section of program CAPANL in which the proportion of the required land characteristics (the validity) is calculated.

The substitution of a land characteristic (see point (d)) will depend upon the secondary land data set. A comparison of the validity of the maps from the analyses of the same land use on different land, would be meaningless as the actual set of land characteristics used may differ. Thus the validity does not include any substituted land characteristics so that it is based on a common set and may be compared.

(e) The capability tables stored in CAPT will only be required if the land characteristic they refer to is also required. If a composite land use is being analysed, the rows in those tables referring to the individual land uses which have been combined, must also be combined together. In subroutine TABGPH (Fig.28), array IND is compared with array INDCT containing the code numbers of the land characteristics whose capability is derived from a table. When such a characteristic is found, the first row of the table dealing with it is written into the temporary control array CT. The second row of this array is initialized to 10,0. The relevant rows of the capability table in CAPT are each compared with this second row to find the minimum capability value. A new array INCT, containing the land characteristic number and the number of columns for each capability table stored in CT, is created as well.

(f) The x-scale of certain capability graphs viz. Group B (Section 3.5.6) varies between the land use types. Subroutine TABGPH (Fig.29) checks the capability graph numbers given in ICGD for each land characteristic to find those graph numbers which differ between the relevant land

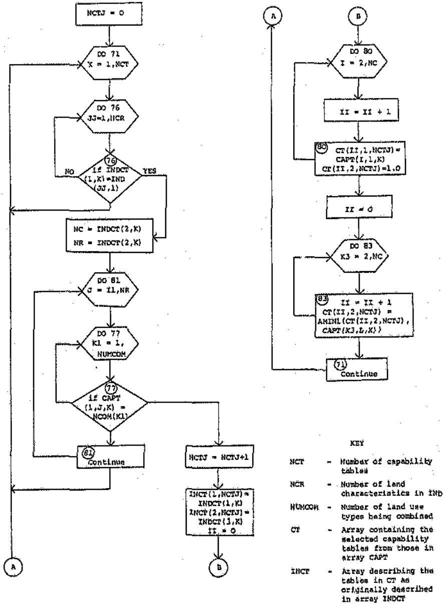
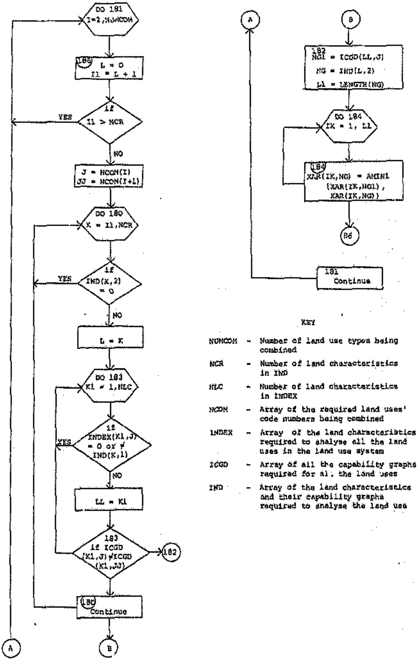


Fig.28 Simplified flowchart of the section of subroutine TABGPH in which the required capability tables are selected.



KEY

NUMCOM - Number of land use types being combined

NCR - Number of land characteristics in IND

NLC - Number of land characteristics in INDEX

NCOM - Array of the required land uses' code numbers being combined

INDEX - Array of the land characteristics required to analyse all the land uses in the land use system

ICGD - Array of all the capability graphs required for all the land uses

IND - Array of the land characteristics and their capability graphs required to analyse the land use

Fig.29 Simplified flowchart of the section of subroutine TABGPH dealing with the selection of the required capability graph.

... ypes. When this situation is found, the x co-ordinate ... all the graphs concerned are retrieved and compared per point. Those of the first graph stored are substituted by the lowest values from all the graphs. This ensures that the capability graph incorporates the whole range of possible measured values. It is essential that all the graphs from which the capability of the same land characteristic may be derived, have the same number of points. This subroutine will be unnecessary if the desired data bank is available in which these changes and the combinations described in points (c) - (h) can be made. The execution time and the storage requirements of the program would be decreased. At present, storage for both the permanent and temporary co... ...l data arrays is needed.

(g) If it is desired, the temporary control arrays may be written as a new permanent data set. A subsequent ...ob analysing the same combination of land use types may then retrieve this set, thus omitting steps (c) to (h). Subroutine PUT writes all the control data arrays, substituting the temporary ones where necessary, to the output specified by the user. They are written in the sequence in which they will be retrieved.

(h) Subroutine INFO prints out:-

(i) A table of the land use types and their code numbers which may be analysed within the land use system (or the foreclosure of options in land use) being analysed.

(ii) INDEX for this land use system (or the foreclosure of options in land use) ie. the land characteristics required to analyse each land use type.

(iii) The table of the land characteristics with their upper and lower limits and weights to be used in the analysis of the land for the land use type or composite land use type being studied. This table also indicates those characteristics which are used to calculate the usable surface area.

(i) The main capability analysis subroutine, EVAL, is entered. The order of the land characteristics stored per grid cell in the secondary land data set will probably differ from the order given in INDEX and thus the temporary array IND, which is based on the former. An array IPOS, is set up giving the stored position of each required land characteristic in the grid cell, in the order required by array IND.

(j) Two main arrays to be mapped are set up by EVAL viz. CAP which stores the final percentage capability value for each cell, and LIM which stores the number of land characteristics per grid cell whose values fall outside the specified limits as well as indicating cells with missing values amongst the data measured. This latter information is important as the overall capability of the cell will have been lowered as a result of this missing value and not due to the land itself. These two arrays are printed on the line printer as grid maps, the latter only by request. Owing to the CPU limitation, CAP and LIM may only be of dimensions (50, 50) ie. equivalent to the overlay dimensions in program OVER3. If the dimensions of the secondary land data sets exceed this, it has already been divided into sections by the program SETUP. Each section is separately retrieved, analysed and CAP and LIM written into a temporary data set from which they are retrieved and mapped after all the sections have been analysed.

LIM and CAP are initialized to zero before the land data are read in per grid cell. The co-ordinates of each cell are stored in CORD. If all the land characteristic values for a cell are zero, that cell is considered to be outside the map boundaries and is ear-marked by being given a value of -99,9 in both LIM and CAP. These cells will be printed as blanks.

(k) For each cell within the map boundary, the values of all the required land characteristics are compared with the permissible limits stored in BL and TL. If the value of a limiting land characteristic lies outside these limits, no further analysis of the cell occurs, and its capability is zero. It is earmarked by adding 100 to the relevant grid cell number in LIM. This value is chosen as it is doubtful that the number of land characteristics which are limiting for any cell will exceed it particularly as no land use requires the evaluation of this number of land characteristics at present. The number of the grid cell is removed before LIM is printed.

The position of a limiting land characteristic in the grid cell is found (Fig.30) by comparing the code numbers in IND with those in IEX, which is the array storing the numbers of the limiting characteristics, in a do loop until the code numbers in each correspond. The value of the do loop variable is that of the position of the land characteristic in IND and it can be used to indicate its position in the grid cell, via IPOS (see Fig.30). This method is used

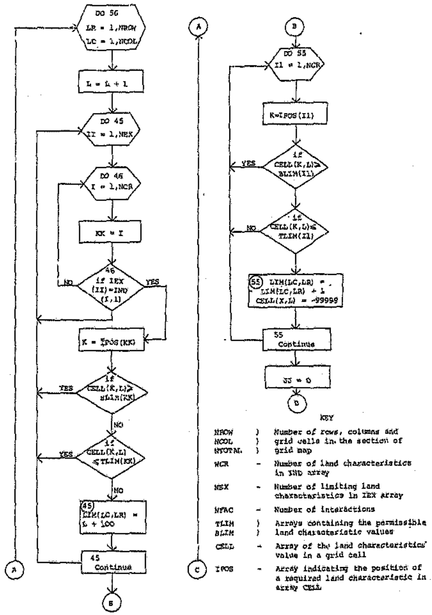
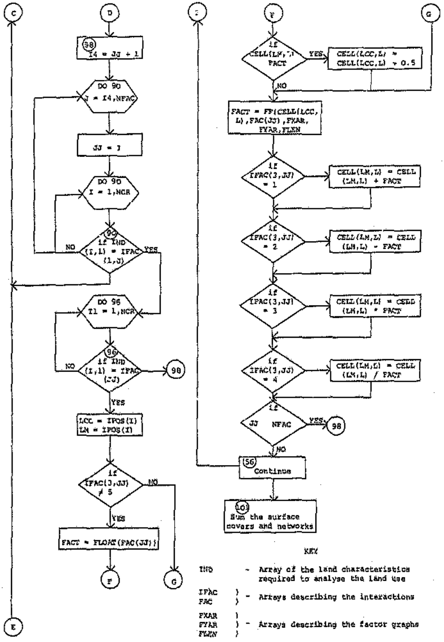


Fig.30 Simplified flowchart of a section of subroutine EVAL dealing with the permissible limits of the land characteristics and the interrelationship between particular pairs of them.



KEY

IND - Array of the land characteristics required to analyse the land use

IFAC)
FAC) - Arrays describing the interactions

FXAR)
FYAR) - Arrays describing the factor graphs
FLEN)

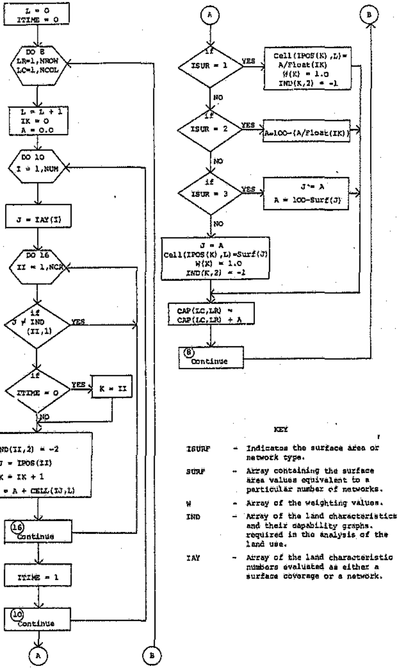
Fig.30 (contd.)

whenever the position of a land characteristic in the grid cell is needed.

If the value of any non-limiting land characteristic lies outside its permitted limits, the value of the relevant grid cell in LIM is incremented by one and the measurement value for that land characteristic is set at -9999,9 (Fig. 30) so that a capability value is not derived for it.

(l) The values of any land characteristic involved in an interaction are modified (Fig.31) as directed by the information in array IFAC together with the factor graphs on appropriate columns in the capability tables. IFAC stores the code numbers of both characteristics involved in the interaction and whether the value of the characteristic to be modified is added, subtracted, multiplied or divided by the factor derived from the factor graph.

(m) Subroutine COVER (Fig.31) calculates the total usable surface area from the cover of those land characteristics representing both non-usable and usable surface area. Any networks present are considered to have a surface coverage which is usable in the case of non-inhibiting networks and non-usable for inhibiting networks. The number of each type of network present is converted into a cover value given by the user and stored in array ISURF. A default set of cover values (Section 3.5.5.1)is used if the user omits to give this information. Land characteristics which are either representative of non-usable surface area or inhibiting networks are not included any further in the analysis as the cover present depends on the cell size (Section 3.5.5.1). These characteristics



KEY

ISURF	-	Indicates the surface area or network type.
SURF	-	Array containing the surface area values equivalent to a particular number of networks.
W	-	Array of the weighting values.
IND	-	Array of the land characteristics and their capability graphs. required in the analysis of the land use.
IAY	-	Array of the land characteristic numbers evaluated as either a surface coverage or a network.

Fig.31 Simplified flowchart of subroutine COVER in which the usable surface area for a land use is calculated.

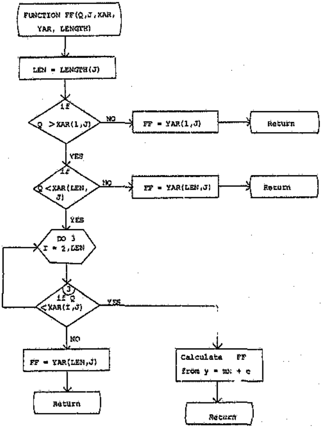
are earmarked by changing their graph number stored in IND to -2. However, a characteristic representing usable surface area indicates a surface which is necessary for the land use eg. water recreation requires a water surface. Thus the presence of such coverages is important. The presence of non-inhibiti. ~ networks may also enhance the capability of a cell. Therefore the presence of a usable surface area or a non-inhibiting characteristic increases the capability of the cell by 10. These characteristics are earmarked by changing their graph number in IND to -1 except for the first characteristic encountered for either group and is present in the land data set. This action means that the cell's capability is only increased once as no capability value is derived for any characteristics with graph numbers less than zero. A zero value indicates that a capability table is needed.

OVER3 stores a fifty per cent cover for all land characteristics whose surface area coverage is required. The reasons for this value being stored have been given in Section 4.4.1.2 Thus it is possible for the total usable area present to exceed 100 per cent. This situation is covered by determining the mean cover present.

(n) For each cell which has no limiting land characteristic the capability ratings of each land characteristic is derived from capability graphs or tables, provided that the land characteristic value is not missing or equal to -9999,9. In both these cases, the capability rating is zero. If the capability rating of a land characteristic is to be derived from a capability graph, function FF is called. This function (Fig.32)(which is a modification of that received from P Furness (1977, personal communication) returns the y value (capability value) corresponding to a given x value (the land characteristic measured value) from the relevant capability graph. Function FF interpolates linearly between the y co-ordinates of each graph segment to pin-point the position of the x-value with respect to the x-scale. The y-value is calculated using the equation for a straight line graph viz. $y = mx + c$, and returned. The use of this equation demands that the shape of each graph be composed of linear sections.

If a capability table is needed, array INCT is searched to find the capability table in array CT from which the capability value for the characteristic in question is derived. Once this table has been found, the columns in its first row are searched to find the value corresponding to the value of the land characteristic measured. When this has been found, the capability value in the corresponding column of Row 2 is retrieved.

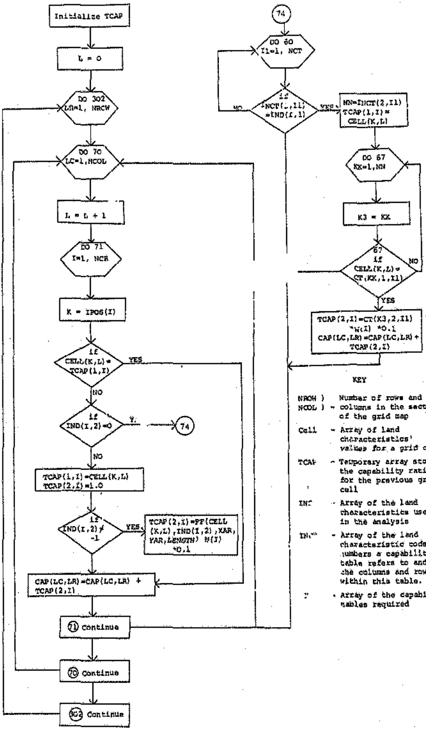
The derived capability values are weighted (Section 3.5.7) and added to the capability value already present in array CAP for that cell. However, if a l[illegible] characteristic value is the same as that in the prev[illegible] the capability table or graph is not retriev[illegible] instead, the capability value derived for the latter cell and stored in an array TCAP, is added into array CAP (Fig.33). This decreases the execution time as the number of searches and entries into function FF are decreased.



KEY

Q	-	Land characteristic value
J	-	Capability graph number
XAR) YAR) LENGTH)	-	Arrays containing the capability graphs

Fig.32 Simplified flowchart of function FF which derives the y-value from a graph for a given x-value. Modified from Furniss (1977, personal communication).



KEY

NROW) NCOL)	- Number of rows and columns in the section of the grid map
Cell	- Array of land characteristics' values for a grid cell
TCAP	- Temporary array storing the capability ratings for the previous grid cell
IND	- Array of the land characteristics used in the analysis
INCT	- Array of the land characteristic code numbers a capability table refers to and the columns and rows within this table.
CT	- Array of the capability tables required

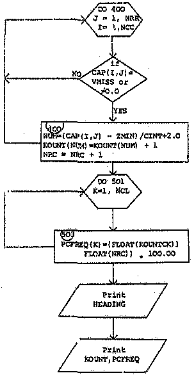
Fig.33 Simplified flowchart of the section of subroutine EVAL in which the overall capability of a grid cell is calculated.

In steps (k) to (m), any land characteristic which has a missing value or is outside the permitted limits, and any grid cell which lies outside the map boundaries or has a limiting land characteristic whose value lies outside the permitted limits, are omitted.

(o) Each capability value in CAP is divided by the product of the number of land characteristics actually analysed and their weights. A final percentage value is stored. This division allows the capability maps of the same land use type for different lands having a different number of measured land characteristics to be compared.

(p) CAP and LIM for each map section are mapped separately using overprinting. The darkest shade indicates the highest capability. Ten different shades covering the range of capability values from 0 - 100 per cent are used for printing CAP. This range does not apply to LIM and ten different shades are printed, depending upon the range of values within the array. Care must be exercised when comparing the LIM line printer map with that from CAP as the symbols ie. shades, will not represent the same values. The frequency and percentage frequency of the grid cells/shade are calculated and printed by subroutine CLASS (Fig.34).

(q) The existing line printer at this computer centre prints eight lines per inch, causing a distortion of the map sides by a ratio of 5:4 ie. five characters across and four lines down represent 1 sq cm (MacDougall, 1976). By printing each grid cell ie. each value in LIM or CAP, as four characters down by five characters across the page, this



KEY

CINT	-	Interval between each class (shade) calculated previously
ZMIN	-	Minimum value in capability array CAP
NCL	-	Number of shades
VMISS	-	Missing data value
NRR } NCC }	-	Number of rows and columns in this grid map section

Fig.34 Simplified flowchart of the section of subroutine CLASS in which the frequency of the different shades mapped is calculated.

distortion is removed. The number of characters, from one to ten, printed per cell across and down the page, may be chosen by the user. The default is a 5:4 ratio. This choice necessitated that the map output format be variable, its exact nature being set up by the program. It is also possible for the section being mapped to exceed the page width, necessitating that it also be printed in sections.

(r) All maps eg. the capability map, the usable surface area map, etc. are printed by subroutine MAP (Fig. 35). For each grid cell, the shade representative of its values is calculated provided it is not outside the map boundaries or, in the case of LIM, is not a cell with a missing value or a limiting land characteristic,and written into array SCALZ n times where n is the product of the number of characters per cell across and down the page. The symbols used in printing each shade are stored in array TABLE2 A maximum of four symbols are combined to give one shade. Each line of the map is printed separately with the value of the y co-ordinate and side outlines after the x-co-ordinates and top outline have been printed. The array LINE is filled with the relevant symbols from TABLE2 according to the values stored in SCALZ. When the particular section has been completely printed (this section may be a complete section of the grid map or a section of it if it exceeds the page width) the bottom outline is printed.

(s) Once all the required land use types for all the land data sets have been analysed, an index of the map shades and the values which they represent are printed by subroutine MAPIND. The program then terminates.

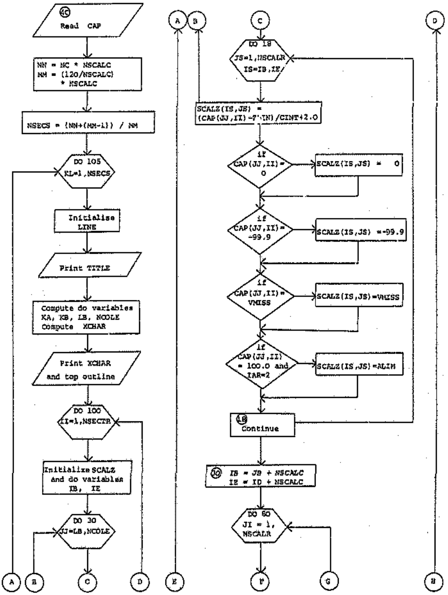
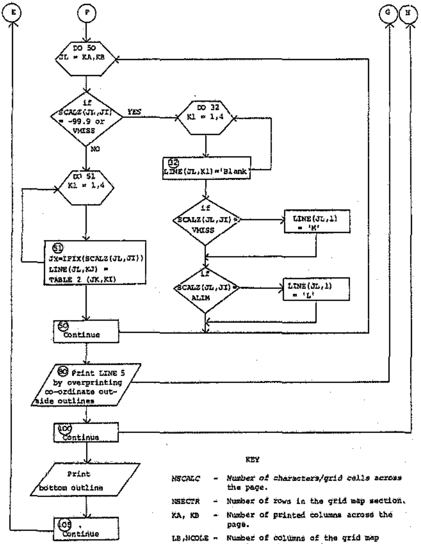


Fig.35 Simplified flowchart of the main section of subroutine MAP to illu-trate the steps in printing a lineprinter map.



KEY

NSCALC - *Number of characters/grid cells across the page.*

NSECTR - Number of rows in the grid map section.

KA, KB - Number of printed columns across the page.

LB,NCOLE - Number of columns of the grid map section to be printed.

VMISS - Missing data value.

ALIM - Symbol 'L' denoting a cell excluded by a limiting land characteristic.

CINT - Class (shade) interval computed in subroutine CLASS.

ZMIN - Minimum datum value for that grid map section, computed in subroutine CLASS.

IAR - Unit number on which CAP array is written.

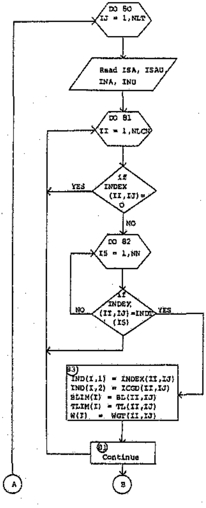
Fig.35 (contd.)

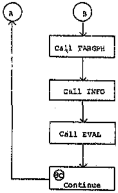
A full understanding of the capability map is only obtained if it is compared with the map showing the cells with limiting land characteristics and those with land characteristics whose measured values are outside the permitted range or are missing. In the last two cases the overall capability of the cell is decreased, while limiting characteristics cause an overall capability of zero. A low or zero capability may therefore be due to any one of these reasons. The map of the usable surface area will indicate the usefulness of a cell with respect to the area available.

If a foreclosure of the options in la ... s required for a land data set being analysed, it is performed before that for any land use type requested. The mean steps taken are as described above with the following differences:-

(i) Subroutine FORE (Fig.36) calls the subroutines TABGPH (sets up the temporary array CT for all the capability tables needed), INFO (prints tables of relevant information) and EVAL (derives the capability for each grid cell). Once subroutine FORE has been called, the main section of the program is not re-entered until the foreclosure of options in land use analysis is complete. Subroutines TABGPH, INFO and EVAL are called for each land use system analysed (after the array IND containing the code numbers of the characteristics required, has been set up) and a capability map is printed.

(ii) The land characteristics representing either usable or non-usable surface area, or inhibiting and non-inhibiting networks differ per land use system. Since these





KEY

NLT	-	Number of land use systems
ISA, ISAU, INA, INU	} -	Arrays containing the land characteristics describing usable or non-usable surface area and non-inhibiting and inhibiting networks
INDEX, ICGD, BL, TL, WGT	} -	Arrays containing the land characteristics, their capability graphs, their permissible limits and their weightings required to analyse all the land use systems
INDT	-	Array containing the land characteristics available in the secondary land data set at the required survey scale
IND, BLIM, TLIM, W	} -	Array of the land characteristics, their permissible limits and their weightings used to analyse the land use system IJ
NN	-	Number of land characteristics in array INDT
NLCH	-	Number of land characteristics in array INDEX

Fig.36 Simplified flowchart of a section of subroutine FORE dealing with the selection of the land characteristics, their capability graphs, weightings and permissible limits required to analyse the land use systems for the foreclosure of options in land use.

arrays are linear, the information for each land use system cannot be read in at the same time as is done for other arrays, eg. INDEX, ICGD, TL and BL where each row refers to a different land use system. Thus when each land use system is analysed these four arrays and the number of land characteristics within each, much be read in.

(iii) No combination of the land use systems analysed in this foreclosure of options is allowed. Thus the relevant rows in arrays INDEX, ICGD, TL, BL and CAPT are written directly into IND, TLIM, BLIM and CT, respectively, with no combinations required. Also no variation in the x-scale of any of the capability graphs exists.

4.6 Versatility of the Land Capability Analysis Procedure

An important objective of this study was that the computerised procedure should be versatile with different options available to the user. The options available may be divided into those which affect the execution of CAPANL and those which change the information contained in the control data sets ie. the editing of these sets.

4.6.1 The Options available in the Execution of CAPANL

(a) The temporary control arrays set up in a job may be kept, and may be retrieved and used in subsequent jobs.

(b) A line printer map of a particular land characteristic stored in the secondary land data set may be printed for the whole or a selected portion of this data set. The subroutines involved in retrieving the control arrays, and performing the capability analysis are by-passed. More than one land characteristic may be printed per job.

Each is printed separately and its range of values is divided into ten classes. Care must be exercised when these maps are compared with other maps as the shades printed will represent different values, even if a comparison is made between maps of the same land characteristic, but at different grid cell sizes. When a small grid cell is used, other values may be included which are lost in a map with a large grid cell size and thus the range of values may not be the same.

(c) A maximum of five different secondary land data sets may be analysed in one run. This number may be increased if additional data descriptive job control language is given. For each, the whole or only a portion of the set need be analysed. A foreclosure for the options in land use may be performed for all, none or some of the data sets.

Any number of land uses may be analysed per secondary land data set.

(d) The land capability analysis and the usable surface area maps for a land use are always printed unless the former contains no values greater than zero and the values in the latter are all the same. However, the map showing the number of limiting land characteristics per cell and those cells with missing values, is only printed when requested by the user.

(e) The number of characters printed per grid cell across and down the page may vary independently of each other from one to ten so that the distortion caused by the line printer may be removed and square cells printed.

(f) The land capability analysis may be performed at a large or small survey scale (Section 3.4).

(g) The default of -0,9 which value represents missing data in the secondary land data set is not used if the user specifies another value.

(h) Any combination of land use types to form a composite land use may be analysed for any land use system.

(i) Other surface area values equivalent to a number of networks may be given if the default values are not required. These are listed in Section 3.5.5.1.

These options are all dealt with by the capability analysis program CAPANL. The particular commands required for selecting the various options, and the required order of these are given in Table 71.

The program is written to evaluate a number of land use types per land data set within the same or different land use systems for n data sets. For every land use analysed all the data specified in this Table 71 are given even if the land data set is the same as the previous one analysed. This is because the land data read cannot be kept in the CPU due to the limitations of its size and must thus be reread each time they are to be analysed. If the previous data set is a selected portion of the secondary land data set, and the same portion is still required it is not reselected if the unit number to which it has been written ie. unit number 3 is given for NLS (Table 71). This is the unit to which a temporary data set of the portion selected has been written. The foreclosure of options in land use should be performed when that land data set is first analysed for any land use.

A number of land data sets may be evaluated for the same land use type if the land data set information given is

Table 71 - The Data Required to Execute the Land Capability Analysis Program CAPANL

OPTION	SYMBOL	FORMAT		
Number of characters down and across the page per grid cell, value one if the default missing datum value is not to be used; the user given missing datum value.	NSCALR, NSCALC, MISS, V MISS.	3I3 F10.3		
Unit number on which the secondary land data are written; the code number of the land characteristic which is to be mapped separately.	ID, M	2I3		
Value one if a particular portion of the secondary land data is to be selected, the unit number to which this selected portion is to be written if a permanent data set is required; west, east, south, north co-ordinates of this portion.	ISEL, OUTD; XW, XE, YS, YN	2I3, 4F10.3		
Value one for the following:-				x land data sets
Analysis of the foreclosure of options in land use; performance of the capability analysis at a detailed survey scale; print the array LIM (see Section 4.5); default set of surface area values equivalent to a number of networks is not to used. The unit number to which the temporary control arrays are to be written if desired; the unit number from which the temporary control arrays from a previous job are to be retrieved; the unit number on which the land use to be analysed is written; the number of land use type to be combined.	*IFORE, ISS, NLIM, ISURF,* KEEPJ, NPREVJ, NLS, NUMCOM	8I3	n land uses	
Surface area values equivalent to a number of networks from 1-10.	SURF	10F5.1		
Land use type numbers to be combined	NCOM	26I3		

repeated with no changes except for NUMCOM which is given a zero value. The advantage of this is that the control data are not reread as those which are already in the CPU may be used. Thus the retrieval of these data from the peripheral storage, is omitted. The temporary control arrays will remain the same and thus are not set up again. However, if the land use types are to be analysed at a different survey scale, NUMCOM must not be zero so that the control data are changed to suit that scale.

4.6.2 <u>The Editing of the Control Data Sets</u>

Editing options available are:-

(i) The Addition of one or more new land use systems.

(ii) Addition of one or more land use types.

(iii) Addition of one or more land characteristics.

(iv) Changing of the information contained in these data sets.

(v) Addition of factor graphs, capability tables and capability graphs.

These options, except for (i) are dealt with by an interactive program PREP (see Fig.37) which must be executed on the Wits system. It is thus written in Wits FORTRAN. It may be transferred to another system if the necessary changes to make it compatible with that system are made. Standard FORTRAN may not be executed on the Wits system and thus it cannot be used interactively at this computer centre. By being interactive, the user is guided in his choice of options and their implementation and so unnecessary error is prevented. This advantage was considered to be greater than the restriction upon its transfer between systems.

Considering each option in turn (the arrays referred to have all been described previously in Section 4.4.2):-

(a) Each control data set consists of one land use system. A new land use system may be added by simply entering the data into a new data set. The sequence and format of the data must agree with that specified by subroutine GET in the capability analysis program CAPANL.

(b) The addition of n new land use types to a land use system requires that a row for each land use type ie. n rows be added, to the arrays INDEX, ICGD, TL and BL. Each capability table in CAPT will require the addition of extra rows if the land characteristic which they refer to is to be analysed for any of the new land use types. The names and numerical codes and the land use types are added to arrays ANAM and ICNLT. The additional data are read directly into the control arrays, each land use type being read in separately as illustrated in Fig.37, p.255.

(c) A new land use type is added before the addition of any land characteristic. Thus the data added to arrays INDEX, ICGD, TL or BL, which refer to all land use types, must also include the new land use type. Any number of land characteristics may be added, each being dealt with separately. The data required are additional columns to arrays INDEX, ICGD, TL, BL and IFAC (if it is involved in an interaction) and to INDCT and CAPT if its capability is derived from a table. Otherwise, the capability graph is added if the one to be used is not already present. If the characteristic is limiting, the code number is added to array IEX in which case no capability graph or table are required. A factor graph may need to be added, or if the interaction analysis involves the addition of a column to an existing capability table, the whole capability table must be given as a completely new capability table.

(d) Any values in the control arrays may be changed. The need for this will arise as further research information becomes available. It may also be necessary to change the values in arrays TL and BL if a specific land use is to be analysed. In order to incorporate these changes, changes may also be necessary in values in the capability tables and capability graphs. If a land characteristic representative of a surface area or a network has been added in option (c) its code number must be added where necessary to the arrays ISA, ISAU or INA and INU. The code number must also be added to the array IS for the survey scale at which it is analysed. If it is not analysed at one of the scales a zero for the code number of the characteristic which may be substituted, is stored.

The editing of the control data sets require that the users know the exact position within any array which is to be changed. The disadvantage of this is that the responsibility for the accuracy of the change is placed upon the user. The advantage is that the execution time is not increased by including search routines to find and replace the relevant data. Where more than one data item is asked for by the interactive program, the user must respond with the same number. If only some of the items asked for are to be changed, the user must reply as though they are all to be changed, giving the value already present in the control array for those which are to remain the same. If this is not done, zeros or incorrect data will be read into the control arrays.

The order in which the various control arrays are changed is given in Fig.37. Any number of values may be changed within each array. Each array is considered separately and all changes to that particular array are performed before the following array is considered.

(e) Any number of new factor graphs, capability tables or graphs may be added. The need for this option may arise as further research information becomes available, or a user may wish to analyse a land characteristic in a manner different to that given.

PREP reads the whole control data set from the data base into the CPU. When the editing is complete, the data set is written to the output space of the Wits terminal system which is the only output unit immediately available to a program executed by this system. The output space is easily stored in the Wits data base system by choosing the appropriate Wits commands (Wits 850, 1977) once the program has terminated. From there, it can be written to any other device as required. The program PREP could have been written to re-run each time a different control data set is to be edited without terminating the program between the editings. However, each edited set would be written sequentially to the output terminal space and at the end of the job, one output file consisting of edited control data sets would be present and would need to be separated using

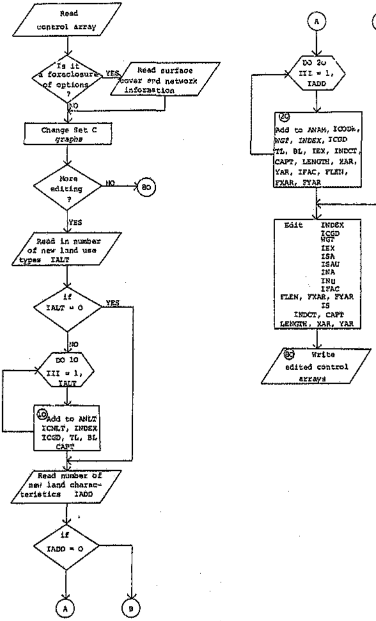


Fig.37 Simplified flow chart of a section of subroutine PREP dealing with the addition of new data and the editing of a control data set.

(See text for the definitions of the variable names.)

the Wits Editor (Wits 850, 1977). But it is simpler for a user unfamiliar with the system to terminate the program between the editing of a different control data set and to store the edited set in the Wits data base before retrieving and editing another set.

4.7 The Interactive Execution of the Land Capability Analysis Procedure

It is desirable that the whole procedure, from digitising a land survey map to obtaining the final capability map, should be interactive to allow the user to change the data at various points, redirect the order of execution of various programs, edit the control data sets, etc. Any interactive program at the centre must be written in Wits FORTRAN. This is basically the same as standard FORTRAN (Wits 860, 1977) but there are a few important differences:-

(a) The length of a variable and the dimensions of an array must be declared before their appearance in a common statement. This means that statements such as Common A (4,5) are not allowed.

(b) Block data and data statements are invalid.

(c) The end parameter on the read statement is not recognised viz.Read (6, 10, End = 99).

(d) Comment lines only need a blank in column two.

(e) No continuation lines are allowed.

(f) Only two output and input areas are available viz. the terminal screen or the terminal output space and the keyboard or a Wits data file.

Points (a), (d) and (e) will restrict the transfer of the procedure to another installation.

Points (a) and (c) are required by the programs OVER3 and CAPANL.

Point (f) restricts the output devices to two. OVER3 and CAPANL both require a greater number of such devices including the facility to write and read from temporary data sets.

Thus the whole procedure cannot be completely interactive, nor can it be executed completely independently from the Wits system as the digitiser is connected to it. Therefore, both the Wits system and the open system at this computer centre are used.

A suite of interactive programs have been written which direct the user in the execution of the whole procedure. They are:-

(a) CONTOR (Section 4.4.1.1). This interactive program receives and writes the digitised points of a map to the terminal output space.

(b) DIGIT saves this output space under the file name COXXYY interactively and the final edited version is stored in the Wits data base system under a new file name given by the user.

Steps (a) - (c) result in the creation of a primary land data set.

(d) SET is an interactive program which writes the data required from the user to set up the secondary land data set to the terminal output space. This output space is stored as a file XXSET.

(e) CREATE takes the file XXSET, inserts it as the data for program SETUP (Section 4.4.1.2) and submits the program for execution in the open system.

(f) OVER copies OVER3 (Section 4.4.1.2) into a file OVPGM. This action is taken because the filename of the primary land data set and the data set name of the secondary land data set into which the overlay of the former is to be written, must be changed in the JCL[1] commands of the program. The original program is not changed so that subsequent users are not influenced in any way by the actions of previous users.

(g) OVDATA is an interactive program which writes the data required from the user to execute OVER3, to the terminal output space.

(h) COMB stores the output space in a file ODDD, inserts it as data into OVPGM and submits this for execution in the open system.

Steps (d) - (h) result in the overlay of a primary land data set. These steps must be repeated until this latter data set is complete. The number of repetitions depends on the number of primary data sets overlaid in one execution of OVER3. All these data sets may be overlaid in one job.

---

1. JCL is the Job Control Language governing the execution of a computer program.

(i) EVAL copies the interactive editing program PREP into a file EVPREP so that the control data file names in the JCL may be changed without changing the original program. EVPREP is executed and the edited control data set is written to the terminal output space.

(j) CONTRL stores this output space under the file name WATPXG and inserts it into the file INFO ready for the execution of CAPANL.

Steps (i) and (j) result in a file INFO containing the edited control data to analyse a land use. If land uses from several land use systems are to be analysed in one run of the program CAPANL these steps are repeated for each land use system. Each edited control data set is inserted after the previous one in INFO. Thus the order in which the different land use systems are analysed depends upon the order in which the user edits their control data sets. The editing program must be entered even if no editing is required, so that INFO is set up.

(k) EVDATA is an interactive program which writes the data required (Table 71) from the user to execute CAPANL for several land use types in one or more land use systems for one or more secondary land data sets, to the terminal output space.

(l) ANAL stores this output space under the filename EV123, copies CAPANL into a file EVPGM and inserts EV123 into EVPGM as data. The data set names of the secondary land data sets to be analysed and the filename into which any temporary control arrays are to be stored permanently

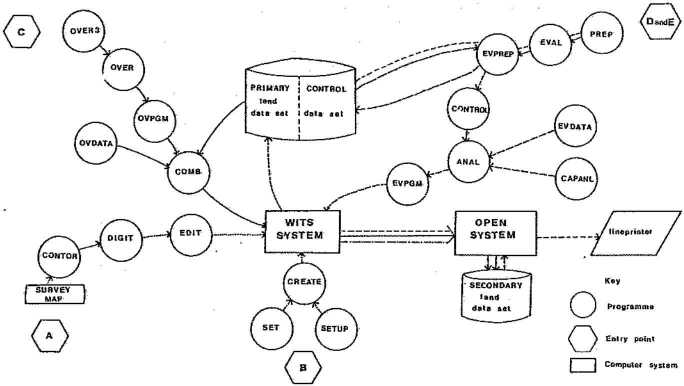


Fig.38 The components of the interactive land capability procedure indicating the linkages between them and the possible points of entry (A-E) (See text for explanation.)

are given by the user. The program is submitted to the open system for execution.

If the temporary control arrays from more than one land use analysis are to be kept, they are written into one file. At the end of the job, the arrays from the different analyses must be separated using the Wits editor (Wits 850, 1977). More than one file could be provided but this may still be less than the number required as there is no upper limit to the number of land uses analysed per job. Thus the separation of some of them may still be required. Also the execution of the whole job is increased as each file must be transferred back into the Wits data base system.

Steps (k) and (l) result in the land capability analysis of several secondary land data sets for a number of land uses.

(m) INSTR is a Wits file containing the instructions guiding the user through the procedure. Its execution is initiated by displaying the first lines of this file.

There are three other programs which are necessary for the system to run, namely:

INTERP (Section 4.2) which interpolates discrete points; READ, which reads and writes a secondary land data set to hard copy; and COPY, which copies a secondary data set to a given data set. Printouts of all the programs are given in Section 4.8.

A simplified, overall view of the linkages between the various components of the procedure is given in Fig.38. Various entry points into the procedure are available:-

(A) The digitization of a map, its subsequent editing and storage as a primary land data set.

(B) The creation of a secondary land data set.

(C) The addition of an overlaid primary land data set into the secondary land data set.

(D) The editing of a control data set without the execution of a land capability analysis.

(E) A land capability analysis with or without the editing of a control data set. The procedure can be taken to any desired stage, without necessarily completing the entire procedure.

The two fundamental programs of the procedure are OVER3 (the overlay program) and CAPANL (the land capability analysis program). These two programs can be readily transferred between computer installations. CONTOR, SETUP, EDIT, EDITLF, EDITPT, EVDADA, PREP AND OVDATA are the fundamental interactive programs which can be transferred. The remaining programs, excluding READ, COPY and INTERP, contain Wits commands to link these programs together for which complementary software at other installations would be required.

At this computer installation, the primary land data sets, the control data sets and the programs are stored in the Wits data base system. The secondary land data sets are stored on tape or disc in the open system. This division is necessary as the latter are written and read unformatted and thus cannot be written accurately into the Wits data base system. The primary land data sets are initially written into this system and are therefore not removed. Should these sets be removed at a later stage they would need to be transferred back to the Wits data base system before any of the interactive programs can access them. The control data sets are also accessed by interactive programs and are stored in the Wits data base system.

4.8 The Computer Programs of the Interactive Land Capability Analysis Procedure

```
C      FILE 1 OF THE LAND CAPABILITY ANALYSIS PROCEDURE 1980 (C.HAMMOND)
C
C
THIS FILE CONTAINS ALL THE INSTRUCTIONS FOR DIGITIZING A MAP,EDITING
THE DIGITIZED FILES,SETTING UP A PERMANENT DATA SET WHICH WILL CONTAIN
THE OVERLAYS,OVERLYING THE DIGITIZED FILES AND RUNNING A CAPABILITY
ANALYSIS. THE FOLLOWING ENTRY POINTS INTO THE PROCEDURE ARE POSSIBLE :-

1) A SURVEY MAP IS TO BE DIGITISED. ENTER /D INSTR 17,44
2) A DIGITISED DATA SET IS TO BE EDITED. ENTER /D INSTR 17,41
3) A SECONDARY LAND DATA SET IS TO BE CREATED. ENTER /D INSTR 41,43
4) A CONTROL DATA SET IS TO BE EDITED. ENTER /D INSTR 91,103
5) A LAND CAPABILITY ANALYSIS IS TO BE PERFORMED. ENTER /D INSTR 77,115


ENTER /XEQ CONTOR

IF ANY DELETIONS OF CONTOURS (IE.POLYGONS,NETWORKS, OR CHAINS OF POINTS)
OR INDIVIDUAL POINTS AREA REQUIRED, USE THE WITS EDITOR
TO REMOVE THEM. (THE EDITTING PGMS. ASSUME THAT ALL SUCH DELETIONS OF
ERRONEAOUS DIGITIZED POINTS HAVE BEEN MADE). OTHERWISE ENTER:
       /XEQ E        (POLYGONS)
       /XEQ EDITLF   (NETWORKS)
       /XEQ EDITPT   (POINTS)
AS APPROPRIATE


THE FILE TO BE EDITED MUST BE STORED UNDER THE FILENAME COXXYY.
IF THIS IS NOT SO, INSERT THE FILE INTO THIS BY :-
       ENTER /EMP
             /SA COXXYY
             /UP COXXYY
             /INS FILENAME
             /E

THEN ENTER /D INSTR18,44


AT THE END OF THE RUN, ENTER /KEP FILENAME (THE USER MUST GIVE HIS OWN NAME)
FOLLOWED BY /RET FILENAME .

TO OVERLAY EACH OF THE DIGITIZED,EDITTED DATA FILES, ENTER /XEQ OVER ,
OR /XEQ SET IF THE PERMANENT OVERLAY DATA SET HAS NOT BEEN CREATED.


WHEN THIS JOB HAS BEEN EXECUTED SUCCESSFULLY, ENTER /XEQ OVER


THE DIGITIZED,EDITTED DATA FILES ARE SEPARATELY OVERLAID WITH A SQUARE
GRID OF GIVEN DIMENSIONS. THESE DIMENSIONS MUST BE CONSTANT FOR ALL THE DATA
WRITTEN INTO ONE PERMANENT OVERLAY DATA SET. THIS SET MUST HAVE BEEN
PREVIOUSLY CREATED. IF THIS HAS NOT BEEN DONE, ENTER
       /XEQ SET

THE FILENAME OF THE DIGITIZED DATA TO BE OVERLAID & THE PERMANENT OVERLAY
DATA SET INTO WHICH THE RESULTS OF THE OVERLAY ARE TO BE WRITTEN, MUST
BE GIVEN.ENTER:
       /UP OVPGM
       /D /36,40
GIVE THE CORRECT FILE NAME BY REPLACING THE WHOLE LINE . ENTER :
       /REP /L            (L IS LINE NUMBER)
(IF THE ORIGINAL LINE IS DESIRED WHEN A REPLACEMENT HAS BEEN REQUESTED,
ENTER /CA . THIS WILL CANCEL THE REPLACEMENT)
NOTE THE LAST TWO NUMERICAL DIGITS IE.FOR SYS20  - 20, THIS IS THE UNIT
FROM WHICH THAT FILE WILL BE READ & WILL BE REQUIRED AS DATA
AT A LATER STAGE.
THE FILENAME DUMMY NEED NOT BE REPLACED IF <5 FILES ARE TO BE OVERLAID
WHEN THIS IS COMPLETE GIVE THE PERMANENT OVERLAY DATA SET NAME, ENTER /REP /779
THEN ENTER :
       /E
ENTER /XEQ OVDATA


IF MORE DIGITIZED DATA SETS ARE TO BE OVERLAID ENTER /XEQ OVER
IF THE OVERLAY DATA SET HAS BEEN COMPLETED ENTER /D 76,91 .


THE APPROPRIATE FILES OF THE CONTROL ARRAYS FOR THE ANALYSIS OF A LAND
USE SYSTEM OR THE FORECLOSURE OF OPTIONS ARE COMBINED INTO ONE FILE INFO.
THIS FILE IS CREATED EVERY TIME EVAL IS EXECUTED UNLESS THAT FROM A PREVIOUS
RUN WAS SAVED. THESE CONTROL ARRAYS MUST BE GIVEN PER DATA SET TO BE ANALYSED.
IF THAT FROM A PREVIOUS RUN IS REQUIRED (IT MUST NOT BE CALLED INFO)
ENTER :
       /PUR INFO  (THIS SAVED FILE MAY NOT BE CALLED INFO)
       /EMP
       /UP
       /INS FILENAME
       /E
       /SA INFO
DO NOT RUN PREP.     ENTER /XEQ EVDATA

TO EDIT A CONTROL DATA SET, ENTER /XEQ EVAL. IGNORE THE FINAL COMMAND

THE CONTROL DATA SET TO BE EDITED IS INSERTED INTO THE PROGRAM EVPREP BY
ENTRYING :
         /UP EVPREP
         /CH /F,L #DATA#
IMMEDIATELY AFTER THIS LINE ENTER:
         /INC FILENAME
         /E
         /XEQ EVPGM
IGNORE THE LAST COMMAND IN THE PROGRAM.
C
C
TO SETUP INFO FOR A SERIES OF CONTROL DATA SETS TO BE ANALYSED IN ONE JOB,
EVPREP EDITS THE CONTROL ARRAYS & INSERTS THE EDITED ARRAYS INTO FILE INFO
ENTER:
       /UP EVPREP
       /CH /F,L #DATA#
IMMEDIATELY AFTER THIS LINE ENTER :
       /INC FILENAME
       /E
       /XEQ EVAL
```

```
REPEAT THIS PROCEDURE UNTIL ALL THE REQUIRED CONTROL DATA SETS HAVE BEEN
INSERTED. THEN ENTER /XEQ EVDATA
IF ONLY ONE CONTROL DATA SET IS TO BE USED ENTER /XEQ EVAL

THE MATH ANALYSIS PROGRAM MAY NOW BE RUN

THE PERMANENT OVERLAY DATA SET NAMES FOR ALL THOSE TO BE ANALYSISED MUST
BE GIVEN. ENTER :
      /UP EVPGM
      /D FACM.W
REPLACE THESE LINES AS NECESSARY. THE LINE FORMAT & THE DATA SET NAME MUST
BE CORRECT.
THE ORDER OF THE LINES DISPLAYED,CORRESPOND TO UNITS 11-15

THEN ENTER :
      /E
      /OS EVPGM

*************************************************************************************************************

                                                    FILE    CONTOR

*************************************************************************************************************

C       FILE 2 OF THE LAND CAPABILITY ANALYSIS PROCEDURE 1984 (C.HANNING)
C
C
C
XPUR COXXYY
XI
C               PROGRAM TO READ IN POINTS ON CONTOUR
C               PRODUCES FILE WITH FOLLOWING FORM :
C               CONTOUR VALUE (QUANTITATIVE,QUALITATIVE)
C               NUMBER OF POINTS ON CONTOUR
C               CONTOUR POINTS (X,Y)
      REAL X(500),TITLE(20)
      REAL Y(500)
/INC OCOM(MRX)
      INTEGER FOUT
      REAL P(2)
      INTEGER BUT,TAB
      TR=.TRUE.
      REPLY=.TRUE.
      IN=9
      OUT=6
      EROUT=8
      FOUT=2
      IE=0
      NP=0
      WRITE(OUT,100)
  100 FORMAT(T2,'CONTOUR  INPUT ROUTINE')
      WRITE(OUT,121)
  121 FORMAT(T2,' TYPE IN THE TITLE OF THE MAP')
      READ(IN,501) (TITLE(I),I=1,20)
  501 FORMAT(20A4)
      WRITE(FOUT,501) (TITLE(I),I=1,20)
  101 CONTINUE
      WRITE(OUT,300)
  300 FORMAT(T2,'TYPE IN THE ORIGIN (X,Y) FOLLOWED BY THE X & Y ENDPOINTS RESPECTIVELY')
      READ(IN,301) XMIN,Y1,XMAX,Y2
  301 FORMAT(4Y)
      YMAX=Y2
      YMIN=Y1
      IF(Y2.GT.Y1) GO TO 310
      YMAX=Y1
      YMIN=Y2
      WRITE(OUT,304)
  304 FORMAT(T2,'YMAX & YMIN HAVE BEEN REVERSED SO THAT THE Y ORIGIN IS NOW YMAX')
  310 WRITE(FOUT,302) XMIN,XMAX,YMIN,YMAX
  302 FORMAT(4F10.3)
      CALL AXES
  102 CONTINUE
      WRITE(OUT,103)
  103 FORMAT(T2,'TYPE IN Z VALUE & ITS CODE VALUE (Y,A4)')
      READ(IN,104) Z,A
  104 FORMAT(Y,A4)
      NP=NP+1
      WRITE(OUT,110)
  110 FORMAT(T2,'DIGITISE POINTS ONE BY ONE')
      WRITE(OUT,112)
  112 FORMAT(T2,' USE BUTTON 1 TO END INPUT, BUTTON 2 TO ERASE LAST POINT')
      WRITE(OUT,1121)
 1121 FORMAT(T2,' OR /BR 2 TO END')
      N=0
      IB=IE+1
    1 CONTINUE
C             LOOP READING POINTS TILL END POINT (BUT =8)
      CALL DIGTRA(TAB,BUT,P)
      IF(BUT.EQ.0) GO TO 2
      IF(BUT.EQ.4) GO TO 11
      N=N+1
      X(N) =P(1)
      Y(N) =P(2)
      WRITE(OUT,120) N,P
  120 FORMAT(T2,I13,2F10.3)
      GO TO 1
   11 CONTINUE
      N=N-1
      GO TO 1
    2 CONTINUE
      IE=IE+N
      WRITE(FOUT,200) Z,A,IB,IE
  200 FORMAT(F10.3,1X,A4,1X,2I5)
      WRITE(FOUT,2001) N
 2001 FORMAT(I15,' POINTS')
      WRITE(FOUT,201) (X(I),I=1,N)
      WRITE(FOUT,201) (Y(I),I=1,N)
  201 FORMAT(8F10.3)
      WRITE(OUT,202)
  202 FORMAT(T2,' BUTTON 2 -ANOTHER CONTOUR'/T2,'BUTTON 3 - NEW AXES ')
C     THE OUTPUT FILE(FOUT) IS KEPT FOR EDITING
      WRITE(OUT,203) NP
  204 FORMAT(T2,' /GA FOLLOWED /XEQ DIGIT -ENDS DIGITIZING'/T2,' NUMBER OF CONTOURS = ',I5)
      CALL DIGTRA(TAB,BUT,P)
      IF(BUT.EQ.4) GO TO 102
      IF(BUT.EQ.2) GO TO 101
      STOP
/INC DIG(MRX)
/E R
```

```
****************************************************************************************************
                                                FILE   DIGIT
****************************************************************************************************
C       FILE 2  OF THE LAND CAPABILITY ANALYSIS PROCEDURE  1980  C. HAMMOND
C
C
C       PROGRAM TO KEEP FILE  COXXYY  WHICH IS THE DIGITISED OUTPUT FILE FROM
C       PROGRAM  CONTOR.
C       INSTRUCTIONS TO EDIT THIS DATA SET ARE DISPLAYED.
KEEP COXXYY
C       DISPLAY INSTRUCTIONS
SD INSTR 8,23
****************************************************************************************************
                                                FILE   ECOM
****************************************************************************************************
C
C       THIS FILE IS EXECUTED IN ASSOCIATION WITH EDIT,EDITLF & EDITPT.
C       IT CONTAINS THE DIMENSIONS FOR THESE THREE PROGRAMS AND READS IN THE
C       CODES FOR THE QUALITATIVE DATA STORED IN THE DIGITISED MAP WHICH IS
C       TO BE EDITED.
        DIMENSION TITLE(20),ANAM(25),CODE(25),Y(800),X(800)
        DIMENSION INDEXD(45),UNITS(3),YP(800),XP(800)
        REAL*8 D
        LOGICAL TR
C
        TR=.TRUE.
        WRITE(6,300)
300     FORMAT(T2,' THIS PROGRAM EDITS THE DIGITISED DATA')
        WRITE(6,301)
301     FORMAT(T2,//,T2,' THE NUMBER OF DIFFERENT CODE NAMES ?')
        READ(9,110) NV
110     FORMAT(Y)
        WRITE(6,302)
302     FORMAT(T2,///T2,'GIVE EACH CODE NAME AS IT IS WRITTEN IN THE DATA')
        WRITE(6,303)
303     FORMAT(T2,'SET (A4) PLUS ITS NUMERICAL VALUE (Y) ')
        DO 30 J=1,NV
        READ(9,111) ANAM(J),CODE(J)
111     FORMAT(A4,Y)
30      CONTINUE
        DO 50 I=1,NV
        WRITE(6,999) ANAM(I),CODE(I)
999     FORMAT(T2,' ',A4,' ',F11.3)
50      CONTINUE
        WRITE(6,304)
304     FORMAT(T2,///T2,'NOW READING FROM THE DATA SET')
****************************************************************************************************
                                                FILE   EDIT
****************************************************************************************************
C       FILE 4(A) OF THE LAND CAPABILITY ANALYSIS PROCEDUTE 1980 (C.HAMMOND)
C
C
C       THIS PROGRAM EDITS THE DIGITSED MAP FOR DATA WITH A POLYGONAL DISTRIBUTION
C       AND THE RESULTING FILE IS IN THE FORM REQUIRED BY THE OVERLAY PROGRAM
C       OVER2
C
C       UNIT 8 REFERS TO THE UNEDITED FILE
C       UNIT 10 IS THE EDITED FILE
C       UNIT 6 IS THE TERMINAL SCREEN
C       UNIT 9 IS THE KEYBOARD
/INC ECOM
        WRITE(6,1)
1       FORMAT(T2,///,T2,'THE PROGRAM EDITS POLYGON DATA ')
        READ(8,101) (TITLE(I),I=1,20)
        WRITE(10,101) (TITLE(I),I=1,20)
101     FORMAT(20A4)
        READ(8,108) XMIN,XMAX,YMIN,YMAX
108     FORMAT(4F10.3)
        NOPT=1
        WRITE(6,160)
160     FORMAT(T2,' GIVE THE NUMBER OF POLYGONS & INCREMENT BETWEEN THE CO-ORDINATES (I3,F7.3)')
        READ(9,161) NUMBER,CRE
161     FORMAT(I3,F7.3)
        WRITE(6,162)
162     FORMAT(T2,' GIVE THE SCALE & UNITS OF THE DIGITIZED MAP (F7.0,3A4)')
        READ(9,163) SCALE,(UNITS(I),I=1,3)
163     FORMAT(F7.0,3A4)
        WRITE(6,164)
164     FORMAT(T2,' IS A SURFACE AREA BEING MEASURED? YES =001 NO =000 (I3)')
        READ(9,165) ISURF
165     FORMAT(I3)
        IDES=0
        IF(ISURF.EQ.0) GO TO 168
        WRITE(6,167)
167     FORMAT(T2,' ARE THE SURFACE AREAS DISCRETE ? YES =001 NO =000 (I3)
        READ(9,165) IDES
168     WRITE(10,166) NOPT,ISURF,IDES,NUMBER,CRE,SCALE,(UNITS(I),I=1,3)
166     FORMAT(4I3,F7.3,F7.0,3A4)
        WRITE(10,108) XMIN,XMAX,YMIN,YMAX
        IB=1
        IE=0
        IP=0
C       READ FROM THE UNEDITED FILE
120     READ(8,102) A,B,IB1,IE1
102     FORMAT(F10.3,1X,A4,1X,2I5)
        IF(TR) WRITE(6,998) A,B,IB1,IE1
998     FORMAT(F11.3,' ',A4,' ',1X,2I5)
        IF(A.EQ.0.0) GO TO 200
C       RENUMBER THE POLYGONS
        IP=IP+1
        READ(8,106) L,D
106     FORMAT(I4,A8)
C       RENUMBER THE DIGITISED POINTS
```

```
      IE=IE+L
      IBB=1
      IEE=L
      LL=0
      DO 80 J=1,NV
      IF(B.EQ.ANAM(J)) LL=J
80    CONTINUE
C     WRITE TO THE EDITED OUTPUT FILE
      WRITE(10,103) I9,IB,IB,A,D,CODE(LL)
103   FORMAT(I5,1X,2I5,1X,F10.3,1X,A4,1X,F10.3)
      WRITE(10,107) L,D
107   FORMAT(I4,A8)
C     READ THE DIGITISED BOUNDARIES FROM THE INPUT FILE
      READ(8,104) (X(I),I=IBB,IEE)
      READ(8,104) (Y(I),I=IBB,IEE)
104   FORMAT(8F10.3)
      X(IEE)=X(IBB)
      Y(IEE)=Y(IBB)
C     DROP POINTS OUTSIDE THE BOUNDARIES ONTO THE BOUNDARIES THEMSELVES
C     THIS ASSUMES THAT NO POLYGON IS COMPLETELY OUTSIDE
      DO 51 I=1,L
      IF(X(I).LT.XMIN) X(I)=XMIN
      IF(X(I).GT.XMAX) X(I)=XMAX
      IF(Y(I).LT.YMIN) Y(I)=YMIN
      IF(Y(I).GT.YMAX) Y(I)=YMAX
51    CONTINUE
C     WRITE THE EDITED BOUNDARIES TO THE OUTPUT FILE
      WRITE(10,105) (X(I),I=IBB,IEE)
105   FORMAT(8F10.3)
      WRITE(10,105) (Y(I),I=IBB,IEE)
      IB=IE+1
      GO TO 120
200   STOP
      END
/DATA
/INC COMXYY
```

```
*****************************************************************************************************
                                        FILE   EDITLF
*****************************************************************************************************
C     FILE A(8) OF THE LAND CAPABILITY ANALYSIS PROCEDURE 1980 (C.HAMMOND)
C
C
C     THIS PROGRAM EDITS THE DIGITISED MAP FOR DATA IN THE FORM OF NETWORKS
C     THE RESULTING EDITED FILE IS IN THE FORM REQUIRED BY THE OVERLAY PROGRAM
C     OVER3.
/INC ECOM
      WRITE(6,1)
1     FORMAT(T2,///,T2,'THE PROGRAM EDITS NETWORK DATA ')
      READ(8,100) (TITLE(I),I=1,20)
100   FORMAT(20A4)
      WRITE(10,101) (TITLE(I),I=1,20)
101   FORMAT(20A4)
      NOPT=2
      ISURF=0
      WRITE(6,160)
160   FORMAT(T2,' GIVE THE NUMBER OF NETWORKS & INCREMENT BETWEEN THE CO-ORDINATES (I3,F7.3)')
      READ(9,161) NUMBER,CRE
161   FORMAT(I3,F7.3)
      WRITE(6,162)
162   FORMAT(T2,' GIVE THE SCALE & UNITS OF THE DIGITIZED MAP (F7.0,3A4)')
      READ(9,163) SCALE,(UNITS(I),I=1,3)
163   FORMAT(F7.0,3A4)
      IDES=0
      WRITE(10,166) NOPT,ISURF,IDES,NUMBER,CRE,SCALE,(UNITS(I),I=1,3)
166   FORMAT(4I3,F7.3,F7.0,3A4)
      READ(8,108) XMIN,XMAX,YMIN,YMAX
108   FORMAT(4F10.3)
      WRITE(10,108) XMIN,XMAX,YMIN,YMAX
      I9=0
      IE=1
C     READ THE UNEDITED INPUT FILE
120   READ(8,102) A,B,IB1,IE1
102   FORMAT(F10.3,A4,2I5)
      IF(T9) WRITE(6,998) A,B,IB1,IE1
998   FORMAT(F11.3,' ',A4,' ',1X,2I5)
      IF(A.EQ.0.0) GO TO 200
      READ(8,106) L,D
106   FORMAT(I4,A8)
      LL=0
      DO 60 J=1,NV
      IF(B.EQ.ANAM(J)) LL=J
60    CONTINUE
      I=0
      KK=0
      READ(8,104) (X(K),K=1,L)
      READ(8,104) (Y(K),K=1,L)
104   FORMAT(8F10.3)
      DO 10 K=1,L
      I=I+1
      KK=KK+1
C     DROP ANY POINTS LYING OUTSIDE THE BOUNDARY ONTO IT.
C     THIS ASSUMES THAT THE POINT IS JUST OFF THE BOUNDARY DUE TO
C     HUMAN ERROR WHILE DIGITISING.
```

```
C       IF THE POINT IS DROPPED, ERRORS WILL OCCUR IN THE OVERLAY,
C       UNLESS THE NEXT POINT DIGITISED LIES JUST WITHIN THE BOUNDARY.
C       SINCE THIS CANNOT BE ASSUMED TO BE THE CASE, THE ASSUMPTION GIVEN
C       ABOVE IS ACCEPTED.
        IF(X(K).LT.XMIN) X(K)=XMIN
        IF(X(K).GT.XMAX) X(K)=XMAX
        IF(Y(K).LT.YMIN) Y(K)=YMIN
        IF(Y(K).GT.YMAX) Y(K)=YMAX
        IF(K.GT.1) GO TO 370
        XFIR=X(K)
        YFIR=Y(K)
        GO TO 501
C       IF TWO POINTS ARE IDENTICAL, THE BEGINNING OF THE FOLLOWING NETWORK HAS
C       BEEN REACHED. THUS END THE NETWORK BEING READ.
370     IF(Y(K).EQ.YY.AND.X(K).EQ.X(K-1)) GO TO 350
501     YY=Y(K)
        XP(I)=X(K)
        YP(I)=Y(K)
        IF(KK.EQ.L) GO TO 360
        GO TO 10
350     XFIR=X(K-1)
        YFIR=Y(K-1)
        I=I-2
C       RENUMBER THE POINTS AND NETWORKS
360     IE=IB+I-1
        IP=IP+1
C       WRITE TO THE OUTPUT FILE
        WRITE(3,103) IP,IB,IE,A,B,CODE(LL)
103     FORMAT(I5,1X,2I5,1X,F10.3,1X,A4,1X,F10.3)
        WRITE(3,107) I,D
107     FORMAT(I4,A8)
        WRITE(3,109) (XP(M),M=1,I)
109     FORMAT(8F10.3)
        WRITE(3,109) (YP(M),M=1,I)
        I=1
        IB=IE+1
        X(K)=XFIR
        Y(K)=YFIR
        YY=YFIR
10      CONTINUE
        GO TO 120
200     STOP
        END
/DATA
/INC COXXYY

**************************************************************************************************
                                                                FILE   EDITPT
**************************************************************************************************

C       FILE A(C) OF THE LAND CAPABILITY ANALYSIS PROCEDURE 1980 (C.HAMMOND)
C
C
C       THE PROGRAM EDITS THE DIGITISED MAP FOR DATA WITH A DISCRETE POINT
C       DISTRIBUTION. THE RESULTING FILE IS IN THE FORM REQUIRED BY THE OVERLAY
C       PROGRAM OVER2
/INC ECOM
        WRITE(6,1)
1       FORMAT(T2,///,T2,'THE PROGRAM EDITS POINT DATA ')
        READ(5,101) (TITLE(I),I=1,20)
        WRITE(10,101) (TITLE(I),I=1,20)
101     FORMAT(20A4)
        NOPT=3
        ISURF=0
        WRITE(6,160)
160     FORMAT(T2,' GIVE THE NUMBER OF POINTS & INCREMENT BETWEEN THE CO-ORDINATES (I3,F7.3)')
        READ(9,161) NUMBER,CRE
161     FORMAT(I3,F7.3)
        WRITE(6,162)
162     FORMAT(T2,' GIVE THE SCALE & UNITS OF THE DIGITIZED MAP (F7.0,3A4)')
        READ(9,163) SCALE,(UNITS(I),I=1,3)
163     FORMAT(F7.0,3A4)
        IDES=0
        WRITE(10,166) NOPT,ISURF,IDES,NUMBER,CRE,SCALE,(UNITS(I),I=1,3)
166     FORMAT(4I3,F7.3,F7.0,3A4)
        READ(8,108) XMIN,XMAX,YMIN,YMAX
108     FORMAT(4F10.3)
        WRITE(10,108) XMIN,XMAX,YMIN,YMAX
        IP=0
120     READ(8,102) A,B,IB1,IE1
102     FORMAT(F10.3,1X,A4,1X,2I5)
        IF(T7) WRITE(6,999) A,B,IB1,IE1
999     FORMAT(F11.3,' ',A4,' ',1X,2I5)
        IF(A.EQ.0.0) GO TO 200
        READ(8,106) L,D
106     FORMAT(I4,A8)
        LL=0
        DO 80 J=1,NV
        IF(B.EQ.ANAM(J)) LL=J
80      CONTINUE
C       POINT DATA MAYBE DIGITISED AS A CHAIN IF A NUMBER
C       ALL HAVE THE SAME VALUE
        READ(8,109) (X(I),I=1,L)
        READ(8,109) (Y(I),I=1,L)
109     FORMAT(8F10.3)
        DO 10 I=1,L
        IP=IP+1
C       DROP POINTS OUTSIDE THE BOUNDARY ONTO IT.
C       THIS ASSUMES THAT THE POINT SHOULD BE ON THE BOUNDARY BUT IT
C       IS NOT DUE TO HUMAN ERROR WHILE DIGITISING
        IF(X(I).LT.XMIN) X(I)=XMIN
        IF(X(I).GT.XMAX) X(I)=XMAX
        IF(Y(I).LT.YMIN) Y(I)=YMIN
        IF(Y(I).GT.YMAX) Y(I)=YMAX
C       EACH POINT IS WRITTEN SEPARATELY TO THE OUTPUT FILE
        WRITE(10,105) IP,A,B,CODE(LL)
105     FORMAT(I5,1X,F10.3,1X,A4,F10.3)
        WRITE(10,104) X(I),Y(I)
104     FORMAT(2F10.3)
10      CONTINUE
        GO TO 120
200     STOP
        END
/DATA
```

```
*****************************************************************************************
                                                     FILE   SET
*****************************************************************************************
C       FILE 5 OF THE LAND CAPABILITY ANALYSIS PROCEDURE 1980 (C.HAMMOND)
C
C
C       THE PROGRAM WRITES AN OUTPUT FILE OF THE DATA REQUIRED BY PROGRAM SETUP
C       WHICH CREATES THE PERMANENT SECONDARY LAND DATA SET.
C       THE OUTPUT FILE HAS THE FOLLOWING FORM:-
C       THE INCREMENT BETWEEN THE GRID COLS. & ROWS
C       THE TITLE,NO. OF LAND CHARACTERISTICS TO BE INSERTED INTO EACH CELL,THE
C       SCALE OF THE DIGITISED SURVEY MAPS,THE GRID CELL SIZE & UNITS,THE GRID
C       CELL RATIO BETWEEN ITS CO-ORDINATES & THOSE OF THE DIGITSED MAPS,THE
C       EXTREME MAP CO-ORDINATES
C       THE LAND CHARACTERISITIC CODE NO.S IN THE ORDER IN WHICH THEY ARE STORED
C       IN THIS LAND DATA SET
XPUR XXSET
XI
        REAL*8 XW,XE,YS,YN
         DIMENSION TITLE(20),UNITS(3),INDEXD(45)
C
        WRITE(6,7)
7       FORMAT(T2,' THIS PGM. READS IN THE INFORMATION TO BE WRITTEN IN THE')
        WRITE(6,8)
8       FORMAT(T2,' PERMANENT OVERLAY DATA SET,CREATED BY EXECUTING FILE CREATE'///)
        WRITE(6,1)
1       FORMAT(T2,'  THE INCREMENT BY WHICH THE X & Y CO-ORDINATES INCREASE (F7.3) ?')
        READ(9,100) CRE
100     FORMAT(F7.3)
        WRITE(6,2)
2       FORMAT(T2,'  THE TITLE OF THE OVERLAY DATA SET (20A4) ?')
        READ(9,101) (TITLE(I),I=1,20)
101     FORMAT(20A4)
        WRITE(6,3)
3       FORMAT(T2,'  THE TOTAL NUMBER OF VARIABLES THAT THE DATA SET WILL CONTAIN,')
        WRITE(6,4)
4       FORMAT(T2,' THE SCALE & THE UNITS AT WHICH THE MAPS WERE DIGITIZED (I5,F6.0,3A4) ?')
        READ(9,102) NVAR,SCALE,(UNITS(I),I=1,3)
102     FORMAT(I5,F6.0,3A4)
        WRITE(6,5)
5       FORMAT(T2,'  THE CO-ORDINATES OF XW,XE,YS,YN (4F10.3) ?')
        READ(9,103) XW,XE,YS,YN
103     FORMAT(4F10.3)
        WRITE(6,6)
6       FORMAT(T2,'  THE GRID CELL SIZE OF THE OVERLAY (F6.2) ?')
        READ(9,104) GRID
104     FORMAT(F6.2)
        WRITE(6,107)
107     FORMAT(T2,' GIVE ALL THE LAND CHARAC. CODE NUMBERS WHICH WILL BE PRESENT')
        WRITE(6,108)
108     FORMAT(T2,'  WITHIN THIS OVERLAY DATA SET, IN ORDER (26I3)')
        READ(9,106) (INDEXD(I),I=1,NVAR)
        WRITE(10,100) CRE
        WRITE(10,101) (TITLE(I),I=1,20)
        WRITE(10,105) NVAR,SCALE,(UNITS(I),I=1,3),GRID,XW,XE,YS,YN
105     FORMAT(I5,F7.0,3A4,F6.2,4(F10.3))
        WRITE(10,106) (INDEXD(I),I=1,NVAR)
106     FORMAT(26I3)
        WRITE(10,111)
111     FORMAT(T1,'//'/T1,'//')
C         THE OUTPUT FILE IS KEPT
         WRITE(6,110)
110      FORMAT(T2,//,T30,'   ENTER   /XEQ CREATE')
        STOP
        END
XE R
```

```
C       FILE 6  OF THE LAND CAPABILITY ANALYSIS PROCEDURE  1980  C. HAMMOND
C
C
//CMHSETUP JOB 063,CLASS=E
/*ROUTE  PRINT HOLD
//   EXEC FORTXCLG,PARM.FORT=NOSOURCE
//FORT.SYSIN DD *
C
C       THIS PROGRAM CREATES A SECONDARY PERMANENT LAND DATA SET
C       THE DATA SET NAME MUST BE GIVEN BY THE USER.
C
C       THE FORM OF THE DATA SET IS AS FOLLOWS:-
C       THE TITLE OF THE STUDY AREA,THE NO. OF LAND CHARACTERISTICS MEASURED.
C       THE SCALE AT WHICH THE ORIGINAL SURVEY MAPS WERE DIGTISED.THE SIZE OF
C       A GRID CELL & ITS UNITS.THE RATIO OF THE GRID CELL CO-ORDINATES TO
C       THOSE OF THE SURVEY MAP & THE EXTREME MAP CO-ORDINATES.
C       THIS IS FOLLOWED BY THE CODE NUMBERS OF THE LAND CHAR. IN THE
C       ORDER IN WHICH THEY ARE STORED.
C
C       THE ABOVE DATA IS GIVEN BY THE USER (20A4/I5,F7.0,F10.3,3A4,F6.2,4F10.3)
C       & (26I3) AFTER THE GRID CELL CO-ORDINATES HAS BEEN GIVEN (CRE(F7.3))
C       FOR EACH SECTION (NOT EXCEEDING (50,50)) OF THE DATA SET:-
C          NO. OF GRID CELLS  AND  NO. OF COLUMNS AND ROWS
C       FOR EACH CELL:-
C          NO. OF LAND CHARACTERISTIC VALUES
        DIMENSION A(45),UNITS(3),TITLE(20),INDEXD(45)
        REAL*8 LX,BY,RX,TY,NCORD,SCORD,WCORD,ECORD,XX,YY,GRID
        REAL NCORD1
C
        READ(5,15) CRE
15      FORMAT(F7.3)
C       IF NUMX OR NUMY EXCEED 50, THE DATA SET IS WRITTEN IN NN SECTIONS
C       READ INTRODUCTORY INFORMATION
        READ(5,1) (TITLE(I),I=1,20),NVAR,SCALE,SIZE,(UNITS(I),I=1,3),
       *GRID,WCORD,ECORD,SCORD,NCORD
1       FORMAT(20A4/I5,F7.0,F10.3,3A4,F6.2,4F10.3)
        GRID1=GRID
        WCORD1=WCORD
        ECORD1=ECORD
        NCORD1=NCORD
        SCORD1=SCORD
C       WRITE INTRODUCTORY INFORMATION INTO THE FILE BEING CREATED
        WRITE(1) (TITLE(I),I=1,20),NVAR,SCALE,SIZE,(UNITS(I),I=1,3),
       *GRID1,WCORD1,ECORD1,SCORD1,NCORD1
C       DETERMINE THE INCREMENT OF THE GRID CELL CO-ORDINATES
        GRID=GRID*CRE
        WRITE(6,2221) GRID
2221    FORMAT(' ',///10X,' THE INCREMENT BETWEEN EACH GRID COORDINATE
       *IS ',F10.3)
        READ(5,2) (INDEXD(I),I=1,NVAR)
2       FORMAT(26I3)
        WRITE(1) (INDEXD(I),I=1,NVAR)
C       INITIALIZE THE DATA SET
        DO 60 I=1,NVAR
        A(I)=0.0
60      CONTINUE
C       SET THE DIMENSIONS OF THE GRID (50,50) ACCORDING TO THE EXTREME MAP
C       CO-ORDINATES GIVEN.
        BY=SCORD
19      CONTINUE
        TY=BY+(GRID*50.)
        IF(TY.GT.NCORD) TY=NCORD
        LX=WCORD
30      RX=LX+(GRID*50.)
        IF(RX.GT.ECORD) RX=ECORD
        NUMY=0
        NUMX=0
        YY=BY*1.0000000E04
C       COMPUTE THE GRID CO-ORDINATES AND THE NUMBER OF COLUMNS AND ROWS
        DO 5 I2=1,50
        NUMY=NUMY+1
        XX=LX*1.0000000E04
        DO 6 I1=1,50
        NUMX=NUMX+1
        XX=XX+(GRID*1.0000000E04)
        IF(XX.GT.(RX*1.0000000E04)) GO TO 8
6       CONTINUE
8       YY=YY+(GRID*1.0000000E04)
        IF(YY.GT.(TY*1.0000000E04)) GO TO 7
5       CONTINUE
7       CONTINUE
        NUMX=NUMX/NUMY
        NTOTAL=NUMX*NUMY
        WRITE(6,2222) NUMX,NUMY
2222    FORMAT(' ',////////10X,' THE NUMBER OF COLUMNS & ROWS IN THIS
       *SECTION OF THE DATA SET ARE ',I5,1X,I5,' RESPECTIVELY')
C       WRITE THIS DATA SET TO A PERMANENT OUTPUT UNIT
        WRITE(1) NTOTAL,NUMX,NUMY
        YY=BY*1.0000000E04
        DO 20 I=1,NUMY
        XX=LX*1.0000000E04
        DO 21 K=1,NUMX
        X=XX
        Y=YY
        WRITE(1) X,Y,(A(I2),I2=1,NVAR)
        IF(K.EQ.1) WRITE(6,201) X,Y
201     FORMAT(' ',2F10.3)
        XX=XX+GRID*1.0000000E04
21      CONTINUE
        YY=YY+GRID*1.0000000E04
20      CONTINUE
C       LOOP FOR ANOTHER GRID SECTION IF THE MAP DIMENSIONS EXCEED 50 IN ANY
C       DIRECTION
        IF(RX.EQ.ECORD) GO TO 75
        LX=RX
        GO TO 30
75      IF(TY.EQ.NCORD.AND.RX.EQ.ECORD) GO TO 77
        BY=TY
        GO TO 19
77      CONTINUE
        WRITE(6,2223)
2223    FORMAT(' '/////10X,' END OF THE JOB')
        STOP
        END
//GO.FT01F001 DD UNIT=SYSDA,DISP=(OLD,CATLG),SPACE=(TRK,(80,,5)),
//   DSN=ACM.CMH063.LAND,VOL=SER=LIT241,
//   DCB=(RECFM=VBS,LRECL=192,BLKSIZE=1924)
//GO.SYSIN DD *
//
//
```

```
********************************************************************************
                                                  FILE   CREATE
********************************************************************************
C      FILE 7  OF THE LAND CAPABILITY ANALYSIS PROCEDURE  1980  C. HAMMOND
C
C
C      PROGRAM TO KEEP AN OUTPUT FILE FROM PROGRAM  SET,  INSERT IT AS THE
C      DATA FOR PROGRAM  SETUP  AND EXECUTE IT.
C      IT DISPLAYS INSTRUCTIONS TO BEGIN TO FILL THE SECONDARY LAND DATA SET
C      CREATED.
%KEP XXSET
%EMP
C      INSERT  SETUP  AND  XXSET  INTO THE INPUT FILE
%UP
%INS SETUP
%CH /L
%INS XXSET
%E
%OS
C      DISPLAY INSTRUCTIONS
%D INSTP 45,47
%PUR XXSET
```

```
C     FILE 3 OF THE LAND CAPABILITY ANALYSIS PROCEDURE 1983 (C.HAMMOND)
C
C
C
C
C     THE PROGRAM READS IN A PRIMARY DATA SET & OVERLAYS IT WITH A GRID OF
C     SELECTED GRID CELL SIZE.
C     A MAXIMUM OF 5 DIFFERENT DATA SETS ONLY MAY BE RETRIEVED PER JOB, BUT
C     THE INFORMATION REQUIRED TO EXECUTE THE PROGRAM IS :-
C     A) THE NUMBER OF PRIMARY DATA SETS TO BE RETRIEVED
C     B) FOR EACH DATA SET :-
C         1) THE UNIT NUMBER ON WHICH THE DATA SET IS WRITTEN
C         2) THE NUMBER OF DIFFERENT DATA ITEMS TO BE INSERTED INTO THE SECONDARY
C            LAND DATA SET.
C     C) FOR EACH DATA ITEM :-
C         1) THE POSITION IN THE GRID CELL DATA STRING INTO WHICH THIS DATA ITEM
C            IS TO BE INSERTED AS THE PRIMARY LAND DATA SET IS OVERLAID.
C         2) WHETHER A HARDCOPY OF THE OVERLAY ARRAY WHICH IS INSERTED INTO THE
C            SECONDARY LAND DATA SET IS REQUIRED
C         3) THE FORMAT TO READ THE DATA ITEM
C     ANY NUMBER OF DATA ITEMS FROM THE DATA STRING OF EACH DATA SET MAYBE
C     INSERTED INTO THE SECONDARY LAND DATA SET.
C
//CMHOVER JOB 061,CLASS=C
/*ROUTE  PRINT HCLD
//ONE EXEC  TSTC05
//SYS20 DD DSN=&&POLY20,UNIT=SYSRES,DISP=(NEW,PASS),
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=FB,LRECL=132,BLKSIZE=2112)
//SYS21 DD DSN=&&POLY21,UNIT=SYSRES,DISP=(NEW,PASS),
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=FB,LRECL=132,BLKSIZE=2112)
//SYS22 DD DSN=&&POLY22,UNIT=SYSRES,DISP=(NEW,PASS),
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=FB,LRECL=132,BLKSIZE=2112)
//SYS23 DD DSN=&&POLY23,UNIT=SYSRES,DISP=(NEW,PASS),
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=FB,LRECL=132,BLKSIZE=2112)
//SYS24 DD DSN=&&POLY24,UNIT=SYSRES,DISP=(NEW,PASS),
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=FB,LRECL=132,BLKSIZE=2112)
L DUMMY SYS20
L DUMMY SYS21
L DUMMY SYS22
L DUMMY SYS23
L DUMMY SYS24
/*
//TWO EXEC FORTXCLG,PARM.FORT=NOSOURCE,TIME.GO=5
//FORT.SYSIN DD *
C
C
C     DATA SET BEGINS FROM THE TOP LEFT-HAND CORNER.
C     POLYGONS AREA STORED IN A CLOCKWISE DIRECTION. THE
C     INTERSECTIONS BETWEEN POLYGONS ARE DIGITIZED
      COMMON /PARM/IN,BY,TY,LX,RX,GRID,ISURF,INB,IRB,FMT(15)
      COMMON /OVSI/XP(3000),YP(3000),NMAP,NOPT,ISTART(150),IEND(150)
      COMMON /OVERG/VALUE(150),NBT(150),IDES,NOV,IERROR
      COMMON /BOXS/BOX(4,150),X(600),Y(600)
      DIMENSION TITLE(20),UNITS(3),A(50,50)
      DIMENSION INDEXD(50),INDIC(3,10),VARBLE(50)
      REAL LX
      REAL*8 OPT
C
C     XP & YP STORE ALL THE X & Y CO-ORD.S RESPECTIVELY OF THE DIGITIZED
C     PTS.
C     NBT STORES THE POLYGON,LINE OR POINT NUMBER IN THE ORDER
C     IN WHICH THEY ARE DIGITIZED & THUS WRITTEN.
C
      READ(5,6000) NJOB
6000  FORMAT(I3)
      DO 9999 JJJ=1,NJOB
      READ(5,6001) IN,NTIME
6001  FORMAT(2I3)
      DO 9996 III=1,NTIME
      REWIND IN
      REWIND 14
      READ(5,6003) NMAP,IERROR,(FMT(I),I=1,15)
6003  FORMAT(2I3,15A4)
1     FORMAT(2I3,F6.2/15A4)
C
C     IERROR IS 1 IF A PRINTOUT OF THE OVERLAY (IN ITS SECTIONS)
C     IS REQUIRED
C
C     IN IS THE DD CARD WHERE THE DIGITIZED PTS ARE STORED
C     INB IS THE DD CARD WHERE THE BOXES ARE KEPT OR TO BE KEPT
C     READ IN THE CORD OF ALL MAP CORNERS. THIS MUST BE THE SAME
C     FOR ALL THE MAPS OVERLAID SO THAT THE GRID CELL CORRESPONDS
C     TO THE SAME LOCATION
C     THE GRID IS INCREMENTED BY THE GRID CELL SIZE
C     LX - LEFT-HAND X CO-ORD
C     RX - RIGHT-HNAD CO-ORD
C     BY - BOTTOM Y CO-ORD
C     TY - TOP Y CO-ORD
C
C
      INB=14
      READ(IN,2) (TITLE(I),I=1,20),NOPT,ISURF,IDES,NUMBER,CRE,
     *SCALE,AXMIN,AXMAX,AYMIN,AYMAX
2     FORMAT(20A4/4I3,F7.3,F7.0/4F10.3)
C     NMAP IS THE COL OF THE OVERLAY ARRAY WHICH WILL BE FILLED
C     BY THIS DATA
C     ISUR IS 1 IF THE DATA ARE SURFACE COVERAGE
C     NOPT IS THE FORM OF THE DATA -
C     1 - POLYGON; 2 - LINE; 3 - POINT
C     IDES IS 1 IF THE POLYGONS ARE DISCRETE IE. NO POLYGON SHARES A
C     BOUNDARY WITH ANY OTHER POLYGON
C     DEFAULT IS 1
C     NUMBER IS THE NO. OF POINTS,LINES OR POLYGONS DIGITIZED IN
C
      IF(NOPT.EQ.2.OR.NOPT.EQ.3) IDES=0
      IF(NOPT.EQ.0) NOPT=1
      IF(NOPT.EQ.3) GO TO 10
      CALL BOXED(NOPT,NUMBER)
10    IPB=0
      NOV=0
      READ(1) (TITLE(I),I=1,20),NVAR,SCALE,SIZE,(UNITS(I),I=1,3),
     *GRID1,AXMIN,AXMAX,AYMIN,AYMAX
      READ(1) (INDEXD(I),I=1,NVAR)
      GRID=GRID1*CRE
```

```
      WRITE(6,5010) (TITLE(I),I=1,20),NMAP,GRID,GRID
5010  FORMAT(' ',///13X,' THIS IS AN OVERLAY OF ',20A4/
     *43X,' LAND CHARACTERISTIC ',I5/
     *101,20X,'THE RATIO OF THE GRID CELL SIZE TO THE MAP CO-ORDINATES I
     *S ',F10.3/
     *' ',20X,'THE INCREMENT BETWEEN EACH GRID ROW & COLUMN IS ',F10.3)
C
      BY=AYMIN
30    CONTINUE
      NE=0
      TY=BY+(GRID*20.)
      IF(TY.GT.AYMAX) TY=AYMAX
      LX=AXMIN
20    RX=LX+(GRID*20.)
      IF(RX.GT.AXMAX) RX=AXMAX
      DO 4 I1=1,50
      VARBLE(I1)=0.0
      DO 4 I2=1,50
      A(I2,I1)=0.0
4     CONTINUE
      READ(1,END=960) NTOTAL,NUMX,NUMY
      NOV=NOV+1
      INDIC(1,NOV)=NTOTAL
      INDIC(2,NOV)=NUMX
      INDIC(3,NOV)=NUMY
4343  FORMAT(3I5)
C
C     SET UP NBT WITH THE POLYGON NOS. WHICH FALL WITHIN THE
C     DIMENSIONS TY,BY,LX,RX
      DO 52 I1=1,150
      VALUE(I1)=0.0
52    NBT(I1)=0
      DO 53 I2=1,3000
      XP(I2)=0.0
53    YP(I2)=0.0
      K=0
      II=0
      REWIND IN
      IF(NOPT.EQ.3) GO TO 90
      REWIND INB
51    DO 60 NP=1,150
      READ(INB,FMT,END=65) NB,VALUEP
      READ(INB) NUM,OPT
      IB=1
      IE=NUM
      READ(INB) (BOX(I,NP),I=1,4)
      READ(INB) (X(I),I=IB,IE),(Y(I),I=IB,IE)
      IF(BOX(2,NP).EQ.RX.AND.RX.EQ.AXMAX) GO TO 70
      IF(BOX(1,NP).GE.RX) GO TO 60
      IF(BOX(2,NP).LT.LX) GO TO 60
70    IF(BOX(4,NP).EQ.TY.AND.TY.EQ.AYMAX) GO TO 71
      IF(BOX(3,NP).LT.BY) GO TO 60
      IF(BOX(4,NP).GE.TY) GO TO 60
71    K=K+1
      NBT(K)=NP
      VALUE(K)=VALUEP
      ISTART(K)=II+1
      DO 66 I=IB,IE
      II=II+1
      XP(II)=X(I)
66    YP(II)=Y(I)
      IEND(K)=II
60    CONTINUE
      IF(NUMBER.GT.150) GO TO 51
      GO TO 67
90    DO 91 NP=1,3000
      READ(IN,FMT,END=65) NB,VALUEP
C
C     SINCE PT. DATA DOES NOT ENTER BOXED, X & Y ARE WRITTEN IN
C     EDITTED FORM
      READ(IN) XX,YY
      IF(XX.EQ.RX.AND.RX.EQ.AXMAX) GO TO 96
      IF(XX.GE.RX) GO TO 91
      IF(XX.LT.LX) GO TO 91
96    IF(YY.EQ.TY.AND.TY.EQ.AYMAX) GO TO 97
      IF(YY.LT.BY) GO TO 91
      IF(YY.GE.TY) GO TO 91
97    K=K+1
      II=II+1
      NBT(K)=NP
      VALUE(NP)=VALUEP
      ISTART(K)=NP
      IEND(K)=NP
      YP(NP)=YY
      XP(NP)=XX
91    CONTINUE
67    CONTINUE
65    WRITE(6,111) RX,LX,TY,BY
111   FORMAT('  RX LX TY BY ',4F10.3)
      IF(NBT(1).EQ.0) GO TO 69
      IF(K.GT.150) GO TO 60)
      CALL OVER(A,K,NUMX,NUMY,VARBLE,NVAR)
69    IF(RX.EQ.AXMAX) GO TO 75
      LX=RX
      GO TO 30
75    IF(TY.EQ.AYMAX.AND.RX.EQ.AXMAX) GO TO 77
      IPB=1
      BY=TY
      GO TO 30
77    DO 980 II=1,NUMY
      DO 981 KK=1,NUMX
      READ(1,END=950) XX,YY,(VARBLE(JJ),JJ=1,NVAR)
      WRITE(4) XX,YY,(VARBLE(JJ),JJ=1,NVAR)
      IF(KK.EQ.1) WRITE(5,1113) XX,YY,(VARBLE(JJ),J=1,NVAR)
1113  FORMAT(2F10.3,12F5.2)
981    CONTINUE
980    CONTINUE
      READ(1,END=960) NTOTAL,NUMX,NUMY
      NOV=NOV+1
      INDIC(1,NOV)=NTOTAL
      INDIC(2,NOV)=NUMX
      INDIC(3,NOV)=NUMY
      GO TO 77
960   REWIND 1
      WRITE(1) (TITLE(I),I=1,20),NVAR,SCALE,SIZE,(UNITS(I),I=1,3),
     *GRID1,AXMIN,AXMAX,AYMIN,AYMAX
      WRITE(1) (INDEX3(I),I=1,NVAR)
      REWIND 4
```

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      DO 965 I4=1,NOV
      NTOTAL=INDIC(1,I4)
      NUMX=INDIC(2,I4)
      NUMY=INDIC(3,I4)
      WRITE(1) NTOTAL,NUMX,NUMY
      DO 970 J=1,NUMY
      DO 970 I=1,NUMX
      READ(4) XX,YY,(VARBLE(K),K=1,NVAR)
      IF(I.EQ.1) WRITE(6,1113) XX,YY
      WRITE(1) XX,YY,(VARBLE(K),K=1,NVAR)
970    CONTINUE
965   CONTINUE
       WRITE(6,9100) NMAP
9100   FORMAT(' ',//,20X,'STEP IS COMPLETE. LAND CHARACTERISTIC ',I3,
     *' HAS BEEN OVERLAID AND INSERTED INTO THE PERMANENT DATA SET')
      REWIND 1
      REWIND 4
9995  CONTINUE
9999  CONTINUE
      WRITE(6,5011)
5011  FORMAT(' '///20X,' THE JOB HAS BEEN COMPLETED ')
      GO TO 610
801   WRITE(6,5012)
5012  FORMAT('0  ERROR - NUMBER OF POLYGONS,NETWORKS OR POINTS TO BE OVE
     *RLAID EXCEEDS 150')
610   CONTINUE
      STOP
      END
C
      SUBROUTINE BOXED(NOPT,NUMBER)
C
C     THIS SUBROUTINE PLACES A BOX AROUND EACH POLYGON OR LINE
C
      COMMON /PARM/IN,BY,TY,LX,RX,GRID,ISURF,INB,IRB,FMT(15)
      COMMON /BOXS/BOX(4,150),X(600),Y(600)
      REAL FMT1(15)
      REAL*8 DPT
      DATA FMT1/'(I5,','F10.','3)',12*' '/
      NE=0
15    DO 35 NP=1,150
      READ(IN,FMT,END=11) NB,VALUEP
      READ(IN,4) NUM,DPT
      IB=1
      IE=NUM
4     FORMAT(I4,A8)
      READ(IN,3) (X(I),I=IB,IE)
      READ(IN,3) (Y(I),I=IB,IE)
3     FORMAT(8F10.3)
C      INITIALIZE BOX
      BOX(1,NP)=X(IB)
      BOX(2,NP)=X(IB)
      BOX(3,NP)=Y(IB)
      BOX(4,NP)=Y(IB)
C     BOX(1,NP) - LX
C     BOX(2,NP) - RX
C     BOX(3,NP) - TY
C     BOX(4,NP) - BY
C
      DO 30 J=IB,IE
      IF(X(J).LT.BOX(1,NP)) BOX(1,NP)=X(J)
      IF(X(J).GT.BOX(2,NP)) BOX(2,NP)=X(J)
      IF(Y(J).GT.BOX(3,NP)) BOX(3,NP)=Y(J)
      IF(Y(J).LT.BOX(4,NP)) BOX(4,NP)=Y(J)
30    CONTINUE
      IF(ISURF.EQ.1.AND.VALUEP.GE.1.0) VALUEP=80.0
      WRITE(INB,FMT1) NB,VALUEP
      WRITE(INB) NUM,DPT
      WRITE(INB) (BOX(I,NP),I=1,4)
      WRITE(INB) (X(I),I=IB,IE),(Y(I),I=IB,IE)
C
C     MUST DIGITIZE IN EVEN IF VALUE IS ZERO
C     MAY NOT HAVE A CODE OF ZERO
C     CORRECT FOR SURFACE AREA
C     VALUE OF EACH LINE & POINT MUST BE DIFFERENT AS IT IS USED
C     TO DISTINGUISH BETWEEN DIFFERENT LINES & POINTS
35    CONTINUE
      IF(NUMBER.GT.150) GO TO 15
11    REWIND IN
      REWIND INB
      DO 40 I=1,15
      FMT(I)=FMT1(I)
40    CONTINUE
      RETURN
      END
C
      SUBROUTINE OVER(ALAY,NPP,NUMX,NUMY,VARLE,NVAR)
C
C     THIS OVERLAYS A SQUARE GRID UPON MAPPED DATA
C     THE DATA MAY BE POLYGONS,LINES IE. FREE CHAIN, AND POINTS.
C
C     THE DATA SECTION IS RETRIEVED IS OVERLAID & STORED BEFORE THE
C     NEXT SECTION IS RETRIEVED
C
      REAL LX
      COMMON /PARM/IN,BY,TY,LX,RX,GRID,ISURF,INB,IRB,FMT(15)
      COMMON /OVSI/XP(3000),YP(3000),NMAP,NOPT,ISTART(150),IEND(150)
      COMMON /INTER/XI(60),YC,YLC,XFIR
      COMMON /OVERG/VALUE(150),NBT(150),IDES,NOV,IERROR
      DIMENSION XINT(600),VAL(600)
      REAL ALAY(NUMX,NUMY),VARLE(NVAR)
C
C     NOPT =1 - DATA AREA POLYGONS.STORES VALUE.EACH POLYGON MUST
C               BE CLOSED.
C     NOPT =2 - DATA ARE LINES.STORES VALUE OF 1.EACH LINE EQUIVALENT
C               TO 1 POLYGON. IF > 1 LINE IN A CELL,STORES SUM OF THEM.
C     NOPT =3 - DATA ARE POINTS.STORES VALUE. EACH PT EQUIVALENT TO 1
C               POLYGON. IF >1 PT. IN A CELL,STORES MAX. VALUE.
C     XI CONTAINS THE X GRID LINES IE. THE GRID COLUMNS . IF THE DATA
C     ARE POLYGONS THESE X GRID LINES EQ THE MEDIAN LINE FOR EACH
C     COLUMN.
C     XINT CONTAINS THE X INTERCEPT VALUES INTERCEPTING WITH YC.
C     YC IS THE Y GRID LINE IE.GRID ROWS. IF THE DATA ARE POLYGONS
C     YC EQ THE MEDIAN LINE FOR EACH ROW.
C     VAL CONTAINS THE VALUES OF THE LINE OR POLYGON CORRESPONDING
C     WITH INTERCEPT VALUES STORED IN XINT.
C     ALAY CONTAINS THE GRIDDED VALUES. WRITTEN TO OUTPUT.
C
C     I = X GRID LINE OF ALAY
```

```
C       J - Y GRID LINE OF ALAY
C       Y - INCREMENT OF YC
C       X - INCREMENT OF XI
C       YLC - PREVIOUS YC VALUE
C
C
        WRITE(6,3333) (NST(I),I=1,NPP)
 3333   FORMAT(' ',//// POLYGON OR LINE OR POINT NUMBERS SELECTED FOR THE
       * OVERLAY SUBROUTINE :_ ',10(/10X,I=I5))
C
C       ONLY WRITE THE CO-ORDS IF FIRST TIME THAT LAND DATA AT THAT SCALE
C       IS BEING RUN
 10     WRITE(6,2) LX,BY,NUMX,NUMY
 2      FORMAT(' ',///,' THE ORIGIN OF THE MAP PORTION RETRIEVED IS (',
       *2F10.I,') WITH ',I5,' COLUMNS & ',I5,' ROWS')
C       INITIALIZE
        X=LX-GRID*0.5
        IF(NOPT.NE.1) X=LX
        Y=BY-GRID*0.5
        IF(NOPT.NE.1) Y=BY
        YLC=BY
        IF(IRG.EQ.0) YLC=YLC-0.0000001
        YLEN=TY+GRID
C       YLEN DETERMINES WHEN THE OVERLAY HAS BEEN FILLED.
C       THIS MAY BE BEFORE 5 ROWS HAVE BEEN FILLED IE
C       THE DATA MAY NOT COVER THE WHOLE OVERLAY
        J=0
C       SET UP XI
        DO 35 K=1,50
 36     X=X+GRID
        XI(K)=X
        IF(XI(1).LT.LX) GO TO 36
        KX=K
        IF(RX.LT.X) GO TO 37
 35     CONTINUE
 37     CONTINUE
C       BRANCH OFF IF DATA ARE PT. DON'T CALL GEINT
        IF(NOPT.EQ.3) GO TO 599
        IFF=1
 20     J=J+1
        IF(J.EQ.1.OR.IDES.EQ.1.OR.IFF.EQ.1) GO TO 23
        L=I-1
        DO 25 K=IFIR,L
        IF(ALAY(K,J-1).EQ.0.0) ALAY(K,J-1)=ALAY(K-1,J-1)
 25     CONTINUE
 23     IF(J.GT.NUMY) GO TO 60
 21     Y=Y+GRID
        YC=Y
        IF(YC.GE.YLEN) GO TO 60
        IF(YC.LT.BY) GO TO 21
C       CALCULATE THE X INTERCEPTS OF LINE OR BOUNDARY SEGMENTS
C       WITH YC
C       RETURNED IN XINT TOGETHER WITH CORRESPONDING VALUE OF
C       THE LINE OR POLYGON IN VAL
        CALL GEINT(XINT,NI,VAL,NPP,KX)
        IF(NI.LT.1) GO TO 20
        I=0
C       BRANCH OFF IF DATA ARE LINE
        INT=0
        IF(NOPT.EQ.2) GO TO 480
C       SORT XINT INTO ASCENDING ORDER BEFORE FILLING ALAY
        CALL SORT(XINT,VAL,NI,NOPT,IDES)
C       DETERMINE THE FIRST INTERCEPT VALUE WHICH LIES WITHIN THE GRID
        X=LX-GRID*0.5
        DO 13 I2=1,NI
        INT=INT+1
        IF(XINT(I2).LT.X) GO TO 13
        GO TO 14
 13     CONTINUE
 14     CONTINUE
        IF(IDES.EQ.1) GO TO 17
        IF(INT.GT.1) INT=INT-1
C       CORRECT FOR INTERCEPTS FROM NEIGHBOURING POLYGONS
C       MOVE TO THE LAST ONE OF A NUMBER OF IDENTICAL INTERCEPTS
        IF(XINT(INT+2).GT.XI(1)) GO TO 19
 22     IF(INT+2.LT.NI) INT=INT+2
        GO TO 19
C       SET THE OUTERMOST XI LINE OF GRID BY THE LOWEST X INTERCEPT
 17     DO 18 I1=1,KX
        IF(XI(I1).GE.XINT(INT)) GO TO 19
        I=I+1
 18     CONTINUE
 19     CONTINUE
        IBEG=1
        IFF=1
 1252    I=I+1
         IF(INT.EQ.NI.OR.I.GT.KX) GO TO 20
         XC=XI(I)
         IF(XC.LT.LX) GO TO 1252
         IF(NI.EQ.1.AND.IBEG.EQ.1) XC=XC-1
         IBEG=0
 1520    X1=XINT(INT)
         X2=XINT(INT+1)
        IF(X2.EQ.0.0) GO TO 1524
        IEX=2
        IF(IDES.EQ.1) GO TO 1522
 1523   IF(IFIX(X1*1000.).NE.IFIX(X2*1000.)) GO TO 1522
        IF(INT.EQ.1) GO TO 1525
 1526   IF(IFIX(X1*1000.).EQ.IFIX(XINT(INT-1)*1000.)) GO TO 1527
 1525   IF(INT+IEX.GT.NI) GO TO 1524
        X2=XINT(INT+IEX)
        IEX=IEX+1
        GO TO 1523
 1524   X2=XINT(NI)
        GO TO 1522
 1527   INT=INT+2
        GO TO 1520
 1522    IF(XC.LT.X1) GO TO 1252
         IF(XC.GT.X2) GO TO 1521
         ALAY(I,J)=VAL(INT)
        IF(IFF.EQ.1) IFIR=I
        IFF=0
         GO TO 1252
 1521    INT=INT+2
         IF(INT.GT.NI) GO TO 20
         GO TO 1520
C
C
```

```
C       FILLING UP THE GRID IF THE DATA ARE LINES
C
480     CALL SORT(XINT,VAL,NI,NOPT,IDES)
490     INT=INT+1
        IF(XINT(INT).LT.LX) GO TO 490
500     I=I+1
        IF((INT.GT.NI).OR.(I.GT.KX)) GO TO 20
        XC=XI(I)
        IF(XC.LT.LX) GO TO 500
C       ADDS ONE TO THE GRID CELL IF XINT(INT) IS TO THE LEFT OF
C       XC IE. IS WITHIN THE CELL
498     IREJ=3
501      IF(XC.LT.XINT(INT)) GO TO 500
        ALAY(I,J)=1.0
505     INT=INT+1
        IF(INT.GT.NI) GO TO 20
        IF(XC.LT.XINT(INT)) GO TO 500
C       SUMS THE NUM. OF DIFFERENT LINES IN THE CELL
        IF(VAL(INT).EQ.VAL(INT-1)) GO TO 505
        ALAY(I,J)=ALAY(I,J)+1.0
        GO TO 505
C
C       FILLING UP ALAY IF DATA ARE POINT
C
599     NG=0
600     J=J+1
        IF(J.GT.NUMY) GO TO 60
        NI=0
601     Y=Y+GRID
        YC=Y
        IF(YC.LT.BY) GO TO 601
C       STORE THE X VALUE IF POINT IS WITHIN THE CELL DELIMITED
C       BY YC & YLC
        DO 605 IK=1,NPP
        K=NBT(IK)
        IF(YP(K).GT.YC) GO TO 605
        IF(YP(K).LE.YLC) GO TO 605
        NI=NI+1
        XINT(NI)=XP(K)
        VAL(NI)=VALUE(K)
605     CONTINUE
        YLC=YC
        IF(NI.LT.1) GO TO 600
C       SORT INTO ASCENDING ORDER BEFORE FILLING ALAY
        CALL SORT(XINT,VAL,NI,NOPT,IDES)
        INT=0
        I=0
608     INT=INT+1
        IF(XINT(INT).LT.LX) GO TO 608
610     I=I+1
        IF((INT.GT.NI).OR.(I.GT.KX)) GO TO 600
        XC=XI(I)
        IF(XC.LT.XINT(INT)) GO TO 610
        ALAY(I,J)=1.0
C       FILLS UP CELL IF XINT(INT) IS TO THE LEFT OF XC IE.
C       IS WITHIN THE CELL
614     INT=INT+1
        IF(INT.GT.NI) GO TO 600
        IF(XINT(INT).LT.XC) GO TO 615
        GO TO 610
615     ALAY(I,J)=ALAY(I,J)+1.0
        GO TO 614
60      CONTINUE
C       INSET ALAY INTO OVERLAY FILE
        DO 717 I=1,NUMY
        DO 717 J=1,NUMX
        READ(1) XX,YY,VARLE
        VARLE(NMAP)=ALAY(J,I)
        WRITE(4) XX,YY,VARLE
717     CONTINUE
        IF(IERROR.EQ.0) RETURN
C       WRITE ALAY TO OUTPUT IF THIS HAS BEEN REQUESTED
        WRITE(6,3488) NMAP,NOV
3488    FORMAT('1  THE OVERLAY ARRAY OF MAP ',I5,' SECTION ',I5,////)
        DO 718 I=1,NUMY
        WRITE(6,777) (ALAY(J,I),J=1,NUMX)
777     FORMAT(' ',12F10.3)
718     CONTINUE
        RETURN
        END
C
C
        SUBROUTINE GEINT(XINT,NI,VAL,NPP,KX)
C
C       THIS SUBROUTINE DETERMINES THE X INTERCEPT, GIVEN Y INTERCEPT
C
C       XFIR IS THE LOWEST X INTERCEPT
C       TX STORES THE X INTERCEPTS OF POLYGON DATA.
C       XINT IS FILLED FROM THIS SIMULTANEOUSLY CONSIDERING
C       THE INTERCEPT VALUE IN RELATION TO XI ARRAY
C       THIS CORRECTS FOR SITUATION WHERE EACH PT DOES NOT HAVE
C       A PARTNER.
C       YCX2 STORES PT NUMS WHICH HAVE NO PARTNER.
C
        COMMON /OVS1/XP(3000),YP(3000),NMAP,NOPT,ISTART(150),IEND(150)
        COMMON /INTER/XI(50),YC,YLC,XFIR
        COMMON /OVERG/VALUE(150),NBT(150),IDES,NOV,IERROR
        DIMENSION XINT(600),VAL(600),VS(600),XS(600)
        XFIR=1000000.0
C       NG IS THE INDICATOR TO SORT THAT IT IS BEING CALLED FROM GEINT
C       THEREFORE, DONT SORT VAL.
        NI=0
        IF(NPP.EQ.0) RETURN
C       INITIALIZE
        DO 2 IJ=1,600
        XINT(IJ)=0.0
        VAL(IJ)=0.0
2       CONTINUE
        N=10
C
C       VALUE OF I WHICH POINTS TO THE POLY. NO. DOES'NT NECESSARILY
C       BEGIN AT 1 OR INCREMENT BY 1
C
C       BEGIN TO DETERMINE X INTERCEPTS
        DO 1 I=1,NPP
C
        J=ISTART(I)
        IIEND=IEND(I)
```

```
      JS=J
      X2=XP(J)
      Y2=YP(J)
      GO TO 11
5     IF((IEND-JS).EQ.1) GO TO 1
      X1=X2
      Y1=Y2
      X2=XP(J-1)
      Y2=YP(J-1)
C     END PT. OF LINE DATA CONSIDERED UNLESS LINE IS
C     ONLY ONE SEGMENT LONG
      GO TO 18
11    CONTINUE
      J=J+1
      IF((J.EQ.(IEND+1)).AND.(NOPT.EQ.2)) GO TO 5
C     END PTS OF LINE DATA STORED TWICE TO ENSURE
C     INCLUSION
      IF(J.GT.IIEND) GO TO 1
C     SET UP THE LINE SEGMENT, CHECK FOR INTERCEPTION WITH YC
C     FILL XINT & VAL
      X1=X2
      Y1=Y2
      X2=XP(J)
      Y2=YP(J)
18    IF((Y1.GT.YC      .(Y2.GT.YC)) GO TO 11
C
C     BRANCH OFF TO ..ARATE TESTS IF DATA ARE LINE
      IF(NOPT.EQ.2) GO TO 200
C
      IF((Y1.EQ.YC).AND.(Y2.EQ.YC)) GO TO 1311
6000  IF(Y1.EQ.YC) GO TO 1351
      IF(Y2.EQ.YC) GO TO 1352
12    IF((Y1.LT.YC).AND.(Y2.LT.YC)) GO TO 11
17    B=(YC-Y1)/(Y2-Y1)*(X2-X1)
      NI=NI+1
      IF(NI.GT.600) GO TO 131
      XINT(NI)=X1+B
      VAL(NI)=VALUE(I)
      GO TO 11
C
C     STORE X1 IF Y1=YC
1351  NI=NI+1
      IF(NI.GT.600) GO TO 131
      XINT(NI)=X1
      VAL(NI)=VALUE(I)
      GO TO 11
C     STORE X2 IF Y2=YC
1352   NI=NI+1
      XINT(NI)=X2
      VAL(NI)=VALUE(I)
      GO TO 11
C     STORE BOTH X1 & X2 IF LINE SEG. IS HORIZONTAL
1311  NI=NI+2
      IF(NI.GT.600) GO TO 131
      XINT(NI-1)=X1
      VAL(NI-1)=VALUE(I)
      XINT(NI)=X2
      VAL(NI)=VALUE(I)
      GO TO 11
C
C     CHECK FOR INTERCEPTION IF DATA ARE LINE
C
200   IF((Y1.LE.YLC).AND.(Y2.LE.YLC)) GO TO 11
      IF((Y1.EQ.YC).AND.(Y2.EQ.YC)) GO TO 210
      IF((Y1.LE.YC).AND.(Y2.LE.YC).AND.(Y2.GT.YLC)) GO TO 210
      IF((Y1.LE.YC).AND.(Y2.LE.YC)) GO TO 220
      B=(YC-Y1)/(Y2-Y1)*(X2-X1)
      NI=NI+1
      IF(NI.GT.600) GO TO 131
      XINT(NI)=X1+B
      VAL(NI)=VALUE(I)
      GO TO 11
C     LINE SEG ARE HORIZONTAL OR Y1< OR = TO YC AND Y2 DOESN'T
C     INTERCEPT WITH YLC
210   ISEL=0
      X3=AMIN1(X1,X2)
      X4=AMAX1(X1,X2)
C     IF THE SEGMENT INTERCEPTS WITH A GRID CELL BOUNDARY, STORE X1 ONLY
C     OTHERWISE STORE BOTH INTERCEPTS
      DO 211 II=1,KX
      IF((XI(II).LE.X4).AND.(XI(II).GT.X3)) ISEL=1
211   CONTINUE
      IF(ISEL.EQ.0) GO TO 212
      NI=NI+1
      IF(NI.GT.600) GO TO 131
      XINT(NI)=X2
      VAL(NI)=VALUE(I)
212   NI=NI+1
      XINT(NI)=X1
      IF(NI.GT.600) GO TO 131
      VAL(NI)=VALUE(I)
      GO TO 11
C
C     Y1 < OR = TO YC & Y2 INTERCEPS WITH YLC
220   NI=NI+1
      IF(NI.GT.600) GO TO 131
      XINT(NI)=X1
      VAL(NI)=VALUE(I)
C
      GO TO 11
C
131   WRITE(6,1310)
1310  FORMAT(T6,'ERROR, INTERCEPTION COUNT EXCEEDS 600')
      GO TO 10
1     CONTINUE
      IF(NOPT.EQ.1) RETURN
C
C     FOR LINE DATA ONLY, REMOVE DUPLICATE XINT VALUES WHICH ARISE
C     WHEN BOTH X1 & X2 ARE STORED.
230   J=1
      NJ=0
      IF(NI.LE.1) RETURN
      XS(J)=XINT(1)
      VS(J)=VAL(1)
239   DO 240 II=2,NI
      IF((XINT(II).EQ.XINT(II-1)).AND.(VAL(II).EQ.VAL(II-1))) GO TO 240
241   J=J+1
      XS(J)=XINT(II)
```

```
      VS(J)=VAL(I1)
240   CONTINUE
      IF(J.LE.1) GO TO 10
      DO 250 I1=1,J
      XINT(I1)=XS(I1)
      VAL(I1)=VS(I1)
250   CONTINUE
      NI=J
10    YLC=YI
      RETURN
      END
C
C
      SUBROUTINE SORT(X,C,N,IO,NOPT,IDES)
C
C     THIS SUBROUTINE SORTS X INTO ASCENDING ORDER & CHANGES
C     C IN THE SAME MANNER
      INTEGER N
      REAL X(N),C(N)
      IF(N.EQ.0) RETURN
      N1=N-1
      IF(NOPT.EQ.3.OR.IDES.EQ.1) GO TO 1
C
C     IF THE POLYGONS ARE DISCRETE,THERE ARE NO NEIGHBOURING BOUNDARIES
C     CORRECT FOR COMMON INTERCEPT VALUES IE.THOSE WITH A DIFFERENCE OF +0.001
C     OR -0.001 BETWEEN THEM
      DO 20 I=1,N1
      DO 17 K=2,N
      XX=X(I)-0.001
      DO 19 J=1,3
      IF(IFIX(XX*1000.).EQ.IFIX(X(K)*1000.)) GO TO 18
19    XX=XX+0.001
      GO TO 17
18    X(K)=X(I)
17    CONTINUE
20    CONTINUE
1     CONTINUE
      INV=0
      IF(N1.EQ.0) GO TO 12
      DO 11 I=1,N1
      IF(X(I).LE.X(I+1)) GO TO 11
      T=X(I+1)
      X(I+1)=X(I)
      X(I)=T
      CT=C(I+1)
      C(I+1)=C(I)
      C(I)=CT
      INV=1
11    CONTINUE
12    CONTINUE
      IF(INV.NE.0) GO TO 1
      IF(NOPT.EQ.2.OR.IDES.EQ.1) GO TO 31
C     CHECK THAT THE IDENTICAL INTERCEPT VALUES HAVE THE CORRECT ORDER OF THE
C     POLYGON VALUES STORED WITH THEM
      N2=N-2
      IF(N2.EQ.0) GO TO 31
      K=0
      DO 30 I=1,N2,2
      K=K+2
      IF(C(I).EQ.C(K)) GO TO 30
      IF(C(K).EQ.C(K+1)) GO TO 30
      IF(I.EQ.1) GO TO 32
      IF(X(I).EQ.X(I-2)) GO TO 30
C     SWOP THE POSITIONS OF THE INTERCEPTS IF THE POLYGON VALUES ARE ORDERED
C     INCORRECTLY.
32    CT=C(K+1)
      C(K+1)=C(K)
      C(K)=CT
      T=X(K+1)
      X(K+1)=X(K)
      X(K)=T
30    CONTINUE
31    CONTINUE
      RETURN
      END
//GO.FT01F001 DD DSN=ACH.CHH063.LAND,DISP=OLD,UNIT=SYSDA,
// SPACE=(TRK,(20,,)),DCB=(RECFM=VBS,LRECL=192,BLKSIZE=1924),
//   VOL=SER=WIT241
//GO.FT04F001 DD DSN=&&TEMP,UNIT=SYSRES,DISP=NEW,
//   SPACE=(CYL,(1,1),RLSE),
// DCB=(RECFM=VBS,LRECL=192,BLKSIZE=1924)
//GO.FT20F001 DD DSN=&&POLY20,UNIT=SYSRES,DISP=(OLD,PASS)
//GO.FT21F001 DD DSN=&&POLY21,UNIT=SYSRES,DISP=(OLD,PASS)
//GO.FT22F001 DD DSN=&&POLY22,UNIT=SYSRES,DISP=(OLD,PASS)
//GO.FT23F001 DD DSN=&&POLY23,UNIT=SYSRES,DISP=(OLD,PASS)
//GO.FT24F001 DD DSN=&&POLY24,UNIT=SYSRES,DISP=(OLD,PASS)
//GO.FT14F001 DD DSN=&&BOXES,UNIT=SYSRES,DISP=(NEW,PASS),
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=VBS,LRECL=4004,BLKSIZE=4008)
//GO.SYSIN DD *
//
//
```

```
****************************************************************************************************
                                                      FILE   OVER
****************************************************************************************************
C      FILE 9  OF THE LAND CAPABILITY ANALYSIS PROCEDURE  1980  C.HAMMOND
C
C
C      PROGRAM COPIES  OVER3  INTO FILE  OVPGM.  THE INSTRUCTIONS FOR
C      OVERLAYING A WITS FILE ARE DISPLAYED.
XEMP
C      XPUR AND XSA ASSURES THAT IT IS THERE
XPUR DUMMY
XSA DUMMY
XPUR OVPGM
C      COPY  OVER3  INTO  OVPGM
XUP
XINS OVER3
XE
XSA OVPGM
C      DISPLAY THE INSTRUCTIONS
XD INSTR 48,71
****************************************************************************************************
                                                      FILE   OVDATA
****************************************************************************************************
C      FILE 10 OF THE LAND CAPABILITY ANALYSIS PROCEDURE 1980 (C.HAMMOND)
C
C
C      THE PROGRAM WRITES AN OUTPUT FILE CONTAINING THE DATA REQUIRED TO RUN
C      THE OVERLAY PROGRAM OVER3.
C      THE FORM OF THE OUTPUT FILE IS :-
C      NO. OF SEPARATE PRIMARY LAND DATA SETS TO BE RETRIEVED
C      FOR EACH PRIMARY DATA SET :-
C      UNIT FROM WHICH IT IS READ, NO. OF LAND CHARACTERISTICS TO BE INSERTED
C      INTO THE SECONDARY LND DATA SET.
C      FOR EACH LAND CHARACTERISTIC INSERTED :-
C      POSITION IN THE GRID CELL DATA STRING INTO WHICH IT IS TO BE WRITTEN,
C      WHETHER THE OVERLAY ARRAY WHICH IS INSERTED INTO THE SECONDARY LAND DATA
C      SET IS TO BE PRINTED,FORMAT FOR READING THE REQUIRED LAND CHAR. FROM THE
C      DATA STRING OF THE PRIMARY LAND DATA SET.
C
XPUR DDDDD
XI
C
       DIMENSION FMT(15)
C
       WRITE(6,1)
1      FORMAT(T2,' THIS PROGRAM SETS UP THE DATA REQUIRED TO RUN THE OVERLAY PGM.'////)
       WRITE(6,2)
2      FORMAT(T2,' NUMBER OF DATA FILES TO BE OVERLAID ? MAX OF 5 ALLOWED FOR 1 RUN')
       READ(9,100) NJOB
100    FORMAT(V)
       WRITE(10,102) NJOB
102    FORMAT(I3)
       WRITE(6,3)
3      FORMAT(T2//,T2,' THE INFORMATION REQUIRED FOR EACH DATA SET IS DEALT WITH SEPARATELY'////)
       DO 50 II=1,NJOB
       WRITE(6,4)
4      FORMAT(T2,' UNIT NUMBER FROM WHICH THE DATA FILE IS READ ? MUST BE FROM 21-35')
       READ(9,100) IN
       WRITE(6,7)
7      FORMAT(T2,' NUMBER OF TIMES THIS DATA FILE IS TO BE OVERLAID ?')
       READ(9,100) NTIME
       WRITE(10,103) IN,NTIME
103    FORMAT(2I3)
       DO 55 I2=1,NTIME
       WRITE(6,9)
9      FORMAT(T2,' COLUMN NUMBER OF THE OVERLAY SET TO BE FILLED ?')
       READ(9,100) NMAP
       WRITE(6,6)
6      FORMAT(T2,' IS A PRINTOUT OF THE OVERLAY ARRAY REQUIRED ? 1=YES ')
       READ(9,100) IERROR
       WRITE(6,5)
5      FORMAT(T2,'FORMAT FOR READING THE CONTOUR (POLYGON,NETWORK,POINT) NUMBER & VALUE ?')
       READ(9,101) (FMT(I),I=1,15)
101    FORMAT(15A4)
       WRITE(10,104) NMAP,IERROR,(FMT(JJ),JJ=1,15)
104    FORMAT(2I3,15A4)
55     CONTINUE
50     CONTINUE
       WRITE(10,10)
10     FORMAT(T1,'//'/T1,'//')
C      KEEP THE OUTPUT FILE
       WRITE(6,8)
8      FORMAT(T2,///,T2,' ALL THE REQUIRED INFORMATION IS PRESENT. ENTER /XEQ COMB')
       STOP
       END
XE R
****************************************************************************************************
                                                      FILE   COMB
****************************************************************************************************
C      FILE 11  OF THE LAND CAPABILITY ANALYSIS PROCEDURE  1980  C. HAMMOND
C
C
C      THIS PROGRAM KEEPS THE OUTPUT FILE FROM PROGRAM  OVER  AS A FILE
C      DDDDD  AND INSERTS IT AS DATA FOR THE OVERLAY PROGRAM  OVPGM.
C      IT DISPLAYS INSTRUCTIONS FOR CHANGING THE JCL OF  OVPGM  TO REFER TO THE
C        WITS FILES BEING OVERLAID AND THE SECONDARY LAND DATA SET INTO WHICH
C        THE OVERLAID DATA ARE TO BE INSERTED.
C
XKEP DDDDD
XUP OVPGM
XCH /L
C      INSERT DDDDD  AS DATA FOR  OVPGM
XINS DDDDD
XE
XSA OVPGM
C      DISPLAY INSTRUCTIONS
XD INSTR 72,77
```

```
C       FILE 12  OF THE LAND CAPABILITY ANALYSIS PROCEDURE  1980  C. HAMMOND
C
C
C       PROGRAM EDITS A CONTROL DATA SET AND WRITES IT AS AS OUTPUT FILE.
C       THIS IS INSERTED INTO  INFO  BY PROGRAM  CONTRL.
*PUR WATXPO
*I
C
C       CONTROL ARRAYS ARE RETRIEVED FROM THE DD CARD SPECIFIED BY IN
C
        REAL YAR(6,35),FYAR(6,10),XAR(6,35),FXAR(6,10),WGT(45,10)
        REAL TITLES(20),CAPT(45,10,15),ANAM(6,45),ANLT(6,10),TL(45,10),BL(45,10)
        INTEGER ICGD(45,10)
        INTEGER FLEN(10),FAC(10),LENGTH(35),INA(10),INU(5),ICODE(45)
        INTEGER ICNLT(10),INDEX(45,10),INDCT(3,10)
        INTEGER IS(15,2),IEX(10),ISA(15),ISAU(15),IFAC(3,10)
C
       IN=8
       OUT=10
        READ(IN,95) (TITLES(I),I=1,20)
95      FORMAT(20A4)
        READ(IN,104) NLC,NEX,NCT,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,NFAC,NFG
        WRITE(6,149) (TITLES(I),I=1,20)
149     FORMAT(T2,' DATA SET BEING READ IS : '//,' ',20A4,//)
        DO 100 J=1,NLT
100     READ(IN,104) (INDEX(I,J),I=1,NLC)
104     FORMAT(26I3)
        DO 101 J=,NLT
101     READ(IN,108) (TL(I,J),I=1,NL)
        DO 102 J=1,NLT
102     READ(IN,108) (BL(I,J),I=1,NLC)
        DO 103 J=1,NLT
103     READ(IN,110) (WGT(I,J),I=1,NLC)
        READ(IN,104) ((INDCT(I,J),I=1,3),J=1,NCT)
        DO 24 K=1,NCT
        NR=INDCT(2,K)
        NC=INDCT(3,K)
        READ(IN,110) ((CAPT(I,J,K),I=1,NC),J=1,NR)
110     FORMAT(16F5.1)
24      CONTINUE
        DO 105 J=1,NLT
105     READ(IN,104) (ICGD(I,J),I=1,NLC)
        NN=NMAX*2
C       THIS IS NECESSARY AS LC & GRAPH NUM STORED IN PAIRS BUT ONLY
C       NUMBER OF LC CONCERNED IS READ IN
40      READ(IN,104) ((IS(I,J),I=1,NN),J=1,2)
        IF(NEX.EQ.0) GO TO 116
        READ(IN,104) (IEX(I),I=1,NEX)
116     IF(NSA.EQ.0) GO TO 210
        READ(IN,104) (ISA(I),I=1,NSA)
210     IF(NSAU.EQ.0) GO TO 211
        READ(IN,104) (ISAU(I),I=1,NSAU)
211     IF(NNA.EQ.0) GO TO 213
        READ(IN,104) (INA(I),I=1,NNA)
213     IF(NNU.EQ.0) GO TO 214
        READ(IN,104) (INU(I),I=1,NNU)
214     IF(NFAC.EQ.0) GO TO 215
        READ(IN,104) ((IFAC(I,J),I=1,3),J=1,NFAC)
        READ(IN,104) (FAC(I),I=1,NFAC)
215     READ(IN,104) (LENGTH(I),I=1,NCG)
        DO 29 I=1,NCG
        L=LENGTH(I)
29      READ(IN,108) (XAR(LL,I),LL=1,L),(YAR(LL,I),LL=1,L)
108     FORMAT(12F6.1)
        IF(NFG.EQ.0) GO TO 32
        READ(IN,104) (FLEN(I),I=1,NFG)
        DO 15 I=1,NFG
        L=FLEN(I)
        READ(IN,108) (FXAR(LL,I),LL=1,L),(FYAR(LL,I),LL=1,L)
15      CONTINUE
32      DO 16 J=1,NLT
16      READ(IN,113) (ANLT(I,J),I=1,6),ICNLT(J)
        DO 17 J=1,NLC
17      READ(IN,113) (ANAM(I,J),I=1,6),ICODE(J)
113     FORMAT(6A4,I3)
C
        WRITE(6,2000)
2000    FORMAT(T2,' THIS PROGRAM EDITS THE LAND USE DATA PER LAND SYSTEM ')
        WRITE(6,2)
2       FORMAT(T2,' ALL INFORMATION REQUSTED MUST BE GIVEN,EVEN IF ONLY ZERO')
        WRITE(6,2001)
2001    FORMAT(T2,' ANSWERS YES & NO ARE 1 & 0 RESPECTIVELY (I1.) '///)
        WRITE(6,2061)
2061    FORMAT(T2,' IS THIS CONTROL DATA SET FOR THE FORECLUSURE OF OPTIONS ?')
        READ(9,1) IFORE
        IF(IFORE.EQ.0) NTM=NLT
         WRITE(6,3001)
3001     FORMAT(T2,'  X & Y VALUE FOR THE GRAPHS WHICH REQUIRE USER SPECIFIED VALUES ')
90      WRITE(6,3002)
3002    FORMAT(T2,'  GRAPH NUMBER,POINT POSITION & X & Y VALUES (2I3,2F7.2) ?'/)
        WRITE(6,3003)
3003    FORMAT(T2,' WHEN COMPLETE GIVE A ZERO FOR THE GRAPH NUMBER')
        READ(9,1010) NUMG,NC,XVALUE,YVALUE
        IF(NUMG.EQ.0) GO TO 91
        XAR(NC,NUMG)=XVALUE
        YAR(NC,NUMG)=YVALUE
        GO TO 90
91      WRITE(6,3004)
3004    FORMAT(T2,' ARE ANY OTHER CHANGES TO BE MADE ?')
        READ(9,1006) NLIN
        IF(NLIN.EQ.0) GO TO 80
        WRITE(6,2002)
2002    FORMAT(T2,' NUMBER OF NEW AND USE TYPES TO BE ADDED ? ')
        READ(9,1006) IALT
1000    FORMAT(2I3)
        IF(IALT.EQ.0) GO TO 50
        WRITE(6,2102)
2102    FORMAT(T2,' EACH NEW LAND USE TYPE IS DEALT WITH SEPARATELY',///)
        DO 10 III=1,IALT
        NLT=NLT+1
        WRITE(6,2003)
2003    FORMAT(T2,' CODE NUMBER & NAME OF NEW LAND USE TYPE (I3,6A4) ?')
        READ(9,1001) ICNLT(NLT),(ANLT(I,NLT),I=1,6)
```

```
1001  FORMAT(I3,6A4)
      WRITE(6,2004)
2004  FORMAT(T2,'  LAND CHARACTERISTICS EVALUATED (26I3) ? ')
      READ(9,1002) (INDEX(I,NLT),I=1,NLC)
      WRITE(6,2005)
2005  FORMAT(T2,' THEIR GRAPH NUMBERS (26I3) ? (GIVE A ZERO WHERE HAVE NONE)')
      READ(9,1002) (ICGD(I,NLT),I=1,NLC)
1002  FORMAT(26I3)
      WRITE(6,2006)
2006  FORMAT(T2,' THEIR UPPER LIMITS (12F7.2) ?')
      READ(9,1003) (TL(I,NLT),I=1,NLC)
      WRITE(6,4)
4     FORMAT(T2,' THEIR LOWER LIMITS (12F7.2) ?')
      READ(9,1003) (BL(I,NLT),I=1,NLC)
1003  FORMAT(12F7.2)
      WRITE(6,2008)
2008  FORMAT(T2,' IF A CAP.TAB DOES NOT REQUIRE A NEW ROW,GIVE ONLY ZERO VALUES')
      DO 11 I1=1,NCT
      WRITE(6,2007) I1
2007  FORMAT(T2,' NEW ROW FOR',I5,' CAP. TABLE (16F5.1) ?')
      NCT=NCT+1
      NR=INDCT(2,I1)+1
      INDCT(2,I1)=NR
      NC=INDCT(3,I1)
      READ(9,110) (CAPT(I,NR,I1),I=1,NC)
      SUM=0.0
      DO 12 I2=1,NC
      SUM=SUM+CAPT(I2,NR,I1)
12    CONTINUE
      IF(SUM.EQ.0.0) INDCT(2,I1)=INDCT(2,I1)-1
      IF(SUM.EQ.0.0) NCT=NCT-1
11    CONTINUE
10    CONTINUE
30    WRITE(6,5)
5     FORMAT(T2,' NUMBER OF NEW LAND CHARACTERISTICS TO BE ADDED ?')
      READ(9,1006) IADD
      IF(IADD.EQ.0) GO TO 50
      WRITE(6,2108)
2108  FORMAT(T2,' EACH NEW LAND CHARAC. IS DEALT WITH SEPARATELY',////)
      DO 20 III=1,IADD
      NLC=NLC+1
      WRITE(6,2009)
2009  FORMAT(T2,'  THE LAND CHARAC.CODE NUMBER & NAME (I3,6A4) ?')
      READ(9,1001) LCNUM,(ANAM(J,NLC),J=1,6)
      WRITE(6,2010)
2010  FORMAT(T2,'  ITS GRAPH NUMBER & WEIGHT (I3,F5.1) ?')
      READ(9,1004) NUM,W
1004  FORMAT(I3,F5.1)
      DO 21 I1=1,NLT
      ICGD(NC,I1)=NUM
      INDEX(NC,I1)=LCNUM
      WGT(NC,I1)=W
21    CONTINUE
      WRITE(6,2011)
2011  FORMAT(T2,' THE UPPER PERMITTED VALUES FOR ALL THE LAND USE TYPES ')
      WRITE(6,2012)
2012  FORMAT(T2,' INCLUDING ANY WHICH HAVE JUST BEEN ADDED (11F7.2) ?')
      READ(9,1003) (TL(NLC,J),J=1,NLT)
      WRITE(6,6)
6     FORMAT(T2,' THE LOWER PERMITTED VALUES FOR ALL THE LAND USE TYPES ')
      WRITE(6,2012)
      READ(9,1003) (BL(NLC,J),J=1,NLC)
      WRITE(6,2013)
2013  FORMAT(T2,'  THE NUMBER OF COLS & ROWS FOR THE CAP TAB (2I3) ?')
      WRITE(6,2113)
2113  FORMAT(T3,' IF NO CAP. TABLE FOR THIS LAND CHARAC.,GIVE ZERO')
      READ(9,1000) NC,NR
      IF(NC.EQ.0) GO TO 25
      NCT=NCT+1
      INDCT(1,NCT)=LCNUM
      INDCT(2,NCT)=NR
      INDCT(3,NCT)=NC
      WRITE(6,8014)
8014  FORMAT(T2,' GIVE THE CAP TABLE PER ROW (16F5.1)')
      DO 22 I2=1,NR
22    READ(9,110) (CAPT(J,I2,NCT),J=1,NC)
25    WRITE(6,2015)
2015  FORMAT(T2,' IS THIS LAND CHARAC. EXCLUSIVE ?')
      READ(9,1006) N
1006  FORMAT(V)
      IF(N.EQ.0) GO TO 26
      NEX=NEX+1
      IEX(NEX)=LCNUM
26    WRITE(6,2016)
2016  FORMAT(T2,'  THE LENGTH OF THE CAP. GRAPH (I3) ? IF NONE,GIVE ZERO')
      READ(9,1007) LEN
1007  FORMAT(I3)
      IF(LEN.EQ.0) GO TO 28
      NCG=NCG+1
      LENGTH(NCG)=LEN
      WRITE(6,2017)
2017  FORMAT(T2,' GIVE ALL X FOLLOWED BY ALL Y VALUES (11F7.2)')
      READ(9,1003) (XAR(J,NCG),J=1,LEN),(YAR(J,NCG),J=1,LEN)
28    WRITE(6,2018)
2018  FORMAT(T2,' IS THIS LAND CHARAC INVOLVED IN AN INTERRELATIONSHIP ?')
      READ(9,1006) NUM
      IF(NUM.EQ.0) GO TO 20
      WRITE(6,2020)
2020  FORMAT(T2,'  LAND CHARAC NUMBERS OF THOSE MODIFIED,MODIFYING')
      WRITE(6,2021)
2021  FORMAT(T2,' & CODE NUMBER OF HOW MODIFICATION OCCURS (3I3) ?')
      READ(9,1008) LM,LC,NUM
      NFAC=NFAC+1
      IFAC(1,NFAC)=LM
      IFAC(2,NFAC)=LC
      IFAC(3,NFAC)=NUM
      WRITE(6,2022)
2022  FORMAT(T2,'  FAC.GRAPH NUMBER & LENGTH (2I3) ?')
      WRITE(6,3010)
3010  FORMAT(T2,' IF IT ALREADY EXISTS,GIVE LENGTH AS ZERO')
      READ(9,1000) NUMG,LEN
      FAC(NFAC)=NUMG
      IF(LEN.EQ.0) GO TO 20
2023  FORMAT(T2,' GIVE ALL X FOLLOWED BY ALL Y VALUES (11F7.2)')
      NFG=NFG+1
      FLEN(NFG)=LEN
      READ(9,1003) (FXAR(J,NFG),J=1,LEN),(FYAR(J,NFG),J=1,LEN)
20    CONTINUE
```

```
50     WRITE(6,2024)
2024   FORMAT(T2,' IN ALL THE FOLLOWING CHANGES IF A VALUE IS NOT TO ')
       WRITE(6,2025)
2025   FORMAT(T2,' BE CHANGED. THE ORIGINAL VALUE IS GIVEN '///)
51     WRITE(6,2026)
2026   FORMAT(T2,' IS A VALUE PERMITTED TO BE CHANGED ?')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 55
       WRITE(6,2027)
2027   FORMAT(T2,'IS IT UPPER OR LOWER OR BOTH ? (2Y) ')
       READ(9,1009) NT,NB
1009   FORMAT(2Y)
       WRITE(6,2028)
2028   FORMAT(T2,'  COL & ROW POSITION, & UPPER & LOWER VALUE (2I3,2F7.2) ?')
       READ(9,1010) NC,NR,VALUET,VALUEB
1010   FORMAT(2I3,2F7.2)
       IF(NT.EQ.1) TL(NC,NR)=VALUET
       IF(NB.EQ.1) BL(NC,NR)=VALUEB
       GO TO 51
55     WRITE(6,2029)
2029   FORMAT(T2,' IS A LAND CHARAC OR GRAPH TO BE CHANGED ? ')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 56
       WRITE(6,2030)
2030   FORMAT(T2,'  COL & ROW POSITION, LAND CHARAC & GRAPH NUMBERS (4I3) ?')
       READ(9,1011) NC,NR,LCNUM,NUMG
1011   FORMAT(4I3)
       ICGD(NC,NR)=NUMG
       INDEX(NC,NR)=LCNUM
       GO TO 55
56     WRITE(6,2031)
2031   FORMAT(T2,' IS A WEIGHT TO BE CHANGED ?')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 58
       WRITE(6,2032)
2032   FORMAT(T2,'  THE COL. NUMBER & WEIGHTING VALUE (I3,F5.1) ?')
       READ(9,1004) NC,VALUE
       WGT(NC)=VALUE
       GO TO 56
58     WRITE(6,2033)
2033   FORMAT(T2,' IS A LIMITING LAND CHARAC. TO BE CHANGED OR ADDED ?')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 60
       CALL CHANGE(NEX,IEX)
60     DO 1998 IS=1,NTM
       IF(IFORE.EQ.1) READ(IN,104) NSA,NSAU,NAA,NNU
       WRITE(6,2034)
2034   FORMAT(T2,' IS AN AVAILABLE SURFACE AREA LC TO BE CHANGED OR ADDED ?')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 61
       CALL CHANGE(NSA,ISA)
61     WRITE(6,2035)
2035   FORMAT(T2,' IS A NONAVAILABLE SURFACE SREA LC TO BE CHANGED OR ADDED ?')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 62
       CALL CHANGE(NSAU,ISAU)
62     WRITE(6,2036)
2036   FORMAT(T2,' IS AN INHIBITORY LC TO BE CHANGED OR ADDED ?')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 63
       CALL CHANGE(NNU,INU)
63     IF(IS.GT.1) GO TO 1997
       WRITE(6,2037)
2037   FORMAT(T2,' IS A UNINHIBITORY LC TO BE CHANGED OR ADDED ?')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 64
       CALL CHANGE(NAA,INA)
64     WRITE(6,2038)
2038   FORMAT(T2,'IS AN INTERACTION TO BE CHANGED OR ADDED ?')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 66
       WRITE(6,2039)
2039   FORMAT(T2,'  COL POSITION, LC NUMBERS MODIFIED,MODIFYING,')
       WRITE(6,2040)
2040   FORMAT(T2,' & CODE FOR HOW MODIFIED (4I3) ?')
       READ(9,1008) NC,LM,LC,NUM
1008   FORMAT(4I3)
       IFAC(1,NC)=LM
       IFAC(2,NC)=LC
       IFAC(3,NC)=NUM
       IF(NC.GT.NFAC) NFAC=NFAC+1
       GO TO 64
66     WRITE(6,2041)
2041   FORMAT(T2,'ARE ANY CHANGES TO A FAC. GRAPH TO BE MADE ?')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 68
       WRITE(6,2042)
2042   FORMAT(T2,'  GRAPH NUMBER,PT. POSITION,LENGTH & X & Y VALUES (3I3,2F7.2) ?')
       READ(9,1012) NG,NC,LEN,XVALUE,YVALUE
1012   FORMAT(3I3,2F7.2)
       FXAR(NC,NG)=XVALUE
       FYAR(NC,NG)=YVALUE
       IF(LEN.GT.0) FLEN(N)=LEN
       GO TO 66
68     WRITE(6,2054)
2054   FORMAT(T2,' IS A NEW FAC.GRAPH REQUIRED (NOT ASSOCIATED WITH A NEW LC) ?')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 78
       WRITE(6,2056)
2056   FORMAT(T2,'  GRAPH NUMBER & LENGTH OF FAC.GRAPH (2I3) ?')
       READ(9,1000) NUMG,LEN
       NFG=NFG+1
       FLEN(NFG)=LEN
       FAC(NFAC)=NUMG
       WRITE(6,2023)
       READ(9,1003) (FXAR(J,NFG),J=1,LEN),(FYAR(J,NFG),J=1,LEN)
       GO TO 66
78     WRITE(6,2043)
2043   FORMAT(T2,' IS ANY CHANGE OR ADDITION TO BE MADE TO LC IN ARRAY IS ?')
       READ(9,1006) MLIM
       IF(MLIM.EQ.0) GO TO 70
       WRITE(6,2044)
2044   FORMAT(T2,' COL. POSITION,LARGE LC & GRAPH NUMBERS,SMALL LC')
       WRITE(6,2045)
2045   FORMAT(T2,' & GRAPH NUMBERS. ( GIVE ZERO IF NO GRAPH) (5I3) ?')
       READ(9,1013) NC,LM,NUM,LC,NUMG
1013   FORMAT(5I3)
       IS(NC,1)=LM
```

```
      IS(NC,2)=LC
      IS(NC+1,1)=NUM
      IS(NC+1,2)=NUMG
      IF(NC.GT.NMAX) NMAX=NMAX+1
      GO TO 70
70    WRITE(6,2046)
2046  FORMAT(T2,' IS A VALUE IN A CAP. TABLE TO BE CHANGED OR ADDED ?')
      READ(9,1006) NLIN
      IF(NLIN.EQ.0) GO TO 72
      WRITE(6,2047)
2047  FORMAT(T2,'CAP. TAB NUMBER,COL & ROW POSITION & VALUE (3I3,F5.1) ?')
      READ(9,1014) NN,NC,NR,VALUE
1014  FORMAT(3I3,F5.1)
      NC1=INDCT(3,NN)
      IF(NC1.LT.NC) INDCT(3,NN)=NC
      IF(NN.GT.NCT) NCT=NCT+1
      CAPT(NC,NR,NN)=VALUE
      GO TO 70
72    WRITE(6,2050)
2050  FORMAT(T2,' IS A NEW CAP. TABLE REQUIRED (NOT THAT ASSOCIATED WITH A NEW LC) ?')
      READ(9,1006) NLIN
      IF(NLIN.EQ.0) GO TO 76
      WRITE(6,2051)
2051  FORMAT(T2,' NUMBER OF ROWS & COLS FOR CAP. TABLE,& THE LC NUMBER (3I3) ?')
      READ(9,1020) NC,NR,LCNUM
1020  FORMAT(3I3)
      NCT=NCT+1
      INDCT(1,NCT)=LCNUM
      INDCT(2,NCT)=NR
      INDCT(3,NCT)=NC
      WRITE(6,8014)
      DO 23 I2=1,NR
23    READ(9,110) (CAPT(J,I2,NCT),J=1,NC)
      GO TO 72
76    WRITE(6,2048)
2048  FORMAT(T2,' IS A CAP. GRAPH VALUE TO BE ADDED OR CHANGED ?')
      READ(9,1006) NLIN
      IF(NLIN.EQ.0) GO TO 74
      WRITE(6,2049)
2049  FORMAT(T2,' GRAPH NUMBER,PT. POSITION,LENGTH & X & Y VALUES (3I3,2F7.2) ?')
      READ(9,1012) NG,NC,LEN,XVALUE,YVALUE
      XAR(NC,NG)=XVALUE
      YAR(NC,NG)=YVALUE
      IF(LEN.GT.0) LENGTH(NG)=LEN
      GO TO 76
74    WRITE(6,2052)
2052  FORMAT(T2,' IS A NEW CAP.GRAPH REQUIRED (NOT ASSOCIATED WITH A NEW LC) ?')
      READ(9,1006) NLIN
      IF(NLIN.EQ.0) GO TO 80
      WRITE(6,2016)
      READ(9,1007) LEN
      NCG=NCG+1
      LENGTH(NCG)=LEN
      WRITE(6,2017)
      READ(9,1003) (XAR(J,NCG),J=1,LEN),(YAR(J,NCG),J=1,LEN)
      GO TO 74
80    CONTINUE
C
C     WRITE ALL CONTROL ARRAYS TO UNIT  OUT
C
      WRITE(OUT,95) (TITLES(I),I=1,20)
      WRITE(OUT,104) NLC,NEX,NCT,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,NFAC,NFG
      DO 199 J=1,NLT
199   WRITE(OUT,104) (INDEX(I,J),I=1,NLC)
      DO 200 J=1,NLT
200   WRITE(OUT,108) (TL(I,J),I=1,NLC)
      DO 202 J=1,NLT
202   WRITE(OUT,108) (BL(I,J),I=1,NLC)
      DO 203 J=1,NLT
203   WRITE(OUT,110) (WGT(I,J),I=1,NLC)
      WRITE(OUT,104) ((INDCT(I,J),I=1,3),J=1,NCT)
      DO 14 K=1,NCT
      NR=INDCT(2,K)
      NC=INDCT(3,K)
14    WRITE(OUT,110) ((CAPT(I,J,K),I=1,NC),J=1,NR)
      DO 204 J=1,NLT
204   WRITE(OUT,104) (ICGD(I,J),I=1,NLC)
      NM=NMAX+2
41    WRITE(OUT,104) ((IS(I,J),I=1,NM),J=1,2)
      IF(NEX.NE.0) WRITE(OUT,104) (IEX(I),I=1,NEX)
      IF(NSA.NE.0) WRITE(OUT,104) (ISA(I),I=1,NSA)
      IF(NSAU.NE.0) WRITE(OUT,104) (ISAU(I),I=1,NSAU)
      IF(NNA.NE.0) WRITE(OUT,104) (INA(I),I=1,NNA)
      IF(NNU.NE.0) WRITE(OUT,104) (INU(I),I=1,NNU)
9     IF(NFAC.EQ.0) GO TO 13
      WRITE(OUT,104) ((IFAC(I,J),I=1,3),J=1,NF C)
      WRITE(OUT,104) (FAC(I),I=1,NFAC)
13    WRITE(OUT,104) (LENGTH(I),I=1,NCG)
      DO 31 I=1,NCG
      L=LENGTH(I)
31    WRITE(OUT,108) (XAR(LL,I),LL=1,L),(YAR(LL,I),LL=1,L)
      IF(NFG.EQ.0) GO TO 38
      WRITE(OUT,104) (FLEN(I),I=1,NFG)
      DO 35 I=1,NFG
      L=FLEN(I)
      WRITE(OUT,108) (FXAR(LL,I),LL=1,L),(FYAR(LL,I),LL=1,L)
35    CONTINUE
38    DO 36 J=1,NLT
36    WRITE(OUT,113) (ANLT(I,J),I=1,6),ICNLT(J)
      DO 37 J=1,NLC
37    WRITE(OUT,113) (ANAM(I,J),I=1,6),ICODE(J)
1997    IF(IFURE.EQ.0) GO TO 1998
      WRITE(OUT,104) NSA,NSAU,NNA,NNU
      IF(NEX.NE.0) WRITE(OUT,104) (IEX(I),I=1,NEX)
      IF(NSA.NE.0) WRITE(OUT,104) (ISA(I),I=1,NSA)
      IF(NSAU.NE.0) WRITE(OUT,104) (ISAU(I),I=1,NSAU)
      IF(NNA.NE.0) WRITE(OUT,104) (INA(I),I=1,NNA)
      IF(NNU.NE.0) WRITE(OUT,104) (INU(I),I=1,NNU)
1998  CONTINUE
      WRITE(OUT,6000)
6000  FORMAT(T1,'//'/,T1,'//')
      WRITE(6,3000)
3000  FORMAT(T2,'          THE REQUIRED EDITTING IS COMPLETE'/////)
      WRITE(6,3005)
3005  FORMAT(T20,' ENTER  /XEQ CONTRL',///)
      STOP
      END
C
```

```
      SUBROUTINE CHANGE (NUM,IARY)
C
C
C     THIS SUBROUTINE MODIFIES THE INTEGER ARRAYS
C     IEX,INA 'AU,ISA,ISAU
C
      INTEGER IARY(15)
C
100   WRITE(6,2000)
2000  FORMAT(T2,' IS A CHANGE OR ADDITION TO BE MADE ?')
      READ(9,1000) MM
1000  FORMAT(I1)
      IF(MM.EQ.0) RETURN
      WRITE(6,2001)
2001  FORMAT(T2,' GIVE COL.POSITION & LAND CHARAC. NUMBER (2I3)')
      READ(9,153) NC,LCNUM
153   FORMAT(2I3)
      IF(NC.GT.NUM) NUM=NUM+1
      IARY(NC)=LCNUM
      GO TO 100
      RETURN
      END
/DATA
%E R 3600

*********************          ***********************************************************

                                                       FILE   EVAL

******************************************************************************************

C     FILE 13  OF THE LAND CAPABILITY PROCEDURE  1980  C. HAMMOND
C
C
C     THIS PROGRAM COPIES  PREP  INTO FILE  EVPREP
C     IT DISPLAYS THE INSTRUCTIONS FOR SETTING UP FILE  INFO  WHICH WILL
C     CONTAIN THE CONTROL DATA SETS USED IN THE EXECUTION OF  CAPAN.
C
%EMP
%PUR INFO
%PUR EVPREP
C     CREATE  EVPREP  AND  INFO
%SA INFO
%UP
%INS PREP
%E
%SA EVPREP
C     DISPLAY INSTRUCTIONS
%D INSTR104,117,

******************************************************************************************

                                                       FILE   CONTRL

******************************************************************************************

C     FILE 14  OF THE LAND CAPABILITY ANALYSIS PROCEDURE  1980  C. HAMMOND
C
C
C     PROGRAM INSERTS THE [illegible] CONTROL DATA SET FROM PROGRAM  PREP  INTO
C     INFO  AND DISPLAYS THE IN[illegible]CTION TO RERUN  PREP  IF MORE THAN ONE
C     CONTROL DATA SET IS TO BE USED IN THE RUNNING OF PROGRAM  CAPANL
%KEP WATXPO
%UP INFO
%CH /L
C     INSERT AND SAVE THE FILE
%INS WATXPO
%E
%D INSTR114,117
```

```
***************************************************************************************************************
                                                     FILE   EVDATA
***************************************************************************************************************
C
C     FILE 15 OF THE LAND CAPABILITY ANALYSIS PROCEDURE 1980 (C. HAMMOND)
C
C
C     THE PROGRAM WRITES AN OUTPUT FILE OF THE DATA REQUIRED TO RUN CAPANL
C     THE FILE CONTAINS :-
C       NO. OF MAP SYMBOLS PRINTED PER ROW & COL., VALUE 1 IF THE DEFAULT
C     MISSING DATUM VALUE IS NOT TO BE USED.THE USER GIVEN MISSING DATUM VALUE
C     FOR EACH SECONDARY LAND DATA SET ANALYSED :-
C       UNIT NO. ON WHICH THE SECONDARY LAND DATA SET IS WRITTEN.THE CODE NO.
C       OF THE LAND CHARAC. WHICH IS TO BE MAPPED SEPARATELY.
C     FOR EACH LAND USE ANALYSED :-
C     VALUE 1 IF A PARTICULAR PORTION OF THE SECONDARY LAND DATA SET IS TO BE
C     SELECTED.UNIT NO. TO WHICH THE SELECTED PORTION IS TO BE WRITTEN IF A
C     PERMANENT DATA SET IS REQUIRED.WEST.EAST.SOUTH.NORTH CO-ORDINATES OF
C     THIS PORTION.
C       VALUE OF 1 FOR THE FOLLOWING OPTIONS :-
C       ANALYSIS OF THE FORECLOSURE OF OPTIONS IN LAND USE.PERFORMANCE OF THE
C       CAPABILITY ANALYSIS AT THE DETAILED SCALE.PRINT THE MAP OF THE
C       LIMITING LAND CHAR..DEFAULT SET OF SURFACE ARE VALUES EQUILVALENT TO A
C       NO. OF NETWORKS IS NOT TO BE USED.UNIT NO. TO WHICH THE TEMPORARY
C       CONTROL ARRAYS ARE TO BE WRITTEN IF DESIRED.UNIT NO. FROM WHICH THE
C       TEMPRUARY CONTROL ARRAYS FROM A PREVIOUS JOB ARE TO BE RETRIEVED. UNIT
C       NO. ON WHICH THE CONTROL DATA FOR THE LAND USE TO BE ANALYSED IS
C       WRITTEN.NO. OF LAND USE TYPES TO BE COMBINED.
C       THE SURFACE AREA VALUES EQUIVALENT TO A NUMBER OF NETWORKS FROM 1 - 10
C       IF THE DEFAULT SET IS NOT REQUIRED.
C       LAND USE TYPE NO.S TO BE COMBINED.
C
C     THE OUTPUT FILE IS INSERTED AS DATA INTO A COPIED FILE OF CAPANL. BY
C     PROGRAM ANAL.
C
CXI
C
      INTEGER NCOM(10)
      INTEGER ISS
      REAL SURF(10)
      REAL*8 VMISS,XW,XE,BY,TY
C
      OUT=10
      WRITE(6,1)
1     FORMAT(T2,' THIS PROGRAM SETS UP THE INFORMATION REQUIRED BY THE EVAL PGM.')
      WRITE(6,2)
2     FORMAT(T2,' ANSWERS YES & NO ARE 1 & 0 RESPECTIVELY')
      WRITE(6,3020)
3020  FORMAT(T2,' AN ANSWER MUST BE GIVEN FOR ALL REQUESTED INFORMATION, EVEN IF ONLY ZEROS AREGIVEN':
      WRITE(6,3021)
3021  FORMAT(T2,' GIVE SCALING FACTOR FOR ROWS & COLS. (2I3) OF THE MAP PRODUCED ')
      WRITE(6,3022)
3022  FORMAT(T2,'  BY THIS JOB ? DEFAULT OF 5 & 4 USED IF ZEROS ARE GIVEN')
      READ(9,1000) NSCALR,NSCALC
1000  FORMAT(2I3)
      VMISS=-0.9
      WRITE(6,3024)
3024  FORMAT(T2,' IS THE DEFAULT MISSING VALUE(-0.9) TO BE USED ?')
      READ(9,1001) MISS
      IF(MISS.EQ.0) WRITE(6,3054)
3054  FORMAT(T2,'  THE DESIRED MISSING VALUE (F10.3) ?')
      IF(MISS.EQ.0) READ(9,1060) VMISS
1060  FORMAT(F10.3)
      WRITE(OUT,3037) NSCALR,NSCALC,MISS,VMISS
3037  FORMAT(3I3,F10.3)
      MN=0
      IOP=0
      ISEL=0
      WRITE(6,3025)
3025  FORMAT(T2,' DATA SETS DEALT WITH SEPARATELY. MAX.OF 5 DIFF.SETS ALLOWED.BUT EACH CAN BE RERUN')
3090  WRITE(6,3026)
3026  FORMAT(T2,' UNIT NUMBER  (ZERO GIVEN IF NO MORE ARE REQUIRED) ')
      WRITE(6,3056)
3056  FORMAT(T2,'FROM WHICH DATA SET IS READ? THESE NUMBERS MUST BE FROM 11-15  ')

      READ(9,1001) ID
      IF(ID.EQ.0) GO TO 3092
      WRITE(6,3126)
3126  FORMAT(T2,'  IF A LC IN THE DATA SET IS TO BE MAPPED,GIVE ITS COL POSITION (I3)')
      READ(9,1001) M
      IF(MN.GT.0.AND.ISEL.GT.0.AND.ID.EQ.IOP) ID=3
      MN=0
      IF(M.GT.0) GO TO 3091
      WRITE(6,3057)
3057  FORMAT(T2,' IS AN ANALYSIS OF FORECLOSURE IN OPTIONS REQUIERD ?  ')
      READ(9,1001) IFORE
      WRITE(6,3058)
3058  FORMAT(T2,' ARE THE CONTROL ARRAYS FROM A PREVIOUS JOB TO BE USED? ')
      READ(9,1001) NPREVJ
      WRITE(6,3027)
3027  FORMAT(T2,' IS ANALYSIS TO BE AT A SMALL SURVEY SCALE  & IS A MAP SHOWING NUM.')
      WRITE(6,3028)
3028  FORMAT(T2,' OF LIMITING LC.S PER CELL TO BE PRINTED ? (2Y) ')#
      READ(9,1062) ISS,NLIM
1062  FORMAT(2Y)
      IF(NPREVJ.EQ.0) GO TO 3060
      NUMCOM=1
      KEEPJ=0
      GO TO 3091
3060  WRITE(6,3029)
3029  FORMAT(T2,' ARE THE CONTROL ARRAYS FOR THE LAND USE TYPE(GIVEN NEXT)')
      WRITE(6,3051)
3051  FORMAT(T2,' TO BE KEPT ? ')
      READ(9,1001) KEEPJ
      ISURF=0
      WRITE(6,3038)
3038  FORMAT(T2,'ARE THE DEFAULT SET OF SURFACE VALUES TO BE USED 1=NO ?')
      READ(9,1001) ISURF
      IF(ISURF.EQ.0) GO TO 4001
      READ(9,1002) (SURF(I),I=1,10)
1002  FORMAT(10Y)
4001  WRITE(6,3030)
3030  FORMAT(T2,'  NUMBER OF LAND USE TYPES (WITHIN A PARTICULAR SYSTEM)')
      WRITE(6,3052)
3052  FORMAT(T2,'WHICH ARE TO BE COMBINED TO MAKE ONE LAND USE ?')
      READ(9,1001) NUMCOM
```

```
1001   FORMAT(Y)
       WRITE(6,3031)
3031   FORMAT(T2,' GIVE LAND USE TYPE NUMBERS (WITHIN THE PARTICULAR SYSTEM) TO BE COMBINED (26I3) ?')
       READ(9,104) (NCOM(I),I=1,NUMCOM)
104    FORMAT(26I3)
       WRITE(6,3036)
3036   FORMAT(T2,' UNIT NO. ON WHICH THE CONTROL ARRAYS FOR THIS LAND USE ARE WRITTEN ?')
       READ(9,1001) NLS
3091   WRITE(6,3032)
3032   FORMAT(T2,' IS A PARTICULAR SECTION OF THE DATA SET TO BE ANALYSED OR MAPPED ?')
       READ(9,1001) ISEL
       MN=M
       IOP=IO
       IF(ISEL.EQ.1) GO TO 3093
       XW=0.0
       XE=0.0
       YS=0.0
       YN=0.0
       GO TO 3096
3093   WRITE(6,3033)
3033   FORMAT(T2,' GIVE WEST,EAST,SOUTH & NORTH CO-ORDINATES (4F10.3)')
       READ(9,1034) XW,XE,YS,YN
1034   FORMAT(4F10.3)
       WRITE(6,3034)
3034   FORMAT(T2,' GIVE OUTPUT UNIT IF THIS SELECTED PORTION IS TO BE KEPT (I3)')
       READ(9,1000) OUTO
3096   WRITE(OUT,1000) IO,M
       IF(M.GT.0) GO TO 3094
       WRITE(OUT,1008) IFORE,ISS,NLIM,ISURF,KEEPJ,NPREVJ,NLS,NUMCOM
1008   FORMAT(8I3)
       IF(NPREVJ.EQ.0) WRITE(OUT,104) (NCOM(I),I=1,NUMCOM)
3094   WRITE(OUT,3035) ISEL,OUTO,XW,XE,YS,YN
3035   FORMAT(2I3,4(F10.3))
       GO TO 3090
3092   WRITE(OUT,1000) IO
       WRITE(OUT,600)
600    FORMAT(T1,'//'/,T1,'//')
       WRITE(6,4000)
4000   FORMAT(T20,' JOB IS COMPLETE       ENTER /XEQ ANAL')
C      KEEP THE OUTPUT FILE AS FILE EV123
       STOP
       END
XE R 3600
```

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******************************************************************************************************
                                                    FILE    CAPANL
******************************************************************************************************
C       FILE 16 OF THE LAND CAPABILITY ANALYSIS PROCEDURE 1983 (C. HAMMOND)
C
C                  LAND CAPABILITY ANALYSIS PROGRAM  1980 (C.M.HAMMOND)
C                  ---------------------------------------------------
C
C       THE WEIGHTED CAPABILITY OF LAND TO SUPPORT A LAND USE IS EVALUATED AT A
C       SMALL OR LARGE SURVEY SCALE. THE EVALUATION IS GUIDED BY THE
C       INFORMATION CONTAINED IN THE CONTROL DATA SET FOR THE LAND USE
C       SYSTEM(LUS) UNDER WHICH THE LAND USE(LU) IS CLASSIFIED.
//CMMFORC2 JOB 063,CLASS=D
/*SETUP          TAPE=(TFM001,SL,NO)
/*ROUTE  PRINT HOLD
/*JOBPARM FORMS=BLK8
//ONE EXEC WITSTOO3
//SYS21 DD DSN=&&CON21,UNIT=SYSRES,DISP=(NEW,PASS),
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=FB,LRECL=132,BLKSIZE=2112)
//SYS22 DD DSN=&&CON22,UNIT=SYSRES,DISP=(NEW,PASS),
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=FB,LRECL=132,BLKSIZE=2112)
//SYS23 DD DSN=&&CON23,UNIT=SYSRES,DISP=(NEW,PASS),
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=FB,LRECL=132,BLKSIZE=2112)
//SYS24 DD DSN=&&CON24,UNIT=SYSRES,DISP=(NEW,PASS),
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=FB,LRECL=132,BLKSIZE=2112)
//SYS25 DD DSN=&&CON25,UNIT=SYSRES,DISP=(NEW,PASS),
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=FB,LRECL=132,BLKSIZE=2112)
//SYSIN DD *
L DUMMY SYS21
L DUMMY SYS22
L DUMMY SYS23
L DUMMY SYS24
L DUMMY SYS25
/*
//   EXEC FORTXCLG,PARM.FORT=NOSOURCE,TIME.GO=2
//FORT.SYSIN DD *
C
C
C
C
C       A MAXIMUM OF  5 DIFFERENT SECONDARY LAND DATA SETS MAY BE
C       EVALUATED FOR A MAXIMUM OF 5 DIFFERENT LU(INCLUDING THE FORECLOSURE OF OPTIONS).
C        A MAXIMUM OF 5 OUTPUT DATA SETS MAY BE WRITTEN.
C
C
C        THE FOLLOWING RESULTS ARE PRINTED :-
C
C       A) FOR EACH LUS :-
C          1) A TABLE OF THE LUTS WHICH MAY BE EVALUATED .
C          2) A TABLE OF THE LAND CHARACTERISTICS(LC) EVALUATED FOR EACH
C             LAND USE TYPE(LUT) .
C
C       B) FOR EACH LU WITHIN THE LUS :-
C          1) A TABLE OF THE LCS WITH THEIR PERMITTED RANGE OF VALUES & WEIGHTS
C          2) THE FREQUENCY & PERCENTAGE FREQUENCY OF EACH CAPABILITY CLASS
C             IN THE PRINTED MAP .
C          3) A LAND CAPABILITY MAP .
C          4) THE FREQUENCY & THE PERCENTAGE FREQUENCY OF EACH CLASS IN THE
C             THE MAP SHOWING THE USABLE SURFACE AREA.
C          5) THE MAP OF THE USABLE SURFACE AREA.
C          6) THE FREQUENCY & PERCENTAGE FREQUENCY OF EACH CLASS IN THE MAP
C             DESCRIBED IN POINT B 7 .
C          7) A MAP SHOWING THE GRID CELLS WITH LC'S VALUES FALLING OUTSIDE THE
C             PERMITTTED RANGE OR WITH MISSING VALUES .
C
C       C) AT THE END OF THE JOB, AN INDEX OF THE MAP SYMBOLS PRINTED PER CLASS .
C
C
C
C        THE DATA CONTROLLING THE EXECUTION OF THE JOB ARE :-
C
C        1) THE NUMBER OF MAP SYMBOLS PER GRID CELL DOWN & ACROSS THE OUTPUT
C           PAGE (MAXIMUM IS 10), WHETHER THE DEFAULT MISSING VALUE (-0.9) IS
C           TO BE USED & IF NOT, THE SELECTED MISSING VALUE .
C           (NSCALR,NSCALA,MISSN,VMISS (3I3,F10.3)).
C        2) THE UNIT (11 - 15) ON WHICH THE SECONDARY LAND DATA SET IS WRITTEN.
C       THE COL. POSITION IN EACH GRID CELL OF THE LC TO BE MAPPED.
C           (ID,M (2I3))
C        3) THE SELECTION OF A PARTICULAR PORTION OF THE LAND, THE OUTPUT
C           UNIT (41 - 45) TO WHICH THIS IS TO BE WRITTEN IF IT IS TO BE KEPT,
C           & THE WEST,EAST,SOUTH & NORTH MAP CO-ORDINATES BOUNDING THE SELECTED
C           PORTION .
C           (ISEL,CUTO,XW,XE,YS,YN (2I3,4F10.3))
C       4) THE VALUE ONE FOR THE FOLLOWING OPTIONS :-
C          A) THE EVALUATION OF THE FORECLOSURE OF OPTIONS
C          B) THE SURVEY SCALE AT WHICH THE ANALYSIS IS TO BE EVALUATED
C          C) THE PRINTING OF THE MAP DESCRIBED UNDER POINT B(7) ABOVE .
C          D) THE USE OF THE DEFAULT SET OF SURFACE AREA VALUES
C          E) THE UNIT (41 -45) ON WHICH THE TEMPORARY CONTROL DATA SETS
C             FOR THE LUS ARE TO BE WRITTEN IF THEY ARE TO BE KEPT .
C          F) THE USE OF THE TEMPORARY CONTROL ARRAYS KEPT FROM A PREVIOUS RUN .
C          G) THE UNIT (21 - 25) ON WHICH THE CONTROL DATA SET FOR THE LUS TO
C          H) THE NUMBER OF LUTS TO BE COMBINED .
C             BE EVALUATED IS WRITTEN .
C             (IFORE,ISS,NLIM,ISURF,KEEPJ,NPREVJ,NLS,NUMCOM (8I3))
C       5) THE SURFACE AREA VALUES EQUIVALENT TO A NUMBER OF NETWORKS IF THE
C          DEFAULT SET ARE NOT REQUIRED.
C        6) THE LUT CODE NUMBERS WHICH ARE TO BE COMBINED .
C           (NCOM (10I3))
C
C        POINTS 2 - 5 ARE REPEATED PER LAND DATA SET OR LU TO BE EVALUATED .
C
C
C        7) A BLANK CARD ENDS THE JOB .
C
C
        COMMON /PARM/YAR(6,37),FYAR(6,6),FXAR(6,6),FLEN(6),FAC(6),
      1IEX(10),ISA(15),ISAU(15),IFAC(3,6)
        COMMON /PARM1/TITLES(30),NPREVJ,NEX,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,
      1NFAC,NPLS,NLS,IFORE,NUMCOM,NR
        COMMON /PARM2/XAR(6,37),ICOD(56,12),NCOM(10),LENGTH(37),INA(10),
      1INU(5)
        COMMON /PARM3/ANAM(6,56),ICODE(56),ICHLT(12),ANLT(6,12)
        COMMON /PARM4/NPDATA,NLIM,NSCALR,NSCALC,NFIT,VAL,VMISS,ISS,
      *ASURF(10)
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```
      COMMON /PARMD/UNITS(3),TITLE(20),XW,XE,YS,YN,SCALE,GRID,
     1NSECTR,INDEXD(55),NVAR
      REAL NCORD
      INTEGER PLEN,FAC
      DIMENSION NPRES(16),INCT(8,11),INDCT(3,11),INDEX(55,12),
     1TID(55,2),TL(55,12),BL(55,12),BLIM(55),TLIM(55),WGT(55,12),
     2W(55),IS(55,2),CAPT(20,12,15),INOT(55),CT(20,12,15)
      CL=10.0
      ITIME=0
      NPDATA=0
      NPLS=0
C
C     NPDATA KEEPS THE ID NUMBER OF THE PREVIOUS DATA SET
C     NPLS KEEPS THE LS NUMBER OF THE PREVIOUS LAND SYSTEM
C
C      READ THE DATA CONTROLLING THE EXECUTIN OF THE JOB.
C      THE MAPS ALL HAVE THE SAME SYMBOLS PRINTED PER GRID CELL.
      READ(5,599) NSCALR,NSCALC,MISS,VMISS
599   FORMAT(3I3,F10.3)
C     MISS IS ZERO IF THE DEFAULT MISSING VALUE IS NOT REQUIRED
C     THIS INDICATOR IS NECCESSARY AS VMISS MAY BE 0.00 & THUS THE
C     LACK OF A GIVEN VALUE IE.0.0 CAN'T BE USED TO INDICATE THAT
C     THE DEFAULT IS REQUIRED
C     VMISS IS THE MISSING VALUE. DEFAULT IS -0.9
C
      IF(MISS.EQ.1) VMISS=-0.9
2000  READ(5,600) ID,M
600   FORMAT(2I3)
C     IF BOTH A MAP & AN EVALUATION ARE REQUIRED, THEY ARE
C     TREATED AS SEPARATE STEPS
C
      IF(ID.NE.NPDATA) ITIME=0
      IF(ID.EQ.0) GO TO 9000
      READ(5,10) ISEL,OUTO,XW,XE,YS,YN
10    FORMAT(2I3,4F10.3)
      READ(ID) (TITLE(I),I=1,20),NVAR,SCALE,SIZE,(UNITS(I),I=1,3),
     1GRID,WCORD,ECORD,SCORD,NCORD
C
      READ(ID) (INDEXD(I),I=1,NVAR)
      IF(NPDATA.NE.ID) WRITE(6,40)
40    FORMAT('0 THE LAND DATA SET BEING READ IS :-')
      IF(NPDATA.NE.ID) WRITE(6,41) (TITLE(I),I=1,20),ID,NVAR,SCALE,
     *SCORD,NCORD,WCORD,ECORD,SIZE,(UNITS(I),I=1,3)
41    FORMAT('0',20A4//20X,'( STORED ON DD CARD ',I3,' )',//10X,
     *' DATA SET HAS',I5,' LAND CHARACTERISTICS '//10X,
     *' THE MAP WAS DIGITIZED AT A SCALE OF 1 :',F8.0//10X,
     *' THE MAP OVERLAID EXTENDS ',F11.3,' TO ',F11.3,' NORTH AND',
     *F11.3,' TO ',F11.3,' EAST'//10X,
     *'  THE OVERLAY GRID CELL IS ',F7.1,2X,3A4,' SQUARE')
      IF(ISEL.EQ.0) GO TO 418
      WRITE(6,42) YS,YN,XW,XE
42    FORMAT(////,'  THE PORTION OF THE MAP SELECTED FOR THIS JOB
     *EXTENDS ',F11.3,' TO ',F11.3,' NORTH AND ',F11.3,' TO ',F11.3,
     *' EAST')
      YS=YS*10000.0
      YN=YN*10000.0
      XW=XW*10000.0
      XE=XE*10000.0
C     SELECT THE PORTION OF THE DATA SET BOUNDED BY XW,XE,YN,YS
      IF(OUTO.EQ.0) OUTO=3
      CALL RETR(ID,OUTO)
      GO TO 419
418   XW=WCORD*10000.0
      XE=ECORD*10000.0
      YN=NCORD*10000.0
      YS=SCORD*10000.0
419   IF(M.EQ.0) GO TO 206
      NV=NVAR
      VAL=0.0
      NLIM=0
      NFIT=1
C     NFIT IS 1-THE MAP CLASSES DO NOT CORRESPOND
C     DIRECTLY WITH THE RANGE 0-100%
C      PRINT A MAP OF THE LC IN POSITION M OF EACH CELL
      CALL MAP(ID,NV,CL,M)
      REWIND ID
      NPDATA=ID
      GO TO 2000
206   READ(5,601) IFORE,ISS,NLIM,ISURF,KEEPJ,NPREVJ,NLS,NUMCON
601   FORMAT(8I3)
      IF(ISURF.GT.0) READ(5,7) (SURF(I),I=1,ISURF)
7      FORMAT(10F8.1)
      ILT=NLS
      NFIT=0
C
      IF(IFORE.EQ.0) GO TO 20
C
C      PERFORM THE FORECLOSURE OF OPTIONS IN LU FOR THE LAND DATA SET.
      INF=NLS
C      READ THE CONTROL DATA SET.
       CALL GET(NLC,NCT,CAPT,WGT,INDEX,INDCT,TL,BL,IS,INF)
      NKEEP=NUMCON
      NUMCON=1
       CALL FORE(ID,INF,NCT,NLC,BL,TL,WGT,INDEX,CAPT,INDCT,IS,CL)
      NUMCON=NKEEP
C
C     READ IN THE LUT CODE NUMBERS TO BE COMBINED
C
20    IF(NUMCON.GT.0) READ(5,6) (NCCN(I),I=1,NUMCON)
6     FORMAT(26I3)
      IF(NUMCON.EQ.0) GO TO 2000
      NCR=0
C      READ THE CONTROL DATA SET IF THE LUS DIFFERS FROM THE PREVIOUS ONE.
      IF(NPLS.NE.NLS) CALL GET(NLC,NCT,CAPT,WGT,INDEX,INDCT,TL,BL,IS,ILT

      NLCN=NLC
205   DO 37 J=1,NLT
      DO 37 I=1,NLCN
      IF(INDEX(I,J).NE.0) GO TO 37
      TL(I,J)=999999.9
      BL(I,J)=0.0
37    CONTINUE
C
C     SETUP INDT CONTAINING THE LC NUMBERS PRESENT IN THE DATA SET,
C     REQUIRED AT THE SELECTED SURVEY SCALE
C     ISS = 1 IS FOR LARGE SCALES
C
      NRS=1
```

```
      NRSA=0
C      NRS & NRSA INDICATE THE ROW OF THE SELECTED & THE ALTERNATIVE SURVEY
C      SCALE IN IS RESPECTIVELY.
      II=0
      IF(IBS.EQ.1) GO TO 145
      NRS=2
      NRSA=1
145   DO 150 I=1,NMAX
      NR=NRS
      NRA=NRSA
      ITURN=0
      IF(IS(I,NRS).LE.0) GO TO 160
      ITURN=1
160   DO 151 J=1,NVAR
      IF(INDEXD(J).NE.IABS(IS(I,NR))) GO TO 151
      II=II+1
      INOT(II)=IABS(IS(I,NR))
151   CONTINUE
      IF(ITURN.EQ.1) GO TO 150
      NR=NRSA
      NRA=NRS
      GO TO 148
150   CONTINUE
      NN=II
C
C      COMPUTE THE VALIDITY OF THE MAP.
      JJ=0
      IK=0
      NREQ=0
      DO 215 IS=1,NMAX
      IJ=IS(IS,NRS)
      IF(IJ.LE.0) GO TO 215
      IF(IS.EQ.1) GO TO 214
      IF(IS(IS-1,NRS).EQ.IJ) GO TO 215
214   DO 216 I6=1,NUMCOM
      II=NCOM(I6)
      DO 217 I7=1,NLCN
217   IF(INDEX(I7,II).EQ.IJ) GO TO 218
216   CONTINUE
      GO TO 215
C      SUM THE NUMBER OF LCS. REQUIRED.
218   NREQ=NREQ+1
      DO 219 I8=1,NVAR
219   IF(IJ.EQ.INDEXD(I8)) GO TO 220
      GO TO 215
220   IK=IK+1
C      SUM THE NUMBER OF REQUIRED LCS. AVAILABLE IN THE DATA SET.
215   CONTINUE
      VAL=FLOAT(IK)/FLOAT(NREQ)
C      SET UP THE TEMPORARY CONTROL INDEX ARRAY (IND), LIMITS (TL,BL) &
C      WEIGHTS (W) FOR THIS COMBINED LUT.
C
      DO 2011 J=1,NLCN
C      DETERMINE WHETHER A LC IS REQUIRED.
      K=0
      DO 200 I=1,NUMCOM
      II=NCOM(I)
      IF(INDEX(J,II).EQ.0) GO TO 200
      DO 38 IS=1,NN
38    IF(INDEX(J,II).EQ.INOT(IS)) GO TO 202
      GO TO 200
202   IF(I.EQ.1) GO TO 203
      IF(INDEX(J,II).EQ.INDEX(J,NCOM(I-1))) GO TO 203
      IF(INDEX(J,NCOM(I-1)).EQ.0) GO TO 203
C      A COLUMN IN INDEX CANNOT BE OMITTED EVEN IF A LC. IS NOT USED.
C      IT MUST BE FILLED WITH ZERO
      WRITE(6,5017) J
5017  FORMAT('0  ERROR - INCORRECT LC NUMBER IN INDEX COLUMN ',I5)
      GO TO 9001
C      THE LUT CODE IS STORED IF THE LC. IS REQUIRED.
203   K=K+1
      NPRES(K)=II
200   CONTINUE
      IF(K.EQ.0) GO TO 2011
      JJ=JJ+1
      IK=NPRES(1)
      BLIM(JJ)=BL(J,IK)
      TLIM(JJ)=TL(J,IK)
      IND(JJ,1)=INDEX(J,IK)
      IND(JJ,2)=ICGD(J,IK)
      W(JJ)=WGT(J,IK)
      IF(K.EQ.1) GO TO 2011
      DO 201 I=2,K
      II=NPRES(I)
C      THE HIGHEST WEIGHTING VALUE & MINIMUM VALUE, THE LOWEST MAXIMUM VALUE
C      FOR A LC FROM ALL THE LUT TO BE COMBINED, ARE CHOSEN.
      IF(BL(J,II).GT.BLIM(JJ)) BLIM(JJ)=BL(J,II)
      IF(TL(J,II).LT.TLIM(JJ).AND.INDEX(J,II).NE.0) TLIM(JJ)=TL(J,II)
      IF(INDEX(J,II).NE.0) IND(JJ,1)=INDEX(J,II)
      IF(ICGD(J,II).NE.0) IND(JJ,2)=ICGD(J,II)
      IF(WGT(J,II).GT.W(JJ)) W(JJ)=WGT(J,II)
201   CONTINUE
2011  CONTINUE
205   NCR=JJ
      DO 400 I=1,NSAU
      DO 400 J=1,NCR
      IF(ISAU(I).EQ.IND(J,1)) W(J)=-10.0
400   CONTINUE
      DO 401 I=1,NNU
      DO 401 J=1,NCR
      IF(INU(I).EQ.IND(J,1)) W(J)=-10.0
401   CONTINUE
C      CHECK FOR ERROR
      DO 204   ,NCT
      DO 204   ,NCR
      IF(INOCT(I,T).NE.IND(J,1)) GO TO 204
      IF(IND(J,2).EQ.0) GO TO 204
      WRITE(6,5018) IND(J,1)
5018  FORMAT('0  ERROR - GRAPH AND TABLE PRESENT FOR LC NUMBER ',I5)
      GO TO 9001
204   CONTINUE
C      CHECK FOR ERROR
C      CHECK THAT LC IN IND IS EX,CAPT,CAPG,IFAC  -
59    NP=0
      DO 85 I=1,NCR
      KK=IND(I,1)
      IF(KK.EQ.0) GO TO 85
      IF(IND(I,2).GE.1) GO TO 85
```

```
      DO 94 J=1,NEX
94    IF(KK.EQ.IEX(J)) GO TO 35
      DO 94 K=1,NCT
94    IF(KK.EQ.INDCT(1,K)) GO TO 85
      DO 95 LL=1,NFAC
95    IF(KK.EQ.IFAC(2,LL)) GO TO 85
      GO TO 87
86    NF=NF+1
      GO TO 35
87     IF(NSAU.EQ.0) GO TO 88
      DO 96 J=1,NSAU
96    IF(KK.EQ.ISAU(J)) GO TO 85
88    IF(NNU.EQ.0) GO TO 89
      DO 97 J=1,NNU
97     IF(KK.EQ.INU(J)) GO TO 85
89    IF(NSA.EQ.0) GO TO 90
      DO 98 J=1,NSA
98    IF(KK.EQ.ISA(J)) GO TO 85
90    IF(NNA.EQ.0) GO TO 85
      DO 99 J=1,NNA
99    IF(KK.EQ.INA(J)) GO TO 85
      WRITE(6,412) KK
412   FORMAT('0  ERROR - STATUS NOT GIVEN FOR LC NUMBER ',I5)
      GO TO 9001
85    CONTINUE
C      CHOSE THE CAPABILITY TABLES (CAP.TAB.) & CHANGE THE X-SCALE OF THE
C      CAPABILITY GRAPHS (CAP.G.) AS REQUIRED .
      CALL TABGPH(NCR,NLC,0,NCT,NCTJ,CT,CAPT,INDCT,INCT,IND,INDEX)
      IF(KEEPJ.GT.0) CALL PUT(KEEPJ,NCR,NCTJ,CT,W,IND,TLIM,BLIM,INCT,
     *IS,ITIME)
C     SAVE THE TEMPORARY CONTROL ARRAYS OF THIS JOB IF DESIRED.
C      PRINT THE TABLES.
300   CALL INFO(0,INDEX,TLIM,BLIM,W,IND,NCR,NLCN)
301   DO 403 J=1,NCR
403   IF(W(J).EQ.-10.0) W(J)=0.0
C      ENTER THE CAPABILITY ANALYSIS SUBROUTINE.
1000  CALL EVAL(ITIME,IO,NCR,NCTJ,TLIM,BLIM,IND,W,CT,INCT,CL,H)
      NPDATA=IO
      NPLS=NLS
      REWIND IO
      GO TO 2000
C     RETURN TO EVALUATE A DIFFERENT LAND DATA SET &/OR A LU.
C
C      PRINT THE MAP INDEX & END THE JOB.
C     LT ,  OR A NEW LT IS TO BE SET UP. IT IS POSSIBLE FOR
C     BOTH TO OCCUR
9000  CALL MAPIND(CL)
9001  STOP
      END
C
      BLOCK DATA
      COMMON /INCMAP/TABLE2(11,4)
      COMMON /PARMM/NPDATA,NLIM,NSCALR,NSCALC,NFIT,VAL,VMISS,ISS,
     *SURF(10)
      REAL TABLE2
      DATA TABLE2/'-','.','+','*','/','*','/','O','O','$','X','A',
     15*' ','-','-','*','*','-','X',
     29*' ',2*'C',
     310*' ','V'/
      DATA SURF/10.0,40.0,40.0,60.0,80.0,100.0,100.0,100.0,100.0,100.0/
      END
C
      SUBROUTINE GET(NLC,NCT,CAPT,WGT,INDEX,INDCT,TL,BL,IS,IN)
C
C     CONTROL ARRAYS ARE RETRIEVED FROM THE UNIT SPECIFIED BY IN
C
      COMMON /PARM/YAR(6,37),FYAR(6,6),FXAR(6,6),FLEN(6),FAC(5),
     1IEX(10),ISA(15),ISAU(15),IFAC(3,6)
      COMMON /PARM1/TITLES(20),NPREVJ,NEX,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,
     1NFAC,NPLS,NLS,IFORE,NUMCOM,NF
      COMMON /PARM2/XAR(6,37),ICOD(56,12),NCOM(10),LENGTH(37),INA(10),
     1INU(5)
      COMMON /PARM3/ANAM(6,56),ICODE(56),ICNLT(12),ANLT(6,12)
      INTEGER FLEN,FAC
      DIMENSION INDEX(56,12),INDCT(3,11),TL(56,12),BL(56,12),
     1CAPT(20,12,15),IS(58,2),WGT(56,12)
C
      IF(NPREVJ.EQ.0) GO TO 20
C
C     READ THE TEMPORARY CONTROL ARRAYS WRITTEN DURING A PREVIOUS JOB
      READ(IN,99) NUMCOM
99    FORMAT(I3)
      READ(IN,98) (TITLES(I),I=1,20)
98    FORMAT(20A4)
      READ(IN,104) NLC,NEX,NCT,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,NFAC,NFG
C
C     NLC - NUMBER OF LC REQUIRED BY THE LUS
C     NEX - NUMBER OF LIMITING LC
C     NCT - NUMBER OF CAP. TAB.
C     NCG - NUMBER OF CAP. G
C     NMAX - NUMBER OF LC IN IS
C     NSA - NUMBER OF LC REPRESENTING PERMISSIBLE LAND SURFACES
C     NSAU - NUMBER OF LC REPRESENTING NONPERMISSIBLE LAND SURFACES
C     NNA - NUMBER OF LC REPRESENTING NONINHIBITING NETWORKS
C     NNU - NUMBER OF LC REPRESENTING INHIBITING NETWORKS
C     NLT - NUMBER OF LUT IN THE LUS
C     NFAC - NUMBER OF INTER-RELATIONSHIPS
C     NFG - NUMBER OF FACTOR GRAPHS
      READ(IN,104) NCCN
      READ(IN,104) ((INDEX(I,J),I=1,NLC),J=1,2)
      READ(IN,108) (TL(I,1),I=1,NLC),(BL(I,1),I=1,NLC)
      READ(IN,110) (WGT(I,1),I=1,NLC)
      READ(IN,104) ((INDCT(I,J),I=1,2),J=1,NCT)
      DO 10 K=1,NCT
      NC=INDCT(3,K)
      IF(NC.EQ.0) NC=1
10    READ(IN,110) ((CAPT(I,J,K),I=1,NC),J=1,2)
      GO TO 40
20    CONTINUE
C
C     READ IN THE CONTROL DATA SET
      READ(IN,98) (TITLES(I),I=1,20)
      READ(IN,104) NLC,NEX,NCT,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,NFAC,NFG
104   FORMAT(25I3)
C     READ THE INDEX,LIMITS & WEIGHTING ARRAYS
      DO 499 J=1,NLT
499   READ(IN,104) (INDEX(I,J),I=1,NLC)
      DO 300 J=1,NLT
```

```
500     READ(IN,108) (TL(I,J),I=1,NLC)
        DO 501 J=1,NLT
501     READ(IN,108) (BL(I,J),I=1,NLC)
        DO 502 J=1,NLT
502     READ(IN,110) (WGT(I,J),I=1,NLC)
C       READ THE CAP.TAB.
        READ(IN,104) ((INDCT(I,J),I=1,3),J=1,NCT)
        DO 25 K=1,NCT
C       AN OMITTED CAP.TAB. IS GIVEN AS ZERO
        NR=INDCT(2,K)
        NC=INDCT(3,K)
        IF(NC.EQ.0) NC=1
        IF(NR.EQ.0) NR=1
        READ(IN,110) ((CAPT(I,J,K),I=1,NC),J=1,NR)
110     FORMAT(16F5.1)
25      CONTINUE
C       READ THE CAP. G INDEX ARRAY
        DO 503 J=1,NLT
503     READ(IN,104) (ICGD(I,J),I=1,NLC)
40      READ(IN,104) ((IS(I,J),I=1,NMAX),J=1,2)
        IF(NEX.NE.0) READ(IN,104) (IEX(I),I=1,NEX)
15      IF(IFORE.EQ.1) GO TO 4
        IF(NSA.NE.0) READ(IN,104) (ISA(I),I=1,NSA)
        IF(NSAU.NE.0) READ(IN,104) (ISAU(I),I=1,NSAU)
        IF(NNA.NE.0) READ(IN,104) (INA(I),I=1,NNA)
        IF(NNU.NE.0) READ(IN,104) (INU(I),I=1,NNU)
C
C       READ THE CAP. G & THE FACTOR GRAPHS
4       IF(NFAC.EQ.0) GO TO 5
        READ(IN,104) ((IFAC(I,J),I=1,3),J=1,NFAC)
        READ(IN,104) (FAC(I),I=1,NFAC)
5       READ(IN,104) (LENGTH(I),I=1,NCG)
        DO 30 I=1,NCG
        L=LENGTH(I)
30      READ(IN,108) (XAR(LL,I),LL=1,L),(YAR(LL,I),LL=1,L)
108     FORMAT(11F7.2)
        IF(NFG.EQ.0) GO TO 32
        READ(IN,104) (FLEN(I),I=1,NFG)
        DO 35 I=1,NFG
        L=FLEN(I)
        READ(IN,108) (FXAR(LL,I),LL=1,L),(FYAR(LL,I),LL=1,L)
35      CONTINUE
C       READ THE NAMES OF THE LUT & LC & THEIR CODES
32      DO 36 J=1,NLT
36      READ(IN,113) (ANLT(I,J),I=1,6),ICNLT(J)
        DO 37 J=1,NLC
37      READ(IN,113) (ANAM(I,J),I=1,6),ICODE(J)
113     FORMAT(6A4,I3)
C       PRINT THE HEADING
        IF(IFORE.EQ.0) GO TO 120
955     WRITE(6,92)
92      FORMAT('1 THE EVALUATION OF THE FORECLOSURE IN OPTIONS IN LAND USE
       *')
        WRITE(6,91) (TITLES(I),I=1,20),IN
91      FORMAT('0'//////////,' ',20A4//20X,'( STORED ON UNIT ',I3,' )')
        RETURN
956     WRITE(6,93)
93      FORMAT('1 THE LAND USE SYSTEM CONCERNED IS :- ')
120     WRITE(6,90) (TITLES(I),I=1,20),IN,(NCOM(I),I=1,NUMCOM)
90      FORMAT('0'//////////,' ',20A4//20X,'( STORED ON DD CARD ',I3,' )',
       *//'0',3X,'THE LAND TYPES BEING COMBINED ARE ',10I5)
        RETURN
        END
C
        SUBROUTINE PUT(OUT,NLC,NCT,CT,W,IND,TLIM,BLIM,INCT,
       *IS,ITIME)
C
C       THIS SUBROUTINE WRITES THE TEMPORARY CONTROL ARRAYS TO THE OUTPUT
C       UNIT OUT
C       OUT
C
        COMMON /PARM/YAR(6,37),FYAR(6,6),FXAR(6,6),FLEN(6),FAC(6),
       1IEX(10),ISA(15),ISAU(15),IFAC(3,6)
        COMMON /PARM1/TITLES(20),  ?IVJ,NEX,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,
       1NFAC,NPLS,NLS,IFORE,NUM
        COMMON /PARM2/XAR(6,37),  (6,12),NCOM(10),LENGTH(37),INA(10),
       1INU(5)
        COMMON /PARM3/ANAM(6,56),ICODE(56),ICNLT(12),ANLT(6,12)
        INTEGER FLEN,OUT,FAC
        DIMENSION IND(56,2),INCT(2,11),TLIM(56),BLIM(56),
       1CT(20,12,15),W(56),IS(58,2)
C
        WRITE(OUT,99) NUMCOM
99      FORMAT(I3)
        WRITE(6,95) (TITLES(I),I=1,20)
95      FORMAT(20A4)
        WRITE(OUT,104) NLC,NEX,NCT,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,NFAC,NFG
        WRITE(OUT,104) (NCOM(I),I=1,NLC)
        WRITE(OUT,104) ((IND(I,J),I=1,NLC),J=1,2)
        WRITE(OUT,108) (TLIM(I),I=1,NLC),(BLIM(I),I=1,NLC)
        WRITE(OUT,110) (W(I),I=1,NLC)
110     FORMAT(15F6.1)
        WRITE(OUT,104) ((INCT(I,J),I=1,2),J=1,NCT)
        DO 10 K=1,NCT
        NC=INCT(2,K)
        IF(NC.EQ.0) NC=1
10      WRITE(OUT,110) ((CT(I,J,K),I=1,NC),J=1,2)
104     FORMAT(26I3)
40      WRITE(OUT,104) ((IS(I,J),I=1,NMAX),J=1,2)
        IF(NEX.GE.1) WRITE(OUT,104) (IEX(I),I=1,NEX)
        IF(NSA.GE.1) WRITE(OUT,104) (ISA(I),I=1,NSA)
        IF(NSAU.GE.1) WRITE(OUT,104) (ISAU(I),I=1,NSAU)
        IF(NNA.GE.1) WRITE(OUT,104) (INA(I),I=1,NNA)
        IF(NNU.GE.1) WRITE(OUT,104) (INU(I),I=1,NNU)
        IF(NFAC.EQ.0) GO TO 5
        WRITE(OUT,104) ((IFAC(I,J),I=1,3),J=1,NFAC)
        WRITE(OUT,104) (FAC(I),I=1,NFAC)
5       WRITE(OUT,104) (LENGTH(I),I=1,NCG)
        DO 30 I=1,NCG
        L=LENGTH(I)
30      WRITE(OUT,108) (XAR(LL,I),LL=1,L),(YAR(LL,I),LL=1,L)
108     FORMAT(11F7.2)
        IF(NFG.EQ.0) GO TO 32
        WRITE(OUT,104) (FLEN(I),I=1,NFG)
        DO 35 I=1,NFG
        L=FLEN(I)
        WRITE(OUT,108) (FXAR(LL,I),LL=1,L),(FYAR(LL,I),LL=1,L)
35      CONTINUE
```

```
32    DO 36 J=1,NLT
36    WRITE(OUT,113) (ANLT(I,J),I=1,6),ICNLT(J)
      DO 37 J=1,NLC
37    WRITE(OUT,113) (ANAM(I,J),I=1,6),ICODE(J)
113   FORMAT(6A4,I3)
      RETURN
      END
C
      SUBROUTINE TABGPH(NCR,NLC,IJ,NCT,NCTJ,CT,CAPT,INDCT,
     1INCT,IND,INDEX)
C
C     THIS SUBROUTINE SETS UP THE REQUIRED CAP.TABS. & CHANGES THE X-SCALE
C     OF THOSE CAP.G WITH DIFFERENT X-AXES DEPENDING UPON THE LUT IE.SET G
C      CAPABILITY GRAPHS.
C
      COMMON /PARV/YAR(6,37),FYAR(5,6),FXAR(5,6),FLEN(5),FAC(5),
     1IEX(10),ISA(15),ISAU(15),IFAC(3,6)
      COMMON /PARM1/TITLES(20),NPREVJ,NEX,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,
     1NFAC,NPLS,NLS,IFORE,NUMCOM,NF
      COMMON /PARM2/XAR(6,37),ICGD(56,12),NCOM(10),LENGTH(37),INA(10),
     1INU(5)
      DIMENSION INCT(3,11),INDCT(3,11),IND(56,2),CAPT(20,12,15),
     1CT(20,12,15),INDEX(56,12)
      INTEGER FLEN,FAC
C
C     SET UP CT & INCT
      NCTJ=0
      DO 71 K=1,NCT
      IFLAG=0
C     FIND THE CAP TABLE REQUIRED FOR A LC
      DO 76 JJ=1,NCR
      IF(INDCT(1,K).EQ.IND(JJ,1)) GO TO 69
76    CONTINUE
      GO TO 71
69    NR=INDCT(2,K)
      NC=INDCT(3,K)
C     CHOOSE THE ROWS FROM THE CAP.TABS. REQUIRED FOR THE LUTS COMBINED
      L=1
90    I1=L+1
      DO 81 J=I1,NR
      L=J
      DO 77 K1=1,NUMCOM
      IF(IFORE.EQ.0) NT=NCOM(K1)
      IF(IFORE.EQ.1) NT=IJ
77    IF(IFIX(CAPT(1,J,K)).EQ.NT) GO TO 79
81    CONTINUE
      GO TO 71
79    IF(IFLAG.GE.1) GO TO 82
C     WRITE THE LC VALUES OF ROW ONE OF THE CAP.TAB INTO ROW 1 OF CT
C     WRITE THE LC CODE & NUMBER OF COLUMNS IN THE CAP.TAB INTO INCT
      IFLAG=1
      NCTJ=NCTJ+1
      INCT(1,NCTJ)=INDCT(1,K)
      INCT(2,NCTJ)=INDCT(3,K)
      II=0
C     CHOOSE THE LOWEST CAP.RATING & WRITE IT INTO ROW 2 OF THE CAP.TAB IN CT
      DO 80 I=2,NC
      II=II+1
      CT(II,1,NCTJ)=CAPT(I,1,K)
      CT(II,2,NCTJ)=1.0
80    CONTINUE
82    II=0
      DO 83 K3=2,NC
      II=II+1
      CT(II,2,NCTJ)=AMIN1(CT(II,2,NCTJ),CAPT(K3,L,K))
      IF(IFORE.EQ.1) CT(II,2,NCTJ)=CAPT(K3,L,K)
83    CONTINUE
      IF(L.EQ.NR) GO TO 71
      GO TO 90
71    CONTINUE
C     CORRECT THOSE GRAPHS WHICH HAVE DIFFERENT X-SCALES, DEPENDING
C     UPON THE LUT.
405   IF(IFORE.EQ.1) RETURN
C     FIND A LC WITH DIFFERENT CAP.G NUMBERS FOR THE LUTS COMBINED
C     FORECLOSURE IS NOT CONCERNED WITH THIS SECTION AS NO COMBINATIONS
C     ARE POSSIBLE. EACH LS IS DEALT WITH SEPARATELY & THUS THE
C     DIFFERENT X SCALES ARE CATERED FOR BY DIFFERENT GRAPH NUMBERS.
      IF(NUMCOM.EQ.1) RETURN
      DO 181 I=2,NUMCOM
      L=0
186   I1=L+1
      IF(I1.GT.NCR) GO TO 181
      J=NCOM(I)
      JJ=NCOM(I-1)
      DO 180 K=I1,NCR
      IF(IND(K,2).EQ.0) GO TO 180
      L=K
      DO 183 K1=1,NLC
      IF(INDEX(K1,J).EQ.0) GO TO 183
      IF(INDEX(K1,J).NE.IND(K,1)) GO TO 183
      LL=K1
      IF(ICGD(K1,J).NE.ICGD(K1,JJ)) GO TO 182
183   CONTINUE
180   CONTINUE
      GO TO 181
C     THE X - SCALE OF THE GRAPH FOR THE FIRST LUT IN NCOMB IS CHANGED
C     THE LOWEST X VALUE FROM THE CAP. GS. CONCERNED IS CHOSEN FOR EACH
C     POINT
182   NG1=ICGD(LL,J)
      IF(NG1.EQ.0) GO TO 186
      NG=IND(L,2)
      L1=LENGTH(NG)
C     GRAPHS MUST ALL BE SAME LENGTH,EVEN IF PADDING IS NECESSARY
      DO 184 IK=1,L1
184   XAR(IK,NG)=AMIN1(XAR(IK,NG1),XAR(IK,NG))
      GO TO 186
181   CONTINUE
      RETURN
      END
C
      SUBROUTINE INFO(IJ,INDEX,TLIM,BLIM,W,IND,NLC,NN)
C
C     THIS SUBROUTINE PRINTS A TABLE OF THE INDEX ARRAY FOR THE
C     FORECLOSURE & EACH LUS. ALSO THE IND,TL,BL,W ARRAYS FOR
C     EACH LUS IN THE FORECLOSURE & EACH LUT IN A LUS BEING
C     EVALUATED, ARE PRINTED.
C
      COMMON /PARM1/TITLES(20),NPREVJ,NEX,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,
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```
     1NFAC,NPLS,NLS,IFORE,NUMCOM,NF
      COMMON /PARM2/XAR(6,37),ICOD(56,12),NCOM(10),LENGTH(37),INA(10),
     1INU(5)
      COMMON /PARM3/ANAM(6,56),ICODE(56),ICNLT(12),ANLT(6,12)
      DIMENSION INDEX(56,12),TLIM(56),BLIM(56),W(56),IND(56,2),
     1A(12,56)
      REAL*8 FORM,TYPE,TYPES,SYSM
      DATA STAR/'*'/,HOR/'-'/,TYPE/'  TYPE  '/,TYPES/' TYPES '/,
     1SYSM/' SYSTEM '/
      DATA USA/'U'/
C
      FORM=TYPE
      IF(NUMCOM.GT.1) FORM=TYPES
C     IF THE LUS HAS PREVIOUSLY BEEN EVAL. OR IT IS NOT THE FIRST
C     LUS OF THE FORECLOSURE, DO NOT REWRITE INDEX ,ANLT,ICNLT
      IF(IJ.GT.1) GO TO 85
C     IF A PREVIOUS LUT FORM THIS LUS HAS ALREADY BEEN ANALYSISED IN
C     THE RUN, DO NOT REWRITE THIS TABLE
      IF(NLS.EQ.NPLS) GO TO 85
55    IF(IJ.EQ.0) GO TO 65
C     PRINT THE TABLE OF THE LAND USE TYPES & THEIR CODES WITHIN THE LUS
C     OR THE LUS WITHIN THE FORECLOSURE OF OPTIONS
      WRITE(6,16)
16    FORMAT('0 THE TABLE OF THE LAND USE SYSTEMS AND THEIR CODES
     *EVALUATED FOR THE FORECLOSURE OF OPTIONS IN LAND USE'///,14X,
     *'LAND SYSTEM',11X,'CODE')
      FORM=SYSM
      GO TO 75
65    WRITE(6,13)
13    FORMAT('0 THE TABLE OF THE LAND USE TYPES AND THEIR CODES
     *EVALUATED WITHIN THIS LAND USE SYSTEM'///,10X,
     *'LAND USE TYPE',18X,'CODE')
75    DO 77 J=1,NLT
77    WRITE(6,17) (ANLT(I,J),I=1,6),ICNLT(J)
17    FORMAT(8X,6A4,7X,I4)
       IF(IJ.EQ.0) GO TO 19
C     PRINT THE TABLE OF THE LCS & THEIR CODES
      WRITE(6,61) (ICNLT(I),I=1,NLT)
61    FORMAT('1 THE TABLE OF THE LAND CHARACTERISTICS REQUIRED FOR THE
     *EVALUATION FOR THE FORECLOSURE OF OPTIONS IN LAND USE',
     *///,7X,'LAND CHARACTERISTICS',5X,'CODE',10X,
     *'LAND SYSTEM CODE'/42X,10(I3,2X))
        GO TO 45
19    WRITE(6,10) (ICNLT(I),I=1,NLT)
10    FORMAT('1  THE TABLE OF THE LAND CHARACTERISTICS REQUIRED FOR AN
     *EVALUATION OF EACH LAND USE TYPE WITHIN THIS LAND USE SYSTEM'///,
     *7X,'LAND CHARACTERISTICS',6X,' CODE',10X,'LAND USE TYPES',
     */42X,12(I3,2X))
45    DO 60 J=1,NLT
      DO 50 I=1,NN
      A(J,I)=STAR
50    IF(INDEX(I,J).EQ.0) A(J,I)=HOR
60    CONTINUE
      DO 70 I=1,NN
70    WRITE(6,12) (ANAM(J,I),J=1,6),ICODE(I),(A(J,I),J=1,NLT)
12    FORMAT(' ',5X,6A4,2X,I5,7X,12(A4,1X))
85    IF(IJ.GT.0) NCOM(1)=IJ
      IF(IJ.GT.1) FORM=SYSM
C     PRINT THE LCS,THEIR PERMISSIBLE VALUES & WEIGHTS USED IN THE EVALUATIO
      WRITE(6,14) FORM,(NCOM(I),I=1,NUMCOM)
14    FORMAT('1',10X,'THE TABLE OF THE PERMISSIBLE UPPER & LOWER LIMITS
     *& THE WEIGHTS FOR THE LAND CHARACTERISTICS'/,
     *' ',10X,'USED IN THE EVALUATION OF THE LAND USE ',A8,10I4/
     *' ',10X,' AT THE SURVEY SCALE REQUESTED & ARE AVAILABLE IN THE LAN
     *D DATA SET'///)
      WRITE(6,21)
21    FORMAT(' ',10X,' THE SYMBOL U INDICATES THOSE CHARACTERISTICS WHIC
     *H ARE ONLY USED TO CALCULATE THE USABLE SURFACE AREA')
      WRITE(6,18)
18    FORMAT('0',40X,' ALL LIMITS ARE INCLUSIVE (FOR UNITS, SEE TEXT)',/
     *//,7X,'LAND CHARACTERISTICS',6X,'UPPER LIMIT',4X,'LOWER LIMIT',
     *5X,'WEIGHT',/)
      II=0
      DO 80 I=1,NLC
81    II=II+1
      IF(ICODE(II).NE.IND(I,1)) GO TO 81
      WT=W(I)
      IF(WT.EQ.-10.0) GO TO 82
      WRITE(6,15) (ANAM(J,II),J=1,6),TLIM(I),BLIM(I),WT
15    FORMAT(5X,6A4,5X,F8.2,6X,F8.2,6X,F6.1)
      GO TO 80
82    WT=USA
      WRITE(6,22) (ANAM(J,II),J=1,6),TLIM(I),BLIM(I),WT
22    FORMAT(5X,6A4,5X,F8.2,6X,F8.2,10X,A4)
80    II=0
      RETURN
      END
C
      SUBROUTINE FORE(IO,INP,NCT,NLCN,BL,TL,WGT,INDEX,CAPT,INDCT,IS,CL)
C
C     THIS SUBROUTINE SETS UP CT INCT IND; READS IN INA,INU,ISA,ISAU
C     AND EVALUATES THE DATA SET FOR FORECLOSURE IN OPTIONS IN LU
C
      COMMON /PARM/YAR(6,37),FYAR(6,6),FXAR(6,6),FLEN(5),FAC(6),
     1IEX(10),ISA(15),ISAU(15),IFAC(3,6)
      COMMON /PARM1/TITLES(20),NPREVJ,NEX,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,
     1NFAC,NPLS,NLS,IFORE,NUMCOM,NF
      COMMON /PARM2/XAR(6,37),ICOD(56,12),NCOM(10),LENGTH(37),INA(10),
     1INU(5)
      COMMON /PARM3/ANAM(6,56),ICODE(56),ICNLT(12),ANLT(6,12)
      COMMON /PARMN/NPDATA,NLIM,NSCALR,NSCALC,NFIT,VAL,VMISS,ISS,
     *SURF(10)
      COMMON /PARMD/UNITS(3),TITLE(20),XW,XE,YS,YN,SCALE,GR(3),
     1NSECTR,INDEXD(56),NVAR
       INTEGER FLEN,OUTO,FAC
      DIMENSION TL(56,12),BL(56,12),TLIM(56),BLIM(56),WGT(56,12),
     1CAPT(30,12,15),CT(20,12,15),INCT(2,11),INDCT(3,11),INDEX(56,12),
     2IND(56,2),W(56),INDT(56),IS(58,2)
C
C     SETUP INAT CONTAINING THE LC NUMBERS PRESENT IN THE DATA SET,
C     REQUIRED AT THE SELECTED SURVEY SCALE
C     ISS = 1 IS FOR LARGE SCALES
C
      NRS=1
      NRSA=2
C     NRS & NRSA INDICATE THE ROWS OF THE SELECTED & NON SELECTED     Y
C     SCALE IN ARRAY IS RESPECTIVELY
      II=0
```

```
      1NFAC,NPLS,NLS,IFORE,NUMCOM,NF
       COMMON /PARM2/XAR(6,37),ICOD(56,12),NCOM(10),LENGTH(37),INA(10),
      1INU(5)
       COMMON /PARM3/ANAM(6,56),ICODE(56),ICNLT(12),ANLT(6,12)
       DIMENSION INDEX(56,12),TLIM(55),BLIM(55),W(56),IND(56,2),
      1A(12,56)
       REAL*8 FORM,TYPE,TYPES,SYSM
       DATA STAR/'*'/,HOR/'-'/,TYPE/'  TYPE  '/,TYPES/' TYPES '/,
      1SYSM/' SYSTEM '/
       DATA USA/'U'/
C
       FORM=TYPE
       IF(NUMCOM.GT.1) FORM=TYPES
C      IF THE LUS HAS PREVIOUSLY BEEN EVAL. OR IT IS NOT THE FIRST
C      LUS OF THE FORECLOSURE, DO NOT REWRITE INDEX ,ANLT,ICNLT
       IF(IJ.GT.1) GO TO 85
C      IF A PREVIOUS LUT FORM THIS LUS HAS ALREADY BEEN ANALYSISED IN
C      THE RUN, DO NOT REWRITE THIS TABLE
       IF(NLS.EQ.NPLS) GO TO 85
85     IF(IJ.EQ.0) GO TO 65
C      PRINT THE TABLE OF THE LAND USE TYPES & THEIR CODES WITHIN THE LUS
C      OR THE LUS WITHIN THE FORECLOSURE OF OPTIONS
       WRITE(6,16)
16     FORMAT('0 THE TABLE OF THE LAND USE SYSTEMS AND THEIR CODES
      *EVALUATED FOR THE FORECLOSURE OF OPTIONS IN LAND USE'///,14X,
      *'LAND SYSTEM',11X,'CODE')
       FORM=SYSM
       GO TO 75
65     WRITE(6,13)
13     FORMAT('0 THE TABLE OF THE LAND USE TYPES AND THEIR CODES
      *EVALUATED WITHIN THIS LAND USE SYSTEM'///,10X,
      *'LAND USE TYPE',18X,'CODE')
75     DO 77 J=1,NLT
77     WRITE(6,17) (ANLT(I,J),I=1,6),ICNLT(J)
17     FORMAT(8X,6A4,7X,I4)
       IF(IJ.EQ.0) GO TO 19
C      PRINT THE TABLE OF THE LCS & THEIR CODES
       WRITE(6,61) (ICNLT(I),I=1,NLT)
61     FORMAT('1 THE TABLE OF THE LAND CHARACTERISTICS REQUIRED FOR THE
      *EVALUATION FOR THE FORECLOSURE OF OPTIONS IN LAND USE',
      *///,7X,'LAND CHARACTERISTICS',5X,'CODE',10X,
      *'LAND SYSTEM CODE'/42X,10(I3,2X))
       GO TO 45
19     WRITE(6,10) (ICNLT(I),I=1,NLT)
10     FORMAT('1  THE TABLE OF THE LAND CHARACTERISTICS REQUIRED FOR AN
      *EVALUATION OF EACH LAND USE TYPE WITHIN THIS LAND USE SYSTEM'///,
      *7X,'LAND CHARACTERISTICS',6X,' CODE',10X,'LAND USE TYPES',
      */42X,12(I3,2X))
45     DO 60 J=1,NLT
       DO 50 I=1,NN
       A(J,I)=STAR
50     IF(INDEX(I,J).EQ.0) A(J,I)=HOR
60     CONTINUE
       DO 70 I=1,NN
70     WRITE(6,12) (ANAM(J,I),J=1,6),ICODE(I),(A(J,I),J=1,NLT)
12     FORMAT(' ',5X,6A4,2X,I5,7X,12(A4,1X))
55     IF(IJ.GT.0) NCOM(1)=IJ
       IF(IJ.GT.1) FORM=SYSM
C      PRINT THE LCS,THEIR PERMISSIBLE VALUES & WEIGHTS USED IN THE EVALUATIO
       WRITE(6,14) FORM,(NCOM(I),I=1,NUMCOM)
14     FORMAT('1',10X,'THE TABLE OF THE PERMISSIBLE UPPER & LOWER LIMITS
      *& THE WEIGHTS FOR THE LAND CHARACTERISTICS'/,
      *' ',10X,'USED IN THE EVALUATION OF THE LAND USE ',A8,10I4/
      *' ',10X,' AT THE SURVEY SCALE REQUESTED & ARE AVAILABLE IN THE LAN
      *D DATA SET'///)
       WRITE(6,21)
21     FORMAT(' ',10X,' THE SYMBOL U INDICATES THOSE CHARACTERISTICS WHIC
      *H ARE ONLY USED TO CALCULATE THE USABLE SURFACE AREA')
       WRITE(6,18)
18     FORMAT('0',40X,' ALL LIMITS ARE INCLUSIVE (FOR UNITS, SEE TEXT)',/
      *//,7X,'LAND CHARACTERISTICS',6X,'UPPER LIMIT',4X,'LOWER LIMIT',
      *5X,'WEIGHT',/)
       II=0
       DO 80 I=1,NLC
81     II=II+1
       IF(ICODE(II).NE.IND(I,1)) GO TO 81
       WT=W(I)
       IF(WT.EQ.-10.0) GO TO 82
       WRITE(6,15) (ANAM(J,II),J=1,6),TLIM(I),BLIM(I),WT
15     FORMAT(5X,6A4,5X,F8.2,6X,F8.2,6X,F6.1)
       GO TO 80
82     WT=USA
       WRITE(6,22) (ANAM(J,II),J=1,6),TLIM(I),BLIM(I),WT
22     FORMAT(5X,6A4,5X,F8.2,6X,F8.2,10X,A4)
80     II=0
       RETURN
       END
C
       SUBROUTINE FORE(IJ,INF,NCT,NLCN,BL,TL,WGT,INDEX,CAPT,INDCT,IS,CL)
C
C      THIS SUBROUTINE SETS UP CT INCT IND; READS IN INA,INU,ISA,ISAU
C      AND EVALUATES THE DATA SET FOR FORECLOSURE IN OPTIONS IN LU
C
       COMMON /PARM/YAF(6,37),FYAR(6,6),FXAR(6,6),FLEN(6),FAC(6),
      1IEX(10),ISA(15),ISAU(15),IFAC(3,6)
       COMMON /PARM1/TITLES(20),NPREVJ,NEX,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,
      1NFAC,NPLS,NLS,IFORE,NUMCOM,NF
       COMMON /PARM2/XAR(6,37),ICOD(56,12),NCOM(10),LENGTH(37),INA(10),
      1INU(5)
       COMMON /PARM3/ANAM(6,56),ICODE(56),ICNLT(12),ANLT(6,12)
       COMMON /PARM4/NPDATA,NLIM,NSCALR,NSCALC,NFIT,VAL,VMISS,ISS,
      *SURF(10)
       COMMON /PARM5/UNITS(3),TITLE(20),XW,XE,YS,YN,SCALE,GRID,
      1NSECTR,INDEXD(56),NVAR
       INTEGER FLEN,CUTO,FAC
       DIMENSION TL(56,12),BL(56,12),TLIM(55),BLIM(56),WGT(56,12),
      1CAPT(20,12,13),CT(20,12,13),INCT(2,11),INDCT(3,11),INDEX(56,12),
      2IND(56,2),W(56),INDT(56),IS(56,2)
C
C      SETUP INDT CONTAINING THE LC NUMBERS PRESENT IN THE DATA SET,
C      REQUIRED AT THE SELECTED SURVEY SCALE
C      ISS = 1 IS FOR LARGE SCALES
C
       NRS=1
       NRSA=2
C      NRS & NRSA INDICATE THE ROWS OF THE SELECTED & NON SELECTED SURVEY
C      SCALE IN ARRAY IS RESPECTIVELY
       II=0
```

```
      IF(ISS.EQ.1) GO TO 149
      NRS=2
      NRSA=1
149   DO 150 I=1,NMAX
      NR=NRS
      NRA=NRSA
      IF(IS(I,NRS).LE.0) GO TO 150
      ITURN=1
148   DO 151 J=1,NVAR
      IF(INDEXD(J).NE.IABS(IS(I,NR))) GO TO 151
      II=II+1
      INDT(II)=IABS(IS(I,NR))
151   CONTINUE
      IF(ITURN.EQ.1) GO TO 150
      NR=NRSA
      NRA=NRS
      GO TO 148
150   CONTINUE
      NN=II
      DO 80 IJ=1,NLT
      I=0
C     READ ISA,ISAU,INA,INAU PER LUS
      READ(INF,21) NSA,NSAU,NNA,NNU
21    FORMAT(25I3)
      IF(NSA.NE.0) READ(INF,21) (ISA(I),I=1,NSA)
      IF(NSAU.NE.0) READ(INF,21) (ISAU(I),I=1,NSAU)
      IF(NNA.NE.0) READ(INF,21) (INA(I),I=1,NNA)
      IF(NNU.NE.0) READ(INF,21) (INU(I),I=1,NNU)
      DO 81 II=1,NLCN
C     SET UP IND,BLIM,TLIM,W PER LUS
      IF(INDEX(II,IJ).EQ.0) GO TO 81
      DO 82 IS=1,NN
82    IF(INDEX(II,IJ).EQ.INDT(IS)) GO TO 83
      GO TO 81
83    I=I+1
      IND(I,1)=INDEX(II,IJ)
      IND(I,2)=ICOD(II,IJ)
      BLIM(I)=BL(II,IJ)
      TLIM(I)=TL(II,IJ)
      W(I)=WGT(II,IJ)
81    CONTINUE
      NL=I
      DO 400 I=1,NSAU
      DO 400 J=1,NL
      IF(ISAU(I).EQ.IND(J,1)) W(J)=-10.0
400   CONTINUE
      DO 401 I=1,NNU
      DO 401 J=1,NL
      IF(INU(I).EQ.IND(J,1)) W(J)=-10.0
401   CONTINUE
C     CHOOSE THE CAP. TABS.
      CALL TABSPH(NL,NLC,IJ,NCT,NCTJ,CT,CAPT,INDCT,INCT,IND,INDEX)
C     PRINT SOME CONTROL ARRAYS AS TABLES
      CALL INFO(IJ,INDEX,TLIM,BLIM,W,IND,NL,NLCN)
      DO 403 J=1,NL
403   IF(W(J).EQ.-10.0) W(J)=0.0
C    EVALUATE THE CAPABILITY OF THE LAND FOR THE LUS
      CALL EVAL(IJ,ID,NL,NCTJ,TLIM,BLIM,IND,W,CT,INCT,CL,M)
      REWIND ID
      READ(ID) (TITLE(I),I=1,20),NVAR,SCALE,(UNITS(I),I=1,3),
     1GRID,XW,XE,YS,YN
      READ(ID) (INDEXD(I),I=1,NVAR)
      NFIT=0
80    CONTINUE
      RETURN
      END
C
      SUBROUTINE RETR(IN,OUT)
C     THIS SUBROUTINE RETRIEVES PART OF THE DATA SET
C     BOUNDED BY CORDS YS,YN,XE,XW INCLUSIVE
C     IF NO PERMANENT OUTPUT OF THIS PORTION IS REQUIRED, IT IS WRITTEN AS A
C     TEMPORARY SET TO UNIT 3
C
      COMMON /PARMO/UNITS(3),TITLE(20),XW,XE,YS,YN,SCALE,GRID,
     1NSECTR,INDEXD(56),NVAR
      REAL B(56)
      INTEGER FLEN,OUT
C
      WRITE(OUT) (TITLE(I),I=1,20),NVAR,SCALE,SIZE,(UNITS(I),I=1,3),
     1GRID,XW,XE,YS,YN
      WRITE(OUT) (INDEXD(I),I=1,NVAR)
16    FORMAT(20A4/I5,F7.0,3A4,F8.2,4F10.3)
200   READ(IN,END=210) NTOTAL,NCOL,NROW
3     FORMAT(3I5)
      WRITE(OUT) NTOTAL,NCOL,NROW
       JJJ=0
      DO 51 J=1,NROW
      JC=0
      DO 50 JJ=1,NCOL
      READ(IN) X,Y,(B(I),I=1,NVAR)
      IF((Y.LT.YS).OR.(Y.GT.YN)) GO TO 51
      IF((X.LT.XW).OR.(X.GT.XE)) GO TO 50
C
C     READ IN TOP AND BOTTOM INCLUSIVELY
      WRITE(OUT) X,Y,(B(I),I=1,NVAR)
      JJJ=JJJ+1
      JC=JC+1
50    CONTINUE
      IF(JC.GE.0) JCC=JC
51    CONTINUE
      NTOTAL=JJ
      NCOL=NCC
      NROW=NTOTAL/JCC
      GO TO 210
212   REWIND OUT
      READ(OUT) (TITLE(I),I=1,20),NVAR,SCALE,SIZE,(UNITS(I),I=1,3),
     1GRID,XW,XE,YS,YN
      READ(OUT) (INDEXD(I),I=1,NVAR)
      WRITE(OUT) NTOTAL,NCOL,NROW
      DO 52 J=1,NTOTAL
      READ(OUT,END=210) X,Y,(B(I),I=1,NVAR)
52    CONTINUE
C     GO TO 200
210   REWIND IN
      IN=OUT
      REWIND OUT
      READ(IN) (TITLE(I),I=1,20),NVAR,SCALE,SIZE,(UNITS(I),I=1,3),
     1GRID,XW,XE,YS,YN
```

```
      READ(IN) (INDEXO(I),I=1,NVAR)
      RETURN
      END
C
      SUBROUTINE EVAL(ITIME,IN,NCR,NCT,TLIM,BLIM,IND,W,CT,INCT,CL,
     *M)
C
C     THIS SUBROUTINE EVALUATES THE SECONDARY (GRIDDED) LAND DATA SET FOR
C     A GIVEN LAND USE.
C
C     THE CAP. MAP(50,50) IS WRITTEN UNFORMATTED TO TEMPORARY DISC 1
C     THE LIMIT MAP(50,50) IS    "         "        "       "   2
C     THE GRID CO-ORDINATES ARE WRITTEN UNFORMATTED TO TEMPORARY DISC 8
C     THE LAND DATA SET IS EVALUATED IN SECTIONS IF ITS DIMENSIONS
C     EXCEED (50,50)
      COMMON /PARM/YAR(6,37),FYAR(6,5),PXAR(5,5),FLEN(5),FAC(5),
     1IEX(10),IDA(15),ISAU(15),IFAC(3,6)
      COMMON /PARM1/TITLES(20),NPREVJ,NEX,NCG,NMAX,NSA,NSAU,NNA,NNU,NLT,
     1NFAC,NPLS,NLS,IFORE,NUMCOM,NF
      COMMON /PARM2/XAR(6,37),ICOD(56,12),NCUM(10),LENGTH(37),IAA(10),
     1INU(5)
      COMMON /PARMN/NPDATA,NLIM,NSCALR, SCALC,NFIT,VAL,VMISS,ISS,
     *SURF(10)
      COMMON /PARMD/UNITS(3),TITLE(20),XW,XE,YS,YN,SCALE,GRID,
     1NSECTR,INDEXO(56),NVAR
      COMMON /PARMC/CAP(50,26),CELL(50,1300),IPOS(56),NTOTAL,NROW,NCOL
      REAL LIM
      INTEGER FLEN,OUT,FAC
      DIMENSION LIM(50,26),CORD(2,1300),IND(56,2),TLIM(56)
      DIMENSION INCT(2,11),CT(20,12,15),W(56),BLIM(56),TCAP(2,56)
      EQUIVALENCE (LIM(1,1),CORD(1,1))
C
      REWIND 1
      REWIND 2
      REWIND 8
      II=0
C     SET UP IPOS WHICH GIVES THE POSITION OF THE LC IN EACH CELL
C     IN THE SEQUENCE REQUIRED BY IND
      DO 1 J=1,NCR
      DO 1 I=1,NVAR
      IF(INDEXO(I).NE.IND(J,1)) GO TO 1
      II=II+1
      IPOS(II)=I
1     CONTINUE
      TOT=II-NSAU-NNU-NEX-NF
      IF(NSA.NE.0) TOT=TOT-NSA+1
      IF(NNA.NE.0) TOT=TOT-NNA+1
500   CONTINUE
      DO 5 LR=1,50
      DO 8 LC=1,50
      CAP(LC,LR)=0.0
8     CONTINUE
C
C     READ IN THE LAND DATA SET
      CORD(1,1)=-0.1
      READ(IN,END=100) NTOTAL,NCOL,NROW
13    FORMAT(3I5)
      L=0
      DO 40 I=1,NROW
      DO 41 K=1,NCOL
      L=L+1
      READ(IN) (CORD(J,L),J=1,2),(CELL(J,L),J=1,NVAR)
      CELL(22,L)=CELL(22,L)/1000.0
      NZ=0
C     INDICATE THOSE CELLS OUTSIDE THE MAP BOUNDARY BY STORING -99.9 IN LIM
      DO 44 J=1,NVAR
44    IF(CELL(J,L).EQ.0.0) NZ=NZ+1
      IF(NZ.EQ.NVAR) CAP(K,I)=-99.9
41    CONTINUE
40    CONTINUE
100   CONTINUE
      IF(CORD(1,1).EQ.-0.1) GO TO 900
      NROW=NROW-1
      WRITE(1) NROW,NCOL
      WRITE(8) (CORD(1,MN),MN=1,NCOL),(CORD(2,MN),MN=1,NTOTAL,NCOL)
      WRITE(2) NROW,NCOL
C     CHECK CELL NOT EXCLUDED DUE TO LIMITING LCS
      L=0
      DO 56 LR=1,NROW
      DO 56 LC=1,NCOL
      LIM(LC,LR)=CAP(LC,LR)
C     L IS CURRENT GRID CELL
      L=L+1
      IF(LIM(LC,LR).EQ.(-99.9)) GO TO 56
59    ITURN=0
      DO 45 II=1,NEX
C     J IS THE LIMITING LC CODE NUMBER IN IEX
      J=IEX(II)
      DO 46 I=1,NCR
      KK=I
      IF(J.EQ.IND(I,1)) GO TO 47
46    CONTINUE
      GO TO 45
C     K IS THE POSITION OF LC IN CELL
C     LIMITING LC. ARE NOT WEIGHTED
47    K=IPOS(KK)
      W(K)=0.0
      IF(CELL(K,L).EQ.VMISS) GO TO 45
      IF((CELL(K,L).GE.BLIM(KK)).AND.(CELL(K,L).LE.TLIM(KK))) GO TO 45
C     LC VALUE IS OUTSIDE THE PERMISSIBLE RANGE,THUS THE GRID CELL NUMBER
C     PLUS 100 IS STORED IN LIM TO INDICATE THAT THIS IS SO
      LIM(LC,LR)=FLOAT(L)+100.0
      CAP(LC,LR)=FLOAT(L)+100.0
      GO TO 56
45    CONTINUE
C     CHECK LIMITS
      DO 55 II=1,NCR
      K=IPOS(II)
      IF(CELL(K,L).EQ.VMISS) GO TO 55
      IF((CELL(K,L).GE.BLIM(II)).AND.(CELL(K,L).LE.TLIM(II))) GO TO 55
C     LC VALUE IS OUTSIDE THE PERMISSIBLE RANGE,THUS ITS VALUE IS CHANGED
C     TO INDICATE THIS. THE VALUE IN LIM IS INCREMENTED
      LIM(LC,LR)=LIM(LC,LR)+1.0
      CAP(LC,LR)=CAP(LC,LR)+1.0
      CELL(K,L)=-9999.9
55    CONTINUE
C     MODIFY THE LC VALUES AS INDICATED BY IFAC FOR EACH INTER-
C     RELATIONSHIP
```

```
57      JJ=0
98      I4=JJ+1
        DO 93 J=I4,NFAC
        JJ=J
        DO 90 I=1,NCR
        IF(IND(I,1).EQ.IFAC(1,JJ)) GO TO 93
90      CONTINUE
        GO TO 96
93      DO 95 II=1,NCR
95      IF(IND(II,1).EQ.IFAC(2,JJ)) GO TO 91
        GO TO 98
91      LCC=IPOS(I)
        LM=IPOS(II)
C       LCC - LC WHICH DOES THE MODIFYING
C       LM - LC WHICH IS MODIFIED
         IF(CELL(LCC,L).EQ.VMISS) GO TO 97
         IF(CELL(LCC,L).EQ.(-9999.9)) GO TO 92
        IF(CELL(LM,L).EQ.(-9999.9).OR.CELL(LM,L).EQ.VMISS) GO TO 92
C
C       5 MEANS THAT THE LC BEING MODIFIED, IS EVAL. BY MEANS OF A CAPT
C       INSTEAD OF THE GRAPH NUM. IN FAC, THE VALUE OF THE MODIFYING LC
C       AT THE CHANGE OVER PT. IS STORED
        IF(IFAC(3,JJ).NE.5) GO TO 94
        FACT=FLOAT(FAC(JJ))
        IF(CELL(LM,L).GT.FACT) CELL(LCC,L)=CELL(LCC,L)+0.5
        GO TO 92
C       DETERMINE THE FACTOR BY WHICH THE LC IS MODIFIED
94      FACT=FF(CELL(LCC,L),FAC(JJ),FXAR,FYAR,FLEN)
        IF(IFAC(3,JJ).EQ.1) CELL(LM,L)=CELL(LM,L)+FACT
        IF(IFAC(3,JJ).EQ.2) CELL(LM,L)=CELL(LM,L)-FACT
        IF(IFAC(3,JJ).EQ.3) CELL(LM,L)=CELL(LM,L)*FACT
        IF(IFAC(3,JJ).EQ.4) CELL(LM,L)=CELL(LM,L)/FACT
         GO TO 92
97       CELL(LM,L)=VMISS
92      CONTINUE
        IF(JJ.LT.NFAC) GO TO 98
96      CONTINUE
C       ADD THE SURFACE AREAS & NETWORKS TOGETHER
101     IF(NSA.GT.0) CALL COVER(W,NCR,ISA,NSA,IND,1)
        IF(NSAU.GT.0) CALL COVER(W,NCR,ISAU,NSAU,IND,2)
        IF(NNA.GT.0) CALL COVER(W,NCR,INA,NNA,IND,0)
        IF(NNU.GT.0) CALL COVER(W,NCR,INU,NNU,IND,3)
        REWIND 9
        WRITE(9) NROW,NCOL
        WRITE(9) ((CAP(LC,LR),LC=1,NCOL),LR=1,NROW)
C       DETERMINE THE TOTAL WEIGHTING VALUE POSSIBLE FOR A CELL
404     TOTW=0.0
        DO 80 J=1,NCR
80       IF(IND(J,2).GE.0) TOTW=TOTW+W(J)
C       DERIVE THE CAP. RATINGS
        L=0
        DO 302 LR=1,NROW
        DO 70 LC=1,NCOL
        L=L+1
        IF(LIM(LC,LR).EQ.(-99.9)) GO TO 72
        IF(LIM(LC,LR).EQ.(FLOAT(L)+100.0)) GO TO 76
58      CAP(LC,LR)=0.0
        DO 71 I=1,NCR
        K=IPOS(I)
        IF(CELL(K,L).EQ.(-9999.9)) GO TO 71
        IF(CELL(K,L).EQ.VMISS) GO TO 73
C       STORE THE PREVIOUSLY WEIGHTED CAP. RATING IF THE LC'S VALUES OF THE
C       IMMEDIATE & PREVIOUS CELLS, ARE THE SAME.
        IF(CELL(K,L).EQ.TCAP(1,I)) GO TO 175
174     IF(IND(I,2).EQ.0) GO TO 74
        IF(IND(I,2).EQ.-2) GO TO 71
        TCAP(1,I)=CELL(K,L)
C       DERIVE THE CAP. RATING FROM A CAP.G. & WEIGHT IT
C       -1 IN IND INDICATES A NON-INHIBITING NETWORK
        TCAP(2,I)=1.0
        IF(IND(I,2).EQ.-1) GO TO 175
        TCAP(2,I)=FF(CELL(K,L),IND(I,2),XAR,YAR,LENGTH)*W(I)*0.1
175     CAP(LC,LR)=CAP(LC,LR)+TCAP(2,I)
        GO TO 71
C       DERIVE THE CAP. RATING FROM A CAP.TAB. & WEIGHT IT
74      DO 60 II=1,NCT
60      IF(INCT(1,II).EQ.IND(I,1)) GO TO 62
        GO TO 71
62      NN=INCT(2,II)
        TCAP(1,I)=CELL(K,L)
        DO 67 KK=1,NN
        K3=KK
67      IF(CELL(K,L).EQ.CT(KK,1,II)) GO TO 68
        GO TO 71
68      TCAP(2,I)=CT(K3,2,II)*W(I)*0.1
        CAP(LC,LR)=CAP(LC,LR)+TCAP(2,I)
71      CONTINUE
         GO TO 70
73      LIM(LC,LR)=VMISS
        GO TO 70
72      CAP(LC,LR)=-99.9
        GO TO 70
76      CAP(LC,LR)=0.0
        LIM(LC,LR)=100.0
70      CONTINUE
C       CONVERT THE WEIGHTED CAP TO A % ACCORDING TO WHAT IS POSSIBLE
C       IF ALL THE LC PRESENTHAD A CAP OF 1.0
        DO 301 LC=1,NCOL
        IF(CAP(LC,LR).EQ.-99.9.OR.CAP(LC,LR).EQ.VMISS) GO TO 303
        IF(CAP(LC,LR).NE.0.0) CAP(LC,LR)=(CAP(LC,LR)/TOTW)*100.
303     CONTINUE
301     CONTINUE
302     CONTINUE
C        WRITE THE CAP & LIM ARRAYS
        WRITE(1) ((CAP(LC,LR),LC=1,NCOL),LR=1,NROW)
        WRITE(3) ((LIM(LC,LR),LC=1,NCOL),LR=1,NROW)
        GO TO 500
900     CONTINUE
        IF(IFORE.EQ.1) WRITE(6,75) ITIME
75      FORMAT('1',10X,'THE LAND CAPABILITY MAP FOR THE FORECLOSURE IN OPT
       *IONS IN LAND USE, LAND SYSTEM ',I3)
        IF(IFORE.EQ.0) WRITE(6,77) (NCOM(I),I=1,NUMCOM)
77      FORMAT('1',10X,' THE LAND CAPABILITY MAP FOR THE LAND TYPES',10I4)
C       PRINT THE MAPS
        CALL MAP(1,LCC,LL,0)
1000    CONTINUE
        RETURN
        END
```

```
C
C
      SUBROUTINE COVER(W,NCR,IAY,NUM,IND,ISUR)
C
C     THIS SUBROUTINE SUMS THE  SURFACE COVER ON NUMBER OF NETWORKS
C
      COMMON /PARMM/NPDATA,NLIM,NSCALR,NSCALC,NFIT,VAL,VMISS,ISS,
     *SURF(10)
      COMMON /PARMC/CAP(50,20),CELL(50,1500),IPOS(50),NTOTAL,AREA,NCOL
      DIMENSION IAY(15),IND(50,2),W(50)
C
      ITIME=0
      L=0
      DO 8 LR=1,NROW
      DO 8 LC=1,NCOL
      L=L+1
      IF(CAP(LC,LR).EQ.(FLOAT(L)*100.0).OR.CAP(LC,LR).EQ.(-99.9)) GO TO
     *8
      IK=0
      A=0.0
      DO 10 I=1,NUM
      J=IAY(I)
      DO 16 II=1,NCR
      IF(J.NE.IND(II,1)) GO TO 16
      IF(ITIME.EQ.0) K=II
      IND(II,2)=-2
      IJ=IPOS(II)
      IF(CELL(IJ,L).EQ.VMISS.OR.CELL(IJ,L).EQ.(-9999.9)) GO TO 16
      IK=IK+1
      A=A+CELL(IJ,L)
16    CONTINUE
      ITIME=1
10    CONTINUE
      IF(IK.EQ.0) GO TO 8
19     IF(ISUR.EQ.1) GO TO 11
       IF(ISUR.EQ.2) GO TO 12
       IF(ISUR.EQ.3) GO TO 13
C     NON-INHIBITING NETWORK - ISUR=0
C     USABLE SURFACE AREA     - ISUR=1
C     NON-USABLE SURFACE AREA - ISURF=2
C     INHIBITING NETWORK      - ISURF=3
14    J=A
      CELL(IPOS(K),L)=SURF(J)
      W(K)=1.0
      IND(K,2)=-1
      GO TO 9
11    A=A/FLOAT(IK)
      CELL(IPOS(K),L)=A
      W(K)=1.0
      IND(K,2)=-1
      GO TO 9
12    A=100.0-(A/FLOAT(IK))
      GO TO 9
13    J=A
      A=100.0-SURF(J)
9     CAP(LC,LR)=CAP(LC,LR)+A
      IF(CAP(LC,LR).GT.100.0) CAP(LC,LR)=100.0
      GO TO 8
8      CONTINUE
C      DIVIDE BY NUMBER OF LC ADDED TOGETHER IN A CELL SINCE COVER IS
C     ALWAYS 50 OR 0 X
C     THUS POSS TO EXCEED 100%
      RETURN
      END
C
C
      FUNCTION FF(O,J,XAR,YAR,LENGTH)
C     THIS FUNCTION RETURNS THE Y VALUE CORRESPONDING TO
C     THE GIVEN X VALUE FOR A GRAPH
C
      REAL XAR(6,37),YAR(6,37)
      INTEGER LENGTH(37)
C
      LEN=LENGTH(J)
      IF(LEN.LE.1.OR.LEN.GT.6) GO TO 5
C     IF THE X-VALUE IS LESS THAN OR GREATER THAN THE X-VALUES OF THE
C     FIRST & LAST X POINTS RESPECTIVELY, RETURN THE CORRESPONDING
C     Y-VALUE
      IF(O.GT.XAR(1,J)) GO TO 1
      FF=YAR(1,J)
      RETURN
1     IF(O.LT.XAR(LEN,J)) GO TO 2
      FF=YAR(LEN,J)
      RETURN
2     OLDX=XAR(1,J)
      DO 3 I=2,LEN
      X=XAR(I,J)
      IF(O.LT.X) GO TO 4
3     OLDX=X
      FF=YAR(LEN,J)
      RETURN
4     IF(LENGTH(J).LT.0) GO TO 6
C     DETERMINE THE Y-VALUE
      SLOPE=(YAR(I,J)-YAR(I-1,J))/(X-OLDX)
      FF=SLOPE*(O-OLDX)+YAR(I-1,J)
      RETURN
C     ITS A STEP FUNCTION, RETURN PREVIOUS Y COORD
6     FF=YAR(I-1,J)
      RETURN
C     ITS A NULL FUNCTION: CONSTANT IS FIRST Y
5     FF=YAR(1,J)
      RETURN
      END
C
      SUBROUTINE MAP(ID,LCC,CL,M)
C
C     THIS SUBROUTINE SCALES THE ARRAY TO BE MAPPED BY A FACTOR OF
C     NSCALC AND/OR NSCALR FORMING ARRAY SCALCZ & PRINTS IT
C
C     NSCALC = NO. OF CHARACS. PER GRID CELL ACROSS THE PAGE
C     NSCALR = NO. OF CHARACS. PER GRID CELL DOWN THE PAGE
C     EG. IF NSCALC = 2, THE SCALE IS 2 CHARAC/CELL
C     IE. 5 CELLS/2.5 CM. ACROSS THE PAGE
C     IF NSCALR IS 2 THE SCALE IS 2 CHARACS./CELL
C     IE.3 CELLS/2.5 CM. DOWN THE PAGE
C     DEFAULT FOR NSCALC IS 4 & THAT FOR NSCALR IS 3 GIVING A SCALE OF
C     1 SQ.CM FOR EACH GRID CELL
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      COMMON /PARMN/NPDATA,NLIM,NSCALR,NSCALC,NFIT,VAL,YMISS,ISS,
     *BUFF(10)
      COMMON /PARMO/UNITS(5),TITLE(20),XW,XE,YS,YN,SCALE,GRID,
     1NSECT,INDEXD(50),NVAR
      COMMON /MAPI/IAIN,CINT,NCOLS,NROWS,IMAP
      COMMON /INCMAP/TABLE2(11,4)
      REAL LINE(126,4),FMT(5),FSP(10),FVAL(10),TABLE2
      REAL*8 SURVEY,ALARGE,SMALL
      INTEGER XCHAR(126,10)
      DIMENSION SCAL2(123,10),TABLE(10,4),
     1DATA(30),CAP(33,30),OUTS(10),OUTT(10),CORD(2,1300)
      EQUIVALENCE (DATA(1),SCAL2(1,1)),
     1(XCHAR(1,1),LINE(1,1))
      DATA FMT/'(1H ','  ,11','X,60','(I1,','I1))'/
      DATA FVAL/'X,60','X,60','X,40','X,30','X,25','X,20','X,17','X,15',
     *'X,13','X,12'/
      DATA FSP/'I1))','1X))','2X))','3X))','4X))','5X))','6X))','7X))',
     *'8X))','9X))'/
      DATA BLANK,HOR,VERTI,PLUS/' ','-','I','+'/
      DATA ALARGE,SMALL/'DETAILED','  BROAD '/
      DATA ALIM,AMISS/'L','M'/
C
C.    FMT IS THE FORMAT USED TO PRINT XCORD. FMT IS INITIALIZED
C     BY THE DATA STATEMENT TO BE THAT FORMULA REQUIRED TO PRINT
C     XCORD WHEN NSCALC = 1.FSP & FVAL ARE THE VALUES WITH WHICH FMT
C     IS UPDATED AS NSCALC MAY BE ANY VALUE FROM 1-10 .
C
C
      REWIND 1
      REWIND 2
      REWIND 8
      REWIND 9
      IMAP=1
C
C     IMAP INDICATES WHETHER THE ARRAY CAP HAS ONLY ZERO VALUES.
C     IF THIS IS SO NO MAP IS PRINTED & IMAP IS GIVEN THE VALUE 0
C      IN SUBROUTINE CLASS
      IEND=0
C
      INCO=1
      IF(ID.EQ.0) GO TO 10
       NTIME=2
6000  CONTINUE
C
C     IF A MAP OF A LC IS REQUIRED, READ THE LAND DATA SET & WRITE THE
C     RELEVANT LC VALUES TO TEMPORARY DISC, UNIT 1
      L=0
      READ(ID,END=6004) NTOTAL,NC,NR
13    FORMAT(3I5)
      WRITE(1) NR,NC
      DO 6003 J=1,NR
      DO 6001 I=1,NC
      L=L+1
      READ(ID) (CORD(K,L),K=1,2),(DATA(II),II=1,LCC)
      NZ=0
      DO 6005 II=1,LCC
6005  IF(DATA(II).EQ.0.0) NZ=NZ+1
      IF(NZ.EQ.LCC) DATA(M)=-99.9
      CAP(I,J)=DATA(M)
6001  CONTINUE
6003  CONTINUE
      WRITE(1) ((CAP(I,J),I=1,NC),J=1,NR)
      WRITE(8) (CORD(1,L),L=1,NC),(CORD(2,L),L=1,NTOTAL,NC)
      GO TO 6000
6004  REWIND 1
      REWIND 8
C      LIM ARRAY IS ONLY PRINTED AFTER CAP ARRAY IF IT IS REQUIRED
      NLIM=0
10    IAR=1
C     IAR INDICATES WHETHER THE CAP OR LIMIT MAP IS BEING READ
C     PRINT THE HEADINGS TO THE MAPS
      NTIME=0
      IF(M.EQ.0) WRITE(6,1) (TITLE(I),I=1,20)
1     FORMAT(' '//////,' ',5X,
     *' THE LAND CAPABILITY MAP FOR ',20A4,/
     *10X,' THE INDEX FOR THE MAP SYMBOLS IS PRINTED AT THE END OF THE J
     *OB')
      IF(M.EQ.0) WRITE(6,2) VAL
      IF(M.NE.0) WRITE(6,3) M
3     FORMAT('0',30X,'MAP OF THE LAND CHARACTERISTIC ',I5)
2     FORMAT('0',5X,' THE PROPORTION OF THE REQUIRED LAND CHARACTERISTIC
     *S WHICH ARE PRESENT IN THE LAND DATA SET IS',F10.3)
      SURVEY=ALARGE
      IF(ISS.EQ.0) SURVEY=SMALL
      IF(M.EQ.0) WRITE(6,4) SURVEY
4     FORMAT('0',30X,'THE ANALYSIS IS PERFORMED AT THE ',A8,' LEVEL')
C
C     DETERMNE THE FREQ. & % FREQ. OF EACH MAP SYMBOL IN THE MAP
      CALL CLASS(IAR,CL,M,INCO)
      IF(IMAP.EQ.0) GO TO 109
      IF(NSCALC.EQ.0) NSCALC=4
      IF(NSCALR.EQ.0) NSCALR=3
      ISTEP=GRID*10.0
C
C     CHANGE THE FORMAT IF NSCALC IS GREATER THAN 1
C
      IF(NSCALC.EQ.1) GO TO 11
      FMT(3)=FVAL(NSCALC)
      FMT(5)=FSP(NSCALC)
C     OUTT & OUTS ARE FILLED TAKING INTO ACCOUNT THE SCALING FACTORS
C     OUTS IS FILLED WITH THE OUTLINE FOR THE SIDES OF THE MAP
C     OUTT IS FILLED WITH THE OUTLINE FOR THE TOP & BOTTOM OF THE MAP
C
11    OUT=PLUS
      OUTT(1)=PLUS
      IF(NSCALC.EQ.1) GO TO 62
      DO 67 KT=2,NSCALC
67    OUTT(KT)=HOR
62    OUTS(1)=PLUS
      IF(NSCALR.EQ.1) GO TO 40
      DO 64 KS=2,NSCALR
64    OUTS(KS)=VERTI
C
40    READ(IAR,END=100) NR,NC
      NCOLS=NC
      NROWS=NR
      NTOTAL=NC*NR
      READ(8) (CORD(1,L),L=1,NC),(CORD(2,L),L=1,NTOTAL,NC)
```

```
C
C         READ THE ARRAY TO BE MAPPED
          READ(IAR,END=91) ((CAP(I,J),I=1,NC),J=1,NR)
91        NSECTR=NR
          NN=NC*NSCALC
C         PRINT THE MAP
C         ALLOWED ONLY 125 CHARACS. ACROSS THE PAGE THUS IF THE SYMBOLS
C         PRINTED PER CELL REQUIRES MORE THAN THIS, THE MAP IS
C         PRINTED IN SECTIONS
C
C         COMPUTE NO. OF MAP SECTIONS (PAGE WIDTHS) ASSUMING 125 CHAR/PAGE
          MM=(120/NSCALC)*NSCALC
          NSECS=(NN+(MM-1))/MM
          LB=1
          NCOLE=120/NSCALC
          INCRE=NCOLE
          KA=1
          LA=NCOLE*NSCALC
          KB=LA
          KE=NCOLE
          I1=1
          IY=CORD(2,1)
C
C         THE VARIOUS DO LOOP DELIMITERS ARE :-
C         KA & KB ARE CONCERNED WITH THE NO. OF COLS. ACROSS THE PAGE
C         /SEC. INCLUDING NSCALC.THEY ARE NOT RELATED TO THE
C         ACTUAL COL. NO. BEING USED AT THAT TIME IN THE ARRAY BEING MAPPED.
C         KA & KE ARE CONCERNED WITH THE NO. OF COLS. ACROSS THE PAGE
C         / SEC. WITHOUT THE SCALING FACTOR. THEY ARE NOT RELATED TO THE
C         ACTUAL COL NOS. BEING USED AT THAT TIME IN THE  ARRAY BEING MAPPED.
C         LB & NCOLE ARE CONCERNED WITH THE ACTUAL COL. NOS. OF THE ARRAY
C         BEING MAPPED WHICH ARE BEING PRINTED IN THE PARTICULAR SECTION
C         NSECTR IS THE ACTUAL NUMBER OF ROWS OF THE ARRAY BEING MAPPED
C         WHICH ARE TO BE PRINTED FOR THAT SECTION
C
          L1=0
          DO 105 KL=1,NSECS
          DO 90 J=1,4
          DO 90 I=1,128
90        LINE(I,J)=BLANK
C         PRINT A TITLE AT THE TOP OF EACH MAP SECTION
          WRITE(6,65) KL,NSECS
65        FORMAT('1THIS IS MAP SECTION',I3,' OF',I3,//)
C
          IF(KL.NE.NSECS.OR.NSECS.EQ.1) GO TO 210
205       KB=NN-(KB*(KL-1))
          KE=NC-(KE*(KL-1))
          NCOLE=NC
210       IF(NSECS.EQ.1) KB=NN
          IF(NSECS.EQ.1) KE=NC
          IF(NSECS.EQ.1) NCOLE=NC
C
C         STORE THE X CO-ORDINATES IN ARRAY XCHAR.
C
          DO 200 LX=KA,KE
          L1=L1+1
          IX=CORD(1,L1)
          XCHAR(LX,1)=IX/1000000000
          XCHAR(LX,2)=MOD((IX/100000000),10)
          XCHAR(LX,3)=MOD((IX/10000000),10)
          XCHAR(LX,4)=MOD((IX/1000000),10)
          XCHAR(LX,5)=MOD((IX/100000),10)
          XCHAR(LX,6)=MOD((IX/10000),10)
          XCHAR(LX,7)=MOD((IX/1000),10)
          XCHAR(LX,8)=MOD((IX/100),10)
          XCHAR(LX,9)=MOD((IX/10),10)
          XCHAR(LX,10)=MOD(IX,10)
200       CONTINUE
C
C         PRINT THE X CO-ORDINATES
C
          IWR=0
          DO 1001 LY=1,10
          NUMB=0
          IF(IWR.EQ.1) GO TO 1003
          DO 1002 LX=KA,KE
1002      IF(XCHAR(LX,LY).GT.0) NUMB=1
          IF(NUMB.EQ.0) GO TO 1001
1003      WRITE(6,FMT) (XCHAR(LX,LY),LX=KA,KE)
          IWR=1
1001      CONTINUE
C         PRINT THE TOP OUTLINE
201       WRITE(6,101) ((OUTT(KT),KT=1,NSCALC),KK=KA,KE)
101       FORMAT(' ',11X,120A1)
          DO 100 II=1,NSECTR
          DO 61 J=1,NSCALR
          DO 61 I=KA,KB
61        SCALZ(I,J)=0.0
          IB=1
          IE=NSCALC
          DO 30 JJ=LB,NCOLE
C         FILL ARRAY SCALZ WITH THE VALUE IN THE MAP ARRAY, THE NUMBER OF
C         REPETITIONS IE. NO. OF MAP SYMBOLS/CELL, BEING GIVEN BY NSCALR
C         NSCALC.
C
12        DO 18 JS=1,NSCALR
          DO 18 IS=IB,IE
          IF(CINT.NE.0.0) SCALZ(IS,JS)=(CAP(JJ,II)-ZMIN)/CINT+2.
          IF(CAP(JJ,II).LE.0.) SCALZ(IS,JS)=1.0
          IF(CAP(JJ,II).EQ.(-99.9)) SCALZ(IS,JS)=-99.9
          IF(IAR.EQ.1) GO TO 18
          IF(CAP(JJ,II).EQ.VMISS) SCALZ(IS,JS)=VMISS
          IF(IAR.EQ.2.AND.CAP(JJ,II).EQ.100.0) SCALZ(IS,JS)=ALIM
18        CONTINUE
25        IB=IB+NSCALC
          IE=IE+NSCALC
30        CONTINUE
C
C         FILL ARRAY LINE WITH THE MAP SYMBOLS STORED IN ARRAY TABLEZ
C
          DO 30 J1=1,NSCALR
          DO 33 JL=KA,KB
          IF(SCALZ(JL,J1).EQ.(-99.9)) GO TO 31
          IF(SCALZ(JL,J1).EQ.VMISS) GO TO 31
          IF(SCALZ(JL,J1).EQ.ALIM) GO TO 31
          DO 31 KI=1,4
          JK=SCALZ(JL,J1)
```

```
      JK=IFIX(SCALZ(JL,JI))
51    LINE(JL,KI)=TABLEZ(JK,KI)
      GO TO 51
31    DO 32 KI=1,4
32    LINE(JL,KI)=BLANK
      IF(SCALZ(JL,JI).EQ.VMISS) LINE(JL,1)=AMISS
      IF(SCALZ(JL,JI).EQ.ALIM) LINE(JL,1)=ALIM
30    CONTINUE
      GO TO 32
C
C     PRINT LINE WITH THE Y CO-ORDINATES & THE SIDE BOUNDARIES
C
63    IF(OUTS(JI).NE.PLUS) GO TO 107
69    WRITE(6,108) IY,OUTS(JI),(LINE(K,1),K=KA,KB),OUTS(JI)
      II=II+NC
      IF(II.GT.NTOTAL) GO TO 110
      IY=CORD(2,II)
108   FORMAT(' ',I10,128A1)
      GO TO 110
107   WRITE(6,106) OUTS(JI),(LINE(K,1),K=KA,KB),OUTS(JI)
106   FORMAT(' ',10X,128A1)
C     OVERPRINT
110   DO 55 KI=2,4
55    WRITE(6,102) (LINE(K,KI),K=KA,KB)
102   FORMAT('+',11X,128A1)
40    CONTINUE
100   CONTINUE
C
C     PRINT THE BOTTOM OUTLINE
      WRITE(6,101) ((OUTT(KT),KT=1,NSCALC),KK=KA,KE)
      LB=LB+INCRE
      NCOLE=NCOLE+INCRE
      IY=CORD(2,1)
      II=0
105   CONTINUE
      GO TO 40
C     PRINT OUT LIM FOR THIS SECTION OF THE MAP ARRAY AT THE SAME SCALE
109   IF(NTIME.EQ.2) RETURN
      IF(NLIM.EQ.0) RETURN
      IMAP=1
      NFIT=1
      REWIND 8
      IEND=0
      IF(NTIME.EQ.1) GO TO 131
      NTIME=1
      IAR=7
       IF(INCO.EQ.0) GO TO 113
      WRITE(6,673)
673   FORMAT('1',5X,' THE MAP OF THE ABOVE SECTION SHOWING THE PERCENTAG
     *E USABLE SURFACE AREA WITHIN EACH GRID CELL')
      GO TO 112
113   WRITE(6,674)
674   FORMAT('0  THE MAP OF THE ABOVE SECTION SHOWING THE PERCENTAGE USA
     *BLE SURFACE AREA IS NOT PRINTED SINCE ALL THE CELLS '/
     *'0           WERE EXCLUDED FROM THE ANALYSIS BY A LIMITING LAND CHAR
     *ACTERISTIC.')
      GO TO 109
131   IAR=2
      NTIME=2
      WRITE(6,671)
671   FORMAT('1',5X,'THE MAP OF THE ABOVE SECTION SHOWING THE NUMBER OF
     *LAND CHARACTERISTICS WHICH ARE OUTSIDE THEIR VALUE RANGE IN EACH C
     *ELL.'///)
      WRITE(6,672)
672   FORMAT(' ',30X,'A LIMITING LAND CHARACTERISITIC GIVES THE CELL THE
     * A VALUE L'/'0',30X,'A MISSING VALUE GIVES THE CELL A VALUE M')
112   CALL CLASS(IAR,CL,M,INCO)
      IF(IMAP.EQ.0.AND .IAR.EQ.9) GO TO 109
      IF(IMAP.EQ.0.AND.IAR.EQ.2) RETURN
      GO TO 40
      END
C
      SUBROUTINE CLASS(IAR,CL,M,INCO)
C
C     THIS SUBROUTINE CALCULATES & PRINTS THE FREQ. & % FREQ. OF THE
C     DIFFERENT MAP SYMBOLS PRINTED.
C
      COMMON /PARMM/NPDATA,NLIM,NSCALR,NSCALC,NFIT,VAL,VMISS,ISS,
     *SURF(10)
      COMMON /MAP1/ZMIN,CINT,NCOLS,NROWS,IMAP
      COMMON /PARMO/UNITS(3),TITLE(20),XW,XE,YS,YN,SCALE,GRID,
     1NSECTR,(NOEXO(56),NVAR
      DIMENSION KOUNT(11),PCFREQ(11),CAP(50,26)
      DATA AL,AM/'L','M'/
C
C     INCO INDICATES WHETHER A MAP OF THE USABLE SURFACE AREA IS TO BE
C     PRINTED. NO MAP IS PRINTED IF ALL THE CELLS ARE EXCLUDED DUE TO A
C     LIMITING LC.
      INCO=1
      NUML=0
      NUMM=0
      NCL=IFIX(CL)+1
      ZMIN=0.0
      ZMAX=100.0C
      IF(NFIT.EQ.0) GO TO 200
C     CALCULATE THE MAP INTERVAL IE. THE VALUE RANGE INCLUDED WITHIN
C     EACH MAP CLASS REPRESENTED BY A DIFFERENT MAP SYMBOL.
4     READ(IAR,END=4) NRR,NCC
      READ(IAR,END=6) ((CAP(I,J),I=1,NCC),J=1,NRR)
6     ZMAX=0.0
      ZMIN=100.0
      L=0
      DO 20 J=1,NRR
      DO 30 I=1,NCC
      L=L+1
      IF(CAP(I,J).EQ.(FLOAT(L)+130.0)) GO TO 20
      IF(CAP(I,J).EQ.-99.9.OR.CAP(I,J).EQ.VMISS) GO TO 20
      IF(CAP(I,J).LT.100.0.AND.CAP(I,J).GT.ZMAX) ZMAX=CAP(I,J)
      IF(IAR.EQ.3.AND.CAP(I,J).GT.ZMAX) ZMAX=CAP(I,J)
      IF(CAP(I,J).LT.ZMIN) ZMIN=CAP(I,J)
20    CONTINUE
      GO TO 2
4     REWIND IAR
C     DETERMINE THE RANGE OF VALUES
200   IF(ZMIN.GT.ZMAX) ZMIN=ZMAX
      RANGE=ZMAX-ZMIN
C     SET CLASS INTERVAL TO VALUE JUST SLIGHTLY LARGER
C     THAN RANGE/NC TO AVOID PROBLEMS WITH THE MAX. VALUE
```

```
      CINT=RANGE/CL+(RANGE/CL)*0.001
C
      DO 300 L=1,11
300   KOUNT(L)=0
C     TABULATE FREQ. DISTRIBUTION
      NRC=1
C     READ THE MAP ARRAY
301   READ(IAR,END=303) NRR,NCC
      READ(IAR,END=305) ((CAP(I,J),I=1,NCC),J=1,NRR)
306   L=0
      DO 400 J=1,NRR
      DO 400 I=1,NCC
      L=L+1
      IF(CAP(I,J).EQ.(FLOAT(L)+100.0)) GO TO 400
      IF(CAP(I,J).EQ.(-99.9)) GO TO 400
      IF(CINT.NE.0.0) NUM=(CAP(I,J)-ZMIN)/CINT+2.
       IF(CAP(I,J).LE.0.0) NUM=1
       IF(IAR.EQ.2.AND.CAP(I,J).EQ.100.0) NUML=NUML+1
      IF(CAP(I,J).EQ.VMISS.AND.IAR.NE.2) GO TO 400
      IF(CAP(I,J).EQ.VMISS) NUMM=NUMM+1
C     INCREMENT NUMTH CLASS
      IF(NUM.LE.11) KOUNT(NUM)=KOUNT(NUM)+1
      NRC=NRC+1
400   CONTINUE
      GO TO 303
C     RETURN IF NO MAP IS TO BE PRINTED
303   IF(NRC.NE.0) GO TO 410
       WRITE(6,53)
53    FORMAT('0 ALL VALUES WITHIN THE MAP ARE ZERO.'/'  NO MAP IS
     *PRINTED ')
       IMAP=0
      GO TO 1000
C
C     COMPUTE % FREQUENCY
410    IF(IAR.NE.9) GO TO 411
       IF(ZMAX.NE.0.0) GO TO 411
      INCO=0
      REWIND IAR
      RETURN
411   DO 501 K=1,NCL
      PCFREQ(K)=(FLOAT(KOUNT(K))/FLOAT(NRC))*100.
501   CONTINUE
      PFREQL=(FLOAT(NUML)/FLOAT(NRC))*100.
      PFREQM=(FLOAT(NUMM)/FLOAT(NRC))*100.
C
C     PRINT RESULTS
      IF(NFIT.EQ.1.AND.IAR.NE.9) WRITE(6,50)
50    FORMAT('0 DISTRIBUTION OF THE LAND CHARACTERISTIC VALUES',/)
      IF(NFIT.EQ.0.AND.IAR.EQ.1) WRITE(6,54)
54    FORMAT('0 DISTRIBUTION OF THE WEIGHTED PERCENTAGE CAPABILITY VALUE
     *S IN THE MAP',/)
      IF(NFIT.EQ.0.AND.IAR.EQ.2) WRITE(6,56)
56    FORMAT('0 DISTRIBUTION OF THE NUMBER OF LIMITING LAND CHARACTERIST
     *ICS IN THE MAP',/)
      IF(NFIT.EQ.1.AND.IAR.EQ.5) WRITE(6,57)
57    FORMAT('0 DISTRIBUTION OF THE USABLE SURFACE AREA IN THE MAP',/)
      WRITE(6,55) NRC,ZMAX,ZMIN,RANGE
55    FORMAT('0DATA SET HAS',I5,'  VALUES',/,
     2'0MAXIMUM IS',F6.1,/,'0MINIMUM IS',F6.1,/,
     3'0RANGE IS',F6.1,/////)
      IF(CINT.EQ.0.0.AND.IAR.EQ.9) GO TO 99
      WRITE(6,66)
66    FORMAT('0MAP SYMBOLS NUMBER  LOWER LIMIT  UPPER LIMIT  FREQUENCY
     *% FREQUENCY')
      CLASST=RANGE/CL
      IF(CLASST.EQ.0.0) GO TO 35
C     PRINT THE RESULTS IF THE MAP IS NOT OF A LAND CAP. ANALYSIS
      IF(NFIT.EQ.0) GO TO 600
      NS=2
      IF(KOUNT(1).NE.0) NS=1
      DO 505 K=NS,11
      BOT=ZMIN+CLASST*(K-2)
      IF(K.EQ.2) BOT=ZMIN
      TOP=BOT+CLASST
      IF(BOT.NE.ZMIN) BOT=BOT+0.01
      IF(K.EQ.1) BOT=0.0
      IF(K.EQ.1) TOP=BOT
      KK=K-1
505   WRITE(6,502) KK,BOT,TOP,KOUNT(K),PCFREQ(K)
502   FORMAT('0',8X,I2,11X,F7.2,6X,F7.2,6X,I4,8X,F6.2)
      KK=12
35    IF(M.NE.0.OR.IAR.EQ.5) GO TO 1000
      WRITE(6,506) AL,NUML,PFREQL
506   FORMAT('0',9X,A4,34X,I4,8X,F6.2)
      KK=13
      WRITE(6,506) AM,NUMM,PFREQM
      IF(ZMIN.NE.ZMAX) GO TO 1000
304   IMAP=0
      WRITE(6,306)
306   FORMAT('0 ALL THE CELLS ARE EXCLUDED FROM THE ANALYSIS BY A LIMITI
     *NG LAND CHARACTERISTIC THUS NO MAP IS PRINTED')
      GO TO 1000
C     PRINT THE RESULTS IF THE MAP IS OF A LAND CAP. ANALYSIS
600   TOP=0.00
      BOT=ZMIN
      DO 605 K=1,11
      KK=K-1
      WRITE(6,502) KK,BOT,TOP,KOUNT(K),PCFREQ(K)
       BOT=TOP+0.01
605   TOP=K*10.00
      GO TO 1000
99    WRITE(6,67)
67    FORMAT('0 ALL THE GRID CELLS HAVE THE SAME PERENTAGE OF USABLE SUR
     *FACE AREA (EQUAL TO THE MAXIMUM VALUE PRINTED ABOVE)'//,
     *30X,' NO MAP IS PRINTED')
       IMAP=0
1000  CONTINUE
      REWIND IAR
      RETURN
      END
C
      SUBROUTINE MAPIND(CL)
C
C     THIS SUBROUTINE PRINTS THE INDEX OF THE PRINTED MAPS
C
      COMMON /INDMAP/TABLE2(11,4)
      REAL TABLE2
      REAL NBLOK(4,4)
```

```
C
C       PRINT THE HEADING
        WRITE(6,70)
70      FORMAT(' ',//////)
        WRITE(6,80)
80      FORMAT('1CLASS NUMBER    GRAY LEVEL')
        NCLASS=0
        DO 90 L=1,11
        N=0
C
C       PRINT 1ST LINE & EACH CHARAC. 4 TIMES
        DO 92 LL=1,4
        DO 91 I=1,4
91      NBLOK(I,LL)=TABLE2(L,LL)
92      CONTINUE
        WRITE(6,110) (NBLOK(I,1),I=1,4)
110     FORMAT('0',17X,4A1)
C
C       OVERPRINT THE FIRST LINE
        DO 95 LL=2,4
95      WRITE(6,115) (NBLOK(I,LL),I=1,4)
115     FORMAT('+',17X,4A1)
C
C       PRINT THE LINES 2 & 3
        WRITE(6,120) NCLASS,(NBLOK(I,1),I=1,4)
120     FORMAT(' ',5X,I2,10X,4A1)
        NCLASS=NCLASS+1
135     N=N+1
        DO 125 LL=2,4
125     WRITE(6,115) (NBLOK(I,LL),I=1,4)
        IF(N.GE.2) GO TO 90
C       PRINT THIRD LINE
        WRITE(6,130) (NBLOK(I,1),I=1,4)
130     FORMAT(' ',17X,4A1)
        GO TO 135
90      CONTINUE
        RETURN
        END
//GO.FT01F001 DD DSN=&&CAPMAP,UNIT=SYSRES,DISP=NEW,
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=VBS,LRECL=2504,BLKSIZE=2504)
//GO.FT02F001 DD DSN=&&SLIMMAP,UNIT=SYSRES,DISP=NEW,
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=VBS,LRECL=2504,BLKSIZE=2504)
//GO.FT03F001 DD DSN=&&DATA,UNIT=SYSRES,DISP=NEW,
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=VBS,LRECL=192,BLKSIZE=1924)
//GO.FT08F001 DD DSN=&&TEMP,UNIT=SYSRES,DISP=NEW,
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=VBS,LRECL=104,BLKSIZE=1044)
//GO.FT09F001 DD DSN=&&SURAREA,UNIT=SYSRES,DISP=NEW,
//   SPACE=(CYL,(1,1),RLSE),DCB=(RECFM=VBS,LRECL=2504,BLKSIZE=2504)
//GO.FT11F001 DD VOL=SER=TFM001,UNIT=TAPE,DISP=OLD,
//   DSN=LEBOWA.COPY,LABEL=(7,SL)
//GO.FT12F001 DD VOL=SER=WIT241,UNIT=SYSDA,DISP=OLD,
// DSN=ACM.CMH063.LAND
//GO.FT13F001 DD VOL=SER=WIT241,UNIT=SYSDA,DISP=OLD,
// DSN=ACM.CMH063.LAND
//GO.FT14F001 DD VOL=SER=WIT241,UNIT=SYSDA,DISP=OLD,
// DSN=ACM.CMH063.LAND
//GO.FT15F001 DD VOL=SER=WIT241,UNIT=SYSDA,DISP=OLD,
// DSN=ACM.CMH063.LAND
//GO.FT20F001 DD UNIT=SYSRES,DISP=NEW,SPACE=(CYL,(1,1),RLSE),
// DCB=(RECFM=FB,LRECL=132,BLKSIZE=3112),
// DSN=&&KEEPJ
//GO.FT21F001 DD DSN=&&CON21,UNIT=SYSRES,DISP=(OLD,DELETE)
//GO.FT22F001 DD DSN=&&CON22,UNIT=SYSRES,DISP=(OLD,DELETE)
//GO.FT23F001 DD DSN=&&CON23,UNIT=SYSRES,DISP=(OLD,DELETE)
//GO.FT24F001 DD DSN=&&CON24,UNIT=SYSRES,DISP=(OLD,DELETE)
//GO.FT25F001 DD DSN=&&CON25,UNIT=SYSRES,DISP=(OLD,DELETE)
//GO.SYSIN DD *
//
//
```

```
*******************************************************************************
                                                       FILE   ANAL
*******************************************************************************
C      FILE 17  OF THE LAND CAPABILITY ANALYSIS PROCEDURE  1980  C. HAMMOND
C
C
C      PROGRAM KEEPS THE OUTPUT FILE  EV123  FROM PROGRAM  EVDATA, COPIES
C      CAPANL  INTO  EVPGM  AND INSERTS  EV123  AS THE DATA FOR THIS PROGRAM.
C      THE INSTRUCTION TO EXECUTE  EVPGM  AND TO CHANGE ITS JCL TO REFER TO THE
C      SECONDARY LAND DATA SET ANALYSED, ARE DISPLAYED.
C
*PUR EV123
*KEP EV123
*PUR EVPGM
*EMP
*UP
C      COPY CAPANL AND INSERT  EV123  AS DATA
*INS WATS
*CH /F,L #//GO.SYSIN DD *#
*INS EV123
*E
*SA EVPGM
*PUR EV123
C      DISPLAY INSTR
*D INSTR 115,133
```

```
//       EXEC FORTXCLG,PARM.FORT=NOSOURCE
//FORT.SYSIN DD *
         DIMENSION X(30),Y(30),Z(30),TITLE(20),MAP(10,10)
         DATA M/6/,NC/0/,MAP/100*0/
C
C        PROGRAM TO INTERPOLATE DISCRETE POINT DATA
C
C
         READ(5,1) (TITLE(I),I=1,20)
         WRITE(6,1) (TITLE(I),I=1,20)
1        FORMAT(20A4)
         DO 301 I=1,30
         READ(5,10) X(I),Y(I),Z(I)
10       FORMAT(3F2.0)
         WRITE(6,20) X(I),Y(I),Z(I)
20       FORMAT(' ',3(5X,F3.0))
         NC=NC+1
301      CONTINUE
         NROWS=NC/3
         NCOLS=NC/3
         NPTS=NC
         MODE=1
         CALL INTERP (X,Y,Z,NPTS,MAP,NROWS,NCOLS,M,MODE)
         STOP
         END
         SUBROUTINE INTERP (R,C,Z,NPTS,MAP,NROWS,NCOLS,M,MODE)
C        POINT CO-ORDINATES STORED IN R(ROWS) & C(COLS)
C        ROW CO-ORDINATES .GE.1.AND.LE.NROWS
C        COL CO-ORDINATES .GE.1.AND.LE.NCOLS
C        NPTS = NO. OF POINTS
C        MAP IS THE OUTPUT MATRIX NROWS BY NCOLS
C        IF MODE = 1,MAP REPRESENTS A RECTANGULAR GRID FOR COMPUTER
C        MAPPING WITH A SIX LINE PER INCH PRINTER
C        M = NO.OF DATA PTS. TO BE USED IN THE INTERPOLATION
C        DIST CONTAINS DISTANCES FROM THE CENTRE OF THE GRID CELL TO
C        ALL DATA POINTS
C        WITHIN CONTAINS DISTANCES TO (ROW1) & VALUES OF (ROW2) DATA PTS.
C        WITHIN SEARCH RADIUS.
         DIMENSION R(NPTS),C(NPTS),Z(NPTS),DIST(100),WITHIN(2,100)
         REAL MAP(NROWS,NCOLS)
         REAL SMAP(10,10),AMAP(10,10)
         DATA SMAP/100*0.0/
C        RADIUS DEFINES THE INITIAL SEARCH RADIUS
C        RADIUS DEFINES THE INITIAL SEARCH AREA SET INITIALL
C        THE VALUE REQUIRED TO CONTAIN M PTS. IF THE PTS. ARE
C        EVENLY DISTRIBUTED
         DO 100 L=1,4
         RADIUS=(2.*(NROWS*NCOLS)/NPTS)**0.5
         SCALER=1
         IF(MODE.EQ.0) SCALER=5./3.
C        START LOOP TO LOOK AT ALL MAP POINTS
         DO 3 J=1,NCOLS
         DO 3 I=1,NROWS
C        CONVERT ROW & COL. DO VARIABLES TO REAL FORM
         ROW=I+0.5
         COL=(J+0.5)*SCALER
C        COMPUTE DISTS. FROM THE CENTRE OF THIS CELL TO ALL DATA POINTS
         DO 4 K=1,NPTS
C        USE MULTIPLICATION INSTEAD OF SQUARING TO SPEED EXECUTION
         DIST(K)=SQRT((ROW-R(K))*(ROW-R(K))+(COL-C(K))*(COL-C(K)))
4        IF(DIST(K).EQ.0.) GO TO 41
         GO TO 45
C        DATA PT COINCIDES WITH CENTRE OF GRID CELL
41       MAP(I,J)=Z(K)
C        FIND ALL PTS. WITHIN THE RADIUS
         GO TO 3
45       MM=0
         DO 40 K=1,NPTS
         IF(DIST(K).GT.RADIUS) GO TO 40
         MM=MM+1
         WITHIN(1,MM)=DIST(K)
         WITHIN(2,MM)=Z(K)
40       CONTINUE
C        IF INSUFFICIENT PTS. INCREASE THE RADIUS BY 25 PER CENT
C        & REDO THE LOOP
         IF(MM.GT.M) GO TO 50
         RADIUS=RADIUS*1.25
         GO TO 45
C        FIND M SMALLEST DISTANCES
C        SORT BY DISTANCES TO FIND M NEAREST POINTS
50       CALL SORT (WITHIN,MM,2,1)
C        SOLVE INTERPOLATION FUNCTION
         SUM1=0.
         SUM2=0.
         DO 7 K=1,M
         SQUARE=WITHIN(1,K)*WITHIN(1,K)
         SUM1=SUM1+WITHIN(2,K)/SQUARE
7        SUM2=SUM2+1./SQUARE
         MAP(I,J)=SUM1/SUM2
         SMAP(I,J)=SMAP(I,J)+MAP(I,J)
C        REDUCE RADIUS IF TOO MANY PTS. ARE FALLING WITHIN SEARCH RADIUS
         IF(MM.GT.2*M) RADIUS=RADIUS*0.9
3        CONTINUE
         WRITE(6,20)
20       FORMAT(/////)
         WRITE(6,21) M
21       FORMAT(' ','NUMBER OF POINTS USED IN INTERPOLATION IS ',I4,//)
         DO 30 I=1,10
30       WRITE(6,25) (MAP(I,J),J=1,10)
25       FORMAT(' ',10F7.3)
         M=M+1
100      CONTINUE
         DO 110 J=1,10
         DO 110 I=1,10
110      AMAP(I,J)=SMAP(I,J)/4.0
         WRITE(6,22)
22       FORMAT(' ',//,'AVG. MATRIX OF ALL INTERPOLATIONS')
         DO 120 I=1,10
120      WRITE(6,25) (AMAP(I,J),J=1,10)
         RETURN
         END
         SUBROUTINE SORT(XX,N,U,V)
C        SORTING ROUTINE BASED ON ALGORITHM 201, ASSOCIATION FOR
C        COMPUTING MACHINERY BY J.BOOTHROYD.
C        SORTS ROWS OF XX(U,N) SO THAT THE ELEMENTS OF ROW V ARE IN
C        ASCENDING ORDER. MAX. OF 25 ROWS
```

```
          INTEGER U,V,W
          REAL XX(U,N),SAVE(25)
          M=N
 100      M=M/2
          IF(M.EQ.0) RETURN
          K=N-M
          DO 400 J=1,K
          I=J
 200      L=I+M
          IF(XX(V,I).LE.XX(V,L)) GO TO 400
          DO 300 W=1,U
          SAVE(W)=XX(W,I)
          XX(W,I)=XX(W,L)
 300      XX(W,L)=SAVE(W)
          I=I-M
          IF(I.GT.0) GO TO 200
 400      CONTINUE
          GO TO 100
          END
//GO.SYSIN DD *
```

```
******************************************************************************
                                                   FILE   READ
******************************************************************************
C      PROGRAM PRODUCES A HARD COPY OF A SECONDARY LAND DATA SET
C
//CMHREAD JOB 063,CLASS=E
/*ROUTE  PRINT HOLD
//  EXEC FORTXCLG,PARM.FORT=NOSOURCE
//FORT.SYSIN DD *
       DIMENSION A(50),TITLE(20),INDEX(50)
       REAL UNITS(3)
C      READ  ND WRITE INTRODUCTORY INFORMATION TO THE DATA SET
       READ  ) (TITLE(I),I=1,20),I1,A1,A7,(UNITS(I),I=1,3),
      *A2,A3,A4,A5,A6
       WRITE(6,1) (TITLE(I),I=1,20),I1,A1,A7,(UNITS(I),I=1,3),
      *A2,A3,A4,A5,A6
1      FORMAT(' ',20A4/' ',I5,F7.0,F10.3,3A4,F6.2,4F10.3)
       READ(1) (INDEX(I),I=1,I1)
       WRITE(6,2) (INDEX(I),I=1,I1)
2      FORMAT(' ',26I3)
C      READ AND WRITE TOTAL NUMBER OF GRID CELLS, ROWS AND COLUMNS IN A SECTION
C      OF THE SECONDARY LAND DATA SET
26     READ(1,END=25) I2,I3,I4
       WRITE(6,3) I2,I3,I4
3      FORMAT(' ',3I5)
       DO 20 K=1,I4
       DO 20 J=1,I3
C      READ AND WRITE LAND CHARACTERISTIC VALUES
       READ(1) X,Y,(A(KK),KK=1,I1)
       IF(K.LE.5) WRITE(6,4) X,Y,(A(KK),KK=1,I1)
4      FORMAT(' ',8F10.3)
20     CONTINUE
       GO TO 26
25     CONTINUE
       STOP
       END
//GO.FT01F001 DD DSN=ACM.CMH063.LAND,UNIT=SYSDA,DISP=OLD,
// VOL=SER=WIT241,SPACE=(TRK,(80,,5)),
//  DCB=(RECFM=VBS,LRECL=192,BLKSIZE=1924)
//
//
```

```
******************************************************************************
                                                   FILE   COPY
******************************************************************************
C      THIS PROGRAM COPIES THE SECONDARY LAND DATA SET FROM UNIT 1 TO UNIT 10
C
C
//CMHCOPY1 JOB 063,CLASS=B
/*ROUTE  PRINT HOLD
/*SETUP            TAPE=(TFM001,SL,YES)
//  EXEC FORTXCLG,PARM.FORT=NOSOURCE
//FORT.SYSIN DD *
       DIMENSION A(50),TITLE(20),INDEX(50)
       REAL UNITS(3)
C
C
C      READ AND COPY THE INTRODUCTORY INFORMATION OF THE SECONDARY LAND DATA
C      SET
       READ(1) (TITLE(I),I=1,20),I1,A1,A7,(UNITS(I),I=1,3),
      *A2,A3,A4,A5,A6
       WRITE(10) (TITLE(I),I=1,20),I1,A1,A7,(UNITS(I),I=1,3),
      *A2,A3,A4,A5,A6
1      FORMAT(' ',20A4/' ',I5,F7.0,F10.3,3A4,F6.2,4F10.3)
       READ(1) (INDEX(I),I=1,I1)
       WRITE(10) (INDEX(I),I=1,I1)
2      FORMAT(' ',26I3)
26     READ(1,END=25) I2,I3,I4
       WRITE(10) I2,I3,I4
3      FORMAT(' ',3I5)
C      READ AND COPY THE LAND CHARACTERISTIC VALUES IN EACH GRID CELL
       DO 20 K=1,I4
       DO 20 J=1,I3
       READ(1) X,Y,(A(KK),KK=1,I1)
       WRITE(10) X,Y,(A(KK),KK=1,I1)
4      FORMAT(' ',8F10.3)
20     CONTINUE
       GO TO 26
25     CONTINUE
       STOP
       END
//GO.FT01F001 DD DSN=ACM.CMH063.LAND,DISP=OLD,VOL=SER=WIT241,
//     UNIT=SYSDA
//GO.FT10F001 DD DSN=LEBEWA.COPYH,UNIT=TAPE,DISP=(OLD,KEEP),
// VOL=SER=TFM001,LABEL=(3,SL),
// DCB=(RECFM=VBS,LRECL=192,BLKSIZE=1924)
//
//
```

CHAPTER 5

A TRIAL RUN OF THE LAND CAPABILITY ANALYSIS PROCEDURE

A land capability analysis in Northern Lebowa was performed in 1973 by a private company of consultants for the then Department of Bantu Administration. The result and data mapped at 1 : 100 000 were made available by kind permission (Swart, 1977) and it was the intention to analyse the data by the method developed in the study and to compare the result with that obtained by the consulting firm. Unfortunately, the data were not all quantitative and an insufficient number of land characteristics had been measured. A section extending from 28,640°west to 29.140°east and 23.000°north to 23.240°south was chosen as a trial area (Fig.39).

Fourteen maps were digitised using program CONTOR, edited by the relevant editing program ie. EDIT (polygons) or EDITLF (networks) or EDITPT (discrete points) and stored as separate primary data sets. Two secondary land data sets were created for a grid cell size of 1,1km^2 and of 0,55km^2 respectively, by overlaying the edited primary land data sets with a grid at a ratio of 1,0 and 0,5 ie. the grid axis was the same in the first instance as that of the digitised maps and halved in the second instance. Twenty-nine land characteristics were retrieved from the primary data sets by selecting different data items from their data string during the overlay process. A further sixteen

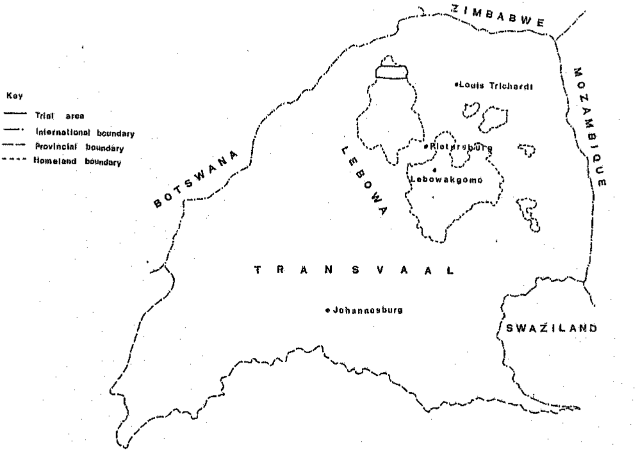


Fig.39 The location of the trial area in the Lebowa Homeland, South Africa

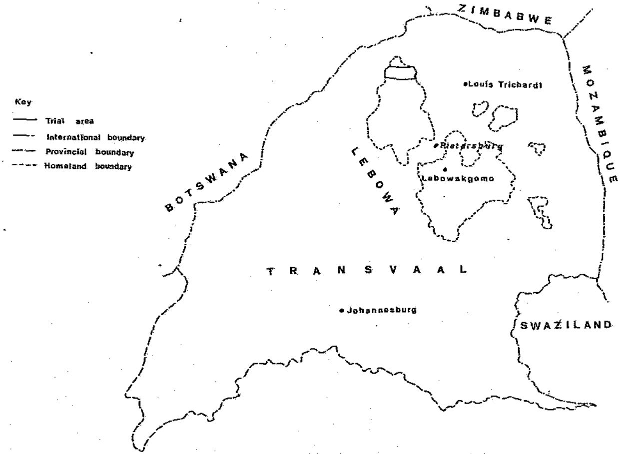


Fig.39 The location of the trial area in the Lebowa Homeland, South Africa

not depicted eg. National Park or not measured at the scale at which the maps were produced, eg. height above water, were assumed to have zero values, giving a total of forty-five land characteristics measured for each cell in the two secondary land data sets (see Table 72). Each had a number of data items which were either a field measurement eg. geological discontinuities, or derived from a field measurement eg. the soil erodibility index was based on the soil type given, in the descriptive data string.

5.1 Presentation of the Results

The program CAPANL prints the name of the study area and its extension. The following information is printed for each land use system analysed on this area:-

(a) Table of the land use types and their code numbers. This is for reference as all land uses in the result are referred to by the latter code numbers.

(b) Table of all the land characteristics required to analyse each land use type ie. a modification of Tables 13, 16, and 18-24.

(c) Table of the land characteristics selected from the above table (b) depending on their presence in the secondary land data set to be analysed and the chosen survey scale ie. whether the land was surveyed at a board (small) or detailed (large) level. This table also prints the permissible limits of each characteristic and its weight or whether it is used to evaluate the usable surface area.

(d) The land capability map, and its validity (ratio of the number of land characteristics present to the number actually required), the map of the usable surface area and

Table 72 - The Land Characteristics Present in the Secondary Land Data Set of a Trial Area in Northern Lebowa

Land Characteristic	Method of Measurement	Land Characteristic	Method of Measurement
LAND COVER		CLIMATE	
Rock surface	A	Climatic N-factor	D
Boulder cover	D	Wind velocity	M
Lake	M	Frost temperature	M
Reservoir	M	January temperature	M
River	M	July temperature	M
Stream	M	Season length	D
RELIEF		Season quality	D
Hillslope element	D	Evaporation	M
Height above water	A	Rainfall total	M
Natural land feature	A	Rainfall energy	D
Gully	A	Runoff total	M
GEOLOGY		BIOLOGICAL CHARACTERISTICS	
Stratigraphic unit	D	Physiognomic vegetation type	D
Natural rock group	D	MAN-MADE STRUCTURES AND BOUNDARIES	
Mineral ore deposit	A	Township	A
Depth to bedrock	D	Industrial area	A
Geological discontinuities	M	Settlement	M
SOIL		Powerline	A
Subsoil texture	M	Railway	A
Soil erodibility index	D	Paved road	A
Soil permeability index	D	National Park	A
Rooting depth	M	Mountain catchment area	A
Depth to water table	D	Wilderness area	A
Soil deficiency	A	Unpaved road	M
Soil toxicity	A		
Soil salinity	D		

Note

A - value of zero stored
D - value stored is derived from a measured value
M - stored value was measured in the field

simple statistics for both maps are printed. The number of land characteristics selected will generally be less as in the example given (Fig.40) unless all those required for the analysis of the land use have been measured.

(e) Map of the number of land characteristics which are outside their permissible limits as well as any grid cell excluded from the analysis by a limiting land characteristic or a missing datum value. This map is only printed if requested but it is valuable in interpreting the land capability map as a grid cell's low capability may be due to any of these factors. If a large number are excluded because of the permissible limits chosen (printed in Table (b)) these may be changed and the analysis redone if desired.

(f) An index of the map symbols is printed at the end of the job.

If another land use is analysed for the same land data set, the information in points (b) to (e) are printed again unless the land use is in the same land use system, in which case Table (b) is omitted. The information in points (a) and (c) to (e) is printed if the same land use is analysed for a different land data set.

The results of the analysis for a foreclosure of options in land use follow the same format except that the information in point (a) and (b) above is only printed once, at the beginning of the analysis. The validity of these maps is not calculated and the analysis is of a general nature ie. the map for a land use system eg.

```
THE LAND DATA SET BEING READ IS :-
NORTHERN LEBOWA LAND DATA (OVERLAID) 1980
              ( STORED ON DD CARD  11 )
       DATA SET HAS   45 LAND CHARACTERISTICS
       THE MAP WAS DIGITIZED AT A SCALE OF 1 : 100000.
       THE MAP OVERLAID EXTENDS       23.030 TO       23.240 NORTH AND
                                      28.840 TO       29.140 EAST

       THE OVERLAY GRID CELL IS      1.1  KILOMETRES   SQUARE


CONTROL DATA FOR THE EXCAVATION LAND USE SYSTEM
              ( STORED ON DD CARD  22 )

  THE LAND TYPES BEING COMBINED ARE      4
THE TABLE OF THE LAND USE TYPES AND THEIR CODES EVALUATED WITHIN THIS LAND USE SYSTEM
```

LAND USE TYPE	CODE
MINERAL ORE DEPOSIT	1
CONSTRUCTION MATERIAL	2
OPEN PIT MINING	3
QUARRY	4
UNDERGROUND MINE	5

THE TABLE OF THE LAND CHARACTERISTICS REQUIRED FOR AN EVALUATION OF

EACH LAND USE TYPE WITHIN THIS LAND USE SYSTEM

LAND CHARACTERISTICS	CODE	LAND USE TYPES 1	2	3	4	5
ROCK SURFACE	1	-	*	*	*	*
BOULDER COVER	2	-	*	*	*	*
LAKE	5	-	-	*	*	*
RESERVOIR	6	-	-	*	*	*
VLEI	7	-	-	*	*	*
RIVER	8	-	-	*	*	*
STREAM	9	-	-	*	*	*
HILLSLOPE ELEMENT	10	-	-	*	*	*
SLOPE GRADIENT	11	-	-	*	*	*
SLOPE LENGTH	12	-	-	*	*	*
HEIGHT ABOVE WATER	14	-	-	*	*	*
NATURAL ROCK GROUP	20	-	*	-	*	-
MINERAL ORE DEPOSIT	21	*	-	*	-	*
DEPTH TO MIN.ORE DEPOSIT	22	-	-	*	-	*
DEPTH TO BEDROCK	23	-	-	-	*	-
GEOLOGICAL DISCONT.	24	-	-	*	*	*
FACTOR OF SAFETY	25	-	-	*	*	*
ROCK HARDNESS	26	-	*	-	*	-
SECONDARY MINERALS	27	-	*	-	*	-
TEN PER CENT FINES	28	-	*	-	*	-
SUBSOIL TEXTURE	29	-	-	*	*	*
TOPSOIL TEXTURE	30	-	-	*	*	*
SOIL ERODIBILITY INDEX	32	-	-	*	*	*
SOIL PERMEABILITY INDEX	33	-	-	*	*	*
DEPTH TO WATER TABLE	35	-	-	*	*	*
CLIMATIC N-FACTOR	46	-	*	-	*	-
WIND VELOCITY	47	-	-	*	*	*
RAINFALL ENERGY	58	-	-	*	*	*
PHYSIOGNOMIC VEGE.TYPE	60	-	-	*	*	*
FLORISITIC VEGE.TYPE	61	-	-	*	*	*
WOODY COVER	62	-	-	*	*	*
TOWNSHIP	68	*	*	*	*	*
INDUSTRIAL AREA	69	*	*	*	*	*
SETTLEMENT	70	*	*	*	*	*
POWERLINE	71	-	-	*	*	*
RAILWAY	72	-	-	*	*	*
PAVED ROAD	73	-	-	*	*	*
MOUNTAIN CATCHMENT AREA	78	*	*	*	*	*
WILDERNESS AREA	79	*	*	*	*	*
UNPAVED ROAD	80	-	*	*	*	*

Fig.40 The land capability for Quarry Sites in the trial area, Northern Lebowa. Grid cell size was 1,1km^2.

THE TABLE OF THE [illegible] UPPER & LOWER LIMITS & THE WEIGHT FOR THE LAND CHARACTERISTICS [illegible] IN THE EVALUATION OF THE LAND USE TYPE 4

THE SYMBOL [illegible] THOSE CHARACTERISTICS WHICH ARE ONLY USED TO CALCULATE THE USABLE SURFACE AREA

ALL LIMITS ARE INCLUSIVE (FOR UNITS, SEE TEXT)

LAND CHARACTERISTICS	UPPER LIMIT	LOWER LIMIT	WEIGHT.
ROCK SURFACE	100.00	0.0	1.0
LAKE	100.00	0.0	U
RESERVOIR	100.00	0.0	U
RIVER	5.00	0.0	1.0
STREAM	5.00	0.0	1.0
HILLSLOPE ELEMENT	5.00	1.00	3.0
GEOLOGICAL DISCONT.	999.99	0.0	1.0
SOIL ERODIBILITY INDEX	8.00	3.50	1.0
SOIL PERMEABILITY INDEX	4.00	1.00	1.0
CLIMATIC N-FACTOR	10.00	1.00	1.0
WIND VELOCITY	20.00	0.0	1.0
RAINFALL ENERGY	30.00	0.0	1.0
PHYSIOGNOMIC VEGE.TYPE	49.00	11.00	1.0
TOWNSHIP	90.00	0.0	U
INDUSTRIAL AREA	90.00	0.0	U
SETTLEMENT	90.00	0.0	U
POWERLINE	5.00	0.0	1.0
RAILWAY	5.00	0.0	1.0
MOUNTAIN CATCHMENT AREA	90.00	0.0	U
WILDERNESS AREA	90.00	0.0	U
UNPAVED ROAD	5.00	0.0	1.0

THE LAND CAPABILITY MAP FOR THE LAND TYPES 4

THE LAND CAPABILITY MAP FOR NORTHERN LEBOWA LAND DATA (OVERLAID) 1980
THE INDEX FOR THE MAP SYMBOLS IS PRINTED AT THE END OF THE JOB

THE PROPORTION OF THE REQUIRED LAND CHARACTERISTICS WHICH ARE PRESENT IN THE LAND DATA SET IS 0.808

THE ANALYSIS IS PERFORMED AT THE BROAD LEVEL

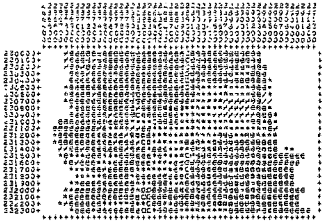
DISTRIBUTION OF THE WEIGHTED PERCENTAGE CAPABILITY VALUES IN THE MAP

DATA SET HAS 961 VALUES
MAXIMUM IS 100.0
MINIMUM IS 0.0
RANGE IS 100.0

MAP SYMBOLS NUMBER	LOWER LIMIT	UPPER LIMIT	FREQUENCY	% FREQUENCY
0	0.0	0.0	0	0.0
1	0.01	10.00	0	0.0
2	10.01	20.00	2	0.21
3	20.01	30.00	3	0.31
4	30.01	40.00	203	21.12
5	40.01	50.00	42	4.37
6	50.01	60.00	643	66.91
7	60.01	70.00	68	7.08
8	70.01	80.00	0	0.0
9	80.01	90.00	0	0.0
10	90.01	100.00	0	0.0

Fig.40 (contd.)

THIS IS MAP SECTION 1 OF 1



THE MAP OF THE ABOVE SECTION SHOWING THE PERCENTAGE USABLE SURFACE AREA WITHIN EACH GRID CELL

DISTRIBUTION OF THE USABLE SURFACE AREA IN THE MAP

DATA SET HAS 961 VALUES

MAXIMUM IS 100.0

MINIMUM IS 94.9

RANGE IS 5.1

MAP SYMBOLS NUMBER	LOWER LIMIT	UPPER LIMIT	FREQUENCY	% FREQUENCY
1	94.86	95.37	1	0.10
2	95.38	95.89	3	0.31
3	95.90	96.40	0	0.0
4	96.41	96.91	0	0.0
5	96.92	97.43	0	0.0
6	97.44	97.94	5	0.52
7	97.95	98.46	0	0.0
8	98.47	98.97	0	0.0
9	98.98	99.49	0	0.0
10	99.50	100.00	952	99.06

THIS IS MAP SECTION 1 OF 1

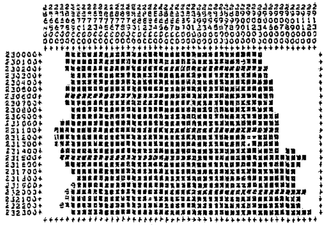


Fig.40 (contd.)

THE MAP OF THE SAME SECTION SHOWING THE NUMBER OF LAND CHARACTERISTICS
WHICH ARE OUTSIDE THEIR VALUE RANGE IN EACH CELL.

A LIMITING LAND CHARACTERISTIC GIVES THE CELL THE A VALUE L
A MISSING VALUE GIVES THE CELL A VALUE M

DISTRIBUTION OF THE LAND CHARACTERISTIC VALUES
DATA SET HAS 961 VALUES
MAXIMUM IS 5.0
MINIMUM IS 1.0
RANGE IS 4.0

MAP SYMBOLS NUMBER	LOWER LIMIT	UPPER LIMIT	FREQUENCY	% FREQUENCY
0	1.00	1.40	186	19.35
1	1.41	1.80	447	46.51
2	1.81	2.20	0	0.0
3	2.21	2.60	299	31.11
4	2.61	3.00	0	0.0
5	3.01	3.40	1	0.10
6	3.41	3.80	0	0.0
7	3.81	4.20	0	0.0
8	4.21	4.60	3	0.31
9	4.61	5.00	0	0.0
10	5.01	5.40	25	2.60
L			0	0.0
M			186	19.35

THIS IS MAP SECTION 1 OF 1

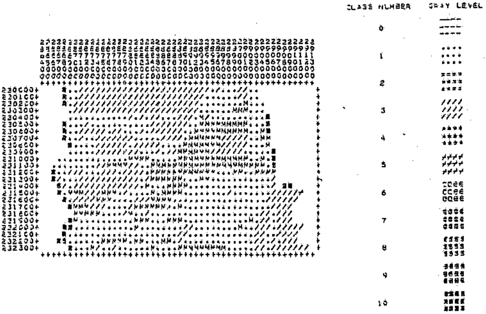


Fig.40 (contd.)

agriculture, analysed for this foreclosure of options indicates a general capability rating of the land for that system (Fig.41).

If another land use eg. urban development, is to be implemented, a land capability analysis for any agricultural land use should be performed to indicate a more specific capability rating of the land (a land use system is a general land use) so that a more definite location of eg. prime agricultural land is determined and the consequence of a foreclosure in this option may be studied.

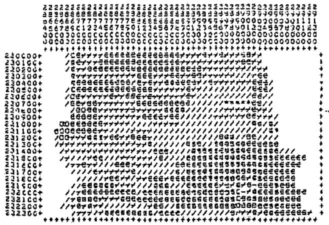
5.2 The Comparison of the Land Capability Analysis Results for Livestock Production on Natural Veld with Associated Dryland Summer Season Cropping, Performed by the Computerised Procedure and by a Manual Method

The results of the land capability analysis performed by the private consultants did not indicate areas of *different* capability for a specific land use as is printed by the procedure. Only areas where six different agricultural land uses may be implemented were shown. Of these six viz. dominantly dryland and crop production, dominantly livestock production with associated crop production divided into three sub-types depending on the relative inputs into either livestock or crop production, and livestock production sub-divided into two on the basis of the pasture grass, the dominantly livestock production - with associated crop production corresponded to a combination of the land use types of farming land, summer season cropping and natural veld pasture given in this study. The permissible lower level for rainfall given in the default agriculture control data set ie. 600 mm a^{-1} was changed to 425 mm a^{-1} to

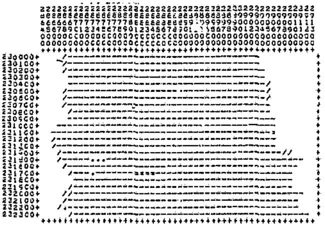
THE TABLE OF THE LAND USE SYSTEMS AND THEIR CODES
EVALUATED FOR THE FORECLOSURE OF OPTIONS IN LAND USE

LAND SYSTEM	CODE
AGRICULTURE	1
FORESTRY	2
CONSERVATION	3
RECREATION	4
EXCAVATION	5
WATER CATCHMENT	6

THE LAND CAPABILITY MAP FOR THE FORECLOSURE IN OPTIONS IN LAND USE, LAND SYSTEM 1



THE LAND CAPABILITY MAP FOR THE FORECLOSURE IN OPTIONS IN LAND USE, LAND SYSTEM 2



THE LAND CAPABILITY MAP FOR THE FORECLOSURE IN OPTIONS IN LAND USE, LAND SYSTEM 3

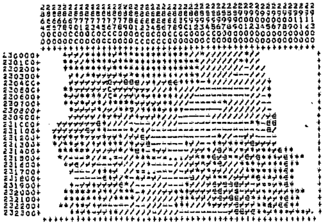
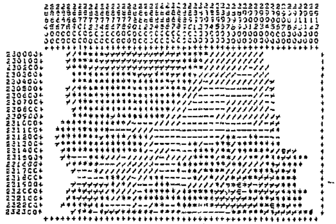
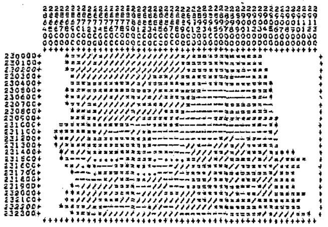


Fig.41 The land capability maps for the foreclosure of options in land use in the trial area, Northern Lebowa. Grid cell size was 1,1km^2.

THE LAND CAPABILITY MAP FOR THE FORECLOSURE IN OPTIONS IN LAND USE, LAND SYSTEM 4



THE LAND CAPABILITY MAP FOR THE FORECLOSURE IN OPTIONS IN LAND USE, LAND SYSTEM 5



THE LAND CAPABILITY MAP FOR THE FORECLOSURE IN OPTIONS IN LAND USE, LAND SYSTEM 6

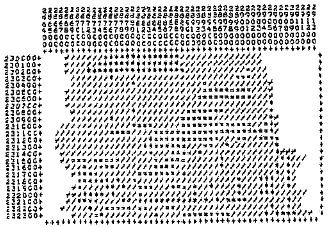


Fig.41 (contd.)

correspond to the permitted range of 310 - 500 mm a^{-1} specified by the consultants. The capability analysis for this composite land use type was performed at a broad scale (Fig.42,2)(where general measurements of a land feature are assessed eg. soil permeability index rather than soil texture) and at a detailed scale (where a specific measurement of the land feature is assessed)(Fig.42.1). The validity of these maps were 0,758 with nineteen per cent of the grid cells containing missing data and 0,587 with eighty per cent of the grid cells containing missing data respectively. Thus the latter is neglected.

Fig.43, the printout of the land capability map from the manual technique, was obtained by digitising the map into a primary data set, overlaying this set with a grid of 1,1km^2 and printing it by selecting the option to print a map of a data item in the data string of the grid cells.

Two analyses, Fig.44.1 and Fig.44.2, were performed, the former weighting the climatic factors while the latter weighted the soil factors. Both gave a maximum capability of five to the area but the proportion of land with this value and the distribution between the remaining capability values derived, differed (Figs 44.1 and 44.2). The map of the limiting land characteristics and missing data were the same. Thus the capability derived is dependent on the weighting given, as was expected, and the ability to vary these weightings to reflect the effect of different land characteristics, planning aims, policies etc. is an important feature of a capability analysis technique. The area suggested by the consultants for the land use

42.1

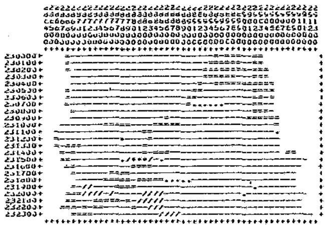
THE ANALYSIS IS PERFORMED AT THE DETAILED LEVEL

THE PROPORTION OF THE REQUIRED LAND CHARACTERISTICS

WHICH ARE PRESENT IN THE LAND DATA SET IS 0.567

THIS IS MAP SECTION 1 OF 1

MAP SYMBOLS NUMBER	LOWER LIMIT	UPPER LIMIT	FREQUENCY	% FREQUENCY
0	0.0	0.0	761	75.15
1	0.01	10.00	10	1.66
2	10.01	20.00	155	16.13
3	20.01	30.00	25	2.60
4	30.01	40.00	4	0.42
5	40.01	50.00	0	0.0
6	50.01	60.00	0	0.0
7	60.01	70.00	0	0.0
8	70.01	80.00	0	0.0
9	80.01	90.00	0	0.0
10	90.01	100.00	0	0.0



42.2

THE ANALYSIS IS PERFORMED AT THE BROAD LEVEL

THE PROPORTION OF THE REQUIRED LAND CHARACTERISTICS

WHICH ARE PRESENT IN THE LAND DATA SET IS 0.733

THIS IS MAP SECTION 1 OF 1

MAP SYMBOLS NUMBER	LOWER LIMIT	UPPER LIMIT	FREQUENCY	% FREQUENCY
0	0.0	0.0	2	0.21
1	0.01	10.00	3	0.31
2	10.01	20.00	225	23.39
3	20.01	30.00	9	0.94
4	30.01	40.00	668	69.44
5	40.01	50.00	55	5.72
6	50.01	60.00	0	0.0
7	60.01	70.00	0	0.0
8	70.01	80.00	0	0.0
9	80.01	90.00	0	0.0
10	90.01	100.00	0	0.0

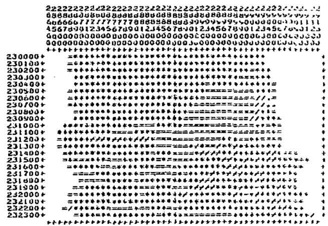


Fig.42 The results of the capability analysis for livestock production on natural veld with associated summer season cropping conducted at the board (small) and detailed (large) survey scale in the trial area, Northern Lebowa. Grid cell size was 1,1km^2.

THE OVERLAY GRID CELL IS 1.1 KILOMETRES SQUARE

THE MAP WAS DIGITIZED AT A SCALE OF 1 : 100000.

THE MAP OVERLAID EXTENDS 23.000 TO 23.240 NORTH AND

28.840 TO 29.140 EAST

MAP SYMBOLS NUMBER	LOWER LIMIT	UPPER LIMIT	FREQUENCY	% FREQUENCY
0	0.0	0.0	28	2.79
1	0.0	0.60	0	0.0
2	0.61	1.20	25	2.49
3	1.21	1.80	0	0.0
4	1.81	2.40	275	27.36
5	2.41	3.00	228	22.69
6	3.01	3.60	0	0.0
7	3.61	4.20	47	4.68
8	4.21	4.80	0	0.0
9	4.81	5.40	214	21.29
10	5.41	6.00	168	16.71

THIS IS MAP SECTION 1 OF 1

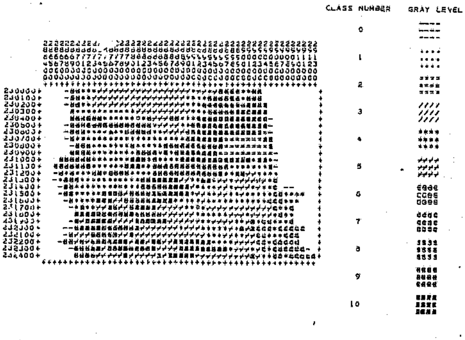


Fig.43 The land capability map for Agricultural Land Use in the trial area, *Northern Lebowa, produced by* a manual overlay method. Grid cell size of this map was 1,1km^2.

THE TABLE OF THE PERMISSIBLE UPPER & LOWER LIMITS & THE WEIGHTS
FOR THE LAND CHARACTERISTICS
THE SYMBOL U INDICATES THOSE CHARACTERISTICS WHICH ARE ONLY USED TO CALCULATE
THE USABLE SURFACE AREA

ALL LIMITS ARE INCLUSIVE (FOR UNITS, SEE TEXT)

LAND CHARACTERISTICS	UPPER LIMIT	LOWER LIMIT	WEIGHT
ROCK SURFACE	90.00	0.0	U
LAKE	90.00	0.0	U
RESERVOIR	90.00	0.0	U
RIVER	5.00	0.0	U
STREAM	5.00	0.0	U
HILLSLOPE ELEMENT	7.00	1.00	3.0
GULLY	90.00	0.0	U
SOIL ERODIBILITY INDEX	8.00	3.50	3.0
SOIL PERMEABILITY INDEX	4.00	2.00	2.0
SOIL DEFICIENCY	0.0	0.0	1.0
SOIL TOXICITY	0.0	0.0	1.0
WIND VELOCITY	20.00	0.0	1.0
JANUARY TEMPERATURE	45.00	0.0	1.0
SEASON LENGTH	999.99	100.00	2.0
SEASON QUALITY	999.99	25.00	4.0
EVAPORATION	9999.99	0.0	1.0
RAINFALL TOTAL	9999.99	425.00	4.0
RAINFALL ENERGY	30.00	0.0	3.0
PHYSIOGNOMIC VEGE. TYPE	33.00	15.00	1.0
TOWNSHIP	90.00	0.0	U
INDUSTRIAL AREA	90.00	0.0	U
SETTLEMENT	90.00	0.0	U
POWERLINE	5.00	0.0	U
RAILWAY	5.00	0.0	U
UNPAVED ROAD	5.00	0.0	1.0

THE LAND CAPABILITY MAP FOR NORTHERN LEBOWA LAND DATA (OVERLAID) 1980
THE INDEX FOR THE MAP SYMBOLS IS PRINTED AT THE END OF THE JOB

MAP SYMBOLS NUMBER	LOWER LIMIT	UPPER LIMIT	FREQUENCY	% FREQUENCY
0	0.0	0.0	2	0.21
1	0.01	10.00	3	0.31
2	10.01	20.00	224	23.28
3	20.01	30.00	10	1.04
4	30.01	40.00	668	69.44
5	40.01	50.00	55	5.72
6	50.01	60.00	0	0.0
7	60.01	70.00	0	0.0
8	70.01	80.00	0	0.0
9	80.01	90.00	0	0.0
10	90.01	100.00	0	0.0

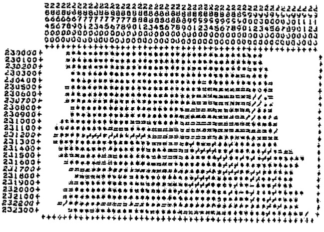


Fig.44.1 The land capability for livestock production on natural veld with associated summer season cropping in the trial area, Northern Lebowa. Climatic factors were given a higher weighting. Grid cell size was 1,1km^2.

THE TABLE OF THE PERMISSIBLE UPPER & LOWER LIMITS & THE WEIGHTS
FOR THE LAND CHARACTERISTICS
THE SYMBOL U INDICATES THOSE CHARACTERISTICS WHICH ARE ONLY USED TO CALCULATE
THE USABLE SURFACE AREA

ALL LIMITS ARE INCLUSIVE (FOR UNITS, SEE TEXT)

LAND CHARACTERISTICS	UPPER LIMIT	LOWER LIMIT	WEIGHT
ROCK SURFACE	90.00	0.0	U
LAKE	90.00	0.0	U
RESERVOIR	90.00	0.0	U
RIVER	5.00	0.0	U
STREAM	5.00	0.0	U
HILLSLOPE ELEMENT	7.00	1.00	1.0
GULLY	90.00	0.0	U
SOIL ERODIBILITY INDEX	8.00	3.50	1.0
SOIL PERMEABILITY INDEX	4.00	2.00	4.0
SOIL DEFICIENCY	0.0	0.0	1.0
SOIL TOXICITY	0.0	0.0	1.0
WIND VELOCITY	20.00	0.0	1.0
JANUARY TEMPERATURE	45.00	0.0	1.0
SEASON LENGTH	999.99	130.00	1.0
SEASON QUALITY	999.99	25.00	1.0
EVAPORATION	9999.99	0.0	1.0
RAINFALL TOTAL	9999.99	425.00	1.0
RAINFALL ENERGY	30.00	0.0	1.0
PHYSIOGNOMIC VEGE. TYPE	33.00	15.00	1.0
TOWNSHIP	90.00	0.0	U
INDUSTRIAL AREA	90.00	0.0	U
SETTLEMENT	90.00	0.0	U
POWERLINE	5.00	0.0	U
RAILWAY	5.00	0.0	U
UNPAVED ROAD	5.00	0.0	1.0

THE LAND CAPABILITY MAP FOR NORTHERN LEBOWA LAND DATA (OVERLAID) 1980
THE INDEX FOR THE MAP SYMBOLS IS PRINTED AT THE END OF THE JOB

MAP SYMBOLS NUMBER	LOWER LIMIT	UPPER LIMIT	FREQUENCY	% FREQUENCY
0	0.0	0.0	2	0.21
1	0.01	10.00	210	21.83
2	10.01	20.00	18	1.87
3	20.01	30.00	80	8.32
4	30.01	40.00	169	17.57
5	40.01	50.00	483	50.21
6	50.01	60.00	0	0.0
7	60.01	70.00	0	0.0
8	70.01	80.00	0	0.0
9	80.01	90.00	0	0.0
10	90.01	100.00	0	0.0

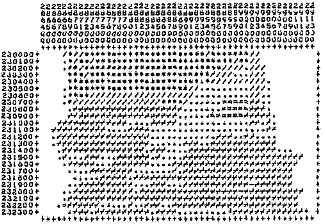


Fig.44.2 The land capability for livestock production on natural veld with associated summer season cropping in the trial area, Northern Lebowa. Soil factors were given a higher weighting. Grid cell size was 1,1km^2.

analysed corresponded classes 4, 5 and 7 in the north-west to a capability of four while the main area for the extensive livestock product, from north to south across the middle of the map, had a general capability of two when the climatic factors were weighted. The same correspondence in area occurred by weighting the soil factors but the capability given was lower. The actual technique used by the consultants is not made known and thus the inclusion of any weighting is unknown. Possibly, both climate and soil were analysed as being of equal importance.

The presentation of only one land use per area does not provide a planner with any information as to the relative capability of the area for different land uses or to the capability ratings given to each area represented as best for a particular land use. The advantage of the results from the computerised technique is that the relative capability of the different areas for a land use is available.

The statistics of the map at a grid cell size of 0,55km^2 (Fig.45) cannot be compared with those for the map at a cell size of 1,1km^2 as the total area analysed was different. A section of the trial area overlaid at the cell size was analysed to illustrate the option of retrieving a selected portion of an area for analysis. Two areas with a capability of two extending from 287 550 to 287 650 east and 287 804 to 287 900 east at 231 100 north in Fig.45 are not present in Fig.42.2 which shows an area of the same capability extending from 288 000 – 288 30 east at the same northerly location. This indicates that the results of a

THE LAND DATA SET BEING READ IS :-

NORTHERN LEBOWA LAND DATA (OVERLAID) 1980

(STORED ON DD CARD 12)

DATA SET HAS 45 LAND CHARACTERISTICS

THE MAP WAS DIGITIZED AT A SCALE OF 1 : 100000.

THE MAP OVERLAID EXTENDS 23.000 TO 23.240 NORTH AND

28.640 TO 29.140 EAST

THE OVERLAY GRID CELL IS 0.6 KILOMETRES SQUARE

THE PORTION OF THE MAP SELECTED FOR THIS JOB EXTENDS

23.000 TO 23.125 NORTH AND 28.640 TO 28.885 EAST

THE LAND CAPABILITY MAP FOR NORTHERN LEBOWA LAND DATA (OVERLAID) 1980

THE INDEX FOR THE MAP SYMBOLS IS PRINTED AT THE END OF THE JOB

THE PROPORTION OF THE REQUIRED LAND CHARACTERISTICS WHICH ARE PRESENT

IN THE LAND DATA SET IS 0.758

THE ANALYSIS IS PERFORMED AT THE BROAD LEVEL

DISTRIBUTION OF THE WEIGHTED PERCENTAGE CAPABILITY VALUES IN THE MAP

DATA SET HAS 1056 VALUES

MAXIMUM IS 100.0

MINIMUM IS 0.0

RANGE IS 100.0

MAP SYMBOLS NUMBER	LOWER LIMIT	UPPER LIMIT	FREQUENCY	% FREQUENCY
0	0.0	0.0	0	0.0
1	0.01	10.00	0	0.0
2	10.01	20.00	81	7.67
3	20.01	30.00	1	0.09
4	30.01	40.00	941	89.11
5	40.01	50.00	33	3.12
6	50.01	60.00	0	0.0
7	60.01	70.00	0	0.0
8	70.01	80.00	0	0.0
9	80.01	90.00	0	0.0
10	90.01	100.00	0	0.0

THIS IS MAP SECTION 1 OF 1

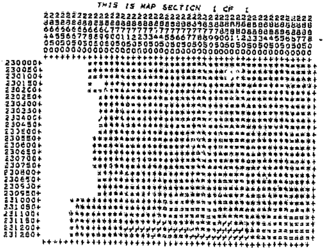


Fig.45 The land capability for livestock production on natural veld with associated summer season cropping in the trial area, Northern Lebowa. Climatic factors were given a higher weighting. Grid cell size was 0,6 (0,55km^2).

capability analysis is a function of the grid cell size as the heterogeneity within a cell is a function of its size. Thus an important feature of a land capability analysis technique should be its performance at any grid cell size as is possible in the procedure developed.

The two blank cells at 286 850 and 286 900 east respectively and 230 150 have zero values for each land characteristic. This situation is recognized by the land capability analysis program as being outside the map boundary. This is not the case and was not expected as the capability of these cells is either two or four and the overlay program was tested for as many situations as was thought possible. For a total of 1 274 cells, only two cells have been affected. Thus the overlay program has an accuracy of ninety-eight per cent.

5.3 Results of the Land Capability Analyses Performed

A full set of capability analyses were performed for all the land use systems as well as a foreclosure of options in land use. For the purposes of this assessment of the method it is unnecessary and would in fact be distracting to present each one. A subset representing a cross-section of the land use systems is therefore presented in Fig.46 and their main capability for the land is given in Table 73. Most land in the trial area is best for informal recreation activities while none are suitable for subtropical forestry which is expected, due to the low rainfall received. The high capability for recreation was not indicated at all by the manual method as the land was not analysed for it. This indicates the importance that the method used should allow for the analysis of different land use types.

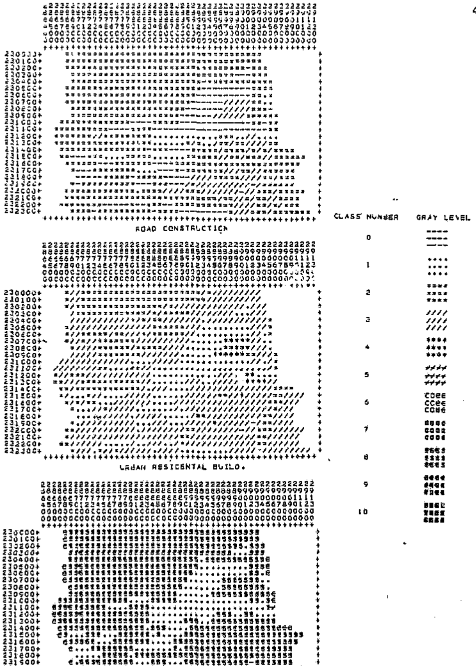


Fig.46 The land capability for road construction, urban residential buildings and informal recreational activities in the trial area, Northern Lebowa. Grid cell size was 1,1km^2.

Table 73 - The Results of the Land Capability Analysis from a Cross-section of Land Use Types and the Foreclosure of Options in Land Use on the Trial Area Overlaid with a Grid Cell Size of 1.1km²

Land Use System	Land Use Type	Land factors given the greatest weighting	Dominant Capability	
			Value	Properties %
Agriculture	Dominant live stock production with associated dryland summer season cropping	Climate	4	69
Forestry	Subtropical forestry on pit-prepared land	Climate	0	100
Conservation	Conservation	Vegetation and soil erosion	0	70
Recreation	Informal activities	Natural land features	8	77
Urban and rural development	Urban residential buildings	Geology	3	53
Communication	Road construction	Geology	2	70
Excavations	Quarry	Relief	6	66
Water catchment	Water catchment	Runoff	4	35
Foreclosure in options	Agriculture	Climate	6	34
	Forestry	Climate	0	96
	Conservation	Vegetation, soil erosion	4	32
	Recreation	Water	4	50
	Excavation	Mineral and rock type	2	51
	Water catchment	Runoff	3	65

The foreclosure of options in land use indicates that except for forestry all the other land use systems may be implemented in the trial area. Thus these systems should be analysed for land uses whose implementation is feasible, to obtain a more detailed analysis of the land (the foreclosure of options is analysed generally) before compiling the final land use plan. The statistics of the foreclosure of options and those of the land use types given in Table 73 cannot be compared because different weightings were used eg. the quarry land use weighted the relief while the excavation land use system weighted the presence of minerals on rock and also the land use was analysed in greater detail.

5.4 Conclusion

Although the data used was not originally in a form directly suitable for this procedure, the trial run has indicated that the results of a land capability analysis using overlay techniques is a function of the grid cell size used. A further influencing factor is the importance of each land variable analysed.

A versatile land capability analysis method allowing for these variables has been developed for any land use and for the analysis of the foreclosure of options in land use.

CHAPTER 6

DISCUSSION

At the commencement of this study it was thought that quantified information as to the various land characteristics which must be analysed for different land uses, the interrelationships between these land characteristics, their relative importances to various land uses, the optimum values for each land characteristic and their range of values required for a land use, would be available. However, as the study progressed it was found that very little of such detailed information was in fact available. What was 'known' was often a subjective assessment or was given in qualitative terms, eg. maize requires a 'high' rainfall. The detailed information outlined above is necessary if land, as an ecological system of interrelated components, is to be understood in such a way that man plans with the land and not against it. Thus a land capability analysis of the land expressed by objective data is a necessary basis for a land use plan. However one of the realizations emerging from this study is that we have very little detailed knowledge of the functions of the land as a complete ecological system.

In the absence of such data, one may query whether all the relevant, more or less constant, land characteristics have been included in the capability analysis of each land use system. Variable land characteristics (eg. soil structure) have been omitted. It is considered that all the major land characteristics have been included for those land qualities considered. However, certain land qualities, considered to be important by a subsequent user of this procedure, may have been omitted and thus certain land characteristics may also have been omitted. All those land qualities known to be important to at least one land use type, have been included. Since it is possible to add land characteristics to the procedure, any possible omissions are easily rectified. It is also possible to add other land use systems to the procedure.

The land characteristics influence the land uses in various ways and were therefore analysed either as limiting land characteristics, control land characteristics, or as land characteristics given a capability rating either from capability tables or from capability graphs. The method chosen for each land characteristic was that which was considered to best reflect the effect of that land characteristic on the overall capability of the land, according to the existing knowledge. No research information specifying how each should be analysed in a capability analysis was found. When these data become available, the methods chosen in this study may need to be changed.

It is appreciated that the complex relationships between the land characteristics are dealt with by simplistic models. This was a deliberate decision since there is insufficient information to express them quantitatively. As this information becomes available, so the necessary changes will be made if these simplistic models need to be rectified, and other interrelationships which may have been omitted, will be added. At this stage the interrelationships are more realistically modelled by erring on the simplistic side, using the information known, rather than by incorporating complexities which are not fully understood.

It is also realised that the form of the capability graphs and the values given in the capability tables are open to criticism due to the lack of necessary data concerning the optimum and range values required by the land characteristics with regard to a land use. Necessary changes may easily be made as more information becomes available.

The overall capability of each land unit (ie. grid cell) is determined without reference to the condition of the neighbouring cells eg. a cell with a large township and industrial area will affect the siting in a neighbouring cell of rural residences, whose emphasis is on the 'naturalness' of the area. This is a limitation of the procedure, but it was not removed as to do so would not have been cost affective with respect to the required extra computer time. The computer time would have been much increased because each time a cell was analysed, search routines to determine various conditions present in all neighbouring cells would have been required. In many cases, the conditions present in neighbouring cells may be shown by analysing the land for other land uses. The results of these analyses may then be compared to give a more complete understanding of the situation. For instance, in the above example a land capability analysis for an industrial land use would have given a high overall capability to cells with industrial centres, especially if that land characteristic had been weighted. The results of this analysis when compared with those from an analysis for residential land use, would indicate the occurrence of incompatible land uses in neighbouring cells as well as in the same cell.

Another limitation of the procedure is that the cover of certain land characteristics is not calculated but is taken to be either zero if absent or fifty per cent if present when the primary data sets are overlaid. The accuracy obtained in calculating the area was not considered to be sufficient compensation for the increased execution time required. Also, by selecting the most appropriate grid cell size (for the objectives of the particular analysis) much of this problem is eliminated. In the case of both of the above limitations, the need for a tool which was usable at low cost was considered of overriding importance. The analysis of various land uses at different grid cell sizes and involving the selection of different weightings was considered to be more desirable and useful than a more accurate but expensive tool whose full potential and usefulness would not be used because of the expense involved.

The execution of the land capability analysis program is not as efficient as was desired due to the absence of a data base system in a form which is useful to ecological users. Such a data base system is a resource inventory in which a data string composed of the measured values of various land characteristics is linked to a georeference.

Each item of data should be retrievable individually. The storage of relatively constant data is desirable, as variable variable data would require constant updating. Thus any variable land characteristic was omitted or substituted by a land characteristic of a more constant nature. For example, vegetation type is measured in preference to vegetation cover as the cover is easily changed or removed, and thus its measured value is of a temporary nature. This study has highlighted the need for such a data base system in South Africa, particularly since detailed and integrated land planning is growing in importance. The data base should be initiated before individual organizations set up their own systems, with their own variable definitions, scale of data storage, etc. as this would preclude any transfer of data between individual systems. Also, the design of such systems may restrict the usefulness of the data eg. if the data are measured and stored in grid cells, the grid cell size may not be that required by a user. Thus, before any data base system is developed, the users should be consulted so that the system will be used. This procedure is one prospective user of the data base system and the potential use of such a system for land planning can be envisaged from the results of this study (Section 5).

The simple data base system set up for this study was executed by the Wits system so that it could be interactive. The advantage of this is that the user is guided step-by-step through the procedure and thus less user error is possible. However, the interactive programs are restricted by the limitations of Wits FORTRAN, eg. no data statements are possible and the Wits data base system cannot store and retrieve unformatted records accurately. Therefore, two systems viz. Wits and the open system at this computer centre, had to be incorporated together. It has meant that the whole procedure is not completely independent of the Wits system,as was desired,so that the procedure could be easily transferred between various computer installations. The Wits system is specific to the computer centre at the University. However, the heart of the procedure, ie. programs OVER3 and CAPANL, is independent of the Wits system and can be easily transferred. Only the interactive property of the procedure would be lost.

An *important feature of the procedure which is* considered to be an improvement of most other studies reviewed (eg. M.L.M.I.S. (Craig, 1979) South Coast Project. Australia (Austin and Cocks, 1977) *is the storage of* digitised map data which are overlaid in the computer for analysis in a grid form by the land capability analysis program. The advantage of this is that the analysis may be performed at any selected grid cell size. The need for this arises due to the unavoidable loss of detail in the maps. The detail captured within a grid cell and the dominance of the values used, may be altered by changing the grid cell size. This is shown by the results of the Lebowa analysis. It also overcomes the problem of data stored at a fixed grid cell size which may cause an important loss of detail, so that the differences and similarities between land are not apparent. This problem is not present in the Canada Land Inventory CLI system (McCormack, 1971) in which digitised maps are stored and overlaid by a complex procedure. The disadvantage of this system, however is that it is complex to use (Walker, 1980, personal communication). In the procedure presented here the emphasis has been on developing a system which will suit the requirements of the user and it must allow for the versatility required by this procedure. Another important feature of the procedure is that the definition of the land use being evaluated depends on the user. It can therefore be used for many land uses, and is not only for a particular land use as occurred for example in the study by Young and Goldsmith (1977) and the procedure of Klingebi l and Montgomery (1961). It will also analyse data surveyed at any scale and by any method ie. the genetic, the landscape and the parametric method, provided that the data measured correspond to the land characteristic defintions. These definitions are for unclassified data. Many studies have used classified ie. a number of classes each representing a range of values, are defined for a land characteristic measured for a particular purpose. The class and not the particular value is recorded for the characteristic data eg. G.E.M. (National Physical Planning Agency, 1977); Kiefer and Robbins (1968); Beaumont <u>et al</u> (1975) and Scotney (1971). The storage of unclassified data means that the data base system can be used for other purposes. Classified data are measured for a particular purpose and are only valuable for that purpose. Any subsequent changes in the classification system are not possible unless the data are remeasured. This procedure uses unclassified data.

The Lebowa results have shown that the procedure is a versatile tool enabling a user to analyse different land uses with different weightings of the land characteristics, at different grid cell sizes. It does not supply all the answers for a land planner but rather detects problems in management and degradation. It may be extended into a land suitability analysis by incorporating economic land characteristics that will measure the inputs and benefits. The procedure versatility and usefulness can be extended if an integrated land capability map is produced. At the moment this is done manually. A map of this sort may be produced by storing the results of each land capability analysis for different land uses. These results would be retrieved and sorted to determine the highest capability for a grid cell. A symbol representing the particular land use to which this refers, would be printed for that grid cell. A further extension of this would be the incorporation of goal programming (eg. Bell, 1976). A land use plan has a number of goals to be realised and generally conflict exists between some of these goals. Goal programming is a distinctive mathematical programming formulation of the problem of coming 'as close as possible to a set of unattainable goals' (Dyer, 1972). It minimizes the discrepancy between goals and thus their achievement even when conflict between the goals exists (Bell, 1976).

The purpose of this procedure is to provide planners with a versatile tool to analyse the land itself for different land uses in different ways, so that the final land plan produced is based on a greater understanding of the land than would be possible in its absence. It is considered that the development of such a tool has been achieved and it is hoped that it will prove to be useful and valuable.

APPENDIX A

List of Persons and Institutes from whom information received was used in the compilation of the permissible limits and optimum values for land use (Tables 13 - 24), and the development of the capability graphs (Figs. 6-14) and tables (Tables 26-60).

Persons

Allison, J.C.S. S.A. Sugar Association Experimental Station, P.O. Mt Edgecombe, 4300, South Africa.

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Zebecheta Citrus Private (Ltd), P.O. Box Zebediela, 0627.

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C
C
C
C         THIS FILE CONTAINS ALL THE CONTROL DATA SETS USED IN THE EXECUTION
C         OF CAPANL, THE LAND CAPABILITY ANALYSIS PROGRAM
C
C
 CONTROL DATA FOR THE AGRICULTURE LAND USE SYSTEM
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  0 44 45 47  0  0  0  0  0  0  0  0  0  0 58 60 61 62 63  0 68 69 70 71 72 73
 78 80
  1  2  3  4  5  6  7  8  9 10 11 12  0 15 17 29 30 32 33 34 35 36 39 40  0 42
  0 44 45 47  0  0  0  0  0  0  0  0  0  0 58 60 61 62 63  0 68 69 70 71 72 73
 78 80
  1  2  3  4  5  6  7  8  9 10 11 12  0 15 17 29 30 32 33 34 35 36 39 40 41 42
 43 44 45 47  0  0  0  0  0  0  0  0  0  0 58 60 61 62 63  0 68 69 70 71 72 73
 78 80
  1  2  3  4  5  6  7  8  9 10 11 12  0 15 17 29 30 32 33 34 35 36 39 40 41 42
 43 44 45 47  0  0  0  0  0  0  0  0  0  0 58 60 61 62 63  0 68 69 70 71 72 73
 78 80
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 78  0
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 78  0
  1  0  0  0  5  6  7  0  0  0  0  0 14 15 17  0  0  0  0  0  0  0  0  0  0  0
  0  0  0  0 48  0 50 51 52  0 54 55 56 57  0 60 61  0  0  0 68 69 70  0  0  0
 78  0
  1  0  0  0  5  6  7  0  0  0  0  0 14 15 17  0  0  0  0  0  0  0  0  0  0  0
  0  0  0  0 48 49  0 51 52  0 54 55 56 57  0 60 61  0  0  0 68 69 70  0  0  0
 78  0
  1  0  0  0  5  6  0  8  9 10 11 12  0  0 17 29 30 32 33  0  0 36 39 40  0  0
  0  0  0  0  0  0  0  0  0  0  0 55 56 57 58 60 61 62  0 66 68 69 70 71 72 73
 78 80
  1  2  3  4  5  6  0  8  9 10 11 12  0 15 17 29 30 32 33 34 35 36 39 40  0 42
  0 44 45 47  0  0  0  0  0  0 54 55 56 57 58 60 61 62  0 66 68 69 70 71 72 73
 78 80
  1  2  3  4  5  6  0  8  9 10 11 12  0 15 17 29 30 32 33 34 35 36 39 40  0 42
  0 44 45 47  0  0  0  0  0  0 54 55 56 57 58 60 61 62  0 66 68 69 70 71 72 73
 78 80
  1  2  3  4  5  6  7  8  9 10 11 12  0 15 17 29 30 32 33 34 35 36 39 40  0 42
  0 44 45 47  0  0  0  0  0  0 54 55 56 57 58 60 61 62  0 66 68 69 70 71 72 73
 78 80
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    0.00    0.00  999.99  999.99  170.009999.999999.99    0.00   45.00   50.00    0.00
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    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00  170.009999.999999.99   30.00   33.00   50.00  100.00
    0.00    0.00   90.00   90.00   90.00    5.00    5.00    5.00   90.00    5.00
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  160.00    0.00   90.00   90.00   12.00   12.00    8.00    4.00  999.99  999.99  100.00
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    0.00    0.00    0.00  999.99  170.009999.999999.99   30.00   33.00   50.00  100.00
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    0.00    0.00    0.00  999.99  170.009999.999999.99   30.00   33.00   50.00  100.00
    0.00    0.00   90.00   90.00   90.00    5.00    5.00    5.00   90.00    5.00
   90.00   15.00   25.00    2.00   90.00   90.00   90.00    5.00    5.00    7.00   12.00
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L.0123	3.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0124	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	0.00	0.00					
L.0125	0.00	00.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
L.0126	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0127	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0128	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0129	0.00	0.00	100.00	25.00	0.00	0.00	425.00	0.00	15.00	0.00	0.00					
L.0130	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
L.0131	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0132	0.00	0.00	0.00	0.00	8.00	7.00	0.00	0.00	0.30	0.00	0.00					
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L.0134	0.00	0.00	100.00	25.00	0.00	0.00	425.00	0.00	15.00	0.00	0.00					
L.0135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
L.0136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0137	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0138	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	12.00					
L.0139	0.00	150.00	0.00	25.00	0.00	0.00	850.00	0.00	2.00	0.00	0.00					
L.0140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
L.0141	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0142	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.50	0.00	0.00					
L.0144	0.00	150.00	0.00	25.00	0.00	0.00	850.00	0.00	2.00	0.00	0.00					
L.0145	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
L.0146	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.50					
L.0147	1.00	0.00	0.00	0.00	1.00	1.00	2.50	2.00	0.00	0.00	0.00					
L.0148	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0149	0.00	0.00	0.00	0.00	0.00	0.00	250.00	0.00	15.00	0.00	0.00					
L.0150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
L.0151	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.50					
L.0152	10.00	0.00	0.00	0.00	1.00	1.00	2.50	2.00	0.25	0.00	0.00					
L.0153	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0154	0.00	0.00	0.00	25.00	0.00	0.00	400.00	0.00	15.00	0.00	0.					
L.0155	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
L.0156	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0					
L.0157	10.00	0.00	0.00	0.00	1.00	1.00	3.00	2.00	0.25	0.00	0.					
L.0158	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.					
L.0159	0.00	0.00	0.00	25.00	0.00	0.00	400.00	0.00	15.00	0.00	0.00					
L.0160	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
L.0161	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.50					
L.0162	10.00	0.00	0.00	0.00	1.00	1.00	3.50	2.00	0.25	0.00	0.00					
L.0163	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
L.0164	0.00	0.00	0.00	25.00	0.00	0.00	400.00	0.00	15.00	0.00	0.00					
L.0165	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
L.0166	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0167	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0168	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0169	1.0	1.0	1.0	1.0	1.0	1.0										
L.0170	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0171	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0172	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0173	1.0	1.0	1.0	1.0	1.0	1.0										
L.0174	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0175	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0176	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0177	1.0	1.0	1.0	1.0	1.0	1.0										
L.0178	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0179	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0180	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0181	1.0	1.0	1.0	1.0	1.0	1.0										
L.0182	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0183	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0184	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0185	1.0	1.0	1.0	1.0	1.0	1.0										
L.0186	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0187	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0188	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0189	1.0	1.0	1.0	1.0	1.0	1.0										
L.0190	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0191	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0192	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0193	1.0	1.0	1.0	1.0	1.0	1.0										
L.0194	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0195	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0196	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0197	1.0	1.0	1.0	1.0	1.0	1.0										
L.0198	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0199	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0200	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0201	1.0	1.0	1.0	1.0	1.0	1.0										
L.0202	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0203	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0204	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0205	1.0	1.0	1.0	1.0	1.0	1.0										
L.0206	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0207	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0208	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0209	1.0	1.0	1.0	1.0	1.0	1.0										
L.0210	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.0	1.0	1.0	1.0	2.0
L.0211	2.0	3.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0212	1.0	1.0	2.0	2.0	4.0	4.0	1.0	4.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L.0213	1.0	1.0	1.0	1.0	1.0	1.0										
L.0214	10 8 9 29 10 13 30 10 13 60 13 27 61 0 [illegible] 66 5 2															
L.0215	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	1.0	5.0	0.0	0.0	0.0	5.0	10.0	5.0
L.0216	2.0	5.0	0.0	0.0	3.0	10.0	10.0	5.0	3.0	5.0	0.0	0.0	0.0	5.0	10.0	5.0
L.0217	4.0	5.0	0.0	0.0	0.0	0.0	7.0	10.0	9.0	5.0	0.0	0.0	0.0	5.0	10.0	5.0
L.0218	10.0	5.0	0.0	0.0	0.0	5.0	10.0	5.0	11.0	5.0	0.0	0.0	0.0	5.0	10.0	5.0
L.0219	12.0	5.0	0.0	0.0	3.0	5.0	10.0	5.0								
L.0220	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	1.0	1.0	5.0
L.0221	4.0	5.0	6.0	7.0	10.0	10.0	6.0	8.0	7.0	6.0	2.0	1.0	5.0	4.0	5.0	6.0
L.0222	7.0	10.0	10.0	8.0	8.0	7.0	6.0	3.0	1.0	5.0	4.0	5.0	6.0	7.0	10.0	10.0
L.0223	8.0	8.0	7.0	6.0	4.0	1.0	5.0	4.0	5.0	6.0	7.0	10.0	10.0	8.0	8.0	7.0
L.0224	6.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0	8.0	8.0	7.0	6.0	5.0	1.0
L.0225	5.0	4.0	5.0	6.0	7.0	10.0	10.0	8.0	8.0	7.0	6.0	10.0	1.0	5.0	4.0	5.0
L.0226	6.0	7.0	10.0	10.0	8.0	8.0	7.0	6.0	11.0	1.0	5.0	4.0	5.0	6.0	7.0	10.0
L.0227	10.0	8.0	8.0	7.0	6.0	12.0	1.0	5.0	4.0	5.0	6.0	7.0	10.0	10.0	8.0	8.0
L.0228	7.0	6.0														
L.0229	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	1.0	8.0	5.0
L.0230	5.0	10.0	9.0	9.0	8.0	5.0	4.0	4.0	3.0	3.0	2.0	5.0	5.0	8.0	10.0	9.0
L.0231	9.0	8.0	5.0	4.0	4.0	3.0	3.0	3.0	5.0	5.0	5.0	10.0	9.0	9.0	8.0	5.0
L.0232	4.0	4.0	3.0	3.0	4.0	0.0	4.0	4.0	8.0	7.0	8.0	10.0	9.0	8.0	8.0	7.0
L.0233	6.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0	8.0	8.0	7.0	6.0	5.0	5.0
L.0234	5.0	5.0	7.0	7.0	7.0	5.0	6.0	4.0	4.0	3.0	3.0	10.0	5.0	5.0	5.0	7.0
L.0235	7.0	7.0	9.0	6.0	4.0	4.0	3.0	3.0	11.0	5.0	5.0	5.0	7.0	7.0	7.0	9.0
L.0236	6.0	4.0	4.0	3.0	3.0	12.0	5.0	5.0	5.0	7.0	7.0	7.0	9.0	6.0	4.0	4.0
L.0237	3.0	3.0														
L.0238	0.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	11.0	12.0	13.0	14.0	15.0	17.0	18.0

```
L.0239  19.0 20.0 24.0 25.0 33.0 41.0 44.0 45.0 47.0 48.0 49.0  1.0  0.0  0.0  0.0  0.0
L.0240   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  7.0  7.0  7.0  7.0 10.0 10.0 10.0
L.0241  10.0  7.0  7.0  0.0  0.0 10.0  2.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
L.0242   0.0  0.0  0.0  0.0  7.0  7.0  7.0  7.0 10.0 10.0 10.0 10.0  7.0  7.0  0.0  0.0
L.0243  10.0  3.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  7.0
L.0244   7.0  7.0  7.0 10.0 10.0 10.0 10.0  7.0  7.0  7.0 10.0 10.0  4.0  0.0  0.0  0.0
L.0245   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  7.0  7.0  7.0  7.0 10.0 10.0
L.0246  10.0 10.0  7.0  7.0  7.0 10.0 10.0  5.0 10.0 10.0  3.0  3.0  0.0  0.0  0.0  0.0
L.0247   7.0  7.0  7.0  7.0  7.0 10.0 10.0 10.0  7.0  5.0 10.0  5.0  5.0  5.0  5.0  0.0
L.0248   0.0  0.0  6.0 10.0 10.0  3.0  3.0  0.0  0.0  0.0  0.0  7.0  7.0  7.0  7.0  7.0
L.0249  10.0 10.0 10.0  7.0  5.0 10.0  5.0  5.0  5.0  5.0  0.0  0.0  0.0  7.0 10.0 10.0
L.0250   3.0  3.0  0.0  0.0  0.0  0.0  7.0  7.0  7.0  7.0  7.0  5.0  5.0  5.0  5.0  1.0
L.0251   0.0  1.0  0.0  0.0  0.0  0.0  0.0  0.0  8.0  0.0 10.0  3.0  3.0  0.0  0.0  3.0
L.0252   0.0  7.0  7.0  7.0  7.0  7.0  5.0  5.0  3.0  5.0  5.0  5.0  5.0  0.0  0.0  0.0
L.0253   0.0  0.0  0.0  9.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  5.0  5.0  5.0  5.0
L.0254   5.0 10.0 10.0 10.0 10.0 10.0 10.0  7.0  1.0  1.0  1.0  1.0  1.0  0.0 10.0  0.0
L.0255   0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0  1.0  1.0  1.0  1.0 10.0 10.0 10.0  7.0
L.0256  10.0 10.0  7.0  1.0  1.0  1.0  0.0  0.0  0.0 11.0  0.0  0.0  0.0  0.0  0.0  0.0
L.0257   0.0  0.0  1.0  1.0  1.0  1.0  1.0 10.0 10.0 10.0  7.0 10.0 10.0  7.0  1.0  1.0
L.0258   1.0 [illegible] 0.0  0.0 12.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0  1.0  1.0
L.0259   1.0  1.0 10.0 10.0 10.0  7.0 10.0 10.0  7.0  1.0  1.0  1.0  0.0  0.0  0.0
L.0260   0.0
L.0261   0.0  1.0  9.0  1.0 10.0  1.0 11.0  1.0 12.0  1.0
L.0262   0  0  0 15  0  0  0  0  0  0 17  1  0  0  0  0  0 21 25 26 29  2  0  0  0 30
L.0263   0  5  6  7  8  0  0  0  0  0  0  0  0  0 14  0  0  0  0 34  0  0  0  0  0  0
L.0264   0  0  0
L.0265   0  0  0 16  0  0  0  0  0  0 17  1  0  0  0  0  0 20 25 26 29  2  0  0  0 30
L.0266   0  5  6  7  0  0  0  0  0  0  0  0  0  0 14  0  0  0  0 35  0  0  0  0  0  0
L.0267   0  0  0
L.0268   0  0  0 15  0  0  0  0  0  0 17  1  0  0  0  0  0 21 25 26 29  2  0  0  3 30
L.0269   4  5  6  7  0  0  0  0  0  0  0  0  0  0 14  0  0  0  0 34  0  0  0  0  0  0
L.0270   0  0  0
L.0271   0  0  0 15  0  0  0  0  0  0 17  1  0  0  0  0  0 22 24 26 29  2  0  0  3 30
L.0272   4  5  6  7  0           0  0  0  0  0  0  0 14  0  0  0  0 34  0  0  0  0  0  0
L.0273   0  0  0
L.0274   0  0  0                    0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.0275   0  0  0                    0 10 11 12  0 13  0  0  0  0  0  0  0  0  0  0  0  0
L.0276   0  0  0
L.0277   0  0  0                    0  0  0  0  0  0  0  0  0  0  0 27  0  0  0  0  0  0
L.0278   0  0  0                 0  0 10 11 12  0 13  0  0  0  0  0  0  0  0  0  0  0  0
L.0279   0  0  0
L.0280   0  0  0  0  0           0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.0281   0  0  0  0  8  0  0 32  9  0 11 12  0 13  0  0  0  0  0  0  0  0  0  0  0  0
L.0282   0  0  0
L.0283   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.0284   0  0  0  0  8  0  0 32  9  0 11 12  0 13  0  0  0  0  0  0  0  0  0  0  0  0
L.0285   0  0  0
L.0286   0  0  0  0  0  0  0  0  0  0 19  1  0  0  0  0  0 20 24  0  0  2  0  0  0  0
L.0287   0  0  0  0  0  0  0  0  0  0  0 12  0 13 14  0  0  0  0  0  0  0  0  0  0  0
L.0288   0  0  0
L.0289   0  0  0 16  0  0  0  0  0  0 18  1  0  0  0  0  0 20 24 26 28  2  0  0  0 31
L.0290   0  5  6  7  0  0  0  0  0  0 11 12  0 13 14  0  0  0  0  0  0  0  0  0  0  0
L.0291   0  0  0
L.0292   0  0  0 15  0  0  0  0  0  0 18  1  0  0  0  0  0 21 24 26 28  2  0  0  0 31
L.0293   0  5  6  7  0  0  0  0  0  0 11 12  0 13 14  0  0  0  0  0  0  0  0  0  0  0
L.0294   0  0  0
L.0295   0  0  0 15  0  0  0  0  0  0 17  1  0  0  0  0  0 20 24 26 28  2  0  0  0 31
L.0296   0  5  6  7  0  0  0  0  0  0 11 12  0 13 14  0  0  0  0  0  0  0  0  0  0  0
L.0297   0  0  0
L.0298   1  2  3  4  5  6  7  8  9-11-12 11 12 14 15 17 29 30 32-25-30 34 35 36 39 40
L.0299  41 42 43 44 45 47 48 49 50 51 52 53 54 55 56 57 58 60 61 62 63 66 68 69 70 71
L.0300  72 73 80  1  0  0  0  5  6  7  8  9 10 10-10-10  0 13 17-33-33 32 33 33  0  0
L.0301  36 39 40  0  0  0  0  0 47 48 49 50 51 52 53 54 55 56 57 58 60 61  0  0 66 68
L.0302  69 70 71 72 73 80
L.0303  14 39 40 49 50
L.0304   1  2  3  5  6  7 15 17 62 68 69 70 78
L.0305   8  9 71 72 73 80
L.0306  12 11  4 32 58  2 30 29  3 35 29  4 57 56  2
L.0307   1  4  2  2  3
L.0308   3  2  3  3  2  2  3  2  2  2  2  2  6  3  2  2  4  4  4  2  2  2  2  2  2  2
L.0309   2  2  2  4  4  2  2  2  2
L.0310   10.00   50.00  160.00   10.00    5.00    0.00
L.0311    0.00  100.00   10.00    0.00
L.0312    0.00  200.001000.00   10.00   10.00    0.00
L.0313    0.00   10.00   20.00   10.00   10.00    0.00
L.0314    0.00   75.00    0.00   10.00
L.0315    0.00   75.00    0.00   10.00
L.0316    0.00    9.00   20.00   10.00   10.00    0.00
L.0317   -2.50    2.50   10.00    0.00
L.0318  150.00  170.00    0.00   10.00
L.0319  100.00  170.00    0.00   10.00
L.0320   25.00   42.00    0.00   10.00
L.0321    0.00  170.00   10.00    0.00
L.0322 -600.00-400.00    0.00  100.00  200.00  400.00    0.00    2.00   10.00   10.00    5.00
L.0323    0.00
L.0324    0.00   10.00   30.00   10.00    9.00    0.00
L.0325    0.00    2.00   10.00    0.00
L.0326    0.00    3.00   10.00    0.00
L.0327    0.50    2.00    4.00   12.00    0.00   10.00   10.00    0.00
L.0328    0.50    2.00    4.00   25.00    0.00   10.00   10.00    0.00
L.0329    0.50    2.00    4.00   60.00    0.00   10.00   10.00    0.00
L.0330    2.50    6.00    0.00   10.00
L.0331    3.00    6.00    0.00   10.00
L.0332    3.50    6.00    0.00   10.00
L.0333    4.00    8.00    0.00   10.00
L.0334    2.00    3.00    0.00   10.00
L.0335    2.00    4.00    0.00   10.00
L.0336    0.25    2.00    0.00   10.00
L.0337    0.90    2.00    0.00   10.00
L.0338    0.25    3.00    0.00   10.00
L.0339    1.50    3.00    0.00   10.00
L.0340    4.00    5.00    6.00    8.00    0.00   10.00   10.00    0.00
L.0341    4.00    5.00    6.00    9.00    0.00   10.00   10.00    0.00
L.0342    0.00    1.00    0.00   10.00
L.0343    0.00    3.00    0.00   10.00
L.0344    0.00    2.00   10.00    0.00
L.0345    0.00    3.00   10.00    0.00
L.0346   5  6  2  4
L.0347    1.00    4.00    8.00   14.00   20.00    1.00    2.00    6.00   14.00   25.00
L.0348    1.00    4.00    5.00    8.00    9.00   12.00    1.00    1.00    2.00    2.00    4.00
L.0349    4.00
L.0350  425.00200.00 425.002000.00
L.0351    5.00   10.00   15.00   20.00    0.01    0.05    0.40    1.00
L.0352 FARMING LAND                001
L.0353 PIT PREPARED LAND           002
L.0354 SPRINKLER IRRIGATION        003
L.0355 SURFACE IRRIGATION          004
L.0356 SUMMER SEASON CROPPING      005
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L.0357 WINTER SEASON CROPPING  006
L.0358 SUBTROPICAL BI/PER CROPS007
L.0359 TEMPERATE BI/PER CROPS  008
L.0360 NATURAL VELD PASTURE    009
L.0361 VELD RECLAIMED PASTURE  010
L.0362 VELD REINFORCED PASTURE 011
L.0363 VELD REPLACED PASTURE   012
L.0364 ROCK SURFACE            001
L.0365 BOULDER COVER           002
L.0366 GRAVEL COVER            003
L.0367 ROCKY DISTRIBUTION      004
L.0368 LAKE                    005
L.0369 RESERVOIR               006
L.0370 VLEI                    007
L.0371 RIVER                   008
L.0372 STREAM                  009
L.0373 HILLSLOPE ELEMENT       010
L.0374 SLOPE GRADIENT          011
L.0375 SLOPE LENGTH            012
L.0376 HEIGHT ABOVE WATER      014
L.0377 KOPPIE                  015
L.0378 GULLY                   017
L.0379 SUBSOIL TEXTURE         029
L.0380 TOPSOIL TEXTURE         030
L.0381 SOIL ERODIBILITY INDEX  032
L.0382 SOIL PERMEABILITY INDEX 033
L.0383 ROOTING DEPTH           034
L.0384 DEPTH TO WATER TABLE    035
L.0385 EXPOSED SOIL LENGTH     036
L.0386 SOIL DEFICIENCY         039
L.0387 SOIL TOXICITY           040
L.0388 SOIL SALINITY           041
L.0389 SOIL PH                 042
L.0390 SODIUM ABSORPTION RATIO 043
L.0391 SOIL CATION EXCHANGE CAP044
L.0392 SOIL ORGANIC MATTER     045
L.0393 WIND VELOCITY           047
L.0394 FROST TEMPERATURE       048
L.0395 JANUARY TEMPERATURE     049
L.0396 JULY TEMPERATURE        050
L.0397 HAIL OCCURRENCE         051
L.0398 FRUITING LENGTH         052
L.0399 SEASON LENGTH           053
L.0400 SEASON QUALITY          054
L.0401 WATER DEFICIT PERIOD    055
L.0402 EVAPORATION             056
L.0403 RAINFALL TOTAL          057
L.0404 RAINFALL ENERGY         058
L.0405 PHYSIOGNOMIC VEGE. TYPE060
L.0406 FLORISTIC VEGE. TYPE    061
L.0407 WOODY COVER             062
L.0408 WOODY DISTRIBUTION      063
L.0409 ANIMAL HOST SPECIES     066
L.0410 TOWNSHIP                068
L.0411 INDUSTRIAL AREA         069
L.0412 SETTLEMENT              070
L.0413 POWERLINE               071
L.0414 RAILWAY                 072
L.0415 PAVED ROAD              073
L.0416 MOUNTAIN CATCHMENT AREA 078
L.0417 UNPAVED ROAD            080
L.0418  CONTROL DATA FOR THE FORESTRY LAND USE SYSTEM
L.0419  50  5  5 24 52  0 13  0  6  4  5  4
L.0420   1  2  3  4  5  6  7  8  9 10 11 12  0 14 15 17 29 30 32 33 34 35 36 39 40 42
L.0421  44 45 47  0  0  0  0  0  0  0  0 58 60 61 62 63 68 69 70 71 72 73 78 80
L.0422   1  2  3  4  5  6  7  8  9 10 11 12  0 14 15 17 29 30 32 33 34 35 36 39 40 42
L.0423  44 45 47  0  0  0  0  0  0  0  0 58 60 61 62 63 68 69 70 71 72 73 78 80
L.0424   1  0  0  0  5  6  7  0  0  0  0  0 13 14 15 17  0  0  0  0  0  0  0  0  0  0
L.0425   0  0 47 48  0 50 51 54 55 56 57  0 60 61  0  0 68 69 70  0  0  0 78  0
L.0426   1  0  0  0  5  6  7  0  0  0  0  0 13 14 15 17  0  0  0  0  0  0  0  0  0  0
L.0427   0  0 47 48 49  0 51 54 55 56 57  0 60 61  0  0 68 69 70  0  0  0 78  0
L.0428    90.00     5.00    10.00     2.00    90.00    90.00    90.00     5.00     5.00     7.00    12.00
L.0429   160.00     0.009999.99    90.00    90.00    12.00    12.00     8.00     4.00   999.99   999.99
L.0430   100.00     0.00     0.00     9.00   100.00   100.00    20.00     0.00     0.00     0.00     0.00
L.0431     0.00     0.00     0.00     0.00    30.00    49.00    50.00   100.00     2.00    90.00    90.00
L.0432    90.00     5.00     5.00     5.00    90.00     5.00
L.0433    90.00    10.00    10.00     3.00    90.00    90.00    90.00     5.00     5.00     7.00    28.00
L.0434   160.00     0.009999.99    90.00    90.00    12.00    12.00     8.00     4.00   999.99   999.99
L.0435   100.00     0.00     0.00     9.00   100.00   100.00    20.00     0.00     0.00     0.00     0.00
L.0436     0.00     0.00     0.00     0.00    30.00    49.00    50.00   100.00     3.00    90.00    90.00
L.0437    90.00     5.00     5.00     5.00    90.00     5.00
L.0438    90.00     0.00     0.00     0.00    90.00    90.00    90.00     0.00     0.00     0.00     0.00
L.0439     0.00   360.009999.99    90.00    90.00     0.00     0.00     0.00     0.00     0.00     0.00
L.0440     0.00     2.00     0.00     0.00     0.00     0.00    20.00     2.50     0.00   999.99     3.00
L.0441   999.99   170.009999.991200.00     0.00    15.00    50.00     0.00     0.00    90.00    90.00
L.0442    90.00     0.00     0.00     0.00    90.00     0.00
L.0443    90.00     0.00     0.00     0.00    90.00    90.00    90.00     0.00     0.00     0.00     0.00
L.0444     0.00   360.009999.99    90.00    90.00     0.00     0.00     0.00     0.00     0.00     0.50
L.0445     0.00     0.00     0.00     0.00     0.00     0.00    20.00   999.99    36.00     0.00     3.00
L.0446   999.99   170.009999.991200.00     0.00    15.00    50.00     0.00     0.00    90.00    90.00
L.0447    90.00     0.00     0.00     0.00    90.00     0.00
L.0448     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     1.00     0.50
L.0449    10.00     0.00    10.00     0.00     0.00     1.00     1.00     3.50     2.00     0.90     1.50
L.0450     0.00     0.00     0.00     4.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
L.0451     4.00     0.00     0.00     0.00     0.00    17.00     0.00     0.00     0.00     0.00     0.00
L.0452     0.00     0.00     0.00     0.00     0.00
L.0453     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     2.00     0.50
L.0454    10.00     0.00    10.00     0.00     0.00     1.00     1.00     2.50     2.00     0.90     1.50
L.0455     0.00     0.00     0.00     4.00     0.00     0.00     0 [illegible]     0.00     0.00     0.00     0.00
L.0456     0.00     0.00     0.00     0.00     0.00    17.00     0.[illegible]     0.00     0.00     0.00     0.00
L.0457     0.00     0.00     0.00     0.00     0.00
L.0458     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
L.0459     0.00     0.00    10.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
L.0460     0.00     0.00     0.00     0.00     0.00     0.00     0.00     2.50     0.00    12.00     0.00
L.0461   250.00     0.00     0.00   550.00     0.00     2.00     0.00     0.00     0.00     0.00     0.00
L.0462     0.00     0.00     0.00     0.00     0.00
L.0463     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
L.0464     0.00     0.00    10.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
L.0465     0.00     0.00     0.00     0.00     0.00     0.00     0.00    -2.50    30.00     [illegible]     0.00
L.0466   250.00     0.00     0.00   900.00     0.00     2.00     0.00     0.00     0.00     0.[illegible]     0.00
L.0467     0.00     0.00     0.00     0.00     0.00
L.0468    1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   3.0   3.0   2.0   1.0   1.0   1.0   1.0
L.0469    2.0   2.0   3.0   2.0   3.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
L.0470    1.0   4.0   4.0   1.0   4.0   3.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
L.0471    1.0   1.0
L.0472    1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   3.0   3.0   2.0   1.0   1.0   1.0   1.0
L.0473    2.0   2.0   3.0   2.0   3.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
L.0474    1.0   4.0   4.0   1.0   4.0   3.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
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L.0475   1.0   1.0
L.0476   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   3.0   3.0   2.0   1.0   1.0   1.0   1.0
L.0477   2.0   2.0   3.0   2.0   3.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
L.0478   1.0   4.0   4.0   1.0   4.0   3.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
L.0479   1.0   1.0
L.0480   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   3.0   3.0   2.0   1.0   1.0   1.0   1.0
L.0481   2.0   2.0   3.0   2.0   3.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
L.0482   1.0   4.0   4.0   1.0   4.0   3.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
L.0483   1.0   1.0
L.0484  10   3   8  29   3  13  30   3  13  60   5  25  61   0   0
L.0485   0.0   1.0   2.0   3.0   4.0   5.0   6.0   7.0   1.0   5.0   0.0   0.0   0.0   5.0  10.0   5.0
L.0486   2.0   5.0   0.0   0.0   3.0  10.  10.   5.0
L.0487   0.0   1.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0  10.0  11.0  12.0   1.0   1.0   3.0
L.0488   4.0   5.0   6.0   7.0  10.0  10.0   8.0   8.0   7.0   6.0   2.0   1.0   5.0   4.0   5.0   6.0
L.0489   7.0  10.0  10.0   8.0   8.0   7.0   6.0
L.0490   0.0   1.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0  10.0  11.0  12.0   1.0   5.0   5.0
L.0491   5.0  10.0   9.0   9.0   6.0   5.0   4.0   4.0   3.0   3.0   2.0   5.0   5.0   5.0  10.0   9.0
L.0492   9.0   8.0   5.0   4.0   4.0   3.0   3.0
L.0493   0.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0  11.0  12.0  13.0  14.0  15.0  17.0  18.0
L.0494  19.0  20.0  24.0  25.0  33.0  41.0  44.0  45.0  49.0   1.0   0.0   0.0   0.0   0.0   0.0   0.0
L.0495   0.0   0.0   0.0   0.0   0.0   0.0   0.0   7.0   7.0   7.0   7.0  10.0  10.0  10.0  10.0   7.0
L.0496   7.0  10.0   2.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
L.0497   7.0   7.0   7.0   7.0  10.0  10.0  10.0  10.0   7.0   7.0  10.0   3.0  10.0  10.0   3.0   3.0
L.0498   0.0   0.0   0.0   0.0   5.0   5.0   5.0   5.0   5.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
L.0499   0.0   0.0   0.0   0.0   4.0   0.0  10.0   3.0   3.0   0.0   0.0   0.0   0.0   5.0   5.0   5.0
L.0500   5.0   5.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
L.0501   0.0
L.0502   0  0  0 17  0  0  0  0  0  0 19  1  0  0  0  0  0  0 22  3  4  5  6  0  0  7
L.0503   8  9 10  0  0  0  0  0  0  0  0 16  0  0  0 23  0  0  0  0  0  0  0  0
L.0504   0  0  0 18  0  0  0  0  0  0 20  1  0  0  0  0  0  0 21  3  4  5  6  0  0  7
L.0505   8  9 10  0  0  0  0  0  0  0  0 16  0  0  0 24  0  0  0  0  0  0  0  0
L.0506   0  0  0  0  0  0  0  0  0  0  0  0  2  0  0  0  0  0  0  0  0  0  0  0  0  0
L.0507   0  0 10 11  0  0 12 13 14  0 15  0  0  0  0  0  0  0  0  0  0  0  0  0
L.0508   0  0  0  0  0  0  0  0  0  0  0  0  2  0  0  0  0  0  0  0  0  0  0  0  0  0
L.0509   0  0 10 11  0  0 12 13 14  0 15 16  0  0  0  0  0  0  0  0  0  0  0  0
L.0510   1  2  3  4  5  6  7  8  9-11-12 11 12 13 14 15 17 29 30 32-29-30 34 35 36 39
L.0511  40 42 44 45 47 48 49 50 51 54 55 56 57 58 60 61 62 63 66 69 70 71 72 73 78 80
L.0512   1  0  0  0  5  6  7  8  9 10 10-10-10 13  0 15 17-33-33 32 33 33  0  0 36 39
L.0513  40  0 44 45 47 48 49 50 51 54 55 56 57 58 60 61  0  0 66 65 70 71 72 73 78 80
L.0514  14 39 40 49 50
L.0515   1  2  3  5  6  7 15 17 62 68 69 70 78
L.0516   8  9 71 72 73 80
L.0517  12 11  4 32 50  2 34 29  3 35 29  4 57 56  2
L.0518   1  4  2  2  3
L.0519   3  4  2  2  2  2  4  2  2  3  2  2  2  2  6  3  2  2  4  4  2  2  2  2
L.0520    10.00   50.00  160.00   10.00    5.00    0.00
L.0521     0.00   90.00  270.00  360.00    0.00   10.00   10.00    0.00
L.0522     2.00    4.00    0.00   10.00
L.0523     0.90    2.00    0.00   10.00
L.0524     1.50    3.00    0.00   10.00
L.0525     0.00  100.00   10.00    0.00
L.0526     4.00    5.00    6.00    9.00    0.00   10.00   10.00    0.00
L.0527     0.00   75.00    0.00   10.00
L.0528     0.00   75.00    0.00   10.00
L.0529     0.30    5.00   20.00   10.00   10.00    0.00
L.0530    -2.50    2.50    0.00   10.00
L.0531     0.00    3.00    0.00   10.00
L.0532    25.00   42.00    0.00   10.00
L.0533     0.00  170.00    0.00   10.00
L.0534  -800.00-400.00    0.00  100.00  200.00  400.00    0.00    2.00   10.00   10.00    5.00
L.0535     0.00
L.0536     0.00   10.00   30.00   10.00    9.00    0.00
L.0537     0.00    2.00   10.00    0.00
L.0538     0.00    3.00   10.00    0.00
L.0539     0.50    2.00    4.00   12.00    0.00   10.00   10.00    0.00
L.0540     0.50    2.00    4.00   25.00    0.00   10.00   10.00    0.00
L.0541     3.50    6.00    0.00   10.00
L.0542    2.500    6.00    0.00   10.00
L.0543     0.00    2.00   10.00    0.00
L.0544     0.00    3.00   10.00    0.00
L.0545   5  6  2  4
L.0546     1.00    4.00    8.00   14.00   20.00    1.00    2.00    6.00   14.00   25.00
L.0547     1.00    4.00    5.00    8.00    9.00   12.00    1.00    1.00    2.00    2.00    4.00
L.0548     4.00
L.0549   600.002000.00 600.002000.00
L.0550     5.00   10.00   15.00   20.00    0.01    0.09    0.40    1.00
L.0551 FARMING LAND                001
L.0552 PIT PREPARED LAND           002
L.0553 SUBTROPICAL FORESTRY        003
L.0554 TEMPERATE FORESTRY          004
L.0555 ROCK SURFACE                001
L.0556 BOULDER COVER               002
L.0557 GRAVEL COVER                003
L.0558 ROCKY DISTRIBUTION          004
L.0559 LAKE                        005
L.0560 RESERVOIR                   006
L.0561 VLEI                        007
L.0562 RIVER                       008
L.0563 STREAM                      009
L.0564 HILLSLOPE ELEMENT           010
L.0565 SLOPE GRADIENT              011
L.0566 SLOPE LENGTH                012
L.0567 ASPECT OF A SLOPE           013
L.0568 HEIGHT ABOVE WATER          014
L.0569 KOPPIE                      015
L.0570 GULLY                       017
L.0571 SUBSOIL TEXTURE             029
L.0572 TOPSOIL TEXTURE             030
L.0573 SOIL ERODIBILITY INDEX      032
L.0574 SOIL PERMEABILITY INDEX     033
L.0575 ROOTING DEPTH               034
L.0576 DEPTH TO WATER TABLE        035
L.0577 EXPOSED SOIL LENGTH         036
L.0578 SOIL DEFICIENCY             039
L.0579 SOIL TOXICITY               040
L.0580 SOIL PH                     042
L.0581 SOIL CATION EXCHANGE CAP    044
L.0582 SOIL ORGANIC MATTER         045
L.0583 WIND VELOCITY               047
L.0584 FROST TEMPERATURE           048
L.0585 JANUARY TEMPERATURE         049
L.0586 JULY TEMPERATURE            050
L.0587 HAIL OCCURRENCE             051
L.0588 SEASON QUALITY              054
L.0589 WATER DEFICIT PERIOD        055
L.0590 EVAPORATION                 056
L.0591 RAINFALL TOTAL              057
L.0592 RAINFALL ENERGY             058
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L.0593 PHYSIOGONOMIC VEGE. TYPE060
L.0594 FLORISTIC VEGE. TYPE     061
L.0595 WOODY COVER              062
L.0596 WOODY DISTRIBUTION       063
L.0597 TOWNSHIP                 068
L.0598 INDUSTRIAL AREA          069
L.0599 SETTLEMENT               070
L.0600 POWERLINE                071
L.0601 RAILWAY                  072
L.0602 PAVED ROAD               073
L.0603 MOUNTAIN CATCHMENT AREA  078
L.0604 UNPAVED ROAD             080
L.0605  CONTROL DATA FOR THE CONSERVATION LAND USE SYSTEM
L.0606  32  0  6  6 33 11  3  2  4  1  1  1
L.0607   5  6  7  8  9 10 11 12 15 16 17 32 36 47 58 60 61 65 67 68 69 70 71 72 73 74
L.0608  75 76 77 78 79 80
L.0609  100.00 100.00 100.00   5.00   5.00   7.00 100.00 999.99 100.00 999.99 100.00
L.0610    8.00 160.00  27.009999.99  48.00  50.00 999.99 999.99  90.00  90.00  90.00
L.0611    5.00   5.00   5.00 100.00 100.00 100.00 100.00 100.00 100.00   5.00
L.0612    0.00   0.00   0.00   0.00   0.00   4.00   0.00   0.00   0.00   0.00   0.00
L.0613    1.00   0.00   0.00   0.00   1.00   0.00   0.00   0.00   0.00   0.00   0.00
L.0614    0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
L.0615   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   4.0   1.0   4.0   1.0   1.0   4.0   4.0
L.0616   4.0   4.0   4.0   1.0   1.0   1.0   1.0   1.0   1.0   3.0   3.0   3.0   3.0   4.0   4.0   1.0
L.0617  10  8  2 16  2  2 60  2 42 61  0  0 65  2  2 67  2  2
L.0618   0.0   1.0   2.0   3.0   4.0   5.0   6.0   7.0   1.0   5.0  10.0  10.0   8.0   5.0   3.0   1.0
L.0619   0.0   1.0   1.0  10.0
L.0620   0.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0  11.0  12.0  13.0  14.0  15.0  17.0  18.0
L.0621  19.0  20.0  22.0  23.0  24.0  25.0  27.0  28.0  29.0  30.0  32.0  33.0  34.0  35.0  36.0  37.0
L.0622  38.0  39.0  40.0  41.0  42.0  43.0  44.0  45.0  47.0  48.0   1.0  10.0  10.0  10.0  10.0  10.0
L.0623  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0
L.0624  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0
L.0625  10.0  10.0  10.0  10.0
L.0626   0.0
L.0627   0.0   1.0   1.0  10.0
L.0628   0.0   1.0   1.0  10.0
L.0629   0  0  0  0  0  0  1  2  0  0  0  3  4  5  6  0  0  0  0  0  0  0  0  0  0  0
L.0630   0  0  0  0  0  0
L.0631   5  6  7  8  9-11-12 11 12 15 16 17 32 36 47 58 60 61 65 67 68 69 70 71 72 73
L.0632  74 75 76 77 78 79 80  5  6  7  8  9 10 10-10-10 15 16 17 32 36 47 58 60 61 65
L.0633  67 68 69 70 71 72 73 74 75 76 77 78 79 80
L.0634   5  6  7 15 17 74 75 76 77 78 79
L.0635  68 69 70
L.0636   8  9
L.0637  71 72 73 80
L.0638  11 12  4
L.0639   1
L.0640   2  3  2  2  3  3
L.0641    0.00  12.00   1.00  10.00
L.0642   10.00  50.00 160.00  10.00   5.00   0.00
L.0643    2.50   6.00  10.00   0.00
L.0644    0.00 100.00  10.00   0.00
L.0645    0.00   5.00  27.00  10.00  10.00   0.00
L.0646    0.00  10.00  30.00  10.00   9.00   0.00
L.0647   5
L.0648    1.00   4.00   8.00  14.00  20.00   1.00   2.00   6.00  14.00  25.00
L.0649 CONSERVATION AREA        001
L.0650 LAKE                     005
L.0651 RESERVOIR                006
L.0652 VLEI                     007
L.0653 RIVER                    008
L.0654 STREAM                   009
L.0655 HILLSLOPE ELEMENT        010
L.0656 SLOPE GRADIENT           011
L.0657 SLOPE LENGTH             012
L.0658 KOPPIE                   015
L.0659 NATURAL LAND FEATURE     016
L.0660 GULLY                    017
L.0661 SOIL ERODIBILITY INDEX   032
L.0662 EXPOSED SOIL LENGTH      036
L.0663 WIND VELOCITY            047
L.0664 RAINFALL ENERGY          058
L.0665 PHYSIOGONOMIC VEGE.TYPE  060
L.0666 FLORISITIC VEGE.TYPE     061
L.0667 PROTECTED PLANT SPECIES  065
L.0668 PROTECTED ANIMAL SPECIES067
L.0669 TOWNSHIP                 068
L.0670 INDUSTRIAL AREA          069
L.0671 SETTLEMENT               070
L.0672 POWERLINE                071
L.0673 RAILWAY                  072
L.0674 PAVED ROAD               073
L.0675 NATIONAL PARK            074
L.0676 PROVINCIAL PARK          075
L.0677 MUNICIPAL PARK           076
L.0678 PRIVATE PARK             077
L.0679 MOUNTAIN CATCHMENT AREA  078
L.0680 WILDERNESS               079
L.0681 UNPAVED ROAD             080
L.0682  CONTROL DATA FOR THE RECREATION LAND USE SYSTEM
L.0683  35  0  7 10 37  5  7  4  2  3  2  2
L.0684   1  2  4  5  6  7  8  9 10 11 12 15 16 17 29 30 32 33 47 58 60 61 62 64 69 71
L.0685  72 73 74 75 76 77 78 79 80
L.0686   0  0  0  5  6  7  0  0 10 11  0  0 16 17  0  0 32 33 47 58 60 61 62 64 69 71
L.0687  72 73 74 75 76 77 78 79 80
L.0688   0  0  0  5  6  7  8  9  0  0  0  0  0  0  0  0  0  0  0  0 60 61  0 64  0  0
L.0689   0  0  0  0  0  0  0  0  0
L.0690   90.00  10.00   3.00  90.00  90.00  90.00   5.00   5.00   7.00  15.00 999.99
L.0691   90.00   0.00  90.00  12.00  12.00   8.00   4.00  20.00  30.00  48.00  50.00
L.0692  100.00   0.00  90.00   5.00   5.00   5.00 100.00 100.00 100.00 100.00  50.00
L.0693   90.00   5.00
L.0694    0.00   0.00   0.00  90.00  90.00 100.00   0.00   0.00   7.00 100.00   0.00
L.0695    0.00 999.99  90.00   0.00   0.00   8.00   4.00  20.00  30.00  48.00  50.00
L.0696  100.00 999.99  90.00   5.00   5.00   5.00 100.00 100.00 100.00 100.00  90.00
L.0697  100.00   5.00
L.0698    0.00   0.00   0.00 100.00 100.00 100.00   5.00   5.00   0.00   0.00   0.00
L.0699    0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00  30.00  50.00
L.0700    0.00 999.99   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
L.0701    0.00   0.00
L.0702    0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   1.00   0.00  10.00
L.0703    0.00   0.00   0.00   1.00   1.00   3.50   2.00   0.00   0.00  15.00   0.00
L.0704    0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
L.0705    0.00   0.00
L.0706    0.00   0.00   0.00   0.00   0.00   0.00   6.00   0.00   1.00   0.00   0.00
L.0707    0.00   0.00   0.00   0.00   0.00   2.50   1.00   0.00   0.00   2.00   0.00
L.0708    0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
L.0709    0.00   0.00
L.0710    0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
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L.0711    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  27.00    0.00
L.0712    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.0713    0.00    0.00
L.0714   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  2.0  4.0  1.0  1.0  1.0  1.0  2.0  2.0
L.0715   1.0  2.0  1.0  1.0  2.0  2.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.0716   1.0  1.0  1.0
L.0717   1.0  1.0  1.0  2.0  2.0  2.0  1.0  1.0  2.0  2.0  1.0  1.0  3.0  1.0  1.0  1.0
L.0718   1.0  2.0  1.0  1.0  2.0  2.0  1.0  3.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.0719   1.0  1.0  1.0
L.0720   1.0  1.0  1.0  3.0  3.0  2.0  3.0  3.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.0721   1.0  1.0  1.0  1.0  2.0  2.0  1.0  3.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.0722   1.0  1.0  1.0
L.0723  10  3  8 16  3  2 29  3 13 30  3 13 60  4 43 61  0  0 64  3  2
L.0724   0.3  1.0  2.0  3.0  4.0  5.0  6.0  7.0  1.0  0.0  0.0  0.0  0.0  3.0 10.0 10.0
L.0725   2.0  8.0  5.0  3.0  8.0 10.0 10.0  8.0
L.0726   0.0  1.0  1.0  1.0  2.0  1.0
L.0727   0.0  1.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 10.0 11.0 12.0  1.0  1.0  5.0
L.0728   4.0  5.0  6.0  7.0 10.0 10.0  8.0  8.0  7.0  6.0  2.0  1.0  5.0  4.0  5.0  0.0
L.0729   7.0 10.0 10.0  8.0  8.0  7.0  6.0
L.0730   0.0  1.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 10.0 11.0 12.0  1.0  5.0  5.0
L.0731   5.0 10.0  5.0  9.0  3.0  5.0  4.0  4.0  3.0  3.0  2.0  5.0  5.0  5.0 10.0  5.0
L.0732   9.0  8.0  5.0  4.0  4.0  3.0  3.0
L.0733   0.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 11.0 12.0 13.0 14.0 15.0 17.0 18.0
L.0734  19.0 20.0 22.0 23.0 24.0 25.0 27.0 28.0 29.0 30.0 32.0 33.0 34.0 35.0 36.0 37.0
L.0735  38.0 39.0 40.0 41.0 42.0 43.0 44.0 45.0 47.0 48.0 49.0  1.0  0.0  0.0  0.0  0.0
L.0736   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  5.0  5.0  5.0  5.0 10.0  0.0 10.0
L.0737  10.0  0.0  0.0  0.0  0.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
L.0738   5.0  5.0  5.0  0.0  0.0  0.0  2.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0 10.0
L.0739  10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0  8.0  8.0  8.0  8.0
L.0740  10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0  8.0  8.0
L.0741   0.0  3.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
L.0742   0.0  0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0 10.0  0.0  0.0  0.0  0.0  0.0
L.0743   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
L.0744   0.0
L.0745   0.0  1.0  2.0  1.0  3.0  1.0
L.0746   0  0  1  0  0  0  0  0  0  5  2  0  0  0  0  0  0 10  3  4  0  0  0  0  0  0
L.0747   0  0  0  0  0  0  0  0  0
L.0748   0  0  0  0  0  0  0  0  0  6  0  0  0  0  0  0  7  9  3  4  0  0  0  0  0  0
L.0749   0  0  0  0  0  0  0  0  0
L.0750   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.0751   0  0  0  0  0  0  0  0  0
L.0752   1  2  4  5  6  7  8  9-11-12 11 12 15 16 17 29 30 32-29-30 47 58 60 61 62 67
L.0753  69 71 72 73 74 75 76 77 78 79 80  1  0  0  5  6  7  8  9 10 10-10-10 15 16 17
L.0754 -33-33 32 33 33 47 58 60 61  0 67 69 71 72 73 74 75 76 77 78 79 80
L.0755  74 75 76 77 79
L.0756   5  6  7 17 62 69 78
L.0757  71 72 73 80
L.0758   8  9
L.0759  11 12  4 32 58  2
L.0760   1  4
L.0761   2  3  3  3  2  2  2  2  3  3
L.0762    0.00    2.00   10.00    0.00
L.0763   10.00   50.00  160.00   10.00    5.00    0.00
L.0764    0.00    5.00   20.00   10.00   10.00    0.00
L.0765    0.00   10.00   30.00   10.00    9.00    0.00
L.0766    2.50    6.50    0.00   10.00
L.0767    3.50    6.50    0.00   10.00
L.0768    1.00    4.00    0.00   10.00
L.0769    2.00    4.00    0.00   10.00
L.0770    0.00    4.00   15.00   10.00   10.00    0.00
L.0771    0.00    0.00  100.00   10.00   10.00    0.00
L.0772   5  6
L.0773    1.00    4.00    8.00   14.00   20.00    1.00    2.00    6.00   14.00   25.00
L.0774    1.00    4.00    5.00    8.00    9.00   12.00    1.00    1.00    2.00    2.00    4.00
L.0775    4.00
L.0776 OPEN SPACE                 001
L.0777 INFORMAL ACTIVITIES        002
L.0778 WATER RECREATION           003
L.0779 ROCK SURFACE               001
L.0780 BOULDER COVER              002
L.0781 ROCKY DISTRIBUTION         003
L.0782 LAKE                       001
L.0783 RESERVIOR                  002
L.0784 VLEI                       003
L.0785 RIVER                      004
L.0786 STREAM                     005
L.0787 HILLSLOPE ELEMENT          010
L.0788 SLOPE GRADIENT             011
L.0789 SLOPE LENGTH               012
L.0790 KOPPIE                     015
L.0791 NATURAL LAND FEATURE       016
L.0792 GULLY                      017
L.0793 SUBSOIL TEXTURE            029
L.0794 TOPSOIL TEXTURE            030
L.0795 SOIL ERODIBILITY INDEX     032
L.0796 SOIL PERMEABILITY INDEX    033
L.0797 WIND VELOCITY              047
L.0798 RAINFALL ENERGY            058
L.0799 PHYSIOGONOMIC VEGE.TYPE    060
L.0800 FLORISITIC VEGE.TYPE       061
L.0801 WOODY COVER                062
L.0802 GAME SPECIES               064
L.0803 INDUSTRIAL AREA            069
L.0804 POWERLINE                  071
L.0805 RAILWAY                    072
L.0806 PAVED ROAD                 073
L.0807 NATIONAL PARK              074
L.0808 PROVINCIAL PARK            075
L.0809 MUNICIPAL PARK             076
L.0810 PRIVATE PARK               077
L.0811 MOUNTAIN CATCHMENT AREA    078
L.0812 WILDERNESS AREA            079
L.0813 UNPAVED ROAD               080
L.0814  CONTROL DATA FOR THE URBAN & RURAL DEVELOPMENT LAND USE SYSTEM
L.0815   1        8 20 42  0 11  4  2  4  3  3
L.0816   1  2  5  6  7  8  9 10 11 12 13 14 15 17 18 19 23 24 25 31 32 33 35 37 38 47
L.0817  58 60 61 62 69 71 72 73 78 79 80
L.0818   1  2  5  6  7  8  9 10 11 12 13 14 15 17 18 19 23 24 25 31 32 33 35 37 38 47
L.0819  58 60 61 62 69 71 72 73 78 79 80
L.0820   1  2  5  6  7  8  9 10 11 12  0 14 15 17 18 19 23 24 25 31 32 33 35 37 38 47
L.0821  58 60 61 62 69 71 72 73 78 79 80
L.0822   1  2  5  6  7  8  9 10 11 12  0 14 15 17 18 19 23 24 25 31 32 33 35 37 38 47
L.0823  58 60 61 62  0 71 72 73 78 79 80
L.0824    90.00   25.00   90.00   90.00   50.00    5.00    5.00    6.00   12.00  999.99  360.00
L.0825  9999.99   90.00   90.00   41.00    8.00  999.95  999.99    2.00   12.00    8.00    3.00
L.0826   999.99  999.99    2.00   20.00   30.00   45.00   50.00  100.00   90.00    5.00    5.00
L.0827     5.00   90.00   90.00    5.00
L.0828    90.00   25.00   90.00   90.00   90.00    5.00    5.00    6.00   20.00  999.99  360.00
```

```
L.0829 9999.99   90.00   90.00   41.00    8.00 999.99 999.99    2.00   12.00    8.00    4.00
L.0830  999.99  999.99    2.00   20.00   30.00  49.00  50.00  100.00   90.00    5.00    5.00
L.0831    5.00   90.00   90.00    5.00
L.0832   90.00   25.00   90.00   90.00   90.00   5.00   5.00    6.00   12.00  999.99    0.00
L.0833 9999.99   90.00   90.00   41.00    8.00 999.99 999.99    2.00   12.00    8.00    4.00
L.0834  999.99  999.99    2.00   20.00   30.00  49.00  50.00  100.00   90.00    5.00    5.00
L.0835    5.00   90.00   90.00    5.00
L.0836   90.00   25.00   90.00   90.00   90.00   5.00   5.00    6.00    5.00  999.99    0.00
L.0837 9999.99   90.00   90.00   41.00    8.00 999.99 999.99    2.00   12.00    6.00    4.00
L.0838  999.99  999.99    2.00   20.00   30.00  49.00  50.00  100.00   90.00    5.00    5.00
L.0839    5.00   90.00   90.00    5.00
L.0840    0.00    0.00    0.00    0.00    0.00   0.00   0.00    1.00    0.30   10.00    0.00
L.0841   10.00    0.00    0.00    1.00    1.00   1.50   0.00    0.00    1.00    2.00    1.00
L.0842    2.00    0.00    0.00    0.00    0.00  11.00   0.00    0.00    0.00    0.00    0.00
L.0843    0.00    0.00    0.00    0.00
L.0844    0.00    0.00    0.00    0.00    0.00   0.00   0.00    1.00    0.30   10.00    0.00
L.0845   10.00    0.00    0.00    1.00    1.00   0.90   0.00    0.00    1.00    2.00    1.00
L.0846    1.00    0.00    0.00    0.00    0.00  11.00   0.00    0.00    0.00    0.00    0.00
L.0847    0.00    0.00    0.00    0.00
L.0848    0.00    0.00    0.00    0.00    0.00   0.00   0.00    1.00    0.30   10.00    0.00
L.0849   10.00    0.00    0.00    1.00    1.00   3.00   0.00    0.00    1.00    2.00    1.00
L.0850    3.00    0.00    0.00    0.00    0.00  11.00   0.00    0.00    0.00    0.00    0.00
L.0851    0.00    0.00    0.00    0.00
L.0852    0.00    0.00    0.00    0.00    0.00   0.00   0.00    1.00    0.30   10.00    0.00
L.0853   10.00    0.00    0.00    1.00    1.00   0.90   0.00    0.00    1.00    2.00    1.00
L.0854    1.00    0.00    0.00    0.00    0.00  11.00   0.00    0.00    0.00    0.00    0.00
L.0855    0.00    0.00    0.00    0.00
L.0856   1.0   1.0   1.0   1.0   1.0   1.0   1.0   4.0   4.0   2.0   1.0   1.0   1.0   1.0   4.0   2.0
L.0857   2.0   1.0   1.0   4.0   1.0   2.0   4.0   4.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
L.0858   1.0   1.0   1.0   1.0   1.0
L.0859   1.0   1.0   1.0   1.0   1.0   1.0   1.0   4.0   4.0   2.0   1.0   1.0   1.0   1.0   4.0   2.0
L.0860   2.0   1.0   1.0   4.0   1.0   2.0   4.0   4.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
L.0861   1.0   1.0   1.0   1.0   1.0
L.0862   1.0   1.0   1.0   1.0   1.0   1.0   1.0   4.0   4.0   2.0   1.0   1.0   1.0   1.0   4.0   2.0
L.0863   2.0   1.0   1.0   4.0   1.0   2.0   4.0   4.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
L.0864   1.0   1.0   1.0   1.0   1.0
L.0865   1.0   1.0   1.0   1.0   1.0   1.0   1.0   4.0   4.0   2.0   1.0   1.0   1.0   1.0   4.0   2.0
L.0866   2.0   1.0   1.0   4.0   1.0   2.0   4.0   4.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
L.0867   1.0   1.0   1.0   1.0   1.0
L.0868  10   5   8  18   5  34  19   5   9  24   5   2  31   5  13  37   5   2  60   5  29  61   0   0
L.0869   0.0   1.0   2.0   3.0   4.0   5.0   6.0   7.0   1.0   5.0   0.0   0.0   2.0   5.0  10.0   0.0
L.0870   2.0   5.0   0.0   0.0   2.0   5.0  10.0   0.0   3.0   5.0   0.0   0.0   0.0   2.0  10.0   0.0
L.0871   4.0   5.0   0.0   0.0   0.0   5.0  10.0   0.0
L.0872   0.0   2.0   3.0   4.0   5.0   6.0   7.0   9.0  10.0  11.0  12.0  14.0  15.0  16.0  17.0  18.0
L.0873  19.0  21.0  22.0  24.0  25.0  26.0  27.0  28.0  29.0  30.0  31.0  33.0  34.0  35.0  37.0  38.0
L.0874  40.0  41.0   1.0  10.0   5.0   2.0  10.0   5.0   2.0   7.0   7.0   7.0   7.0   5.0  10.0  10.0
L.0875  10.0  10.0  10.0   5.0   1.0   5.0   5.0   5.0   2.0   1.0  10.0  10.0   1.0   5.0   5.0   1.0
L.0876  10.0  10.0  10.0  10.0   2.0  10.0   5.0   2.0  10.0   5.0   2.0   7.0   7.0   7.0   7.0   5.0
L.0877   1.0  10.0  10.0  10.0  10.0   5.0   1.0   5.0   5.0   5.0   2.0   1.0  10.0  10.0   1.0   5.0
L.0878    .0   1.0  10.0  10.0  10.0  10.0   3.0  10.0   5.0   2.0  10.0   5.0   2.0   7.0   7.0   7.0
L.0879    .0   5.0  10.0  10.0  10.0  10.0  10.0   5.0   1.0   5.0   5.0   5.0   2.0   1.0  10.0  10.0
L.0880         5.0   5.0   1.0  10.0  10.0  10.0  10.0   4.0  10.0   5.0   2.0  10.0   5.0   2.0   7.0
L.0881    .0   7.0   7.0   5.0  10.0  10.0  10.0  10.0  10.0   5.0   1.0   5.0   5.0   5.0   2.0   1.0
L.0882   0.0  10.0   1.0   5.0   5.0   1.0  10.0  10.0  10.0  10.0
L.0883   0.0   1.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   1.0   5.0   1.0   5.0  10.0   5.0   1.0
L.0884   3.0   5.0   2.0   5.0   1.0   5.0  10.0   5.0   1.0   3.0   5.0   3.0   5.0   1.0   5.0  10.0
L.0885   5.0   1.0   3.0   5.0   4.0   5.0   1.0   5.0  10.0   5.0   1.0   3.0   5.0
L.0886   0.0   1.0   1.0   1.0   2.0   1.0   3.0   1.0   4.0   1.0
L.0887   0.0   1.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0  10.0  11.0  12.0   1.0   1.0   5.0
L.0888   4.0   5.0   5.0   6.0   6.0   3.0   3.0   3.0   3.0   1.0   2.0   1.0   3.0   1.0   5.0   5.0
L.0889   5.0   5.0   3.0   3.0   2.0   2.0   1.0   3.0   1.0   3.0   1.0   5.0   5.0   5.0   5.0   3.0
L.0890   3.0   2.0   2.0   1.0   4.0   1.0   3.0   1.0   5.0   5.0   5.0   5.0   3.0   3.0   2.0   2.0
L.0891   1.0
L.0892   0.0   1.0   1.0   1.0   2.0   1.0   3.0   1.0   4.0   1.0
L.0893   0.0  11.0  12.0  13.0  14.0  15.0  17.0  18.0  19.0  20.0  24.0  25.0  32.0  33.0  34.0  35.0
L.0894  36.0  37.0  38.0  39.0  40.0  41.0  42.0  43.0  44.0  45.0  47.0  48.0  49.0   1.0   1.0   1.0
L.0895   1.0   1.0   1.0  10.0  10.0  10.0  10.0  10.0  10.0   7.0   7.0   7.0   7.0   7.0   7.0   7.0
L.0896   7.0   7.0   5.0   5.0   5.0   5.0   5.0   1.0   1.0   1.0   2.0   0.0   0.0   0.0   0.0   0.0
L.0897   7.0   7.0   7.0   7.0  10.0  10.0   7.0   7.0   7.0   7.0   7.0   7.0   7.0   7.0   7.0   7.0
L.0898   5.0   5.0   7.0   7.0   5.0   5.0   5.0   3.0   0.0   0.0   0.0   0.0   0.0   5.0   5.0   5.0
L.0899   5.0  10.0  10.0   7.0   7.0   7.0   7.0   7.0   7.0   7.0   7.0   7.0   9.0   7.0   7.0   9.0
L.0900   9.0   5.0   6.0   5.0   4.0   0.0   0.0   0.0   0.0   0.0   5.0   5.0   5.0   5.0  10.0  10.0
L.0901   7.0   7.0   7.0   7.0   7.0   7.0   7.0   7.0   7.0   9.0   7.0   7.0   9.0   9.0   5.0   6.0
L.0902   5.0
L.0903   0.0
L.0904   0   0   0   0   0   0   0   0  10   1   2   0   0   0   0   0  16   0   3   0   4  13  19   0   6   7
L.0905   8   0   0   0   0   0   0   0   0   0   0
L.0906   0   0   0   0   0   0   0   0  12   1   2   0   0   0   0   0  15   0   3   0   4  14  18   0   6   7
L.0907   8   0   0   0   0   0   0   0   0   0   0
L.0908   0   0   0   0   0   0   0   0  11   1   0   0   0   0   0   0  17   0   3   0   4  14  20   0   6   7
L.0909   8   0   0   0   0   0   0   0   0   0   0
L.0910   0   0   0   0   0   0   0   0   9   1   0   0   0   0   0   0  15   0   3   0   4  14  18   0   6   7
L.0911   8   0   0   0   0   0   0   0   0   0   0
L.0912   1   2   5   6   7   8   9-11-12  11  12  13  14  15  17-37-38-37-38  23-25  25  31  32-31  35
L.0913  37  37  38  38  47  58  60  61  62  69  71  72  73  78  79  80   1   0   5   6   7   8   9  10  10-10
L.0914 -10  13   0  15  17  18  18  19  19  23  24-24-33  32  33   0-18-19-18-19  47  58  60  61   0  69
L.0915  71  72  73  78  79  80
L.0916  14
L.0917   1   2   5   6   7  15  17  62  69  78  79
L.0918  71  72  73  80
L.0919   8   9
L.0920  11  12   4  32  98   2  35  31   4
L.0921   1   4   2
L.0922   3   4   5   2   2   2   3   3   4   4   4   4   3   3   2   2   2   2   2   2
L.0923   10.00   50.00  160.00   10.00    8.00    0.00
L.0924    0.00   90.00  270.00  360.00    0.00   10.00   10.00    0.00
L.0925    0.50    1.00    1.25    1.50    2.00    0.00    1.00   10.00   10.00    0.00
L.0926    2.00    6.00    0.00   10.00
L.0927    0.00  100.00   10.00    0.00
L.0928    0.00    2.00   10.00    0.00
L.0929    0.00    5.00   20.00   10.00   10.00    0.00
L.0930    0.00   10.00   30.00   10.00    9.00    0.00
L.0931    0.00     .30    4.00    5.00    0.00   10.00   10.00    0.00
L.0932    0.30    1.00    4.00   12.00    0.00   10.00   10.00    0.00
L.0933    0.30    2.00    5.00   12.00    0.00   10.00   10.00    0.00
L.0934    0.30    2.00    5.00   20.00    0.00   10.00   10.00    0.00
L.0935    1.00    2.00    3.00    0.00   10.00    0.00
L.0936    1.00    2.00    4.00    0.00   10.00    0.00
L.0937    0.90   30.00    0.00   10.00
L.0938    1.50   30.00    0.00   10.00
L.0939    3.00   30.00    0.00   10.00
L.0940    1.00   30.00    0.00   10.00
L.0941    2.00   30.00    0.00   10.00
L.0942    3.00   30.00    0.00   10.00
L.0943   8   4   4
L.0944    1.00    4.00    8.00   14.00   20.00     .00    2.00    6.00   14.00   28.00
L.0945    1.00    4.00    5.00    8.00    9.00   12.00    1.00    1.00    2.00    2.00    4.00
L.0946    4.00
```

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L.0947     5.00  10.00  15.00  20.00    0.01    0.09    0.40    1.00
L.0948 RURAL RESIDENTAL BUILD. 001
L.0949 URBAN RESIDENTAL BUILD. 002
L.0950 COMMERCIAL BUILDING     003
L.0951 INDUSTRIAL BUILDING     004
L.0952 ROCK SURFACE            001
L.0953 BOULDER COVER           002
L.0954 LAKE                    005
L.0955 RESERVOIR               006
L.0956 VLEI                    007
L.0957 RIVER                   008
L.0958 STREAM                  009
L.0959 HILLSLOPE ELEMENT       010
L.0960 SLOPE GRADIENT          011
L.0961 SLOPE LENGTH            012
L.0962 ASPECT OF A SLOPE       013
L.0963 HEIGHT ABOVE WATER      014
L.0964 KOPPIE                  015
L.0965 GULLY                   017
L.0966 STRATIGRAPHIC UNIT      018
L.0967 TRANSPORTED SOIL ORGIN  019
L.0968 DEPTH TO BEDROCK        023
L.0969 GEOLOGICAL DISCONT.     024
L.0970 FACTOR OF SAFETY        025
L.0971 SOIL HORIZON TYPE       031
L.0972 SOIL ERODIBILITY INDEX  032
L.0973 SOIL PERMEABILITY INDEX 033
L.0974 DEPTH TO WATER TABLE    035
L.0975 SOIL JOINT STRUCTURE    037
L.0976 SOIL ACTIVITY           038
L.0977 WIND VELOCITY           047
L.0978 RAINFALL ENERGY         058
L.0979 PHYSIOGNOMIC VEGE.TYPE  060
L.0980 FLORISITIC VEGE.TYPE    061
L.0981 WOODY COVER             062
L.0982 INDUSTRIAL AREA         069
L.0983 POWERLINE               071
L.0984 RAILWAY                 072
L.0985 PAVED ROAD              073
L.0986 MOUNTAIN CATCHMENT AREA 078
L.0987 WILDERNESS AREA         079
L.0988 UNPAVED ROAD            080
L.0989  CONTROL DATA FOR THE COMMUNICATIONS LAND USE SYSTEM
L.0990  37  1  8 13 42  0 13  0  6  3  3  3
L.0991   1  2  5  6  7  8  9 10 11 12 14 15 17 18 19 23 24 25 31 32 33 35 37 38 47 58
L.0992  60 61 62 68 69 70 72 73 78 79 80
L.0993   1  2  5  6  7  8  9 10 11 12 14 15 17 18 19 23 24 25 31 32 33 35 37 38 47 58
L.0994  60 61 62 68 69 70 72 73 78 79 80
L.0995   1  0  5  6  7  8  0 10 11  0 14 15 17 18 19 23 24 25 31  0 33 35 37 38  0  0
L.0996  60 61 62 68 69 70 72 73 78 79 80
L.0997    95.00   23.00   95.00   95.00   95.00    5.00    5.00    6.00    8.00 999.999999.95
L.0998    95.00   95.00   41.00    8.00 999.99 999.99     2.00   12.00    8.00    4.00 999.99
L.0999   999.99    2.00   20.00   30.00   49.00   50.00  100.00   95.00   95.00   95.00    5.00
L.1000     5.00   95.00   95.00    5.00
L.1001    95.00   25.00   95.00   95.00   95.00    5.00    5.00    6.00    4.00 999.999999.99
L.1002    95.00   95.00   41.00    8.00 999.99 999.99     2.00   12.00    8.00    4.00   30.00
L.1003   999.99    2.00   20.00   30.00   49.00   50.00  100.00   95.00   95.00   95.00    5.00
L.1004     5.00   95.00   95.00    5.00
L.1005    95.00    0.00   95.00   95.00   95.00    5.00    0.00    7.00   45.00    0.009999.99
L.1006    95.00   95.00   41.00    8.00 999.99 999.99     2.00   12.00    0.00    4.00   30.00
L.1007   999.99    2.00    0.00    0.00   49.00   50.00  100.00   95.00   95.00   95.00    5.00
L.1008     5.00   95.00   95.00    5.00
L.1009     0.00    0.00    0.00    0.00    0.00    0.00    0.00    1.00    0.30   10.00   10.00
L.1010     0.00    0.00    1.00    1.00    0.60    0.00    0.00    1.00    2.00    1.00    1.00
L.1011     0.00    0.00    0.00    0.00   17.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1012     0.00    0.00    0.00    0.00
L.1013     0.00    0.00    0.00    0.00    0.00    0.00    0.00    1.00    0.00   10.00   10.00
L.1014     0.00    0.00    1.00    1.00    0.60    0.00    0.00    1.00    2.00    1.00    1.00
L.1015     0.00    0.00    0.00    0.00   17.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1016     0.00    0.00    0.00    0.00
L.1017     0.00    0.00    0.00    0.00    0.00    0.00    0.00    1.00    0.30    0.00   10.00
L.1018     0.00    0.00    1.00    1.00    0.60    0.00    0.00    1.00    0.00    1.00    1.00
L.1019     0.00    0.00    0.00    0.00   17.00    0.00    0.00    0.40    0.00    1.00    1.00
L.1020     0.00    0.00    0.00    0.00
L.1021   1.0  1.0  1.0  1.0  1.0  1.0  1.0  4.0  4.0  2.0  1.0  1.0  1.0  4.0  2.0  2.0
L.1022   1.0  1.0  4.0  1.0  1.0  2.0  4.0  4.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1023   1.0  1.0  1.0  1.0  1.0
L.1024   1.0  1.0  1.0  1.0  1.0  1.0  1.0  4.0  4.0  2.0  1.0  1.0  1.0  4.0  2.0  2.0
L.1025   1.0  1.0  4.0  1.0  1.0  2.0  4.0  4.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1026   1.0  1.0  1.0  1.0  1.0
L.1027   1.0  1.0  1.0  1.0  1.0  1.0  1.0  4.0  4.0  2.0  1.0  1.0  1.0  4.0  2.0  2.0
L.1028   1.0  1.0  4.0  1.0  1.0  2.0  4.0  4.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1029   1.0  1.0  1.0  1.0  1.0
L.1030  10  4  8 18  4 34 19  4  9 24  4  2 31  4 13 37  4  2 60  4 29 61  0  0
L.1031   0.0  1.0  2.0  3.0  4.0  5.0  6.0  7.0  1.0  5.0  0.0  0.0  0.0  5.0 10.0  0.0
L.1032   2.0  5.0  0.0  0.0  0.0  5.0 10.0  0.0  3.0  5.0  0.0  0.0  3.0  8.0 10.0  6.0
L.1033   0.0  2.0  3.0  4.0  5.0  6.0  7.0  5.0 10.0 11.0 12.0 14.0 15.0 16.0 17.0 18.0
L.1034  19.0 21.0 22.0 24.0 25.0 26.0 27.0 28.0 29.0 30.0 31.0 33.0 34.0 35.0 37.0 38.0
L.1035  40.0 41.0  1.0 10.0  5.0  2.0 10.0  5.0  2.0  7.0  7.0  7.0  7.0  5.0 10.0 10.0
L.1036  10.0 10.0 10.0  5.0  1.0  5.0  5.0  5.0  2.0  1.0 10.0 10.0  1.0  5.0  5.0  1.0
L.1037  10.0 10.0 10.0 10.0  2.0 10.0  5.0  2.0 10.0  5.0  2.0  7.0  7.0  7.0  7.0  5.0
L.1038  10.0 10.0 10.0 10.0 10.0  5.0  1.0  5.0  5.0  8.0  2.0  1.0 10.0 10.0  1.0  5.0
L.1039   5.0  1.0 10.0 10.0 10.0 10.0  3.0 10.0  5.0  2.0 10.0  5.0  2.0  7.0  7.0  7.0
L.1040   7.0  5.0 10.0 10.0 10.0 10.0 10.0  5.0  1.0  5.0  5.0  5.0  2.0  1.0 10.0 10.0
L.1041   1.0  5.0  5.0  1.0 10.0 10.0 10.0 10.0
L.1042   0.0  1.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  1.0  5.0  1.0  0.0 10.0  5.0  1.0
L.1043   3.0  5.0  2.0  5.0  1.0  5.0 10.0  5.0  1.0  3.0  5.0  3.0  5.0  1.0  8.0 10.0
L.1044   5.0  1.0  3.0  5.0
L.1045   0.0  1.0  1.0  1.0  2.0  1.0  3.0  1.0
L.1046   0.0  1.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 10.0 11.0 12.0  1.0  1.0  3.0
L.1047   1.0  5.0  5.0  5.0  5.0  3.0  3.0  2.0  2.0  1.0  2.0  1.0  3.0  1.0  5.0  5.0
L.1048   5.0  5.0  3.0  3.0  2.0  2.0  1.0  3.0  1.0  3.0  1.0  5.0  5.0  5.0  5.0  3.0
L.1049   3.0  2.0  2.0  1.0
L.1050   0.0  1.0  1.0  1.0  2.0  1.0  3.0  1.0
L.1051   0.0 11.0 12.0 13.0 14.0 15.0 17.0 18.0 19.0 20.0 24.0 25.0 32.0 33.0 34.0 35.0
L.1052  36.0 37.0 38.0 39.0 40.0 41.0 42.0 43.0 44.0 45.0 47.0 48.0 49.0  1.0  0.0  7.0
L.1053   0.0  0.0  0.0  7.0  7.0  7.0  7.0 10.0 10.0  7.0  7.0  7.0  7.0  7.0  0.0  7.0
L.1054   7.0  7.0  9.0  7.0  7.0  9.0  5.0  5.0  6.0  5.0  2.0  0.0  0.0  0.0  0.0  0.0
L.1055   7.0  7.0  7.0  7.0 10.0 10.0  7.0  7.0  7.0  7.0  7.0  7.0  7.0  7.0  2.0  9.0
L.1056   7.0  7.0  9.0  9.0  5.0  6.0  5.0  3.0  5.0  5.0  5.0  5.0  5.0  7.0  7.0  7.0
L.1057   7.0 10.0 10.0  7.0  7.0  7.0  7.0  7.0  7.0  5.0  7.0  7.0  7.0  7.0  7.0  9.0
```

```
L.1058    9.0   5.0   6.0   5.0
L.1059    0.0
L.1060    0   0   0   0   0   0   0   0  11   1   0   0   0   0   0  12   0   2   0   3   4  13   0   6   7   8
L.1061    0   0   0   0   0   0   0   0   0   0   0
L.1062    0   0   0   0   0   0   0   0  10   1   0   0   0   0   0  12   0   2   0   3   4  13   0   6   7   8
L.1063    0   0   0   0   0   0   0   0   0   0   0
L.1064    0   0   0   0   0   0   0   0   9   0   0   0   0   0   0  12   0   2   0   3   4  13   0   6   7   8
L.1065    0   0   0   0   0   0   0   0   0   0   0
L.1066    1   2   5   6   7   8   9-11-12  11  12  14  15  17-37-38-37-38  23-25  25  31  32-31  35  37
L.1067   37  38  38  47  58  60  61  62  68  69  70  72  73  78  79  80   1   0   5   6   7   8   9  10  10-10
L.1068  -10   0  15  17  18  16  19  19  23  24-24-33  32  33   0-18-19-18-15  47  58  60  61   0  68  69
L.1069   70  72  73  78  79  80
L.1070   14
L.1071    1   2   5   6   7  15  17  62  68  69  70  78  79
L.1072    8   9  71  72  73  80
L.1073   11  12   4  32  50   2  35  31   4
L.1074    1   4   2
L.1075    3   5   2   3   2   2   3   3   4   4   2   2
L.1076    10.00   50.00  160.00   10.00    5.00    0.00
L.1077     0.50    1.00    1.25    1.50    2.00    0.00    2.00   10.00   10.00    0.00
L.1078     2.00    6.00    0.00   10.00
L.1079     1.00    2.00    4.00    0.00   10.00    0.00
L.1080     0.00  100.00   10.00    0.00
L.1081     0.00    2.00   10.00    0.00
L.1082     0.00    5.00   20.00   10.00   10.00    0.00
L.1083     0.00   10.00   30.00   10.00    9.00    0.00
L.1084     0.00    0.30    5.00   45.00    0.00   10.00   10.00    0.00
L.1085     0.00    0.30    1.00    0.00   10.00   10.00   10.00    0.00
L.1086     0.00    0.30    2.00    4.00   10.00   10.00   10.00    0.00
L.1087     0.60   30.00    0.00   10.00
L.1088     1.00   30.00    0.00   10.00
L.1089    5   6   4
L.1090     1.00    4.00    8.00   14.00   20.00    1.00    2.00    6.00   14.00   25.00
L.1091     1.00    4.00    5.00    8.00    9.00   12.00    1.00    1.70    2.00    2.00    4.00
L.1092     4.00
L.1093     5.00   10.00   14.00   20.00    0.01    0.09    0.40    1.00
L.1094 ROAD CONSTRUCTION              001
L.1095 RAILWAY CONSTRUCTION           002
L.1096 TRANSMISSION LINE CONST.003
L.1097 ROCK SURFACE                   001
L.1098 BOULDER COVER                  002
L.1099 LAKE                           005
L.1100 RESERVOIR                      006
L.1101 VLEI                           007
L.1102 RIVER                          008
L.1103 STREAM                         009
L.1104 HILLSLOPE ELEMENT              010
L.1105 SLOPE GRADIENT                 011
L.1106 SLOPE LENGTH                   012
L.1107 HEIGHT ABOVE WATER             014
L.1108 KOPPIE                         015
L.1109 GULLY                          017
L.1110 STRATIGRAPHIC UNIT             018
L.1111 TRANSPORTED SOIL ORGIN         019
L.1112 DEPTH TO BEDROCK               023
L.1113 GEOLOGICAL DISCONT.            024
L.1114 FACTOR OF SAFETY               028
L.1115 SOIL HORIZON TYPF              031
L.1116 SOIL ERODIBILITY INDEX         032
L.1117 SOIL PERMEABILITY INDEX        033
L.1118 DEPTH TO WATER TABLE           035
L.1119 SOIL JOINT STRUCTURE           037
L.1120 SOIL ACTIVITY                  038
L.1121 WIND VELOCITY                  047
L.1122 RAINFALL ENERGY                058
L.1123 PHYSIOGNOMIC VEGE.TYPE         060
L.1124 FLORISITIC VEGE.TYPE           061
L.1125 WOODY COVER                    062
L.1126 TOWNSHIP                       069
L.1127 INDUSTRIAL AREA                069
L.1128 SETTLEMENT                     070
L.1129 RAILWAY                        072
L.1130 PAVED ROAD                     073
L.1131 MOUNTAIN CATCHMENT AREA        078
L.1132 WILDERNESS AREA                079
L.1133 UNPAVED ROAD                   080
L.1134  CONTROL DATA FOR THE EXCAVATION LAND USE SYSTEM
L.1135   50   1   7  15  43   2   9   6   0   5   4   3
L.1136    0   0   0   0   0   0   0   0   0   0   0   0  21   0   0   0   0   0   0   0   0   0   0   0   0   0
L.1137    0   0   0   0   0  68  69  70   0   0   0  78  79   0
L.1138    1   2   0   0   0   0   0   0   0   0   0  20   0   0   0   0   0  26  27  23   0   0   0   0   0  46
L.1139    0   0   0   0   0  68  69  78   0   0   0  78  79  80
L.1140    1   2   5   6   7   8   9  10  11  12  14   0  21  22   0  24  25   0   0   0  29  30  32  33  35   0
L.1141   47  58  60  61  62  68  69  70  71  72  73  78  79  80
L.1142    1   2   5   6   7   8   9  10  11  12  14  20   0   0  23  24  25  26  27  28  29  30  32  33  35  46
L.1143   47  58  60  61  62  68  69  70  71  72  73  78  79  80
L.1144    1   2   5   6   7   8   9  10  11  12  14   0  21  22   0  24  25   0   0   0  29  30  32  33  35   0
L.1145   47  58  60  61  62  68  69  70  71  72  73  78  75  80
L.1146     0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1147     0.00  999.99    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1148     0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00  100.00
L.1149   100.00    0.00    0.00    0.00   90.00   90.00    0.00
L.1150   100.00  100.0     0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1151     9.00    0.00    0.00    0.00    0.00    0.00  999.99  100.00  100.00    0.00    0.00
L.1152     0.00    0.00    0.00    1.00    0.00    0.00    0.00    0.00    0.00  100.00  100.00
L.1153   100.00    0.00    0.00    0.00   90.00   90.00    0.00
L.1154   100.00  100.00  100.00  100.00   90.00    5.00    5.00    6.00   60.00  999.999999.99
L.1155     0.00  999.99  999.99    0.00  999.99    2.00    0.00    0.00    0.00   12.00   12.00
L.1156     8.00    4.00  999.99    0.00   20.00   30.00   49.00   50.00  100.00   90.00   90.00
L.1157    90.00    5.00    5.00    5.00   90.00   90.00    5.00
L.1158   100.00  100.00  100.00  100.00   90.00    5.00    5.00    6.00   60.00  999.999999.99
L.1159     9.00    0.00    0.00  999.99  999.99    2.00  999.99  100.00  999.99   12.00   12.00
L.1160     8.00    4.00  999.99   10.00   20.00   30.00   49.00   50.00  100.00   90.00   90.00
L.1161    90.00    5.00    5.00    5.00   90.00   90.00    5.00
L.1162   100.00  100.00  100.00  100.00   90.00    5.00    5.00    7.00   30.00  999.999999.99
L.1163     0.00  999.99  999.99    0.00  999.99    2.00    0.00    0.00    0.00   12.00   12.00
L.1164     8.00    4.00  999.99    0.00   20.00   30.00   49.00   50.00  100.00   90.00   90.00
L.1165    90.00    5.00    5.00    5.00   90.00   90.00    5.00
L.1166     0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1167     0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1168     0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1169     0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1170     0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1171     1.00    0.00    0.00    0.00    0.00    0.00   10.00    0.00    0.00    0.00    0.00
L.1172     0.00    0.00    0.00    1.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1173     0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1174     0.00    0.00    0.00    0.00    0.00    0.00    0.00    1.00    5.00    0.00   10.00
L.1175     0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    1.00    1.00
```

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L.1176    3.50   1.00   0.50   0.00   0.00   0.00  11.00   0.00   0.00   0.00   0.00
L.1177    0.00   0.00   0.00   0.00   0.00   0.00   0.00
L.1178    0.00   0.00   0.00   0.00   0.00   0.00   0.00   1.00   5.00   0.00  10.00
L.1179    1.00   0.00   0.00   0.00   0.00   0.00  10.00   0.00   0.00   1.00   1.00
L.1180    3.50   1.00   0.50   1.00   0.00   0.00  11.00   0.00   0.00   0.00   0.00
L.1181    0.00   0.00   0.00   0.00   0.00   0.00   0.00
L.1182    0.00   0.00   0.00   0.00   0.00   0.00   0.00   1.00   0.00   0.00  10.00
L.1183    0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   1.00   1.00
L.1184    2.50   1.00   0.50   0.00   0.00   0.00  11.00   0.00   0.00   0.00   0.00
L.1185    0.00   0.00   0.00   0.00   0.00   0.00   0.00
L.1186   1.0  1.0  1.0  1.0  1.0  1.0  1.0  3.0  3.0  1.0  1.0  4.0  4.0  1.0  1.0  1.0
L.1187   1.0  4.0  4.0  4.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1188   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1189   1.0  1.0  1.0  1.0  1.0  1.0  1.0  3.0  3.0  1.0  1.0  4.0  4.0  1.0  1.0  1.0
L.1190   1.0  4.0  4.0  4.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1191   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1192   1.0  1.0  1.0  1.0  1.0  1.0  1.0  3.0  3.0  1.0  1.0  4.0  4.0  1.0  1.0  1.0
L.1193   1.0  4.0  4.0  4.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1194   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1195   1.0  1.0  1.0  1.0  1.0  1.0  1.0  3.0  3.0  1.0  1.0  4.0  4.0  1.0  1.0  1.0
L.1196   1.0  4.0  4.0  4.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1197   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1198   1.0  1.0  1.0  1.0  1.0  1.0  1.0  3.0  3.0  1.0  1.0  4.0  4.0  1.0  1.0  1.0
L.1199   1.0  4.0  4.0  4.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1200   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1201  10   4   8 20   3  19 24   4   2 29   4 13  30   4 13  60   4  30 61   0   0
L.1202   0.0  1.0  2.0  3.0  4.0  5.0  6.0  7.0  3.0  5.0  0.0  1.0  5.0 10.0  5.0  0.0
L.1203   4.0  5.0  0.0  1.0 10.0 10.0  5.0  0.0  5.0  5.0  0.0  0.0  0.0  7.0 10.0  0.0
L.1204   0.0  1.0  1.5  2.0  2.5  3.0  3.5  4.0  4.5  5.0  5.5  6.0  6.5  7.0  7.5  8.0
L.1205   8.5  9.0  9.5  1.0  7.0  8.0  3.0  3.0  5.0  5.0  6.0  7.0  5.0  5.0  7.0  7.0
L.1206  10.0 10.0  5.0  5.0  5.0  5.0  2.0  7.0  6.0  3.0  3.0  5.0  5.0  6.0  7.0  5.0
L.1207   5.0  7.0  7.0 10.0 10.0  5.0  5.0  5.0  5.0
L.1208   0.0  1.0  3.0  1.0  4.0  1.0  5.0  1.0
L.1209   0.0  1.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 10.0 11.0 12.0  3.0 10.0  8.0
L.1210   6.0  6.0  6.0  6.0  5.0  4.0  3.0  4.0  2.0  1.0  4.0 10.0  8.0  8.0  6.0  6.0
L.1211   6.0  5.0  4.0  3.0  4.0  2.0  1.0  8.0 10.0  8.0  8.0  6.0  6.0  6.0  5.0  4.0
L.1212   3.0  4.0  2.0  1.0
L.1213   0.0  1.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 10.0 11.0 12.0  3.0  5.0  5.0
L.1214   5.0  7.0  9.0  9.0 10.0  9.0  8.0  8.0  6.0  6.0  4.0  5.0  5.0  5.0  7.0  9.0
L.1215   9.0 10.0  9.0  8.0  8.0  6.0  6.0  5.0  5.0  5.0  5.0  7.0  9.0  9.0 10.0  9.0
L.1216   8.0  8.0  6.0  6.0
L.1217   0.0 11.0 12.0 13.0 14.0 15.0 17.0 18.0 19.0 20.0 22.0 24.0 25.0 32.0 33.0 34.0
L.1218  35.0 36.0 37.0 38.0 39.0 40.0 41.0 42.0 43.0 44.0 45.0 47.0 46.0 49.0  3.0  1.0
L.1219   1.0  1.0  1.0  1.0  5.0  5.0  5.0  5.0  2.0 10.0 10.0  7.0  7.0  7.0  7.0  7.0
L.1220   7.0  7.0  7.0  7.0 10.0  7.0  7.0 10.0 10.0  5.0  5.0  5.0  4.0  1.0  1.0  1.0
L.1221   1.0  1.0  5.0  5.0  5.0  5.0  2.0 10.0 10.0  7.0  7.0  7.0  7.0  7.0  7.0  7.0
L.1222   7.0  7.0 10.0  7.0  7.0 10.0 10.0  5.0  5.0  5.0  5.0  1.0  1.0  1.0  1.0  1.0
L.1223   5.0  5.0  5.0  5.0  2.0 10.0 10.0  7.0  7.0  7.0  7.0  7.0  7.0  7.0  7.0  7.0
L.1224  10.0  7.0  7.0 10.0 10.0  5.0  5.0  5.0
L.1225   0.0
L.1226   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.1227   0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.1228   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 14  3 15  0  0  0  0  0  0
L.1229   0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.1230   0  0  0  0  0  0  0  0  8  1  0  0  0 12  0  0  2  0  0  0  0  0 11  4  5  0
L.1231   6  7  0  0  0  0  0  0  0  0  0  0  0  0
L.1232   0  0  0  0  0  0  0  0  8  1  0  0  0  0 13  0  2 14  3 15  0  0 11  4  5  0
L.1233   6  7  0  0  0  0  0  0  0  0  0  0  0  0
L.1234   0  0  0  0  0  0  0  0  9  1  0  0  0 12  0  0  2  0  0  0  0  0 10  4  5  0
L.1235   6  7  0  0  0  0  0  0  0  0  0  0  0  0
L.1236   1  2  5  6  7  8  9-11-12 11 12 14 20 21 22 23-25 25-27-28 27 28 29 30 32-29
L.1237 -30 35 46 47 58 60 61 62 68 69 70 71 72 73 78 79 80  1  0  5  6  7  8  9 10 10
L.1238 -10-10  0 20 21  0  0 24-24 26 26-26-26-33-33 32 33 33  0 46 47 58 60 61  0 68
L.1239  69 70 71 72 73 78 79 80
L.1240  14
L.1241   1  2
L.1242   5  6  7 62 68 69 70 78 79
L.1243   8  9 71 72 73 80
L.1244  11 12  4 20 46  5 32 58  2 35 31  4
L.1245   1  5  4  2
L.1246   3  5  2  2  2  3  3  4  4  2  2  2  2  2  2
L.1247    10.00   50.00 160.00   10.00    5.00    0.00
L.1248     0.50    1.00   1.25    1.50    2.00    0.00    1.00   10.00   10.00    0.00
L.1249     0.00  100.00  10.00    0.00
L.1250     1.00    4.00   0.00   10.00
L.1251     0.50  100.00   0.00   10.00
L.1252     0.00    5.00  20.00   10.00   10.00    0.00
L.1253     0.00   10.00  30.00   10.00    9.00    0.00
L.1254     0.00    5.00  30.00   60.00    0.00   10.00   10.00    0.00
L.1255     0.00    2.00   4.00   30.00    0.00   10.00   10.00    0.00
L.1256     2.50    6.00   0.00   10.00
L.1257     3.50    6.00   0.00   10.00
L.1258     0.00  100.00  10.00    0.00
L.1259     0.00  100.00  10.00    0.00
L.1260    10.00  100.00   0.00   10.00
L.1261     0.00  100.00  10.00    0.00
L.1262   5   6   4
L.1263     1.00    4.00   8.00   14.00   20.00    1.00    2.00    6.00   14.00   25.00
L.1264     1.00    4.00   5.00    8.00    5.00   12.00    1.00    1.00    2.00    2.00    4.00
L.1265     4.00
L.1266     5.00   10.00  14.00   20.00    0.01    0.09    0.40    1.00
L.1267 MINERAL ORE DEPOSIT         001
L.1268 CONSTRUCTION MATERIAL       002
L.1269 OPEN PIT MINING             003
L.1270 QUARRY                      004
L.1271 UNDERGROUND MINE            005
L.1272 ROCK SURFACE                001
L.1273 BOULDER COVER               002
L.1274 LAKE                        005
L.1275 RESERVOIR                   006
L.1276 VLEI                        007
L.1277 RIVER                       008
L.1278 STREAM                      009
L.1279 HILLSLOPE ELEMENT           010
L.1280 SLOPE GRADIENT              011
L.1281 SLOPE LENGTH                012
L.1282 HEIGHT ABOVE WATER          014
L.1283 NATURAL ROCK GROUP          020
L.1284 MINERAL ORE DEPOSIT         021
L.1285 DEPTH TO MIN.ORE DEPOSIT022
L.1286 DEPTH TO BEDROCK            023
L.1287 GEOLOGICAL DISCONT.         024
L.1288 FACTOR OF SAFETY            025
L.1289 ROCK HARDNESS               026
L.1290 SECONDARY MINERALS          027
L.1291 TEN PER CENT FINES          028
L.1292 SUBSOIL TEXTURE             029
L.1293 TOPSOIL TEXTURE             030
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SOIL ERODIBILITY INDEX  032
SOIL PERMEABILITY INDEX 033
DEPTH TO WATER TABLE    035
CLIMATIC N-FACTOR       046
WIND VELOCITY           047
RAINFALL ENERGY         058
PHYSIOGNOMIC VEGE.TYPE  060
FLORISITIC VEGE.TYPE    061
WOODY COVER             062
TOWNSHIP                068
INDUSTRIAL AREA         069
SETTLEMENT              070
POWERLINE               071
RAILWAY                 072
PAVED ROAD              073
MOUNTAIN CATCHMENT AREA 078
WILDERNESS AREA         079
UNPAVED ROAD            080
 CONTROL DATA FOR THE WATER CATCHMENT LAND USE SYSTEM
 25  0  5  8 27  3  6  0  3  1  3  3
  5  6  7 10 11 12 17 29 30 32 33 35 36 57 59 60 61 62 68 69 70 72 73 78 80
100.00 100.00 100.00   6.00 100.00 999.99 100.00  12.00  12.00   0.00   4.00
999.99 160.00  30.009999.99  49.00  50.00 100.00 100.00 100.00 100.00   5.00
  5.00 100.00   5.00
  0.00   0.00   0.00   1.00   2.00   0.00   0.00   1.00   1.00   2.50   1.00
  0.00   0.00   0.00   1.00   2.00   0.00   0.00   0.00   0.00   0.00   0.00
  0.00   0.00   0.00
  1.0   1.0   1.0   1.0   1.0   1.0   1.0   3.0   3.0   1.0   3.0   3.0   4.0   1.0   4.0   3.0
  3.0   1.0   1.0   1.0   1.0   1.0   1.0   4.0   1.0
 10  2  8 29  2 13 30  2 13 60  2 38 61  0  0
  0.0   1.0   2.0   3.0   4.0   5.0   6.0   7.0   1.0   0.0  10.0  10.0   8.0   5.0   1.0   0.0
  0.0   1.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0  10.0  11.0  12.0   1.0   1.0   3.0
  5.0   5.0   6.0   7.0  10.0  10.0   8.0   7.0   5.0   3.0
  0.0   1.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0  10.0  11.0  12.0   1.0   1.0   3.0
  5.0   6.0   6.0   6.0   9.0   7.0   3.0   3.0   2.0   2.0
  0.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0  11.0  12.0  13.0  14.0  15.0  16.0  17.0
 18.0  19.0  20.0  22.0  23.0  24.0  25.0  31.0  32.0  33.0  34.0  35.0  36.0  37.0  38.0  39.0
 40.0  42.0  43.0  44.0  45.0  49.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   3.0
  3.0   3.0   3.0   3.0   5.0   5.0   5.0   5.0   5.0   1.0   1.0  10.0  10.0   5.0   7.0   9.0
  5.0   5.0   5.0   5.0   5.0   5.0   5.0   5.0   5.0   7.0   7.0   1.0
  0.0
  0  0  0  0  1  2  0  0  0  3  4  5  6  7  8  0  0  0  0  0  0  0  0  0  0
  5  6  7-11-12 11 12 17 29 30 32-29-30 35 36 58 59 60 61 62 68 69 70 72 73 78
 80  5  6  7 10 10-10-10 17-33-33 32 33 33  0 36 58 59 60 61  0 68 69 70 72 73
 78 80
  5  6 78
  7 17 62 68 69 70
 72 73 80
 11 12  4 32 58  2 35 29  4
  1  4  2
  3  3  2  2  2  2  3  2
   2.00   6.00 100.00  10.00  10.00   0.00
   0.00  50.00 160.00  10.00   5.00   0.00
   2.50   6.00   0.00  10.00
   1.00   4.00  10.00   0.00
   0.00 100.00  10.00   0.00
   0.00 100.00  10.00   0.00
   0.00  10.00  30.00  10.00   9.00   0.00
   1.00  10.00   0.00  10.00
  5  6  4
   1.00   4.00   8.00  14.00  20.00   1.00   2.00   6.00  14.00  25.00
   1.00   4.00   5.00   8.00   9.00  12.00   1.00   1.00   2.00   2.00   4.00
   4.00
   5.00  10.00  15.00  20.00   0.01   0.09   0.40   1.00
WATER CATCHMENT         001
LAKE                    001
RESERVIOR               002
VLEI                    003
HILLSLOPE ELEMENT       010
SLOPE GRADIENT          011
SLOPE LENGTH            012
GULLY                   017
SUBSOIL TEXTURE         029
TOPSOIL TEXTURE         030
SOIL ERODIBILITY INDEX  032
SOIL PERMEABILITY INDEX 033
DEPTH TO WATER TABLE    035
EXPOSED SOIL LENGTH     036
RAINFALL ENERGY         058
RUNFALL TOTAL           059
PHYSIOGONOMIC VEGE. TYPE060
FLORISTIC VEGE. TYPE    061
WOODY COVER             062
TOWNSHIP                068
INDUSTRIAL AREA         069
SETTLEMENT              070
RAILWAY                 072
PAVED ROAD              073
MOUNTAIN CATCHMENT AREA 078
UNPAVED ROAD            080
 CONTROL DATA FOR THE FORECLOSURE OF OPTIONS IN LAND USE
 41  3 10 19 44  0  0  0  0  6  2  1
  1  5  6  7  8 10 11 14 15  0 17  0  0 29 30 32 33 34 36 39 40  0 47 57 58  0
 60 61 62  0  0 66  0 68 69 70 71 72 73 78  0
  1  5  6  7  8 10 11 14 15  0 17  0  0 29 30 32 33 34 36 39 40  0 47 57 58  0
 60 61 62  0  0  0  0 68 69 70 71 72 73 78  0
  0  5  6  7  8 10 11  0 15 16 17  0  0  0  0 32  0  0 36  0  0  0 47  0 58  0
 60 61  0  0 65  0 67 68 69 70 71 72 73 78 75
  0  5  6  7  8 10 11  0  0 16 17  0  0 29 30 32 33  0  0  0  0  0 47  0 58  0
 60 61 62 64  0  0  0  0 69  0 71 72 73 78 75
  1  5  6  7  0 10 11  0  0  0  0 20 21 29 30 32 33  0  0  0  0 46 47  0 58  0
 60 61 62  0  0  0  0 68 69 70 71 72 73 78 79
  0  5  6  7  0 10 11  0  0  0 17  0  0 29 30 32 33  0  0  0  0  0  0  0 58 59
 60 61 62  0  0  0  0 68 69 70  0 72 73 78  0
  90.00  90.00  90.00  90.00   5.00   7.00  80.009999.99  90.00   0.00  90.00
   0.00   0.00  12.00  12.00   8.00   4.00 999.99 100.00   0.00   0.00   0.00
  20.009999.99  30.00   0.00  49.00  50.00 100.00   0.00   0.00   0.00   0.00
  90.00  90.00  90.00   5.00   5.00   5.0   90.00   0.00
  90.00  90.00  90.00  90.00   5.00   7.00  25.009999.99  90.00   0.00  90.00
   0.00   0.00  12.00  12.00   8.00   4.00 999.99 100.00   0.00   0.00   0.00
  20.009999.99  30.00   0.00  49.00  50.00 100.00   0.00   0.00   0.00   0.00
  90.00  90.00  90.00   5.00   5.00   5.00  90.00   0.00
   0.00 100.00 100.00 100.00   5.00   7.00 100.00   0.00 100.00 999.99 100.00
   0.00   0.00   0.00   0.00   8.00   0.00   0.00   5.00   0.00   0.00   0.00
  27.00   0.009999.99   0.00  48.00  50.00   0.00   0.00 999.99 999.99   0.00
  90.00  90.00  90.00   5.00   5.00   5.00 100.00 100.00
   0.00 100.00 100.00 100.00   5.00   7.00 100.00   0.00   0.00 999.99  50.00
   0.00   0.00  12.00  12.00   8.00   4.00   0.00   0.00   0.00   0.00   0.00
```

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L.1412   20.00    0.00   30.00    0.00   48.00   50.00  100.00  999.99    0.00    0.00    0.00
L.1413   90.00   90.00   90.00    5.00    5.00    5.00   90.00  100.00
L.1414  100.00   90.00   90.00   90.00    0.00    7.00   60.00    0.00    0.00    0.00    0.00
L.1415    9.00  999.99   12.00   12.00    8.00    4.00    0.00    0.00    0.00    0.00   10.00
L.1416   20.00    0.00   30.00    0.00   49.00   50.00  100.00    0.00    0.00    0.00    0.00
L.1417   90.00   90.00   90.00    5.00    5.00    5.00   90.00   90.00
L.1418    0.00  100.00  100.00  100.00    0.00    6.00  100.00    0.00    0.00    0.00  100.00
L.1419    0.00    0.00   12.00   12.00    8.00    4.00    0.00    0.00    0.00    0.00    0.00
L.1420    0.00    0.00   30.00 9999.99   49.00   50.00  100.00    0.00    0.00    0.00    0.00
L.1421   90.00   90.00   90.00    0.00    5.00    5.00  100.00    0.00
L.1422    0.00    0.00    0.00    0.00    0.00    1.00    0.50   10.00    0.00    0.00    0.00
L.1423    0.00    0.00    1.00    1.00    2.50    2.00    0.25    0.00    0.00    0.00    0.00
L.1424    0.00  250.00    0.00    0.00    2.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1425    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1426    0.00    0.00    0.00    0.00    0.00    1.00    0.50   10.00    0.00    0.00    0.00
L.1427    0.00    0.00    1.00    1.00    2.50    2.00    0.90    0.00    0.00    0.00    0.00
L.1428    0.00  850.00    0.00    0.00    2.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1429    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1430    0.00    0.00    0.00    0.00    0.00    1.00    0.00    0.00    0.00    0.00    0.00
L.1431    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1432    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1433    0.00    0.00    0.00    0.00    0.00    3.00    0.00    0.00
L.1434    0.00    0.00    0.00    0.00    0.00    1.00    0.00    0.00    0.00    0.00    0.00
L.1435    0.00    0.00    1.00    1.00    2.50    1.00    0.00    0.00    0.00    0.00    0.00
L.1436    0.00    0.00    0.00    0.00    2.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1437    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1438    0.00    0.00    0.00    0.00    0.00    1.00   60.00    0.00    0.00    0.00    0.00
L.1439    1.00    0.00    1.00    1.00    2.50    1.00    0.00    0.00    0.00    0.00    1.00
L.1440    0.00    0.00    0.00    0.00   11.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1441    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1442    0.00    0.00    0.00    0.00    0.00    1.00    2.00    0.00    0.00    0.00    0.00
L.1443    0.00    0.00    1.00    1.00    2.50    1.00    0.00    0.00    0.00    0.00    0.00
L.1444    0.00    0.00    0.00    0.00    3.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1445    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
L.1446   1.0  1.0  1.0  1.0  1.0  3.0  3.0  1.0  1.0  1.0  1.0  1.0  1.0  2.0  2.0  3.0
L.1447   2.0  3.0  1.0  1.0  1.0  1.0  1.0  4.0  3.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1448   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1449   1.0  1.0  1.0  1.0  1.0  3.0  3.0  1.0  1.0  1.0  1.0  1.0  1.0  2.0  2.0  3.0
L.1450   2.0  3.0  1.0  1.0  1.0  1.0  1.0  4.0  3.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1451   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1452   1.0  1.0  1.0  1.0  1.0  2.0  2.0  1.0  1.0  4.0  1.0  1.0  1.0  1.0  1.0  4.0
L.1453   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  4.0  1.0  4.0  4.0  1.0  1.0  4.0  4.0
L.1454   1.0  1.0  1.0  1.0  1.0  1.0  1.0  4.0  4.0
L.1455   1.0  3.0  3.0  2.0  3.0  2.0  2.0  1.0  1.0  2.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1456   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  2.0  2.0  1.0  3.0  1.0  1.0
L.1457   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1458   1.0  1.0  1.0  1.0  1.0  3.0  3.0  1.0  1.0  1.0  1.0  4.0  4.0  1.0  1.0  1.0
L.1459   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1460   1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
L.1461   1.0  1.0  1.0  1.0  1.0  1.0  1.0  3.0  3.0  1.0  1.0  1.0  1.0  3.0  3.0  1.0
L.1462   3.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  4.0  3.0  3.0  1.0  1.0  1.0  1.0
L.1463   1.0  1.0  1.0  1.0  1.0  1.0  1.0  4.0  1.0
L.1464  10  7  8 16  7  2 29  6 13 30  6 13 60  7 43 61  0  0 64  7  2 65  7  2 66  7
L.1465   2 67  7  2
L.1466   0.0  1.0  2.0  3.0  4.0  5.0  6.0  7.0  1.0  5.0  0.0  0.0  3.0  5.0 10.0  5.0
L.1467   2.0  5.0  0.0  0.0  3.0  5.0 10.0  5.0  3.0  5.0 10.0 10.0  8.0  5.0  3.0  1.0
L.1468   4.0  8.0  5.0  5.0  8.0 10.0 10.0  5.0  5.0  0.0  0.0  1.0 10.0 10.0  5.0  0.0
L.1469   6.0  0.0 10.0 10.0  8.0  5.0  1.0  0.0
L.1470   0.0  1.0  1.0  1.0  2.0  1.0  3.0  1.0  4.0  1.0  5.0  1.0  6.0  1.0
L.1471   0.0  1.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 10.0 11.0 12.0  1.0  1.0  8.0
L.1472   4.0  5.0  6.0  7.0 10.0 10.0  8.0  8.0  7.0  6.0  2.0  1.0  5.0  4.0  5.0  0.0
L.1473   7.0 10.0 10.0  8.0  8.0  7.0  6.0  4.0  1.0  5.0  4.0  5.0  6.0  7.0 10.0 10.0
L.1474   8.0  8.0  7.0  6.0  5.0 10.0  8.0  8.0  6.0  6.0  6.0  5.0  4.0  3.0  4.0  2.0
L.1475   1.0  6.0  1.0  3.0  5.0  5.0  6.0  7.0 10.0 10.0  8.0  7.0  5.0  3.0
L.1476   0.0  1.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 10.0 11.0 12.0  1.0  5.0  5.0
L.1477   5.0 10.0  9.0  9.0  9.0  5.0  4.0  4.0  3.0  3.0  2.0  5.0  5.0  5.0 10.0  9.0
L.1478   9.0  9.0  5.0  4.0  4.0  3.0  3.0  4.0  5.0  5.0  5.0 10.0  9.0  9.0  5.0  5.0
L.1479   4.0  4.0  3.0  3.0  5.0  5.0  5.0  5.0  7.0  9.0  9.0 10.0  9.0  8.0  6.0  6.0
L.1480   6.0  6.0  1.0  3.0  5.0  6.0  6.0  6.0  9.0  7.0  3.0  3.0  2.0  2.0
L.1481   0.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 11.0 12.0 13.0 14.0 15.0 17.0 18.0
L.1482  19.0 20.0 22.0 23.0 24.0 25.0 27.0 28.0 29.0 30.0 32.0 33.0 34.0 35.0 36.0 37.0
L.1483  38.0 39.0 40.0 41.0 42.0 43.0 44.0 45.0 47.0 48.0 49.0  1.0  5.0 10.0  3.0  0.0
L.1484   0.0  0.0  0.0  0.0  7.0  7.0  7.0  7.0  7.0  7.0  7.0  5.0  7.0  0.0  0.0  1.0
L.1485   1.0  0.0  0.0  0.0  0.0  0.0  1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  5.0  0.0
L.1486   0.0  5.0  5.0  3.0  3.0 10.0  2.0  8.0 10.0  3.0  0.0  0.0  0.0  0.0  0.0  5.0
L.1487   5.0  5.0  5.0  5.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
L.1488   0.0  1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
L.1489   5.0  3.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0
L.1490  10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0
L.1491  10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0  0.0  4.0  5.0  6.0  5.0
L.1492   5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0 10.0 10.0
L.1493  10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0
L.1494  10.0 10.0 10.0 10.0  5.0  5.0  0.0  5.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0
L.1495   1.0  1.0  1.0  1.0  1.0  5.0  5.0  5.0  5.0  2.0  2.0 10.0 10.0  0.0  0.0  0.0
L.1496   0.0  7.0  7.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0  7.0  7.0 10.0 10.0  5.0
L.1497   5.0  5.0  6.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  2.0  2.0  2.0  2.0  2.0
L.1498   5.0  8.0  8.0  5.0  1.0  1.0 10.0 10.0  0.0  0.0  0.0  0.0  7.0  9.0  5.0  5.0
L.1499   5.0  5.0  5.0  5.0  5.0  5.0  8.0  5.0  7.0  7.0  0.0  0.0
L.1500   0.0
L.1501   0.0  1.0  1.0  1.0  2.0  1.0  3.0  1.0  4.0  1.0  5.0  1.0  6.0  1.0
L.1502   0.0  1.0  1.0  1.0  2.0  1.0  3.0  1.0  4.0  1.0  5.0  1.0  6.0  1.0
L.1503   0.0  1.0  1.0  1.0  2.0  1.0  3.0  1.0  4.0  1.0  5.0  1.0  6.0  1.0
L.1504   0.0  1.0  1.0  1.0  2.0  1.0  3.0  1.0  4.0  1.0  5.0  1.0  6.0  1.0
L.1505   0  0  0  0  0  0  4  0  0  0  0  0  0  0  0   9 12 14  0  0  0  0 16 18  1  0
L.1506   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.1507   0  0  0  0  0  0  3  0  0  0  0  0  0  0  0   9 12 15  0  0  0  0 16 19  1  0
L.1508   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.1509   0  0  0  0  0  0  8  0  0  0  0  0  0  0  0  10  0  0  0  0  0  0 17  0  1  0
L.1510   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.1511   0  0  0  0  0  0  7  0  0  0  0  0  0  0  0   9 11  0  0  0  0  0 16  0  1  0
L.1512   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.1513   0  0  0  0  0  0  5  0  0  0  0  0  0  0  0   9 11  0  0  0  0  0 16  0  1  0
L.1514   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.1515   0  0  0  0  0  0  6  0  0  0  0  0  0  0  0   9 13  0  0  0  0  0  0  0  1  2
L.1516   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
L.1517   1  5  6  7  8-11-12 11 12 14 15 16 17 20 21 29 30 32-29-30 34 35 39 40 46 47
L.1518  57 58 59 60 61 62 64 65 66 67 68 69 70 71 72 73 78 79  1  5  6  7  8 10 10-10
L.1519 -10  0 15 16 17 20 21-33-33 32 33 33  0 35 39 40 46 47 57 58 59 60 61  0 64 65
L.1520  66 67 68 69 70 71 72 73 78 79
L.1521  14 39 40
L.1522  20 46  5 32 58  2
L.1523   4
L.1524   3  2  4  4  4  4  3  3  2  2  2  2  2  2  2  3  3  3  3
L.1525    0.00   10.00   30.00   10.00    5.00    0.00
L.1526    1.00   10.00    0.00   10.00
L.1527    0.50    2.00    4.00   25.00
L.1528    0.00    0.50    4.00   60.00    0.00   10.00   10.00    0.00
L.1529    0.00    2.00   30.00   60.00    0.00   10.00   10.00    0.00
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L.1530     0.00    2.00    6.00  100.00    0.00   10.00   10.00    0.00
L.1531     4.00    4.00  100.00    0.00   10.00   10.00    0.00
L.1532     0.00   12.00  100.00    0.00   10.00   10.00    0.00
L.1533     2.50    6.00    0.00   10.00
L.1534     3.50    8.00    0.00   10.00
L.1535     1.00    4.00    0.00   10.00
L.1536     2.00    4.00    0.00   10.00
L.1537     4.00    1.00    0.00   10.00
L.1538     0.25    1.00    0.00   10.00
L.1539     0.50    1.00    0.00   10.00
L.1540     0.00    5.00   20.00   10.00   10.00    0.00
L.1541     0.00    5.00   27.00   10.00   10.00    0.00
L.1542   250.00  600.00  800.00    0.00    5.00   10.00
L.1543   850.00  900.001000.00    0.00    5.00   10.00
L.1544     4
L.1545     5.00   10.00   15.00   20.00    0.00    0.10    0.40    1.00
L.1546 AGRICULTURE                 001
L.1547 FORESTRY                    002
L.1548 CONSERVATION                003
L.1549 RECREATION                  004
L.1550 EXCAVATION                  005
L.1551 WATER CATCHMENT             006
L.1552 ROCK SURFACE                001
L.1553 LAKE                        005
L.1554 RESERVIOR                   006
L.1555 VLEI                        007
L.1556 RIVER                       008
L.1557 HILLSLOPE ELEMENT           010
L.1558 SLOPE GRADIENT              011
L.1559 HEIGHT ABOVE WATER          014
L.1560 KOPPIE                      015
L.1561 NATURAL LAND FEATURE        016
L.1562 GULLY                       017
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L.1564 MINERAL ORE DEPOSIT         021
L.1565 SUBSOIL TEXTURE             029
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L.1567 SOIL ERODIBILTY INDEX       032
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L.1572 SOIL TOXICITY               040
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L.1578 PHYSIOGNOMIC VEGE. TYPE     060
L.1579 FLORISTIC VEGE. TYPE        061
L.1580 WOODY COVER                 062
L.1581 GAME SPECIES                064
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L.1583 ANIMAL HOST SPECIES         066
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L.1589 RAILWAY                     072
L.1590 PAVED ROAD                  073
L.1591 MOUNTAIN CATCHMENT AREA     078
L.1592 WILDERNESS AREA             079
L.1593     0 12  0  4
L.1594     1  5  6 17 62 68 69 70 71 72 73 78
L.1595     8 71 72 73
L.1596     0 12  0  4
L.1597     1  5  6 17 62 68 69 70 71 72 73 78
L.1598     8 71 72 73
L.1599     0  4  1  3
L.1600    68 65 70 78
L.1601     8
L.1602    71 72 73
L.1603     3  3  1  3
L.1604     5  6  7
L.1605    17 69 78
L.1606     8
L.1607    71 72 73
L.1608     0  7  4  0
L.1609     5  6  7 62 68 69 70
L.1610     8 71 72 73
L.1611     3  4  1  2
L.1612     5  6  7
L.1613    17 68 69 70
L.1614     8
L.1615    72 73
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